THE USE OF ALTERNATIVE ENERGY TECHNOLOGIES IN BUILDINGS: THE INFLUENCE OF ENGINEERING CONSULTANTS

A thesis submitted for the degree of Engineering Doctorate in Environmental Technology

by

Robert Stewart Cooke

School of Engineering and Design

Brunel University

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ABSTRACT

The UK Government has set the target of reducing CO_2 emissions by 60% by 2050. Energy used by buildings is presently responsible for around half of CO_2 emissions in the UK. There are many established methods for reducing such emissions from building operation but these opportunities are not being seized to their full potential. One of these methods is the use of Alternative Energy Technologies (AETs) integrated into the built environment.

Engineering consultants have a key role in the design of buildings, their energy consumption and the consideration of AETs. The objectives of this thesis are to explore the process of delivery of AETs in building projects, the key factors that influence the viability of these technologies and the capability of engineering consultants to increase their rate of uptake.

While there are many published lists of incentives and restrictions to using these technologies, there are few reports of their impact in practical contexts. Project involvement provided evidence of significant variations in the drivers and barriers to using AETs, the design team perceptions and the approaches used for assessments.

These insights were investigated in detail through participative research techniques. Initial focus groups led to the development of a structured interview programme administered in 2 phases. The first phase of interviews investigated the experiences of 41 participants representing a range of building project stakeholders. The second phase of interviews looks more closely at 24 relevant projects from the perspective of the engineering consultant, investigating the decision-making approaches used and the influence of factors throughout the design process in more detail.

As a result a hierarchy of the importance of specific drivers and barriers to using AETs in building projects was established. It was found that there is a large amount of variation in their importance between projects. Despite this variation the emphasis for assessment methods is on financial terms, largely ignoring more qualitative concerns. This lack of suitable assessment methodologies along with a lack of education, motivation and case study information in the building industry are restricting the use of AETs in UK building projects. It is proposed that to address this, engineering consultants need to be better informed and need to develop and embrace more holistic technology assessment methods that account for qualitative and quantitative considerations.

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- Dr Andrew Cripps, Neil Billet, Robert Okpala, Mark Aplin and all those at Buro Happold Consulting Engineers who have helped as friends and colleagues;
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LIST OF ABBREVIATIONS

AETs	Alternative Energy Technologies
BREEAM	Building Research Establishment Environmental Assessment Method
CBA	Cost-Benefit Analysis
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CSR	Corporate Social Responsibility
DFES	Department for Education and Skills
DTI	Department of Trade and Industry
EAGGF	European Agricultural Grant Guarantee Fund
ECE	External Cost Estimates
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EngD	Engineering Doctorate
EPSRC	Engineering and Physical Science Research Council
IEA	International Energy Agency
kWh	Kilowatt hour
LEA	Local Education Authority
MCDA	Multiple-Criteria Decision Analysis
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
OECD	Organization for Economic Cooperation and Development
ppm	parts per million
PSM	Problem Structuring Method
PV	Photovoltaics
SEI	Sustainable Energy Ireland

EXECUTIVE SUMMARY

I. BACKGROUND INFORMATION

The Engineering Doctorate Programme (EngD) is a four-year research degree, awarded for industrially relevant research, based in industry and supported by a programme of professional development courses. The EngD Programme is sponsored by the Engineering and Physical Science Research Council (EPSRC) and was set up in response to industry needs for more industrially orientated research. The industrial perspective of the work included in this thesis was instigated by Buro Happold Ltd. who also provided additional funding to the EPSRC sponsorship, as required by the EngD Programme.

The work included in this thesis was carried out within the EngD centre managed jointly by Brunel and Surrey Universities. All research projects undertaken at the Brunel/Surrey EngD centre follow the theme of "Environmental Technology" and aim to 'provide graduates with the necessary skills to balance environmental risks with all of the traditional variables of cost, quality, shareholder value and legislative compliance'. The Brunel/Surrey programme aims to balance a number of competing interests. The research engineer must reconcile both academic and industrial requirements of the research while considering the environmental issues inherent in the project undertaken. Figure (i) sums up the three elements of an EngD research project.

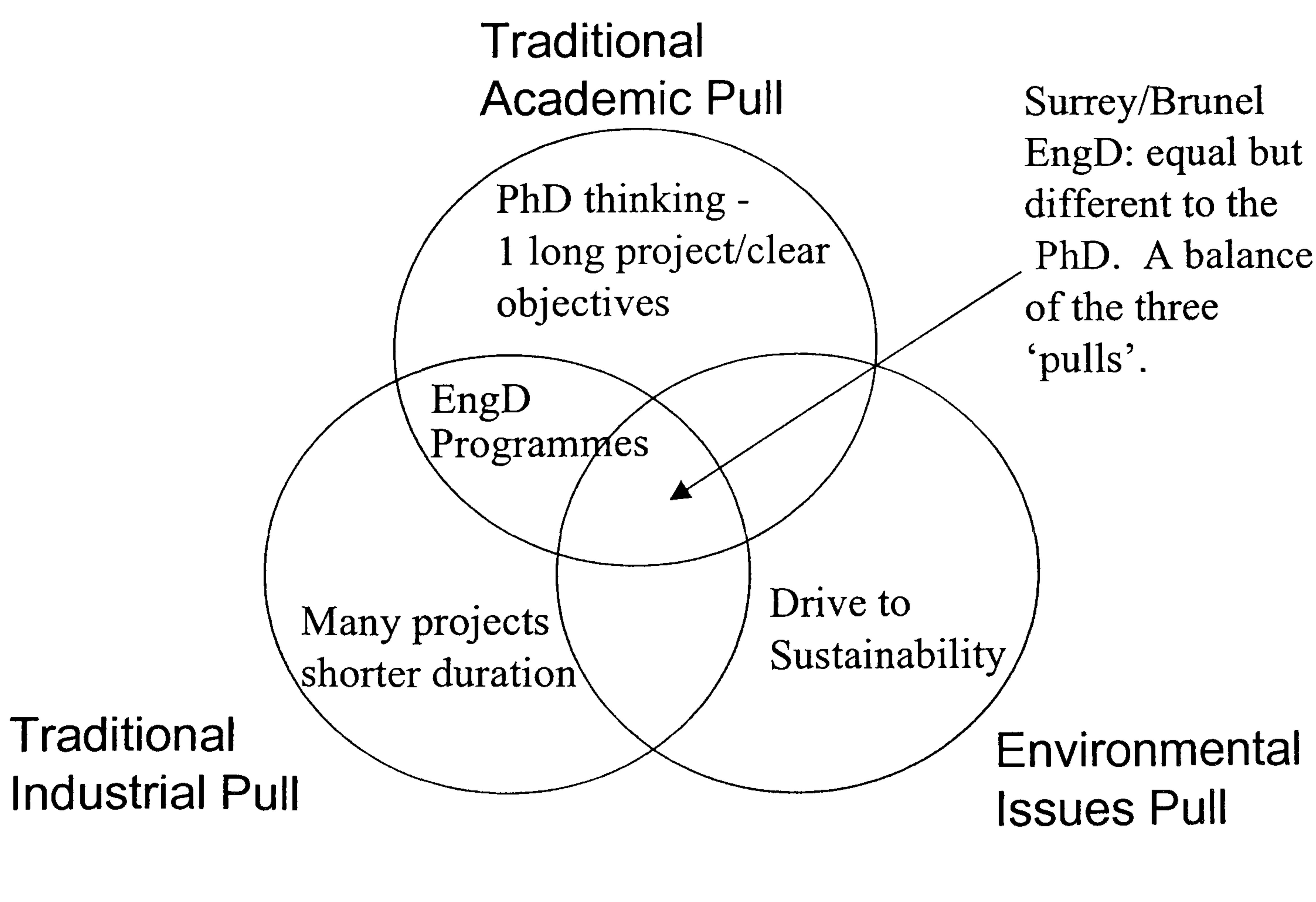

Figure (i) The three elements of an EngD research project

The EngD programme includes complementary courses that must be completed by the EngD candidates. These courses have the following aims:

- To present a view of the relationship between engineering and the environment including sociological aspects.
- To provide professional development in key business skills and competencies.
- To close any gaps in the knowledge required in undertaking the research project.

The programme of courses is comprised of compulsory and elective modules and the completion of a relevant assignment is usually required after each course. The modules taken and successfully completed during this research are as follows:

Year 1	Induction course: Communication & Leadership I
	Life Cycle approaches
	Research methodology
	Risk Perception and communication
	Sustainable development
	Getting started on your writing up
	Environmental hands-on review and audit
	Advanced leadership
Year 2	Environmental auditing and management systems
	Writing a scientific paper
	Decision making for environmental strategy
	Environmental Law
Year 3	Economic approaches
	Energy
	Materials
Year 4	Talking to the media
	Writing up your portfolio
	Finance

The EngD Candidates are also given the opportunity to present their research either orally or through poster presentations, at the annual EngD Conference. The conferences are attended by all EngD Candidates, supervisors and invited delegates. Papers written for the conference by the Research Engineer are included in published proceedings.

From the research conducted in this thesis, the following papers were written and published for the EngD conferences:

Cooke R, Cripps A, and Kolokotroni M (2003) *The design of an anaerobic digester for reducing the environmental impact of a zoo building*, Proc. Engineering Doctorate in Environmental Technology Annual Conference 2003, Brunel University and the University of Surrey, 25-26 June 2003.

Cooke R S., Cripps A. J. and Kolokotroni M. (2005) *An investigation of barriers to the integration of AETs into building design*, Proc. 2005 Conference for the Engineering Doctorate in Environmental Technology, Brunel University and the University of Surrey, 11-12th January 2005, pp. 61-70.

Presentation at the EngD conferences provides the opportunity to develop and practice a number of essential skills, including writing a paper, communication of scientific material orally and visually and presenting in front of a large audience. Orally presenting at the EngD conferences contributed to clarifying an understanding of the research. Exposure to queries concerning the research from members of the conference audience was extremely valuable in gauging its legitimacy from a wider academic perspective.

In addition to attending courses, submitting assignments and presenting the results of their project to the EngD Conferences, Research Engineers complete a progress report every six months. The aim of these progress reports is to inform the EngD Programme Management Committee and supervisors of the progress made towards the completion of research projects at given stages during the programme.

This section gives a brief introduction to the EngD Programme in order to describe the overall framework of the research work included in this thesis. The following sections of the executive summary describe in more detail the research carried out. This includes a description of the research topic and research project objectives (Section II). A summary of the research methods applied and the main results generated from these are presented in Section III. Details of the papers published in scientific refereed journals and conference proceedings (Section IV). Finally Section V lists participation of the Research Engineer in commercial projects to give an understanding of the experience gained by the Research Engineer during the 4 years of the EngD Programme.

II. INTRODUCTION TO THE RESEARCH TOPIC AND OBJECTIVES

This section briefly introduces the research topic and describes the objectives of the research project.

Research topic

Around 80% of World primary energy production is from fossil fuels (IEA, 2005). This use of fossil fuels significantly adds to global carbon dioxide emissions, which are thought to play a key role in adding to the greenhouse effect. To help combat the threat of climate change the Governments of many countries (including the UK) have agreed to targets for reducing carbon dioxide and other greenhouse gas emissions.

In the UK energy consumption in buildings is estimated to be equivalent to around 46% of total primary energy use, producing a similar proportion of total carbon dioxide emissions (ECD, 2001; CIBSE, 2003). Therefore to help meet Government targets it is necessary to design buildings to be more energy efficient and to incorporate alternative energy technologies (AETs, defined in Section 2.1.2.4). Engineering consultants have a key role in the design of buildings, their energy consumption and the consideration of AETs. This research project investigates the building design process, the selection of energy technologies and the engineers' role in making these selections.

Research objectives

In line with the above, the main aim of this research programme has been to:

- Develop an understanding of AETs and how they can be integrated into building projects.
- Understand the process of delivery of building projects and how the consideration of AETs can form a part of this.
- Understand how the work of engineering consultants can increase the chance of uptake of AETs in building projects.
- Understand what the key factors are that lead to successful use of AETs in building projects.
- Use this combined understanding to help improve the delivery of AETs.

III. RESEARCH METHODS AND MAIN RESULTS

This section summarises the research methods and main research results from the research project carried out as part of this EngD Programme and presented in detail in the following chapters of this research portfolio.

Initial approach

The initial approach to the research project was to gain practical experience of the building design process and the consideration of AETs. Through this process of project involvement it was possible to develop:

- A better understanding of AETs and their use in practical applications
- Experience of a range of building projects at different design stages, and the decision approaches used therein.
- Contacts and useful case-studies from within the industry
- A basic methodology for the assessment and selection of AETs.

Each of the projects provided evidence of different drivers and barriers to using AETs, different perceptions and different approaches for assessment favoured by the design teams. From this experience a hypothesis was developed such as follows:

> "Environmental conditioning in buildings is a major source of anthropogenic CO2 emissions, and these could be substantially reduced by better design and construction. New and renewable energy technologies embodied in buildings are technically capable of making a significant contribution to this, but opportunities are being missed because of a lack of understanding within the project team and poor communication of potential future benefits. It is proposed that the use of more holistic appraisal techniques would improve understanding and communication within the project team, hence leading to these technologies being considered and thus used more frequently."

This hypothesis was then challenged, through a period of participative research that investigated the experiences of a wide range of building project stakeholders.

Participative research

The participative research process was comprised of three parts; an initial focus group study followed by two phases of personal interviews.

After defining the aims of the study, 2 focus group sessions were held, firstly with engineers from Buro Happold and secondly with selected participants representing different building stakeholder groups. These sessions were used as practice sessions for road-testing and refining questions and also for defining a list of common drivers and barriers. The outcome from the 2nd focus group was very positive, however there were difficulties finding people with sufficient experience of AETs who would all be available to participate. Thus the personal interview approach was chosen as a more appropriate method for completing a larger study.

The first phase of interviews was a qualitative and partly quantitative investigation of building project stakeholders in the UK. It was conducted between October 2003 and May 2004 to explore the approaches used in assessing AETs and how actions and perceptions vary in the industry. 41 personal interviews were conducted in all with participants chosen because of previous experience of considering AETs in building projects.

The conclusions from this study with building project stakeholders have showed that:

- There is a lack of experience of installing AETs in buildings in the UK, and the understanding of these technologies is variable.
- There are a number of key factors that affect the viability of implementing AETs in building projects.
- There are a number of drivers and barriers to the use of AETs in buildings, and the relevance of each of these varies between projects, with time and with the technology.
- The high capital cost and subsequently long payback period is seen as the most significant barrier, and is the main focus of existing assessment approaches.
- No structured approaches to assessment that specifically address AETs and the drivers and barriers to implementation are being used in the industry. Further education and new approaches to assessment are required, to move the emphasis away from capital cost and toward the benefits provided by AETs.
- Building services engineers play a key role in the technology selection process and also in raising awareness of AETs in the industry.

The second phase of interviews looks more closely at 24 relevant projects in turn, forming case studies that can be compared against the more general insights and conclusions generated in Phase I. This project-specific study investigates in more detail the decision-making approaches used and the influence of factors throughout the design process.

The results of this study are subject to much less variation than in Phase I for the following reasons:

- Only building services engineers are interviewed, so removing the variation of perspectives between the different stakeholder types.
- Each project is assessed in turn and in detail, so answers are specific rather than general observations. This makes it easier to recognise any relationships of cause and effect.
- Some of the projects have only considered a small number of the AETs, and in some cases only one in depth. This allows for specific technology drivers, barriers and other issues to be brought out more clearly.

The results of the Phase II interviews highlighted the importance of recognising opportunities for using AETs very early in the project, and gaining a commitment from the client to considering them as part of the building design. The factors affecting the viability of AETs are highly project variable and there is no essential formula for success. In the projects where AETs were maintained in the project through to construction many of the barriers were considered as less important than in for other projects. In particular there was further evidence of the importance of reducing ignorance and improving communication in the design team for increasing the chances of integrating AETs into building projects.

These interviews also reinforced the understanding that simple financial payback calculations are the most common form of technology assessment, and that other considerations are often presented within a written technical report summarising technical pros and cons. Many of the projects covered included AETs into the construction stage of the building process, often due to financial viability, or due to a specific driving force from the architect or client. This emphasises the absence of refined and structured decision tools that can accommodate qualitative and quantitative considerations in a holistic and transparent manner.

Following the completion of analysis of each study a comparison was made between the two, the main conclusions from this comparison are:

- In the project-specific interviews a greater proportion of the respondents suggested that AETs were considered as important parts of the project.
- The scores attributed to barriers by the mixed stakeholder participants are far higher than those in the project-related interviews.

- 'Ignorance and lack of understanding' was judged to be much less of a barrier in the Phase II interviews. This issue was much less of a factor in the projects where AETs were considered through to construction. This highlights the importance that ignorance plays in influencing the viability of AETs, and the role of engineering consultants in reducing its impact.

These results suggest that in successful projects ways have been found to reduce barriers and to allow positive drivers to overcome them. The role that the consulting engineer has to play and the impact that they can have on reducing the impact of ignorance through obtaining and disseminating accurate information has been shown to be key.

A general conclusion from this research, in response to the hypothesis proposed early in the research project is as follows:

> "This detailed study of opinions and actions within the building industry has shown that the lack of understanding of AETs from within design teams is a significant problem across the industry. This ignorance and a lack of communication of potential benefits restrict the use of AETs in building projects, and engineering consultants can play a key role in reducing the effect of this through education and development of new approaches to technology assessments. The use of more holistic approaches to technology appraisal has been shown to help improve the viability of AETs, though the selection and application of such techniques still need developed and applied in practice."

IV. ORIGINAL CONTRIBUTION TO THE BODY OF KNOWLEDGE AND PUBLICATIONS

The particular facets of the work that are original contributions to knowledge include:

- The presentation of results from an investigation of experiences within the UK building industry of integrating AETs into buildings.
- Presentation of a hierarchy of drivers and barriers to the use of AETs in UK building projects.
- Development of an understanding of the role of engineers and how they can make a difference in trying to increase the use of AETs in building projects.
- The establishment of an insight into what makes for successful integration of AETs in UK building projects.

List of publications

The research carried during this EngD programme have been published, both in peer reviewed journals and presented at academic international conferences.

Peer Reviewed Journal Papers

1. Cooke, R., Cripps, A. and Kolokotroni, M. (2006) ***Eden project biomass energy crop feasibility study***, International Journal of Low Carbon Technologies, Manchester University Press, Vol. 1, Number 1, January 2006.
2. Cooke, R., Cripps, A., Kolokotroni, M. and Irwin, A. (XXXX) ***Alternative energy technologies in buildings: stakeholder perceptions***, submitted to Building Research & Information on 5th October 2005.

Peer Reviewed Conference Papers

1. Cooke, R., Cripps, A. and Kolokotroni, M. (2004) ***Eden project biomass energy crop feasibility study*** Proceedings of the 3rd International Conference on Sustainable Energy Technologies, Nottingham, UK, 28-30 June 2004.

V. INVOLVEMENT IN COMMERCIAL PROJECTS

In the spirit of the EngD Programme, the Research Engineer has gained valuable engineering experience by participating in commercial projects carried out by the sponsoring organisation Buro Happold Consulting Engineers. The integration of AETs into building projects has required a number of roles to be performed by the research engineer throughout the project design and construction process. These roles and some examples of where they have been applied during the process of the research project are detailed in Table (i).

Table (i) A summary of roles performed in example projects

Role	Detail	Example Projects
Planning	Strategy documents	Convoy's Wharf; Lower Lea Valley; The Village; The Calyx
Brainstorming	Initial review of options	Halley VI; Kuwait University
Selection	Advising of appropriate systems and scales	Eden project; Royal Mills; Queens University Library Belfast
Modelling	Analysis of energy loads, system performance, costs and carbon emissions	Bermondsey Spa; Schools for the future; Corby Academy
Technology study	In-depth analysis of a specific system	Copenhagen Elephant House; Eden Biomass Feasibility Study; CHP loads
Guidance	Production of educational material	Biomass Procurement Guidelines
Construction	Final selection, system specification and procurement	Eden Biomass; Kensington Academy
Review	Monitoring and checking performance	Carterton leisure centre

These projects are described in more detail in Chapter 7 of the thesis.

CHAPTER 1 INTRODUCTION

1 INTRODUCTION

This introductory chapter briefly describes why the subject of using Alternative Energy Technologies (AETs) in building projects is an important research area, the rationale behind this research project, the project objectives and the process that has led to the completion of this thesis.

1.1 Energy context

World energy production was predicted by the International Energy Agency (IEA) to be 10,579 million tonnes of oil equivalent in 2004 (IEA, 2005) with around 11.3% from renewable and waste sources, 6.5% from Nuclear, 2.2% from Hydro power stations and 80% from fossil fuels. Around 60% of this energy is used by industrialised countries, which make up only 20% of the population (Elliott, 2003).

One of the significant environmental impacts of energy generation is the production of carbon dioxide (CO_2) through burning fossil fuels, which is thought to play a key role in adding to the greenhouse effect (Elliott, 2003). The IEA (2005) estimated World CO_2 emissions from energy use as 24,983 Million tonnes in 2004, with around 51% produced by OECD countries of which UK emissions account for 540 million tonnes CO_2. Since 1760 the level of atmospheric CO_2 has increased from around 280 parts per million (ppm) to 368 ppm in 2000 (Elliott, 2003). This increase, fuelled by increased CO_2 emissions, has contributed to the greenhouse effect and the increase in average world temperatures indicated in Figure 1.1. The Earth's surface temperature is shown year by year (vertical bars) and approximately decade by decade (black line). There are uncertainties in the annual data (thin black whisker bars represent the 95% confidence range) due to data gaps, random instrumental errors and uncertainties.

Over the last 140 years the best estimate is that the global average surface temperature has increased by $0.6 \pm 0.2°C$ (IPCC, 2001). Due to this effect, in 1997 at the UN climate change conference in Kyoto, industrialised countries were set greenhouse gas emission limits. The targets set are for Global emissions reductions of 5.2% below 1990 levels between the years 2008 and 2012, with the EU assigned a target of 8% reductions, which incorporates a 12.5% target for the UK (DTI, 2005).

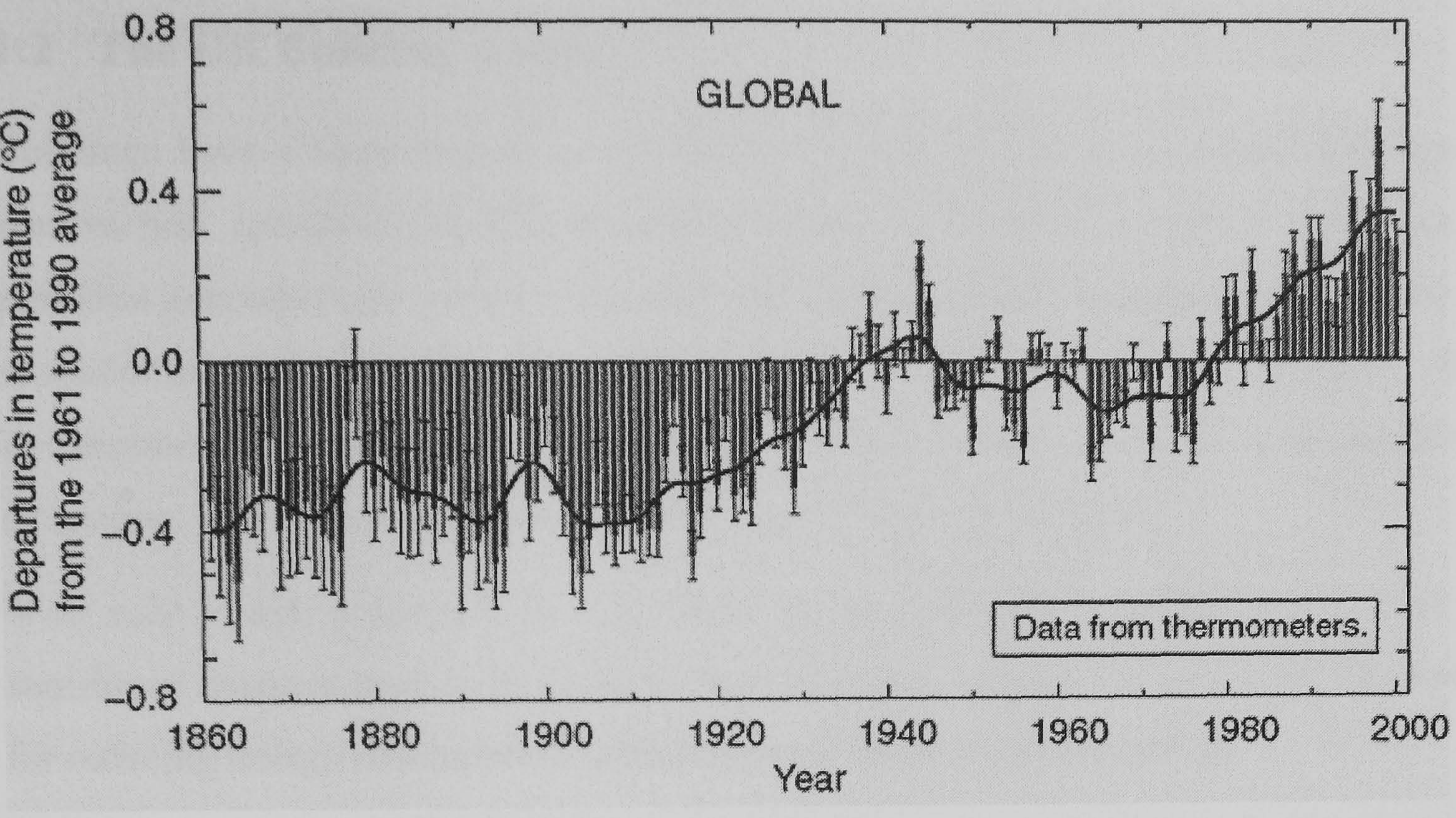

Figure 1.1 Variations of the Earth's surface temperature (IPCC, 2001).

Beyond the initial Kyoto Protocol targets, the UK Government has announced an aspiration of reducing carbon equivalent emissions by 60% by 2050 (DTI, 2003) in their recent Energy White Paper.

1.2 The UK Building context

Buildings have a large impact on the global environment throughout their life, through construction, operation and final decommissioning, in the form of material use, waste and pollution generated and energy consumed. Of these phases the operational period generally produces the greatest impacts and within this energy use is a major factor (Horsley, 2002). For instance, in the UK energy consumed in buildings causes around 46% of annual CO2 emissions, with half of this from domestic properties (Bordass, 2001).

With such a high proportion of CO_2 emissions stemming from buildings it is clear that significant changes need to be made to how buildings perform and are used. The options for reducing energy consumption in buildings are broadly summarised as:

- Harness passive building design principles, including use of insulation and passive solar heating.
- Increase the efficiency of electrical and mechanical systems and appliances.
- Influence user behaviour toward minimising consumption through education and the use of control systems.

Meanwhile the environmental impact of the energy consumed can be reduced through the use of more efficient or renewable 'Alternative energy technologies'.

All of these techniques have been proven to be technically and economically feasible for the reduction of environmental impacts of energy use in buildings (Hawken et al., 1999; Brown, 2001; Scrase, 2001). However, despite stricter building regulations for energy conservation and energy saving approaches becoming more commonplace in the UK, the resulting impact reductions are not meeting the targets set. As shown in Figure 1.2 and 1.3, for domestic properties, energy consumption and CO_2 emissions from buildings are not reducing in line with the UK targets for a 60% reduction by 2050. This is despite great improvements in energy efficiency and a switch from solid fuels to, the less carbon-rich, natural gas.

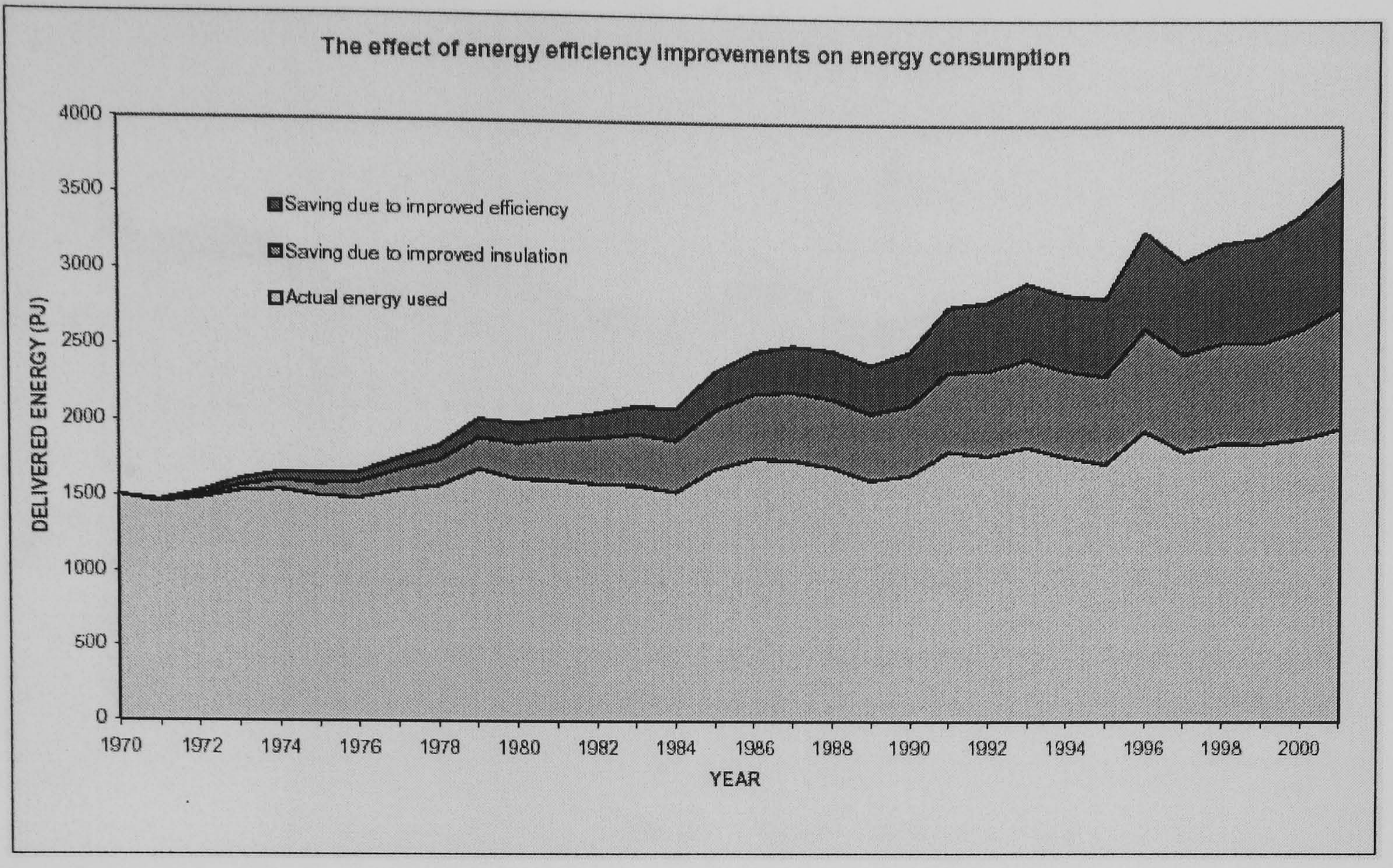

Figure 1.2 The effect of energy efficiency improvements on energy consumption in UK domestic buildings, 1970 – 2001 (Shorrock and Utley, 2003).

The four options for reducing energy consumption and the resultant CO_2 emissions have limitations to use that vary between buildings, but past experience and future scenario modelling show that they all have an important role to play in reducing emissions. Shorrock and Utley (2003) show that previous CO_2 emission reductions have stemmed from a combination of each of these 4 measures, though adverse changes in user demands have largely offset any benefits made by the other 3 approaches. For instance, overall heat loss by the average dwelling reduced by 31% between 1970 and 2001, however more dwellings and a higher average internal temperature has meant that actual energy consumption has risen. Meanwhile in their 40% House project the Environmental Change Institute (ECI, 2005) have demonstrated that achieving 60% reductions in CO_2 from domestic properties by 2050 is not straightforward because 'it is not simply a matter of applying a few new technologies in a uniform way'. Some of the limitations recognised by this study include:

- Low knowledge levels,
- Limited access to capital for home improvements,
- Not all new construction leads to energy conservation,
- Energy conservation is often not a priority (ECI, 2005).

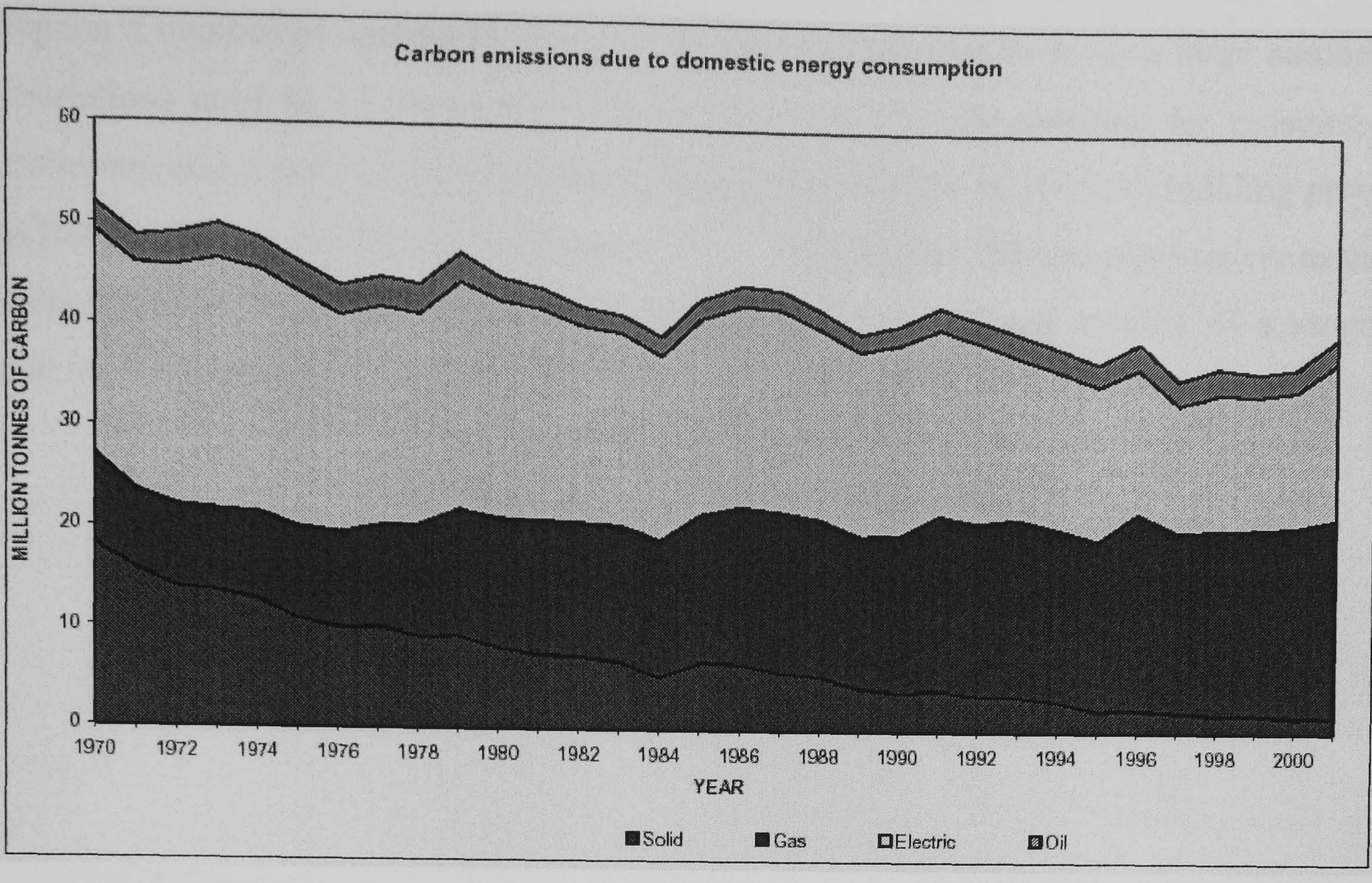

Figure 1.3 Carbon emissions due to domestic energy consumption, 1970 – 2001 (Shorrock and Utley, 2003).

As such the uptake of these methods is very slow, and methods to stimulate uptake such as changes to Building Regulations have very little immediate effect due to the slow rate of new construction; with only about 1% of the building stock replaced by new construction and 2.5% subject to major refurbishment each year (Bordass, 2001). Meanwhile there are physical limitations to the amount of energy that can be saved in existing buildings, and user demands are changing, which largely negates any energy saving from technical changes.

In order to make the substantial changes required the building industry needs to understand and address these limitations where possible and make the most of opportunities as they arise. But at present this potential is not being met; Bordass (2001) suggests that new buildings are often more energy intensive and can be profligate, poorly assembled, wastefully equipped and carelessly managed. This is despite the technical potential to: 'virtually eliminate heating requirements; often avoid refrigeration cooling; improve the efficiency of ventilation, lighting and equipment; and upgrade design, control and management'. He concludes that the main opposition to low energy commercial buildings seems to be the lack of serious market interest and insufficient building performance understanding from designers, managers, users and government.

It is clearly important to reduce the level of CO_2 emissions from UK buildings, for this to happen a number of approaches need to be applied, however to do so a large number of restrictions need to be overcome. This thesis focuses on the potential for reducing the environmental impact of building energy use through the use of AETs in building projects in particular. It comprises an investigation into the effective drivers and barriers to using these technologies in the UK through participative research and a study of a range of completed projects.

1.3 Objectives of the research project

The reduction of non-renewable energy use within buildings is known to offer significant environmental benefits and in particular a reduction in the release of CO_2.

The building consultant plays an important role in the design and refurbishment of buildings and so impacts on their environmental performance. Four methods for doing this are: passive design, energy efficient components, altering the users operating culture and the use of AETs. Each of these areas has potential for important research, however only one factor can be considered in more depth here. The barriers to developing an energy efficient building through passive design and the use of efficient appliances has been covered internationally e.g. Lovins (1992) and with respect to UK construction e.g. Sorrell (2003). Meanwhile operating culture is not easily influenced by the actions of building consultants.

- Therefore, it was decided that this research project will investigate the role of AETs and how building consultants can help to increase their level of deployment in building projects.

It is not the role of the building consultant to develop new technologies but to integrate suitable systems into the built environment. AETs are readily available and are applicable within buildings. However, to date there has been a very low level of deployment except for within demonstration or exemplar projects, for example Buro Happold (a leading building consultancy) have consulted on over 10,000 projects and less than 50 have included AETs to construction. There are clear drivers for increasing the use of AETs within the UK and due to their modular nature building integration provides an ideal opportunity for doing this. The integration of AETs also has potential for application with both new and existing building, which widens the scope for deployment.

- It is therefore the aim of this research to investigate the barriers to using these technologies in building projects and how the building consultant can work to break these barriers down.

One of these barriers is the complexity of design and lack of simple rules of comparison within the building industry, and Scoones (2001) suggests there are no independent comparative evaluations suitable for publication. He also states that there are technically feasible solutions to the present demands however problems of effective service delivery, efficiency of technology and economies of scale often limit renewables.

- This research project aims to investigate the evaluation methods used in the industry, and to consider how the approach followed by the building consultant can impact on the perceived viability of using AETs.

The objectives for reaching this overall aim are detailed in the form of a logical project flowchart within Figure 1.4.

The contribution to knowledge that this research will provide is a greater understanding of:

- Barriers to integrating AETs into building projects,
- Techniques being used for assessing these technologies, and
- Approaches available to building consultants for reducing these barriers and so improving the consideration of AETs in building designs.

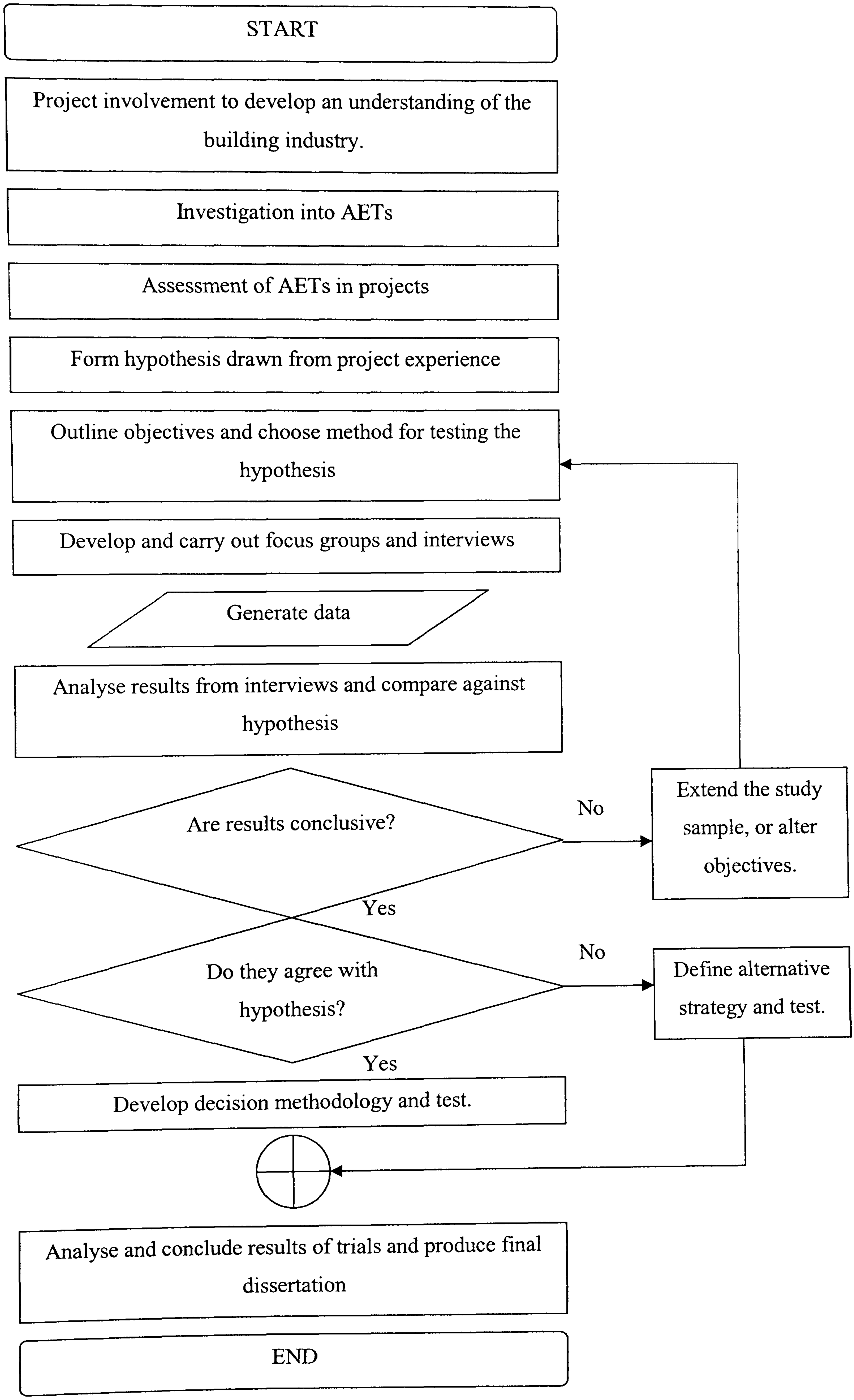

Figure 1.4 Research project progress

1.4 Approach

This research has been completed in a number of phases, with a development phase involving the use of focus groups and a first phase of interviews of 41 building project stakeholders, before a final phase of project-specific interviews.

From the initial case study experience a hypothesis was developed such as follows:

> "Environmental conditioning in buildings is a major source of anthropogenic CO2 emissions, and these could be substantially reduced by better design and construction. New and renewable energy technologies embodied in buildings are technically capable of making a significant contribution to this, but opportunities are being missed because of a lack of understanding within the project team and poor communication of potential future benefits. It is proposed that the use of more holistic appraisal techniques would improve understanding and communication within the project team, hence leading to these technologies being considered and thus used more frequently."

It is the aim of this research to challenge this hypothesis by investigating the perceptions of different project stakeholders[1] with regards to the selection of AETs in building projects.

The research process was designed according to the work of Oppenheim (1992), to ensure that the research does not merely lead to an interesting 'fact-gathering' activity, but has scientific merit. The first part of this process was to generate a research plan, which can be seen in Figure 1.5.

1.4.1 Investigation objectives

The key objectives of this investigation were to test whether or not it was common perception that:

- There is lack of understanding of AETs within the building industry.
- There is no common structured methodology for assessing these technologies and for openly communicating each stakeholder's perceptions of pros and cons.

Other aspects to be investigated were:

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[1] Project stakeholders have been defined here as those persons with a direct influence over the building design and in particularly the decision to select an appropriate energy supply for that project. These are summarised as clients, developers, planning officers, contractors, suppliers, architects, building consultants, project managers and renewable energy consultants.

- The level of experience held with regards to the consideration of AETs.
- Whether stakeholders found that the consideration of these technologies was an important aspect within the design of buildings.
- What they felt the main drivers and barriers were to considering these technologies.
- How different stakeholders felt that the building industry could help to improve the level of implementation of these technologies and who within the industry might be best placed to make these changes.

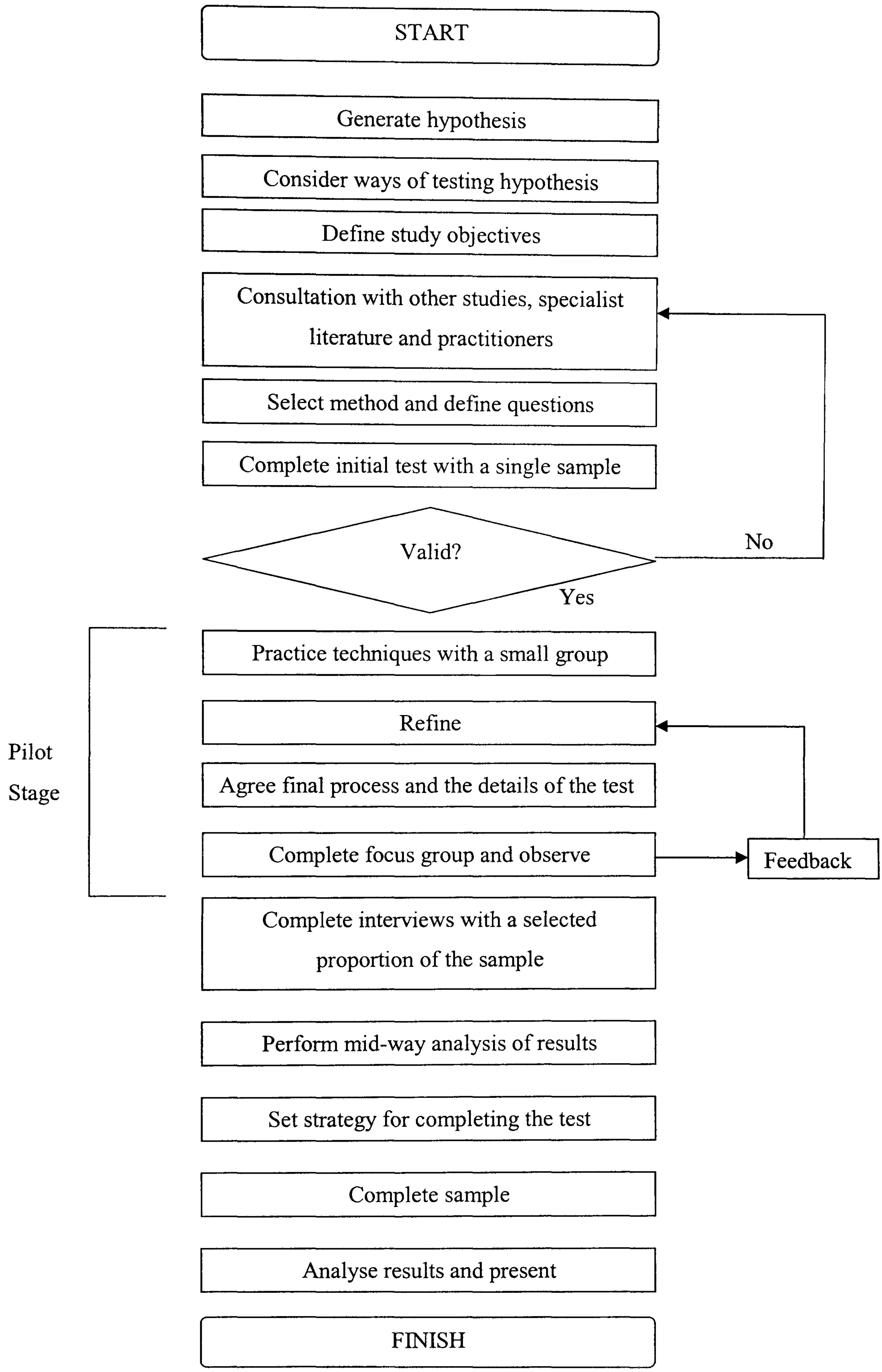


Figure 1.5 Investigation process flowchart

1.5 Description of the structure of the thesis

Chapter 1 outlined the environmental and political importance of moving towards using AETs and introduced the objectives and development of this research project in line with this need.

Chapter 2 illustrates building energy use in the UK, and the associated environmental impacts. Approaches to reducing the carbon emissions produced during the operational life of buildings are discussed and the rationale for integrating AETs into building designs is explained. This is followed by a description of other research into the factors that influence the viability of AETs and their use in providing more sustainable buildings. The chapter is concluded with a description of decision-making techniques and the potential for their use in the selection of AETs in building projects.

Chapter 3 describes the methodology used for developing an approach to participative research, designed to obtain the perceptions and experiences of building project stakeholders. The aim of this research is to define the most effective way that building consultants can help to increase the use of AETs in building projects. This chapter describes the rationale behind using a qualitative research approach and application of this approach in 3 phases.

Chapter 4 presents the results from 41 personal interviews held with a selection of building project stakeholders. The answers to each of the 8 questions are presented in turn, with a summary of answer categories, diagrammatic presentation of the answers and an explanation of salient themes. This chapter concludes with cross-question analysis and a reflection on the main points of interest.

Chapter 5 presents the results from 24 project-specific interviews held with building services engineers within Buro Happold. Similar questions were used to those in the stakeholder interview process and the answers to each of the 8 questions are presented in turn. This chapter concludes with a description of each of the projects in turn and cross-question analysis reflecting on the main points of interest.

Chapter 6 provides a comparison of the results from the first phase of interviews with those from the project-specific interviews. This provides an opportunity to further clarify some of the conclusions from the interview phases and also highlight differences in experience due to specific project characteristics.

Chapter 7 reflects on four years of project experience and describes the varying levels of success of trying to integrate AETs into building designs. A wide range of projects are introduced, together with a description of my involvement, the energy technology selection process and the factors that had the most influence over the final decision. This chapter concludes with the presentation of technology fact sheets developed for use by building services engineers, formed from the experience gained through involvement in these projects.

Chapter 8 concludes this thesis with a summary of the main objectives of the research project, the methodologies used and the key conclusions from the results obtained, highlighting the unique nature of this research and the contribution to knowledge achieved.

1.6 Summary of Chapter 1

World energy production is predominantly fossil fuel based, making up 80% of the mix. Carbon equivalent emissions from energy use are thought to significantly add to the greenhouse effect. In an attempt to reduce this impact there are international and UK targets for reducing these emissions. One of the opportunities for doing this is the replacement of fossil fuel technologies with AETs.

To help realise this opportunity the main aims of this research programme have been to:

- Develop an understanding of AETs and how they can be integrated into building projects.
- Understand the process of delivery of building projects and how the consideration of AETs can form a part of this.
- Understand how the work of engineering consultants can increase the chance of uptake of AETs in building projects.
- Understand what the key factors are that lead to successful use of AETs in building projects.
- Use this combined understanding to help improve the delivery of AETs.

CHAPTER 2 LITERATURE REVIEW OF BARRIERS TO THE INTEGRATION OF AETS IN BUILDINGS

2 LITERATURE REVIEW OF BARRIERS TO THE INTEGRATION OF AETS IN BUILDINGS

This Chapter illustrates building energy use in the UK, and the associated environmental impacts. Approaches to reducing the carbon emissions produced during the operational life of buildings are discussed and the rationale for integrating AETs into building designs is explained. This is followed by a description of other research into the factors that influence the viability of AETs and their use in providing more sustainable buildings. The chapter is concluded with a description of decision-making techniques and the potential for their use in the selection of AETs in building projects.

2.1 Environmental impacts of energy consumption in buildings

This section introduces the importance of energy use in buildings and the methods available for reducing the environmental impacts from this energy use.

2.1.1 Building energy use

As outlined in Chapter 1, this research project considers how building services consultants can help to minimise the environmental impact of buildings. Buildings have a large impact on the global environment and building designers and owners play a significant role in shaping present and future environmental impacts (Bordass, 2001).

It has been estimated that in the UK around 46% of UK primary energy is consumed in buildings, producing an equal proportion of anthropogenic CO_2 emissions (ECD, 2001; CIBSE, 2003). In 2004 98.3% of the energy supplied in the UK was from fossil fuel or nuclear sources (DTI, 2005a). For the UK to be able to meet its aims of reducing CO_2 emissions by 60% before 2050 (PIU, 2002), it has been shown that there must be major reductions in building energy use and increases in the proportion of energy supplied from new and renewable sources (ECI, 2005).

Energy is required in a building for two distinctive reasons (Abel et al., 1990): (a) for maintenance of the internal climate, which is dependent on external conditions and user behaviour; and (b) energy use as a function of the building, independent of external conditions.

Abel et al. (1990) suggest that the energy requirements dependent on the external environment are:

- Energy compensation due to energy transmission through the building structure
- Heating or cooling to compensate for infiltration
- Tempering the air in controlled ventilation systems (to avoid the effect of draughts)
- Cooling to compensate for solar heat gains.

Whilst the energy requirements independent of external conditions is used for:

- Domestic hot water;
- Local cooling to compensate for latent and sensible heat gains from people, appliances, etc.;
- Additional lighting;

- Operation of electrical appliances and forms of transportation, i.e. computers, lifts, etc.

The energy required to meet the demands of the building user will be provided through the design of the building and the building services, either of an active or passive nature. Hence the design of building services is an important consideration as they greatly influence the capital and running costs of a building, its impact on the environment and its ability to provide safety, health and comfort to occupants (ECD, 2001).

2.1.2 Methods for reducing environmental impacts

Horsley (2002) suggests there are three factors that influence the energy performance of a building: the building design, the services and systems design and efficiency, and the behaviour of the building's occupants. Therefore there are four possible methods of reducing the environmental impacts of energy use in building operation:

- Harnessing the natural environment through passive building design,
- Technical innovation improving the efficiency of building systems and appliances,
- Influencing the operating culture of owners and users toward minimising consumption,
- Changing the nature of the energy source from centralised power generation and fossil fuels to renewable energy and local distributed generation.

The first three of these methods are ways of reducing energy consumption, while the fourth method is a way of reducing the environmental impact of this energy consumption and is the focus of this research project.

2.1.2.1 Environmental building design

Environmental building design is sometimes termed passive design, with the aim of using the natural 'passive' environment to provide a low energy building and minimise the need for 'active' building services. Common design concepts for this are given by CIBSE (2003) as follows:

- System integrated design
- Passive solar design
- Understanding and designing for internal heat gains
- Using natural ventilation and natural daylighting
- Increased thermal insulation and the use of thermal storage to offset peak loads

- Heat recovery
- Use of free cooling
- Minimise distribution losses

However there are many factors that will affect the potential for using passive design techniques. Along with final use, occupancy and purpose, CIBSE (2003) list some of the main features of a building that will affect this potential and so the need for active building services:

- Building location – climatic influence, shelter, surrounding buildings, etc.
- Orientation – solar and wind effects.
- Form and Shape – Thermal response, glazing, height, use of atria, materials, etc.
- Ventilation and daylighting strategy

2.1.2.2 Energy efficiency

The technical innovations capable of reducing building energy use include:

- Heating, cooling and ventilation system efficiency improvements – fans, pumps, controls, etc.
- Improvements in the energy efficiency of and level of waste heat generation from internal 'living' equipment such as computers, televisions, lights, etc.

This would include an increased level of environmental design with every aspect of a building, from pumps and drives through to lighting and process equipment. The building consultant can try to specify energy efficient technologies where possible, however it is commonly beyond their realm to influence the purchase of internal appliances. The client/user may also have a requirement or preference for particular appliances or systems to be used.

2.1.2.3 Operating culture

The operating culture within a property varies with its function and the nature of the residents. It is an important factor that can lead to a building consuming far more or less energy than could be predicted or designed for. Building consultants need to consider user behaviour in the design as well as lessons from how buildings are used through monitoring and analysis. Additionally, by making occupants more aware of building services, how they work and their effect on the environment it may be possible to minimise excessive energy use. However, these factors are relatively unpredictable, variable through time and cannot always be easily influenced by the building consultant.

2.1.2.4 Alternative energy

Traditional buildings in the UK use fossil fuels such as natural gas for heat requirements and electricity for power, supplied via the National Grid. The use of AETs could replace this with more efficient 'new' supply methods or with energy from renewable sources. Hence the term 'alternative' can also be replaced by 'New and Renewable' in the context of this research project. A resource can be defined as renewable if "their rate of consumption does not reduce their future availability" (Gomez et al, 1999).

The technologies considered within this research project are limited to those that can provide practical environmental improvements as compared to traditional supply systems; therefore blue-sky technologies are not considered. Scoones (2001) provides an informed overview of active renewable and hybrid technologies suitable for application in UK built environments. The most relevant of these alternative technologies are considered further in this research project, given in alphabetical order as follows:

- Biomass and waste fuels
- Combined heat and power
- Ground source heat pumps
- Micro-Hydro power
- Solar photovoltaic
- Solar thermal
- Wind

Omitted from this list are renewable technologies not considered applicable within the built environment, such as geothermal hot-dry rock, large-scale hydro, ocean technologies and large wind turbines (in excess of 1MW). The use of passive solar technology is not included because it is considered an aspect of environmental building design.

The production of heat and electricity from renewable energy in the UK is represented in Table 2.1. When considering that UK primary energy demand in 2004 was 247.3 million tonnes of oil equivalent, the proportion of primary energy from renewables equates to only 1.7% (DTI, 2005a). This reflects how limited the use of renewables is at present.

Table 2.1 Total use of renewable sources and wastes, thousand tonnes of oil equivalent (DTI, 2005a)

Year	Solar heating and photovoltaics	Onshore and offshore wind	Large-scale Hydro	Biofuels	Geothermal aquifers	Non-biodegradable wastes	All renewables and wastes
1996	8.7	41.9	291.7	1527.7	0.8	247.9	2118.7
1997	8.9	57.4	358.4	1611.7	0.8	288.3	2325.5
1998	9.2	75.4	440.0	1705.0	0.8	352.4	2582.7
1999	9.4	73.1	458.8	1893.1	0.8	321.8	2757.1
2000	11.2	81.3	437.3	2043.2	0.8	305.6	2879.4
2001	13.4	83.0	348.7	2243.4	0.8	320.7	3010.1
2002	16.3	108.0	411.7	2429.4	0.8	343.4	3309.6
2003	20.0	110.5	277.5	2816.5	0.8	339.2	3564.7
2004	24.9	166.4	423.9	3198.3	0.8	329.4	4143.7

Supporting these clear environmental drivers for the development of AETs are the following government targets:

- The EU Renewables Directive; this gives the UK the target of providing 10% of the electricity consumed from renewable sources, by 2010 (DTI, 2003a).
- The Government target of achieving at least 10 GWe of Good Quality CHP capacity by 2010, with around 5.6 GWe installed at the end of the year 2004 (DTI, 2005a).

2.2 Barriers to reducing environmental impacts from energy use in buildings

The previous section introduced the methods available for reducing the environmental impact of building energy use. This section presents research that reflects on why, in general, these techniques are not being used in UK buildings, reflecting on the factors that restrict more sustainable building design.

Buildings have a large impact on the global environment throughout their life, through construction, operation and final decommissioning, in the form of material use, waste and pollution generated and energy consumed. Of these phases the operational period generally produces the greatest impacts and within this energy use is a major factor (Horsely, 2002).

Reducing the environmental impacts of energy used in buildings is important and economically feasible using a number of readily available techniques (Hawken et al., 1999; Brown, 2001; Scrase, 2001), including energy-saving techniques and the use of distributed new and renewable energy technologies (Lovins et al., 2002). There are a number of barriers to each of these approaches, considered throughout the world. For instance, studies have been completed relating to:

- The USA (Brown, 2001; Bourgeois et al, 2003)
- Worldwide (Dincer, 1999; Charters, 2001; Beck and Martinot, 2004)
- Developing nations (Martinot and McDoom, 2000; Painuly, 2001)
- The UK (Scrase, 2001; Sorrell, 2003; Foxon et al, 2005)

The factors influencing construction of low energy buildings are covered in numerous studies (Lovins, 1996; Hawken et al., 1999; Sorrell, 2003; Foxon, 2003; Vine et al., 2003), many such studies are reviewed by Weber (1997) and barriers are summarised as:

- Market Barriers (Jaffe and Stavins, 1994; Brown, 2001;) such as lack of financial incentives for developers (Monaghan and Hobbs, 1995; Scrase, 2001) the low priority of energy issues (Brown, 2001) and lack of knowledge of benefits (de Groot et al, 2001);
- Institutional barriers (Hewett, 2001; de Groot et al., 2001),
- Organisational barriers, including communicational flaws (Scrase, 2001; Mills et al., 2003);
- and Behavioural barriers including professional conservatism, uncertainty and risk (Scrase, 2001; Mathew et al., 2005; Mills et al., 2003).

This shows that, along with financial and technical issues, there are clearly some important cultural issues around more sustainable construction (Cole and Lorch, 2003) including:

- The balance of incentives for designers favours inefficient buildings (Lovins, 1992).
- The dissemination of new knowledge, and adaptation of new approaches in UK construction is poor (Gann, 2003).
- Because of information gaps in the building industry the benefits of energy efficient products are not being valued (Brown, 2001).
- More awareness of environmental impacts in building design is required (Mackley and Milanos, 2001; Bartlett and Howard, 2000).

With such a diversity of barriers it is empirically impossible to find a simple answer to why an energy and environmental impact reduction measure is not undertaken in each case (Weber, 1997). This diversity ensures that many different stakeholders hold an influence over improving the likelihood of using energy efficiency or alternative energy approaches in building projects, for example:

- Local government projects can help to show the way, test new approaches, learn from experience and disseminate results (Theaker and Cole, 2001).
- Feedback from projects to the designers is essential for improving design (Cohen, et al. 2001).
- The design team, and a less fragmented, more integrated and informed design approach are crucial to success (Cole, 2000; Theaker and Cole, 2001, Lovins, 1996; Hawken et al., 1999). This is recognised by Scrase (2001) who highlights the importance of individual roles at the design stage of building projects, suggesting that clients and architects have little interest in improving efficiency and engineers are left to 'overcome the effects of inappropriate building design'.
- Design decisions strongly influence building in-use energy use and environmental impacts (Andreu and Oreszczyn, 2004).
- The behaviour of building occupants is also an important factor affecting energy performance (Horsley, 2003), while building performance also influences occupant satisfaction, health and well-being (Standeven et al., 1998).

This section has shown that there are a wide range of barriers to reducing the environmental impact from the operation of buildings and that there are a number of stakeholders influential in addressing these barriers. The following section highlights how these points are relevant for AETs and their use in buildings.

2.3 Factors affecting the use of AETs

The use of AETs in buildings is a key factor for reducing their environmental impacts. This section reflects on research into the use of these technologies worldwide, the factors that restrict their use and recommendations for overcoming these restrictions.

For the purposes of this research, AETs are defined as renewable energy technologies and CHP embedded generation. Trends showing that the use of renewable energy throughout the world is increasing, though at a slower rate than overall energy consumption, are presented by IEA (2005) and the need for and potential for expansion of renewables is discussed by Sayigh (1999). Meanwhile, targets and trends showing the existing shortfall in the use of CHP and renewables in the UK are published by the DTI (2005a).

The increased use of AETs in the UK is important because, amongst other drivers (REPP, 2001) it meets UK policies (DTI, 2003) and reduces environmental impacts and social impacts (Hohmeyer, 2002), though local social concerns must be considered (Elliott, 2003). With Lovins, et al (2002) suggesting it should be a political priority due to these overall societal, economic, engineering and environmental benefits (Lovins et al., 2002).

The integration of AETs into construction faces a number of barriers. These barriers vary throughout the world, are site and situation specific (Painuly, 2001; Pohl and Gisler, 2003; Shove, 1998), but need to be addressed. Studies have been completed that highlight the barriers to using AETs and provide recommendations for addressing these barriers.

For instance some technology specific studies have been performed for the different technologies, such as:

- Bioenergy (Roos et al., 1999; Rosch and Kaltschmitt, 1999),
- CHP (Bourgeois et al., 2003), and
- Solar Photovoltaics (Oliver and Jackson, 1999; DTI, 1999).

The investigation of market and political barriers and the success of policy options for addressing these are covered in many cases including:

- Internationally (Charters, 2001) including the IEA (2003), who have looked at the effect of Government policies on market development through reviewing case-study performance, market barriers and the role for governments to play in reducing them;
- For developing countries (Worrel et al., 2001; Green, 1999; Maldonado and Marquez, 1996) and
- Developed countries (Pohl and Gisler, 2003; Medhurst et al., 1997) including the UK

(Elliott, 2003). For which, a list of ten rules for defining policies to assist development of more sustainable energy systems are suggested by Elliott (2003), whilst Lovins et al. (2002) provide over 20 policy recommendations for the USA.

Along with these technology-focussed and policy-focussed studies there are also broader, location specific studies, as follows:

- Lovins et al, (2002) discuss 207 general barriers, including 10 challenges that building developers face in looking to employ distributed energy technologies.
- In the context of developing countries, Painuly (2001) suggests 40 barrier elements within 7 categories. Maldonado and Marquez (1996) offer similar barriers summarised into 4 main barrier categories: Market, Technological or R&D, Institutional and Socio-economic; together with 'a lack of technology assessment and selection methodology'.
- Using their framework for analysing innovation, Foxon et al. (2005) consider the factors affecting renewable energy in the UK construction industry from the evidence of gaps in the innovation chain, listing 4 risk factors and 6 other barriers. One of their conclusions is that skills are currently lacking in key areas and need to be developed from R&D through to applied engineering.

Despite research recognising these barriers the lag in the adoption of renewable energy technologies is frequently attributed to the difficulties of overcoming them (Martinot and McDoom, 2000).

Generating an understanding of specific barriers in each context is important for defining policies for improvement (Brown, 2001). The generic treatment of barriers is inadequate for the purposes of preparing projects. Only some of the barriers will be present in any specific situation. The challenge in preparing projects to overcome these barriers is to identify the most relevant and operative barriers in a specific context and to address only those (Martinot and McDoom, 2000).

A framework for assessing locally specific barriers through stakeholder participation was developed by Painuly (2001) and applied by Reddy and Painuly (2004) in a state in India. This study confirmed that technical and economic barriers are not always primary. Shove (1998) conducted international research that showed that technical potential is irrelevant and that all decisions are dependent on social and contextual factors, thus 'technical' and 'non-technical' should not be separated. Roos et al. (1999) produced a similar framework for defining the importance of drivers and barriers to bioenergy to inform policy makers and potential market developers of site-specific issues. Mathew et al. (2005) show an approach to reducing investment risk by developing standard methods for assessment based on a mass of collected information from past projects.

The lag in the adoption of renewable energy technologies is frequently attributed to the difficulties of overcoming barriers – including imperfect capital markets, institutional barriers, poor market acceptance, financing risks and uncertainties, transactions costs not included in market prices, and lack of skilled personnel (Martinot and McDoom, 2000).

It is clear that, despite the policy focus of much of the literature, institutional support will not solve all the problems faced (Douthwaite, 2002) as technical change is a social and highly contextual process (Shove, 1998). There are suggestions for changes in the technology selection process, to account for external (environmental, social and financial) costs along with the direct financial costs (Charters, 1996; Elliott, 2003) and for improving the level of knowledge of technologies and their associated impacts/benefits (Roos, 1999; Worrell et al., 2001; Charters, 2001). This need for change in the approach of selection methods and the options available are discussed in the following section.

2.4 Energy technology selection

This section investigates the approaches available for informing and making energy technology selections and reflects on how these are applied in practice.

Because of the complex nature of designing buildings and selecting energy supply options there is a need to apply structured decision-making approaches. Through practical experience of assisting in the development of building designs and technology selections (as detailed in Chapter 7) it is clear that structured approaches are not being applied. In the UK the selection of energy technologies by policy makers (Elliott, 2003) and in construction projects (Horsley, 2002) is predominantly by simple economic cost criteria, ignoring social and environmental concerns. This is compounded by the fact that the cost advice given by consultants is conservative, based on misconceptions of high capital cost and low value return, which is hugely damaging (Bartlett and Howard, 2000). For AETs to stand a better chance of implementation this common practice needs to be altered, appraisals need to be better informed (Bartlett and Howard, 2000) and account for the value of the environment (Lovins and Lovins, 2001).

In support of these observations it has been shown in Canada that giving design teams more time and funding to consider future building energy performance and energy options in more detail has a positive outcome in implementing alternatives (Larsson and Clark, 2000). Along with additional time, environmental considerations can be better understood by following a participatory approach in decision-making (Wakeford, 2004). Consciousness of these other concerns can also be drawn out by using a set of criteria for making decisions that cover all the issues of sustainability (Elliott, 2003).

However, in the UK even where there are existing tools for informing more sustainable building design, including whole life costing and environmental performance approaches, a lack of reliable data and standard approaches have restricted their use (Bartlett and Howard, 2000). This section presents an investigation into some of the options for standard approaches to decision making, their use and how appropriate they may be in the assessment of AETs in building projects.

2.4.1 Introduction to decision making

Academics have studied the process of decision making from two perspectives: descriptive and prescriptive. Descriptive analysis examines decisions and uses tools to explain and outline how decisions are made without attempting to improve the quality of the decision. Prescriptive analysis uses problem structuring methods and modelling tools to help make better decisions under the assumption that people want to make rational and correct decisions (Clemen, 1996). The decision analysis methods discussed further within this document are prescriptive in nature, in the attempt to improve the results of the decision process. Additionally we are concerned primarily with problems with environmental considerations, which commonly involve a significant degree of complexity and uncertainty.

Some of the appropriate analysis methods are as follows:

- Financial analysis
- Cost-effectiveness analysis
- Cost/benefit analysis (CBA)
- Environmental economics
- Problem Structuring Methods (PSMs)
- Multiple-criteria decision analysis (MCDA)

2.4.2 Description of analysis methods

Financial analysis is a simple financial cost and revenue analysis. The most basic form is the calculation of a simple economic payback, though more detailed analysis is becoming commonplace with the assessment of future value (discounting) and the use of Whole Life Costing techniques.

Cost-effectiveness analysis again looks at purely economic costs, though also includes the cost of lost opportunity and external costs incurred, such as taxpayer costs (DETR, 2000).

Cost/benefit analysis tries to value expected impacts purely in financial terms, under the willingness-to-pay principle (DETR, 2000). This can be very difficult to do, as social and environmental issues are difficult to quantify as a financial cost. There will also be a number of factors that cannot be quantified in monetary terms, and these have to be considered alongside the measurable impacts.

Environmental economics, also referred to as environmental externalities assessment and external cost estimates (ECE), attempts to apply a monetary value to Environmental Impacts. An example of environmental economics is 'ExternE', a European accounting framework for the assessment of externalities associated with different electricity generation systems (CEC, 1997). Through extensive research values have been generated that express the financial cost of a human life, of global warming, visual impact, etc. However, these Figures are based on a large number of assumptions that the user may not be aware of or able to understand.

Problem Structuring Methods (PSMs) are low-tech decision support tools that provide decision assistance for management/expert groups. This is achieved by providing them with a better understanding of different stakeholders perceptions of various risks and values, allowing them to generate an agreement on the nature and boundaries of the system and to develop a shared commitment to action (Horlick-Jones, 2003). PSMs are usually diagrammatical in nature, Clemen (1996) offers two such methods, influence diagrams and decision/value trees, and reference should be made to this work for detailed descriptions.

Multiple-Criteria Decision Analysis (MCDA) does not attempt to value impacts in monetary terms but tries to compare the perceived value of different impacts that may be difficult to quantify, through qualitative assessment. In this method 'hard' data from other forms of analysis is combined with 'soft' social opinion from various stakeholders to produce a more holistic form of analysis.

MCDA allows the analysis of alternatives that may differ on several criteria by understanding the true value (and not just financial value) of each element of the decision. Some characteristics of MCDA, given by the DETR (2000), are that it:

- Combines hard data with informed judgement,
- Distinguishes between facts and value judgements,
- Accommodates for uncertainty, and
- Can accommodate multiple conflicting objectives.

And hence some of the advantages of MCDA are:

- No consensus is necessary,
- It allows complex problems to be handled,
- The robustness of results can be explored,
- It provides an audit trail, and
- Gives a coherent and consistent base.

2.4.3 Building design and the use of decision making tools

Bartlett and Howard (2000) look at the way green buildings are valued and call for construction professionals to be better informed about their benefits to be able to encourage key stakeholders to make more 'sustainable' decisions. They look at the role of the client (tenant, developer, institutional investor and owner-occupier) and their different perceptions of value. Conservative advice from cost consultants based on general misconceptions of high capital cost and low value return is commonplace and hugely damaging as they provide key advice to the client throughout the project life.

The existing process of selecting technology options in the construction industry is based primarily on early project structuring through briefing and brainstorming and analysis via unclassified judgement, practical calculations (size, output, etc.), familiarity and financial assessment. Crucially all options will be finally judged based on time and monetary cost criteria, usually in the aim of capital cost cutting. Even tools highlighted for providing best value in construction (Kelly et al., 2002) are monetary-based and take little account of qualitative aspects.

Hawken et al. (1999) agree that one of the ways towards 'greening construction' is to change the decision-making approaches being used. The existing fractured design process where specialists have separate responsibilities needs to be changed, in favour of an approach where all stakeholders design the building together in a multidisciplinary round-table manner. This supports the use of decision support tools such as PSM and MCDA approaches.

Chung and Poon (1996) suggest that CBA is not appropriate for making environmental decisions as they usually undervalue or disregard environmental qualities. They also disregard the use of purely qualitative analyses, as they are vague and subjective, leading to controversies between parties with different vested interests. Their conclusion is that MCDA is more appropriate because it accommodates quantitative and qualitative information with less subjectivity.

The ExternE approach is compared with a multi-criteria approach with respect to assessment of different energy technologies by Mirasgedis and Diakoulaki (1997). They conclude that though the results from the two methods differ they are similar in magnitude and so offer similar recommendations, hence they suggest that tools such as ExternE are relevant. ExternE also produces results in financial terms, which allows comparison with monetary factors. However, environmental and social impacts, such as the value of a human life, can be seen as subjective and that they should not be represented by a single monetary value. With this Stirling (1995) argues that multi-criteria approaches constitute the more rigorous means to incorporate environmental concern in decision making, and thus are considered to be the ideal method for use in this research.

Bartlett and Howard (2000) consider tools for informing more sustainable building design, covering whole life costs and environmental performance. Whole life costing has been restricted by a lack of complete data on actual building performance being available. Environmental indicator tools have also been uncommon in the past but are being used increasingly due to agreed standard methods and greater interest within the industry.

One of the issues of decision-making is the lack of accurate information. This inhibits all of the approaches described here. Brown (2001) suggests that decision-making complexities are another source of imperfect information that can confuse decision-makers and inhibit ''rational'' decision-making. One way of reducing complexities is to reduce the level of uncertainty from the problem. To help inform the project team Smith (2002) has developed a decision support tool for the selection of 'new and renewable energy systems'. This is a modelling tool that can be used to provide performance estimates of the technologies in a given context, giving predictions of financial, environmental and technical performance.

Another way of reducing uncertainty (Mathew, 2005) is the use of actuarial pricing to inform future investments, based on feedback from previous investments. An extensive database of projects, their construction costs and operational performance is required, which is then used to predict potential future costs and savings. Such an investment tool could also be used for financial assessment of renewable energy investments. This approach reduces the level of uncertainty around financial assessments, however it also requires a 'critical mass' of data and to be continually updated. Such a system may be beyond building consultancies in the UK because of the number of case studies required, and so more appropriate for a major energy supply company or through the role of Government.

2.5 Conclusions to Chapter 2

Though there are references to many barriers, opportunities and techniques relevant for assessing AETs in building projects, there have been no investigations identified which cover how selections are being made in the UK building industry and what informs these decisions. There are a large number of factors that influence the viability of AETs and so the selection of energy technologies is a complex problem. The values, knowledge, perception and preferences of each member of the design team has a strong influence over the design of a building, use of innovation and selection of technologies.

The focus of this research project is on uncovering the role of engineering consultants, the assessment methods used and the key factors that influence the viability of integrating AETs into building projects in the UK. This investigation follows a similar approach to that suggested by Painuly (2001) and followed in a number of similar investigations with different contexts (Lovins, 1992; Larsson and Clark, 2000; Reddy and Painuly, 2004).

2.6 Summary of Chapter 2

The use of AETs in building projects can help to reduce the environmental impact of energy use in buildings. The reduction of environmental impacts from energy use is in line with recent Government policy, however the use of AETs in buildings is still very rare. The use of AETs in buildings is restricted by a vast number of barriers, including technical, financial, social and institutional barriers. These factors have been recognised across the world, and impact on the quest for more sustainable buildings and the generation and use of energy in general. Many of the studies have compiled lists and descriptions of barriers and measures for improvement, without attempting to rank them in terms of their importance. It is also common for these studies to be the result of external observations rather than providing detailed cases studies or being the result of participatory research.

The complexity and unique nature of every application leads to two factors:

- The drivers and barriers vary in importance between the studies completed and depending on the intended audience, for instance studies used to inform policy present different conclusions than those informing technology developers, etc. It is important to define the most important factors for each context so that solutions can be tailored to these specific requirements. The context of installing AETs in building projects in the UK has not been investigated, and needs to be investigated before potential solutions can be developed.
- The complex nature of drivers and barriers that change between each application emphasises the difficulties faced in selecting appropriate applications for AETs. This leads us to consider that more holistic techniques for informing decision-making should be used. Of the techniques considered MCDA appears to have potential for supporting more transparent decision-making and for taking account of factors that may be difficult to quantify, such as social and environmental impacts.

CHAPTER 3 METHODOLOGY AND RESEARCH DESIGN

3 METHODOLOGY AND RESEARCH DESIGN

This chapter describes the methodology used for developing an approach to participative research, designed to obtain the perceptions and experiences of building project stakeholders. The aim of this research is to define the most effective way that building consultants can help to increase the use of AETs in building projects. This chapter describes the rationale behind using a qualitative research approach and application of this approach in 3 phases.

3.1 Development of approaches

For the development of the approach used, social research literature by Krueger (1998), Oppenheim (1992) and Poole (2002) were consulted. The processes covered were then discussed with previous EngD students and staff from Brunel and Surrey Universities, with experience of completing similar exercises (Lowry, 2003; Hunton-Clarke, 2003; Wehrmeyer, 2003).

From these options it was decided that the study would focus on gaining largely qualitative data and allow participants to discuss their experiences openly, building on any insights as they arose. Then as results became more repetitive and predictable, more quantitative methods could be used. It was decided that the investigation would begin using a participatory approach with open questions, to allow participants to discuss the topics and work together to cover a large number of issues. These would take the form of focus groups, the results of which would influence the design of questions for personal and telephone interviews.

The first phase of the participative research process began with a series of focus groups, used to develop a set of questions that could then be used for personal interviews. The focus groups were quickly followed by interviews with 41 stakeholders, broadly representing 8 different stakeholder groups. The conclusions from these interviews led to the development of a second phase of interviews, with the objective of highlighting specific project experiences.

3.2 Focus group

3.2.1 Development

The advantage of using focus groups is that they encourage interaction among the respondents and allow people to change their opinions after discussion with others (Krueger, 1998). However, it is very difficult to bring together groups of building professionals during the working week without any foreseeable personal benefit. Additionally the open nature of the discussion provides highly descriptive and qualitative results that can take a long time to analyse. It may thus have proven expensive and time consuming to use this method alone. The use of personal and telephone interviews was used for further analysis to reduce the time for the study while keeping a personal nature and allowing participants the advantage of human interaction.

This approach closely follows the process used by Poole (2002) that used initial focus groups to develop a set of interview questions, the results of which were reviewed. These results were seen as relatively exhaustive so were then used to form quantitative analysis in the form of a survey, from which a larger sample was generated that could help qualify the results from the qualitative interviews.

For the focus group work open questions were used because they are good for idea generation and can provide a truer reflection of respondents beliefs (Oppenheim, 1992). When these questions were used again for the interviews some were altered into a more closed format to provide more statistical results from the responses generated in the focus groups.

In the design of the questions and their delivery there are a number of important aspects to consider (Oppenheim, 1992). These are listed here with additional text indicating where each may prove relevant in this case:

- Clarity – This is a potential problem with the use of technical and open questions.
- Leading Questions – This has been closely guarded against where possible.
- Phrasing – Avoiding positive and negative aspects.
- Embarrassing Questions – Not applicable in this context
- Hypothetical Questions – Some questions may be hypothetical depending on the nature of the respondent.
- Prestige Bias – People may bias their answers to shed a better light on themselves, though reference to actual projects should reduce this

After developing and testing questions based on the objectives of this investigation, a trial focus group was held. It was attended by a small group of engineers with varying levels of experience. The objective of this session was to trial the questions and to practice facilitating a focus group. This included obtaining a suitable room, testing different transcript recording techniques and becoming familiar with trying to focus a group of strangers toward answering the questions in a structured manner. The session lasted for one hour and proved to be valuable experience.

This initial pilot provided the stepping-stone for the completion of a structured focus group with different stakeholders from within the building industry. Again the questions were refined based on the experience of the first focus group along with direction from Krueger (1998), Hunton-Clarke (2003) and Wehrmeyer (2003).

Possible participants for the session were contacted through consulting with other company employees, previous acquaintances, conference attendance lists and through a mail-shot by The Energy Institute to its London members. From this, it was possible to gain contact with stakeholders with different backgrounds, professions and experiences, though all were familiar with considering AETs in their designs. This process produced a list of over twenty willing contacts, from which around six were required to complete the initial focus group, with others used for the later interviews.

3.2.2 Application

The structured focus group session was held on 8th August 2003 in London, attended by a group of 6 stakeholders with different backgrounds, professions and experiences, the details of which are provided in Table 3.1. Each member had experience of considering AETs in building projects, and each held a senior position within their organisation.

Table 3.1 Details of focus group participants

Name	Role	Title	Company
Rob Cooke	Facilitator	Research Engineer	Buro Happold
Andrew Cripps	Assistant facilitator	Research Group manager	Buro Happold
Craig Anders	Architect	Partner / Design Director	Cole Thompson Associates / INTEGER
Neil Billet	B.S. Engineer	Partner	Buro Happold
Ian Guest	B.S. Engineer		Buro Happold

Adrian Jackson-Robins	Project Management		Davis Langdon Consultants
John Morgan	Architect		Allies & Morrison
Michael Pawlyn	Architect	Associate	Nicholas Grimshaw & Partners

The objectives of the focus group were to:

- Test and develop a series of structured questions to be used for personal interviews, through brainstorming and sharing experiences.
- Generate a rich set of data from experienced professionals capable of exploring an issue from different perspectives.
- Produce a first set of results towards understanding how members of a building design team can help improve the effective implementation of new and renewable energy technologies in building projects.

The questions used and conclusions drawn from the answers given are as follows:

<u>Question 1 – What technologies do you consider are covered by the heading 'new and renewable energy technologies'?</u>

- It is useful to define the list of technologies at the beginning of the process to ensure everyone begins with the same understanding.

<u>Question 2 – From the definition used for the purposes of this research please indicate at which stage you have considered these technologies in building projects. The options for this are concept design, detailed design and construction.</u>

- There is a consistent consideration of the various options at concept stage (apart from for hydropower). However there is a noticeable lack of consideration for Biomass energy and CHP beyond concept stage.

<u>Question 3 – How much of a part does the consideration of these technologies have to play in building projects? How does this compare with other aspects of the design?</u>

- The importance of using AETs depends on the individual project and the client involved. These technologies are often seen as extras to the core scheme, so not as important as other aspects.

- When a group is 'enlightened' these technologies are seen as more important.

Question 4 – Based on your experience, what have been the drivers for using these technologies in building projects?

- The main drivers were image, a sense of responsibility and economics, with subsidies being a unanimous last place.

Question 5 – Based on your experience, what are the main barriers for using these technologies in building projects?

- An outstanding barrier was high capital cost.
- There is a common theme that financial aspects are primary issues, as positive and negative.

Question 6 – In the building design process how are the negative and positive aspects of these technologies considered and compared?

- Beyond the consideration of financial payback there was little other mention of other techniques for the comparison of different energy technologies.
- Another point of issue made was risk and uncertainty, but there was no offer of how these points are compared.

Question 7 – In the selection of energy technologies how are quantifiable factors compared against some of the less tangible factors?

- There was a key point that members of each design team will have different views on the same issue and it is essential to have the key arguing tools available to ensure that negative views can be overcome.
- The need for accurate information and proof of previous experience/success is essential. Understanding the specific project and client needs and providing appropriate solutions was also reiterated.

Question 8 – How can the building industry help to improve the effective implementation of new and renewable energy technologies?

- Precedence studies, post occupancy analysis and accurate and readily available information in a suitable format is required. Who needs this information was not really defined, whether it be all parties or select members, though consultants were seen as having a key role with regards to communication.
- The government needs to keep forcing energy as an important issue.
- The subject of existing buildings is crucial if we are to make significant changes. It was not clear how building consultants could play an effective role in this area.

The session lasted for about one and a half hours in total, including twenty minutes of discussion following on from the final structured question. The level of involvement from the participants was very high and a large amount of rich information and insights came from the session. Along with these insights the group also provided a very useful list of drivers and barriers that allowed questions 4 and 5 to be refined into a more qualitative and comparative format for the interviews. These interviews will be now be used to generate a much larger sample to provide more concrete evidence for analysis and the generation of conclusions, as discussed further in Chapter 4.

3.2.3 Interim conclusions

In summary some interim conclusions from the focus group work are as follows:

- financial costs and benefits are considered the most important by people within the building industry and that only financial techniques are used for system comparisons. This seems to back-up the proposals for development of a new decision tool, but still requires more data to be scientifically valid.
- The focus group results also suggest that building consultants are seen to play an important role in the integration of AETs and the breaking down of uncertainty/knowledge barriers.

3.3 Interviews

3.3.1 Introduction

The results of the focus group work helped to prepare and test a list of questions that could be used for a programme of interviews. Focus groups allowed a range of answers to be given and for definitions to be agreed, however they were not suitable in this case for data collection and analysis. The participants in this research are 'elite', from specific professions and with specific experience not commonplace in the building industry. It is these people's experiences that are important and so the data capture process used was personal interviews, through face-to-face meetings and pre-arranged telephone interviews. This method ensures that the data collection process is faster and avoids ruling out stakeholders because they are too busy to attend a focus group whilst maintaining the facility to obtain descriptive answers.

The personal and telephone interviews began in October 2003, with 41 interviews completed by 22 April 2004, consisting of 5 participants broadly representing each of the 8 predefined stakeholder groups (with 6 participants representing building services engineers). This small sample does not provide a statistically significant representation of the stakeholder groups, but is chosen to give a broad insight into a range of views across the industry.

3.3.2 Ethics and safety

Though this is not a contentious subject the study is based on personal experiences and opinions and the participants need to feel that they can give their full and honest opinion without fear of reproach. Therefore the research methodology was developed with reference to the British Sociological Association's Statement of Ethical Practice (BSA, 2002) and to the guidance provided by Arskey and Knight (1999).

The participants selected represented a range of stakeholders and from a broad range of backgrounds, though it was essential that each had experience of building projects that had considered using AETs in the design process. Contacts were generated via other engineers at Buro Happold, through meeting relevant people at conferences and then through suggestions made by participants. Therefore most introductions were 'cold', with participants not knowing the interviewer in any capacity. This introduction period was used to determine whether the contact would be a suitable participant and willing to take part.

The introduction and interview process used in this study follows the concept of 'informed consent'. Measures have been taken to safeguard participant's privacy and welfare and their right to choose whether or not to take part. Each participant was provided with a detailed description of the research, its purpose and of the questions being used before they took part in the interviews. They each had the opportunity to reject the invitation to complete the interview at any time before and during the process. This process was chosen based on the suggestion from Arskey & Knight (1999) that:

> "If the research format is a relatively innocuous structured questionnaire, then it is sufficient to present a short description of the research and what is involved, making it clear that respondents are free to refuse to answer any questions they consider private, embarrassing or whatever. Here the emphasis is on accuracy rather than comprehensiveness."

This initial contact included explanation of the basis for the research, the reason for needed their opinion and the time and thoughts that were required from the contact. This was followed by an email, a typical example of which is as follows:

As a brief introduction; I am trying to complete personal interviews with various stakeholders in the building industry (clients, contractors, planners, etc.) regarding the integration of new and renewable energy technologies into the built environment. The results from these interviews will inform my work toward an Engineering Doctorate in the long term and a journal paper in the short term.

I would appreciate it if you could help me by sparing 30 minutes of your time to partake in a telephone interview in the next week or so. Alternatively if you feel that you do not have the time I would appreciate it if you could help me by recommending another colleague or contact.

After this initial contact the question format was also forwarded to the potential participant and a date arranged for the discussion to take place. Sometimes this date was close to immediate and other times it was planned for a number of weeks in advance. In all cases the participant was given the opportunity to read all of the questions and a background description to the investigation, before the interview took place.

This background description included:

- The purpose and nature of the study.
- Contact details of the researcher.
- Details of the supporting organisations, Brunel University and Buro Happold.

- Details of the questions being asked
- The anticipated length of the interview
- The intended use of the information, publication within the EngD thesis and in a refereed journal paper.

Each of the participants was given the opportunity to reject the invitation to answer any of the questions, and in a few cases the participants did ask to pass on questions 4 and 5, because they felt they could not answer them sufficiently. At other times participants held back on mentioning the names of specific projects to maintain confidentiality, and this has been respected.

In the interests of privacy all names have been removed through the analysis process, with each participant attributed a code according to their stakeholder group, for instance participant A1 is the first architect interviewed. The detail of this coding is presented further in Appendix A.

3.3.3 Selection of participants

This section introduces the sample used for interviews and then discusses how the answers generated have been organised and categorised for analysis.

The final sample obtained for this phase of interviews broadly fit the stakeholder descriptions given in Table 3.2.

Table 3.2 Interview sample for Phase I interviews

Suppliers	5
Consultants	5
B.S engineer	6
Contractor	5
Architect	5
Project management / Q.S	5
Planner	5
Client	5

The definitions used are broad in their nature, as no two roles will be identical and the experiences gained within those roles will vary for each participant. Each of the participants had a varying level of experience of the building industry and of the consideration of AETs. It is not the aim of this research to make general assumptions that the views expressed are representative of the whole industry, but only to make distinctions within the sample used. It is the first aim that in conducting this research again the method used could be replicated, however it is not possible to promise that the results and conclusions obtained from this repetition would be the same.

People do not fit neatly into these definitions. The building industry is not consistent in its roles, in the way that people will play a different role in each project they undertake. The level of control and influence a party has will vary from project to project. Some of the participants had an education and previous experience of other roles within the industry, or in other industries.

Many of the participants had held previous roles, such as a client who trained as an architect and a contractor who had gained a doctorate in the geology of glaciers. Some participants held senior roles and had overseen a number of projects, some had only had experience of one particular application, others may only recently have become involved in the consideration of these technologies, or in the building industry, whilst others had been involved at a hands-on level. Some participants felt that they would not be able to provide much in the way of new insights or useful answers, especially where they felt they had a limited experience. Some participants were very forthright with their views, especially with the points they felt strongly about and had clearly spoken about before. There was a varying response from people of different ages, from retired practitioners who had seen alternative technologies of many different forms in the past, to company directors working on the 'cutting edge' to recent graduates still learning the ways of the industries, and perhaps optimistic for the future.

In the description of the participants below the names of the persons and their organisation has been removed but included are their stakeholder group a description of their role in their company and the interview date. Other particular professional experiences are sometimes included within the interview text. Additional information that is held and could be added is: an approximation of their age, details of their involvement in projects, details of their experience of AETs, how they came across in the interview, whether they were rushed for time and details of how the came to be a participant in this investigation.

The participants have been coded in terms of their stakeholder group and the order in which they were completed. This sample has been made up with the following participants:

Code	**Stakeholder**	**Role**	**3.3.3.1 Date**
A1	Architect	Practising academic and low impact building designer	15/12/2003

A2	Architect	Partner	16/12/2003
A3	Architect	Retired Professor	16/12/2003
A4	Architect	Senior partner	23/12/2003
A5	Architect	Senior partner	23/03/2004
B1	B.S engineer	Project engineer	12/12/2003
B2	B.S engineer	Associate	24/12/2003
B3	B.S engineer	Associate	15/03/2004
B4	B.S engineer	Partner	23/03/2004
B5	B.S engineer	Group director	14/04/2004
B6	B.S engineer	Partner	15/04/2004
C1	Client	Engineer, responsible for energy and water efficiency	04/03/2004
C2	Client	Head of conservation design	10/03/2004
C3	Client	Energy conservation officer	14/04/2004
C4	Client	Head of mechanical services	16/04/2004
C5	Client	Head of sustainable development	19/04/2004
O1	Consultant	Consultant	23/10/2003
O2	Consultant	Consultant	11/12/2003
O3	Consultant	Sustainability consultant	16/12/2003
O4	Consultant	Academic, working with planners. Previously energy manager for local authority	02/03/2004
O5	Consultant	Energy services consultant/CHP advisor	18/03/2004
P1	Planner	Head of planning	22/12/2003
P2	Planner	Energy officer, sustainability/planning	13/03/2004
P3	Planner	Sole practitioner for town planning	22/03/2004
P4	Planner	Director of operational services	24/03/2004
P5	Planner	Partner	15/04/2004
Q1	Project management	Sustainability consultant	16/12/2003

Q2	Project management	Leisure development manager	18/03/2004
Q3	Project management	Client project manager	14/04/2004
Q4	Project management	Group manager	15/04/2004
Q5	Project management	Associate	15/04/2004
S1	Supplier	Projects manager	23/10/2003
S2	Supplier	Sales director	23/10/2003
S3	Supplier	Managing director	10/12/2003
S4	Supplier	Finance director	16/12/2003
S5	Supplier	Technical manager	02/03/2004
T1	Contractor	Senior engineer	15/12/2003
T2	Contractor	Principal building services manager	11/03/2004
T3	Contractor	CSR manager	15/04/2004
T4	Contractor	Director	19/04/2004
T5	Contractor	Environmental manager	21/04/2004

A breakdown of additional information from the interviews that may add further depth and understanding of the nature of the interviews is provided in Appendix A.

3.3.4 Questions

As mentioned before, the development of the questions used for the structured interviews came through the focus groups, practice interviews with trial participants and discussions with supervisors. They are designed to be clear, concise, not leading and to provide results that are relevant to the aims of the research. The main aim of the research is to investigate how the role of the building services engineer can influence more frequent use of AETs. To do this it is necessary to define the main drivers and barriers in the building industry for doing this are, and to define how the building design approach takes account of these. The role of the building services engineer and the approaches used for making design decisions in the consideration of energy technologies are both key factors in this research.

The questions used in the interview were designed to uncover the experience of participants, their experiences of drivers and barriers, the approaches being used for assessment and how the industry can influence further use of AETs. The process was designed to take no less than 30 minutes, and no more than 1 hour under reasonable circumstances. Eight questions were used as a basis for focussing the comments made by participants, though they were not closed questions and were used to inform rather than restrict the nature of answers.

The final question format used in the interview process is as follows:

1. What technologies do you consider are covered by the heading 'new and renewable energy technologies'?

2. From the definition used for the purposes of this research please indicate at which stage you have considered these technologies in building projects. The options for this are: (A) concept design, (B) detailed design and (C) construction. Please also list any projects of significance.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP

3. How much of a part does the consideration of these technologies have to play in building projects? How does this compare with other aspects of the design?

4. Based on your experience, what have been the drivers for using these technologies in building projects? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies		Image		Planning	
Environment, e.g. Climate change		Long-term economics		Lack of infrastructure	
Politics		Corporate social responsibility		Plant space	

5. Based on your experience, what are the main barriers for using these technologies in building projects? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee		Proximity to resource		Cost (High capital and slow payback)	
Climate (variable)		Ignorance and lack of		Perceived risk	

		understanding			
Stubbornness of energy industry		Incoherent Policy and Planning constraints		Unsuitable site	
Maintenance		Complexity		Unproven	
Lead time in construction		Environmental and Ecological impacts		Communication and common language	

6. In the building design process how are the negative and positive aspects of these technologies considered and compared?

7. In the selection of energy technologies how are quantifiable factors compared against some of the less tangible factors?

8. How can the building industry help to improve the effective implementation of new and renewable energy technologies?

- With reference to Question 3, how can these technologies be made to play a greater part within the building design?
- With reference to Question 7, what approaches should be used for comparison of quantifiable and less tangible aspects?
- How important is the building consultants role in the selection of these technologies and how they can best influence their integration into buildings?

3.3.5 Question design

These questions were developed through discussions with colleagues and supervisors and also altered slightly during the interview process. Some changes of note are the development of questions 4 and 5 into closed questions based on the headings produced from previous focus group analysis. The first three interviews used an open format without the use of scoring, and it was soon obvious that the results being produced would be difficult to compare and may miss important insights. The used of a pre-defined list of drivers and barriers saves time used in the interview process are provided at the rear of this report in Appendix A. Each question is analysed in turn within this chapter and the results summarised in the following chapters.

This final format of interview questions were designed to:

- Question their perspective of what constitutes new and renewable energy technologies.
- Assess their experience of considering these technologies in building projects and to

understand how successful the technologies were in reaching various stages of the design process.

- Test whether the inclusion of AETs is perceived to be an important consideration in building design and hence whether the detailed assessment of these technologies can be justified.
- Determine the major drivers and barriers to using AETs in building projects. This judgement is used to justify whether existing methods or other decision making approaches would reflect these drivers and barriers more adequately.
- Allow reflection of which areas can be influenced by the work of the building consultant, and so help to focus future study.
- Investigate the methods used in for addressing drivers and barriers and making system selections in practice. This should reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.
- Ask: "how can the building consultant best influence the drivers and barriers to using AETs, if at all". This allows earlier points to be revisited and expanded upon and should help summarise whether or not it is worth the building consultant trying to influence the decision making approaches being used, or if another route is more worthwhile.

3.3.6 Note taking and transcription

The method used for obtaining the results was note-taking as opposed to tape or video recording. Note taking provides partial transcripts capturing the key sections of the interview. It is a relatively cheap approach and is quick to do. The purpose of note taking was to gain a sense of the things that mattered to the participants, to capture those on the spot and to focus the answers whilst they were being generated. Because of the time constraints the interview answers were generally concise and focussed directly on the questions in turn, with only few instances of entering into other subjects.

Participants were of an 'elite' nature and so it was necessary to take any opportunity available for conducting the interviews. When the opportunity arose the interview was conducted as fluidly as possible, with the interviewer (working alone) taking notes in typed or written form as quickly and concisely as possible. Because the notes were taken in this way the participants were warned before hand and the interview was paused and reversed where necessary to allow the notes to catch up. Because of this discussions had to be quite tightly managed. Answers tended, as is common, to have a complex, wandering and looping structure. Immediate note-taking allowed for reconfirmation and clarification of points that were not clear while the interview was taking place.

After each interview was completed the notes were checked immediately for spelling and grammatical errors, which were mostly due to typing errors, and to adjust comments reduced to shortened forms during initial capture.

The problems with the style of interview chosen include the following:

- The notes do not capture the comments made by the interviewer, so miss the exact wording of questions, sub-questions and any direction given.
- Many meanings are reduced to the neatness of note summaries, disguising the complexity and subtlety of the interviews.
- It is not possible to capture pauses and other personal attributes, such as attitude and reaction.

However Arksey and Knight (1999) recognise that a level of intuition in note-taking is to be expected to some degree: "Decisions are made about the ways in which speech is represented, there are invariably guesses about what was said, and there is the issue of how to turn speech into written prose."

3.3.7 Credibility

There are many limitations to this study, some of them are:

<u>Experience</u>

- Participants do not fit into clean stakeholder groups.
- They are not equally representative of the titles they are given.
- They all have varying levels of experience in the building industry and with regard the consideration of energy technologies.
- Variation in the level of responsibility, influence and involvement in decision making.
- Some have academic influence, or play more of an overseeing role, others have practical hands-on experience.
- Every participants' understanding of the term new and renewable energy technologies was different, some people saw the two terms 'new' and 'renewable' as exclusive to each other, while others considered them to be inclusive, and so 'old renewables' were

not relevant.

- This lack of consistency of definitions and levels of experience possibly explains some of the problems faced when conducting projects. It is interesting to see the different perceptions that people within the building industry have of this technology title, especially those without a firm education of energy and energy systems. Variations in perception are in the nature of human beings so it was always going to be apparent in personal research as conducted here.

Preparation

- In all cases the participant was given the opportunity of seeing the questions before them.
- In some cases they had read and noted answers prior to the interview taking place.

Interview Process

- The interviewer tried to focus every one of the interviews to using a standard definition, explained before beginning question 2. This was to try to maintain consistency throughout the various interviews.
- There is variation in the amount of time it took to conduct each of the interviews
- There was a delay between conducting the focus group and completing the study of around 9 months, during that time the words and approach used has developed with the experience of the interviewer.

The methods used to capture the information have been consistent but have their own limitations:

- It is not always possible to capture everything that is quoted and to some extents there is a natural process of mental selection both by the interviewee and the interview.
- Sometimes the ideas being expressed or attempting to be expressed are not understood in the manner that was intended. Though all attempts were made to repeat and expand on points that did not seem to be immediately clear.
- Because of the personal and interactive nature of the interviews the structured question are used for a basis as an opening but beyond that further questioning is used to probe the points made further.
- It was necessary to channel the participants to focussing on the subject as intended.
- Sometimes aspects of answers are not clear and sometimes the participant can provide an answer that does not seem to relate to the question being asked.

- Some people wanted to answer their own questions and offered questions of their own; this shows an involved thought process but does not always relate fully to the investigation being conducted.

3.3.8 Data analysis approach

"Data analysis is the process of bringing order, structure, and meaning to the mass of collected data. Qualitative data analysis is a search for general statements about relationships among categories of data; it builds grounded theory." (Marshall & Rossman, 1989)

The analysis procedure broadly follows the recommendations of Marshall & Rossman (1989) as follows:

1. Organise the data
2. Generate categories; identify salient themes, recurring ideas or language, and patterns of belief that link people and settings together. This is a "creative process that requires making carefully considered judgements about what is really significant and meaningful in the data."
3. Test the emergent hypotheses against the data. Search through the data, challenge the hypotheses, search for negative instances and incorporate into larger constructs if necessary.
4. Search for alternative explanations of the data. As patterns emerge in the data the researcher must challenge the very pattern that seems so apparent. Search for other, plausible explanations for these data and the linkages among them.
5. Write the report, engaging in the interpretation act, lending shape and meaning to the raw data

In this study the questions have been designed to be independent of each other however also to follow a logical story. Each question directly asks about the project experience of the individual. The early questions allow the respondent to introduce the projects and the reasoning behind the consideration of AETs. This is developed to allow reflection of specific drivers and barriers and the assessment methods that influenced the selection process. The interview is concluded by building on the past comments to ask about the best way forward and the necessary steps for increased use of AETs in building projects.

The analysis of the data involved categorising and grouping common answers for each question in turn whilst also keeping note of insights that were not direct answers to the question. These other insights provide useful context and can influence overall conclusions. After analysis of each question there is a period of analysis of cross-question results, and the results of all analysis used to generate the project conclusions.

3.3.8.1 Generation of categories

The answers have been organised and categorised within each question, through the following stages:

- STEP 1 Edit the transcripts so that they are logical and without typing errors.
- STEP 2 Transfer all results into their relevant answer sheets in Excel.
- STEP 3 Categorise each of the answers and code where necessary.

The categorisation of answers involved taking the quotations from each interview and splitting them into themes as appropriate. For instance each participant may give a number of answers to a single question in the form of a list or a number of different examples.

The raw data was organised by breaking out independent statements. Once each of the statements were separated for each of the questions they could be studied together in depth. Taking one question at a time the statements were grouped into loose categories, this was completed for all answers and then each of the categories reviewed. Qualitative answers can often fit into more than one category or sit between categories. The categories were reviewed a number of times to ensure that the definitions were representative of the answers and also consistent.

Within some of the categories there are also subcategories, for instance many of the answers made reference to using financial calculations, whilst there were also reference to specific methods such as whole life costing. In this case the consideration of whole life costs would be a subcategory of considering costs.

Once the categories were confirmed it was clear that some are identical between questions and that answers are not always directly relevant to the question asked but perhaps more relevant to a different question, or study! From this categories can be seen in two ways – as answers directly relevant to the immediate question or as a cross-question response. The first phase of analysis is concerned only with bringing out the salient themes from each question in turn. This is then followed by cross-question analysis, which involves looking back through the data to ensure that answers from the same participant for different questions are not counted more than once.

3.3.8.2 Test the emergent hypotheses

The categorised data is used to challenge the hypotheses, through searching for disconfirming and confirming information. This interpretation should show either:

- That the original hunch cannot possibly be sustained
- That the original idea needs modifying, perhaps by introducing a new variable.
- That situational or site-specific factors should be considered.
- Further research is needed.

The first test is of the hypotheses is through analysis of the individual questions, one at a time. The direct answers to each question are brought forth and then counted. This gives a numerical answer to the question being asked, allowing a comparison between the number of votes answering in a positive, neutral or negative sense. Colour and context are brought into these responses through selecting typical quotations from the answers that highlight the main points presented, and also through the use of sub-categories where further arguments are made in sufficient numbers.

3.3.8.3 Search for alternative explanations

The patterns and explanations given from analysis of each question in turn can be checked and modified through the use of cross-question analysis. Sometimes an answer may not appear to be significant in each of the questions, but through accounting for all answers across the interviews they can show their prominence.

A number of the answer categories are not directly relevant to the question to which they were given. Sometimes the respondents offered insights that were more relevant to later questions in following their own train of thought through a response. After analysis of each question in turn the answers for each category are analysed across the questions. The most common categories are considered in turn, a process that involves ensuring that answers from respondents are not missed are also are not counted more than once, as participants may well make the same point more than once in an interview.

3.3.8.4 Reporting

Reporting of the results of this analysis process, for each of the 8 questions asked during this first phase of interviews, is provided in Chapter 4 of this thesis. The methodology followed for producing this report is explained as follows:

During the interviews, written notes were taken to record the answers given by the participants, these notes were immediately transferred into the computer. The qualitative answers have been categorised into answer categories appropriate to each question. Numerical answers (to questions 4 and 5) have been transferred into a spreadsheet and the results presented using box and whisker plots, which show the minimum, maximum, median, upper quartile and lower quartile results.

The analysis of the answers given to each question has been developed in the form of an interpretive model, with a summary description of answer categories and illustrative quotations followed by an interpretation. Details of the raw data, broken into the relevant categories, are also provided in Appendix B, for reference.

In terms of category generation, the categories identified for each answer have not been ordered in any particular way, the selection of categories is a trial and error process, and so they are not generally produced in a logical or predefined order. The category headings have not been closely defined and only offer a brief and broad description of the answers given. They are only used here to give a general view of the type of answers given to assess whether the answers are relevant to the objectives of the investigation.

The analysis does not compare the variation in answers between different stakeholder groups or other possible participant categories. Given that each stakeholder is only represented by a sample of 5 or 6 it would be difficult to make sweeping reflections on the views of each group from the answers given.

With further analysis or additional research the following variations could be analysed:

- Core building industry professionals (ABQT): architects (A), building services engineers (B), project managers (Q) and contractors (T), opposed to those not focussed solely on the building industry (COPS): clients (C), consultants (O), planners (P) and suppliers (S).
- Variations in age/number of years experience
- Variations in experience of integrating AETs in building projects.

3.4 Project audit

3.4.1 Introduction

As described in Sections 3.2 and 3.3, Phase I of this investigation comprised a focus group and a series of personal interviews with 41 chosen representatives of the building industry. This study asked a number of questions that investigated general experiences from considering these technologies in building projects. The results of these interviews show that there is a broad range of experiences and opinions held by stakeholders within the construction industry on the subject of alternative energy. This variation is partly due to the different backgrounds of each respondent, the large differences between projects, in terms of project type and design motivations and differences between each technology.

This second phase of the investigation looks more closely at 24 relevant projects in turn, forming case studies that can be compared against the more general insights and conclusions generated in Phase I. This approach has helped to provide an insight into the project-specific drivers and barriers, and investigate the approaches used and influences of the decisions made throughout the design process.

The results were subject to much less variation than in Phase I for the following reasons:

- Only building services engineers are interviewed, so removing the variation of perspectives between the different stakeholder types.
- Each project is assessed in turn and in detail, so answers are specific rather than general observations. This makes it easier to recognise any relationships of cause and effect.
- Some of the projects have only considered a small number of the AETs, and in some cases only one in depth. This allows for specific technology drivers, barriers and other issues to be brought out more clearly.

Using this more directed investigation approach the objectives were to determine:

- Whether the consideration of AETs is commonplace and important in building projects,
- the approaches for comparing and selecting energy technology options being used in practical projects within Buro Happold,
- the effective drivers and barriers to success of AETs, and
- the most effective appraisal approach to use in future, based on the experience of building services engineers.

3.4.2 Research design

As already mentioned, this phase was applied to investigate the different approaches used in practice for a number of selected building projects. Phase I interviews were not specific toward projects or energy technologies; they sought to investigate the general perspectives of industry professionals and identify the range of opinions and experiences. This second phase uses a similar question format but is limited to building services engineers and their experience from specific projects. This approach was followed because it allowed for further clarification of the earlier results, further comparison and more directed analysis. The process for this investigation is represented in Figure 3.1.

As with Phase I of the investigation, a participative research approach was used. It was important to obtain individual experiences of projects, and so a one-to-one interview method was chosen. Because the participants were within the same company it was easier to conduct all interviews on a face-to-face basis rather than phone interviews.

3.4.3 Ethics and safety

A similar process for maintaining ethics and safety within this investigation was used to the first phase of interviews. The nature of the subject is not sensitive and the research is focussed on the general perceptions of the project design process rather than the fine points of individual points of view, hence the process used in this study follows the concept of 'informed consent'.

The participants were introduced to the project objectives and confidentiality arrangements and provided with a copy of the structured question format before each interview was conducted. They were informed that the projects might be used as case studies in the final thesis and within a scientific journal paper, but that the names and details of all study participants would remain confidential. Some direct quotations would be used to illustrate points, but all reference to participants would be coded. The interviews were recorded using audio recording equipment, subject to the participant's agreement.

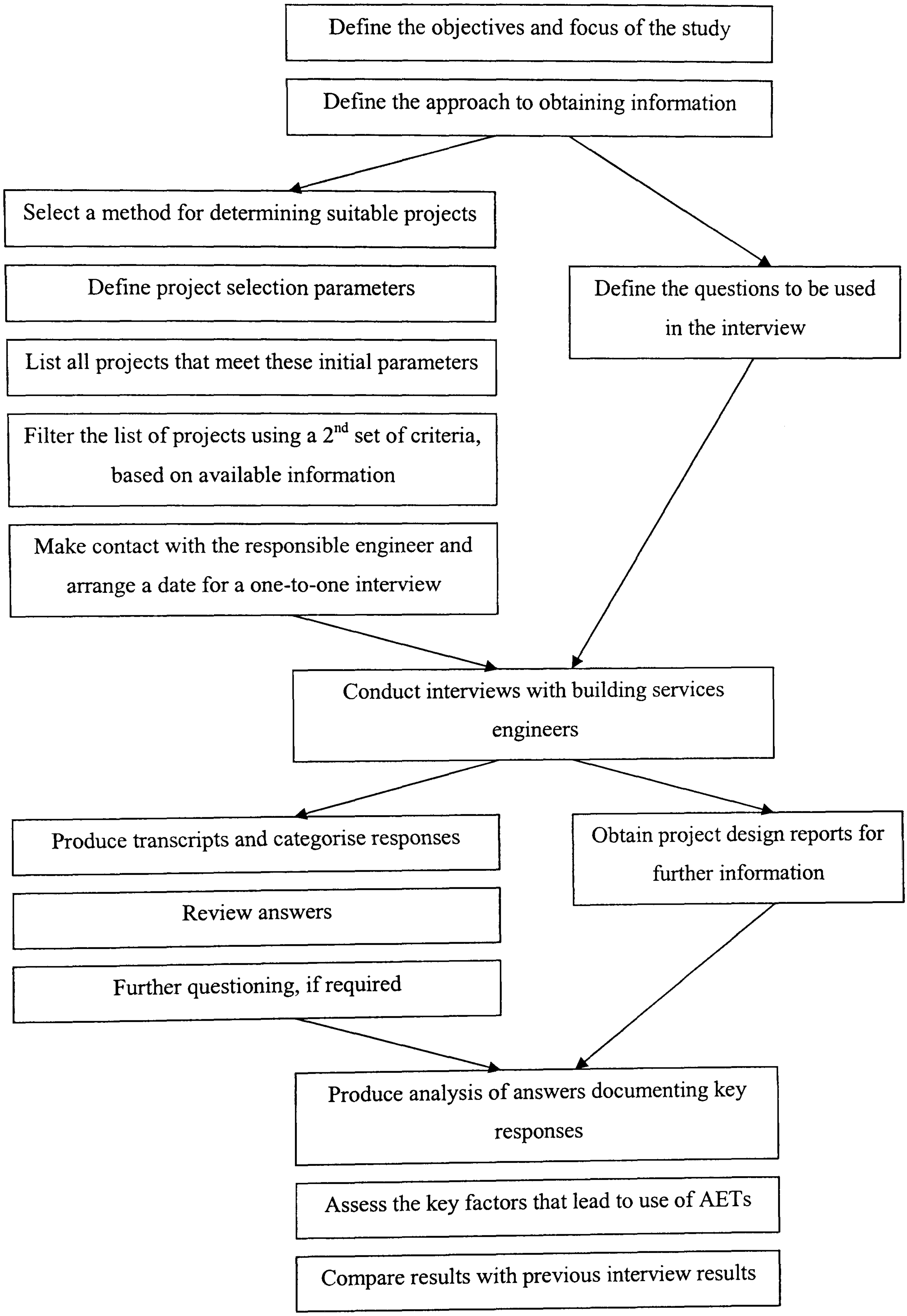


Figure 3.1 Stage II investigation process diagram

3.4.4 Selection of participants

The criteria for selecting projects was originally as follows:

- Project life: Existing projects must have reached tender stage by January 2005 and past projects must have gone to construction stage post January 2002.
- The projects will have had input from building services engineers within Buro Happold, so providing access to design reports at each stage.
- Have considered AETs in the design process. Ideally some of the projects will have included them through to construction.
- Project reports will be readily available
- Key Buro Happold project team members will be available for interview

Selection of projects was proposed to be via a company database labelled the Project Environmental Checklist. This list should be completed at each stage of every project, concept, scheme, detailed and tender stages, with two of the checklist items being the inclusion of renewable energy technologies and on-site energy generation. However, it soon became clear that the projects could not be selected via this database as it is not a compulsory procedure, nor is it completed accurately when used.

Instead projects were chosen through contacting building services group managers and partners for each office who either answered questions on projects where they had personal experience or delegated the responsibility to the relevant engineer. Due to the one-to-one approach used, the internal relevance and a high degree of interest from engineers the response rate was very high and a larger number of projects were reviewed than previously anticipated.

In total 24 projects were reviewed in this process, with one of the projects covered twice (by two different engineers who worked on the same project). It was not originally considered possible to cover this many projects, as this is nearly all the relevant projects in Buro Happold, but due to high levels of enthusiasm from the engineers and the opportunity to obtain so many cases it seemed logical not to restrict the numbers.

There were some major projects that were not included in the research, the BBC White City development, the Royal Mills project in Manchester and the Wessex Water Head Quarters. This was because the engineers were not available at the time, or had moved on to other practices.

The sample of projects used is presented in Table 3.3.

Table 3.3 Phase II projects, identifiable numbers and building types

Number	Project name	Main building type
2762	Techniquest	Exhibition
5420	Lambay island	Special residential
5426	Old Hall Street Liverpool	Hotel/leisure/residential
5538	Finglass swimming pool	Leisure
5671	Genzme HQ	Offices/light industry
5864	Portland Square, Plymouth	Academic
5947	Daintree	Residential/commercial
6076	TAG Aviation	Special commercial
6108	Carterton leisure centre	Leisure
6915	HSE Headquarters	Offices
7238	Copenhagen Elephant House	Exhibition
7272	Nottingham Academy	Academic
7408	Syddansk Uni and Science Park	Academic/entertainment
7427	Eden - Phase 4	Exhibition
7439	West Tallaght Swimming Pool	Leisure
7502	Northampton City Academy	Academic
7609	Liverpool Kensington Academy	Academic
7617	Rehan Electronics	Light industrial
8134	Coillte	Exhibition
8209	Edinburgh University	Academic
8285	Carlyon Bay	Residential/mixed use
8496	Guildford civic hall	Residential/office
8869	Bermondsey Spa Sites E-U	Residential
8933	New Islington Wharf	Hotel/residential

There is a wide range of types of building, their location, the type of client and the overall scale. A short description of each project outlining this diversity is given in Appendix C.

3.4.5 Questions

The questions used are as follows:

1. Please give your perception of the initial project brief and project meetings. Within these were there any references made to aspirations toward considering AETs? For instance aspirations toward innovation, low-energy design, environmental impacts, etc.

2. At what stages of the design were each of the AETs considered?

3. How much of a part did the consideration of these technologies have to play in this project? How does this compare with other aspects of the design? Which project team members were influential in this?

4. What have been the drivers for considering AETs in this project? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies	Image	Planning
Environment, e.g. Climate change	Long-term economics	Lack of infrastructure
Politics	Corporate social responsibility	Plant space

5. What have been the barriers for considering AETs in this project? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee	Proximity to resource	Cost (High capital and slow payback)
Climate (variable)	Ignorance and lack of understanding	Perceived risk
Stubbornness of energy industry	Incoherent Policy and Planning constraints	Unsuitable site
Maintenance	Complexity	Unproven
Lead time in construction	Environmental and Ecological impacts	Communication and common language

6. In the building design process how were the negative and positive aspects of these technologies considered and compared?

7. What techniques were used for informing the decision making process, especially for comparison of quantifiable factors with some of the less tangible factors?

8. What changes would have helped to improve the effective implementation of AETs? Specifically how could the approach of the building consultant help this?

3.4.6 Question development

The questions used were mostly qualitative open questions, however questions 4 and 5 are quantitative. Questions 4, 5, 6 and 7 are very similar to the phase I investigation, whereas questions 1, 2, 3 and 8 changed, to produce more project relevant results. The questions are now more focussed toward the individual project experience rather than general experience and observations. For example question 1 asks about the initial project aspirations, and other questions refer to "this project".

The first three questions are aimed at finding out the level of importance that AETs held during the design process, from inception through to final construction, how this changed, and the roles of project team members in attributing any importance to them. The second set of questions, 4 & 5, ask the engineer about their perception of the effective drivers and barriers to using these technologies, with a list of such influences already provided which were then attributed a numerical score out of 10. The following two questions, 6 & 7, then inquire about the methods used to inform the judgement between energy supply options. These highlight whether qualitative aspects were considered in the selection process and which techniques, if any, were used to inform the judgement of decision makers. All these questions are retrospective, asking about the impacts, considerations and influences of the past; the final question moves the subject onto the future and asks the participant to suggest ways forward, toward helping AETs become more commonplace.

The initial rationale for completing this investigation was the hypothesis that: The use of a multiple criteria decision making approach (by the building consultant) would improve the likelihood of integrating AETs in building projects.

It was understood that there are a number of different factors driving and restricting the use of these technologies, but that many of these would not be influenced by the actions of the building consultant. The building consultant does have an influence over the design and selection of energy systems and so it was necessary to compare how these selections are made and how this could be changed to assist the more widespread use of AETs.

For this hypothesis to be justified – if a good, open and rational decision were made then AETs would be seen in a better light than in the case of considering simple economic payback alone. This must be dependent on the assumption that AETs are an important consideration in the design of a building. If they are not important then there would be little justification behind conducting a detailed and lengthy decision making process.

In summary the interview questions were designed to:

- Discover at what stages AETs were considered in each project.
- Reveal which project team members were influential in promoting or restricting AETs.
- Challenge whether the consideration of AETs is an important part of building projects and affirm whether there is any justification for assessing these technologies in detail.
- Determine the major drivers and barriers to using AETs in building projects. This

judgement is used to justify whether existing methods or other decision making approaches would reflect these drivers and barriers more adequately.

- Allow reflection of which areas can be influenced by the work of the building consultant, and so help to focus future study.
- Investigate the methods used in for addressing drivers and barriers and making system selections in practice. This should reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.
- Ask: 'how can the building consultant best influence the drivers and barriers to using AETs, if at all'. This allows earlier points to be revisited and expanded upon and should help summarise whether or not it is worth the building consultant trying to influence the decision making approaches being used, or if another route is more worthwhile.

3.4.7 Interview recording and transcription

The responses were collected using an audio tape recorder, whilst notes were also taken by the interviewer as a back-up to protect against poor recording or loss of equipment. The use of recording equipment improved the accuracy and depth of the data compared with the note-taking used before. However the use of tape recording equipment did make the process of converting the data into a useable format and then analysis of this data a much lengthier process. The amount of data produced was very large, with some not entirely relevant to the questions and it has taken a lot of time to turn this qualitative information into manageable format and then into groups and categories for analysis.

A transcript is one interpretation of the interview. Transcripts only capture spoken aspects of the interview, missing the setting, context, body and feel... Decisions are made about the ways in which speech is represented, there are invariably guesses about what was said, and there is the issue of how to turn speech into written prose. (Arksey and Knight, 1999)

3.4.8 Credibility

There are many limitations to this study, some of them are:

Experience

- Participants have varying levels of experience in the building industry and with regard the consideration of energy technologies.

- Variation in the level of responsibility, influence and involvement in decision making.
- Variations in perception are in the nature of human beings so it was always going to be apparent in personal research as conducted here.

Interview Process

- There is variation in the amount of time it took to conduct each of the interviews.

The methods used to capture the information have been consistent but have their own limitations:

- Sometimes the ideas being expressed or attempting to be expressed are not understood in the manner that was intended. Though all attempts were made to repeat and expand on points that did not seem to be immediately clear.
- Because of the personal and interactive nature of the interviews structured questions are used for a basis as an opening, but beyond that further questioning is used to probe the points made further.
- It was necessary to channel the participants to focussing on the subject as intended.
- Sometimes aspects of answers are not clear and sometimes the participant can provide an answer that does not seem to relate to the question being asked.
- Some people wanted to answer their own questions and offered questions of their own; this shows an involved thought process but does not always relate fully to the investigation being conducted.

3.4.9 Interpretation

Interpretation of the data involves looking for disconfirming and confirming information, and should show either:

- That the original hunch cannot possibly be sustained
- That the original idea needs modifying, perhaps by introducing a new variable.
- That situational or site-specific factors should be considered.
- Further research is needed.

3.4.10 Data analysis

Each interview was recorded using a audio cassette recorder. These recordings were played back and transcribed into a typed document as accurately as possible. Each interview transcript was then broken down into individual question answers and these answers brought together into a central document that acts as a central library of sorted data. At this point some of the answers were 'cleaned up' so any repetitions, incomplete statements or points that were not relevant to the study were not carried forward.

Each question was then analysed in turn. The main points for each answer given were copied into a spreadsheet and then these results were categorised. Categories were generated through grouping the most popular answers under relevant headings. The answers were transferred into these categories and counted up. This makes it possible to see which were the most popular answer categories and spot any trends between the type of answer given and the type of project, client or other factor.

A number of the answer categories are not directly relevant to the question asked, but do provide more general insights or even answers to some of the later questions. In the presentation of results below the direct question answer categories are presented first for each of the questions, these are then followed by the more general answer categories.

The spread of answer categories and lack of structure in the answers given by participants increases the difficulty of analysing the results of this study. The depth of the data provided provides a number of opportunities for analysing the data from different perspectives including looking at the relevance of project type, client type, initial aspirations, technology type, the support from project team members, and use of assessment methods.

In Chapter 5 the analysis of answers given to each question is developed in the form of an interpretive model, with a summary description of answer categories and illustrative quotations followed by an interpretation. Details of the raw data, broken into the relevant categories, are also provided in Appendix D, for reference.

With further analysis or additional research the following variations could be analysed:

- Comparison with the results from the building services engineers from Phase I.
- Variations in age/number of years experience
- Variations between building types.
- The relevance of clear, early drivers and the selection of appropriate options early in the design process.

3.5 Summary of Chapter 3

This chapter has described the processes used for developing this programme of qualitative research, designed to explore the experiences of a range of building industry stakeholders. After using focus groups to test and develop a list of questions a first phase of 41 interviews were held with selected building project stakeholders. Building on the results of these interviews a second phase of interviews took place, this time with building services engineers, with a project-specific focus.

These two phases of interviews were developed using similar approaches:

For Phase I, participants were selected because of prior experience of projects where AETs had been considered, and the sample obtained through contact at conferences, through past projects and through company networking. In Phase II the process was far simpler, with all participants from within Buro Happold.

Before each interview, the participants were provided with a copy of the interview questions, informed of the purpose of the interviews and ensured that confidentiality would be withheld.

The aims of developing and completing these interviews were:

- To assess how successfully AETs are being integrated in building projects,
- Produce a hierarchy of drivers and barriers to using AETs in the context of the UK building industry,
- Investigate the types of assessment approaches being used in practice and whether they take account of qualitative considerations, and
- Consider how the building industry can help to improve the chances of AETs being used in future projects.

It is not the aim of this research to make sweeping assumptions that the views expressed are representative of the whole industry, as the samples chosen are not statistically representative, but only to make distinctions within the sample used.

The process used for recording results was note-taking (for Phase I) and transcription from a tape recorder (for Phase II). These notes were analysed and the answers categorised for each question in turn, and then the results were re-examined to uncover salient themes across all the questions.

The results of this analysis of the Phase I interviews are presented in Chapter 4, and analysis of the Phase II interviews in Chapter 5, followed by a comparison of the results from the two phases presented in Chapter 6.

CHAPTER 4 RESULTS FROM PHASE I INTERVIEWS

4 RESULTS FROM PHASE I INTERVIEWS

This chapter presents the results from 41 personal interviews held with a selection of building project stakeholders. The analysis approach and reporting format used here is explained in section 3.3.8.

The answers to each of the 8 questions, described in section 3.3.4, are presented in turn, with a summary of answer categories, diagrammatic presentation of the answers and an explanation of salient themes interspersed with direct quotations from participants. The main answer categories to each question have been coded alphabetically and presented in tables. These tables show the main categories, their given code, the number of corresponding answers and a list of the participants that gave these answers, together with informative sub-categories where relevant.

This chapter concludes with the results from cross-question analysis and a reflection on the main points of interest.

4.1 Definition of New and Renewable energy technologies

This section discusses the results from Question 1, which stated:

What technologies do you consider are covered by the heading 'new and renewable energy technologies'?

4.1.1 Introduction

Participants were provided with the list of new and renewable energy technologies defined for this research (as shown in section 3.3.4) and asked to describe their own definition. This led to a discussion regarding the relevance of different energy technologies under this heading. Each participant has a different opinion of the terms 'new and renewable energy' and 'alternative energy' and this question was used to make the participant think about this definition and their experiences.

4.1.2 Categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 5 main categories:

1A This category is formed of answers that made direct reference to any of the technologies listed within the definition given, or reference to the list itself. A 'Direct reference' sub-category is used where reference was made to the list rather than to individual technologies within it.

1B Category 1B compiles the answers that made reference to technologies other than those listed, hence those out of the standard scope of this research.

1C The third category contains answers that disagreed with the inclusion of a technology within the standard definition. These were arguments against a particular technology or group fitting within their understanding of the term 'new and renewable' energy technologies. A sub-category within 1C is reference to Combined Heat and Power (CHP) systems, because of the substantial number of interviewees that questioned its inclusion in the standard definition.

1D Category 1D contains all references made to other 'alternative' building considerations, but not within the definition of new and renewable energy technologies. This is categorised to 'other spheres of thought' because the answers relate to other engineering or architectural approaches.

1E The final category lists any other comments that were made at this point that do not fit within the previous categories. These answers were not common enough to be able to have their own category. Within this is a sub-category containing answers that detailed particular project experience, which are to Question 2.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.1 and summarised in diagrammatical form in Figure 4.1.

The greatest number of responses (18) made reference to one or more of the technologies in the list, or to the list itself. On top of this, sixteen (16) of the interviewees did not provide any registered comment on the list of technologies.

However there were a significant number of responses (12) that questioned the relevance of some technologies, with a particular focus on the inclusion of Combined Heat and Power (CHP), registering 10 times.

Table 4.1 Question 1 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
1A	**Reference to the technologies given in Question 2**	**18**	**A2, A5, B5, C3, P2, P4, Q3, Q4, Q5, S5, T3, T4, T5**
	Direct reference	5	B3, B6, C4, P3, P5
1B	**Additional technologies**	**5**	**A2, B5, Q3, Q5, S5**
1C	**Exclusion of technologies**	**12**	**A5, Q4**
	CHP	10	B1, B3, B6, C3, C4, P1, Q1, Q4, S4, T3
1D	**Reference to other spheres of thought**	**5**	**O4, O5, P3, P5, Q3,**
1E	**Other answers**	**7**	**Q5, S4, S5, T5**
	Project experience	3	C4, C5, Q3,

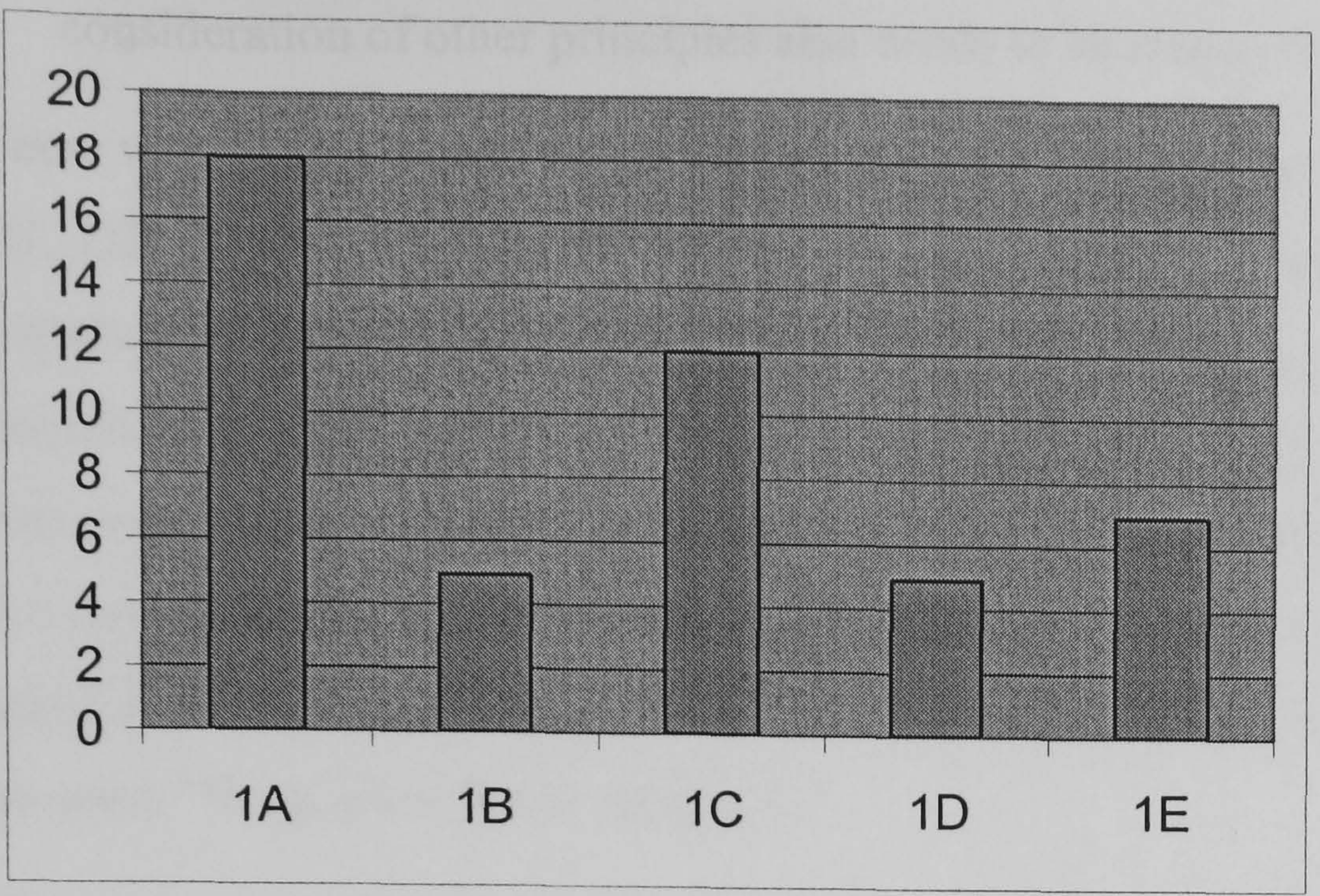


Figure 4.1 Question 1 summary of answers

There were 6 responses mentioning other technologies, additional to the list, including wave and tidal energy and landfill gas, which are large scale forms not typically directly relevant to the built environment.

4.1.3 Discussion

The specific question asked here is about familiarity of the participants with the terms used in the study and is whether there is a consistent understanding of the definition. Participants are aware of the terms being used within their practice, but clearly definitions were not consistent between each participant. Through the initial focus group study, two of the barriers to using these technologies were defined to be 'lack of communication and common language' and 'ignorance and lack of understanding'. The barriers are rated in terms of their importance in Question 5 (Section 4.4) and some of the participants answered that these were not significant. However the results of Question 1 seem to show that there is a lack of consistency in terms of language and understanding.

From the results given in Figure 4.1, it can be seen that the most common answer categories are:

1. [A] Agreement with the technologies provided within the standard definition in Question 2 (18)
2. [C] Some of the technologies listed are not considered to fit under the title 'New and Renewable' (12)
3. [E] Miscellaneous other answers, not directly related to the question (7)
4. [B] & [D] There are other technologies that could fit under the definition &

consideration of other principles also needs to be made (5)

There were no registered answers from 18 of the participants A1, A3, A4, B2, B4, C1, C2, O1, O2, O3, P4, P5, Q2, S1, S2, S3, T1, T2. Question 1 was used predominantly as an introductory question, to begin participants thinking about the technologies and allow any uncertainties to be voiced. Where no answer has been registered, this may be because of time constraints, with some participants in a hurry to complete the questionnaire and cover the more detailed questions as soon as possible. It was not registered when participants asked for a more detailed definition of the headings given in question 2, for instance the question "What does GSHP stand for?".

The most significant observation to be made from these results is the reference to technologies that some participants felt should not be included under the definition and the cases where other technologies or considerations were felt to be relevant. The difference in answers is due to the large variation in backgrounds between the participants. Each person has there own understanding of the definition and this is maybe one of the barriers to using these technologies.

Regarding the technologies being considered, CHP was subject to the greatest level of dispute. Often the dispute was centred around CHP not being considered renewable and also not being considered new. Indeed the use of CHP is not a new concept, seeing as the first power stations were developed this way, with a prime example being the Battersea Power Station providing heat to Westminster in London; and neither is it always renewable, unless a renewable fuel is used. CHP is considered as the provision of energy by standard means on a smaller, local scale, providing efficiency and long term cost benefits over a traditional system. Because of this, CHP is an alternative to traditional centralised power generation; it shares many similar barriers and drivers as the other technologies listed, and is by no means commonplace within the UK. Because of this relative market 'immaturity', it is included within the research as a new technology; and the development of fuel cell and micro-CHP systems is 'new'. Some of the comments made relating to CHP are as follows (Where the codes correspond to each participant as described in section 3.3.3):

> B1 – "CHP is considered old and established, though micro-CHP and fuel cells are new."
>
> C3 – "Don't consider CHP as a renewable, maybe new but not a renewable."
>
> Q5 – "CHP is an alternative. Difficult to label. Combined generation of power

with heat is alternative to traditional."

Another variation was that some of the participants understood the definition to have an inclusive 'and' so the technologies had to be both new and renewable. This was not the original intention, rather that it should cover new technologies and renewable technologies, and with this that the technologies are energy supply technologies suitable for integration within the built environment.

Some of the answers referred to other design issues that should be considered, in particular reference to passive design concepts and energy efficiency.

O4 – "I consider that Energy efficiency measures should be applied before renewable energy is considered."

4.1.4 Conclusions for Question 1

Each participant has a different opinion of the terms 'new and renewable energy' and 'alternative energy' and this question was used to make the participant think about this definition and their experiences. It is an important opening question that tests the familiarity of a term that may not be understood with the clarity required between the various stakeholders who influence decision-making in the building industry.

It was found that there is not a consistent definition available that relates to alternative energy generation technologies suitable for integration into building projects. This was clear before the interviews and was the driver for providing a pre-defined list of technologies. The level of understanding of each of the technologies is variable, whilst opinion of the importance and relevance of each technology is also subjective, with CHP a classic example.

It may not be possible to guarantee a common understanding of a definition or of each of the technology terms that may fit within it. Clearly there is a need for a consistent rationale and further education of key building project stakeholders. This lack of clarity and education is a barrier to conducting research such as the present and provides an unnecessary barrier to the integration of these technologies in projects. If a team cannot agree on terminology and technology definitions then it will take even longer to agree to using them. There was also the opinion amongst some participants that the definition should not relate only to energy generation but that passive solar design, natural ventilation and energy efficiency measures should also be included.

A potential area for further research is to obtain all the possible definitions of 'new and renewable' or 'alternative' energy technologies throughout the UK, and possibly even further afield. Such a study may begin with obtaining definitions from a Government agency such as the Carbon Trust.

4.2 Practical experience of using AETs in building projects

This section presents the results from Question 2, which stated:

From the definition used for the purposes of this research please indicate at which stage you have considered these technologies in building projects. The options for this are: (A) concept design, (B) detailed design and (C) construction. Please also list any projects of significance.

Photovoltaics Solar Thermal Hydro Wind GSHP Bioenergy CHP

4.2.1 Introduction

Question 2 is a closed question that expands on the answers given in Question 1, here the participants are asked to consider the technologies in the pre-defined list above. Then participants are asked to consider all the projects they had been involved with in the past. They are requested to indicate whether any of these projects had involved the consideration or use of these technologies at any phase In their development. Therefore the question does not ask for personal experience but whether the projects in which they were employed had involved these technologies.

4.2.2 Quantitative results

Participants were asked to indicate to which stage the project had included consideration of each of the AETs listed. These stages were coded as A for concept design, B for detailed design and C for construction. A score of 'B' presumes that the option had also been considered at stage 'A' and a score of 'C' that consideration was made at stages 'A' and 'B'. The results presented in Table 4.2 and Figure 4.2 represent the count of these results. This analysis tries to generate an understanding of a success rate and it allows some comparison of the likelihood of these technologies being constructed (upon being considered at first). It does not take into account the number of projects in which each participant has considered these technologies.

Table 4.2 Number of participants involved in building projects that have included AETs, and the stage to which these technologies were included.

	Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
Concept	29	27	11	26	22	27	31
Detailed	15	16	1	6	10	10	17
Construction	11	13	1	5	6	6	14
% completed	38%	48%	9%	19%	27%	22%	45%

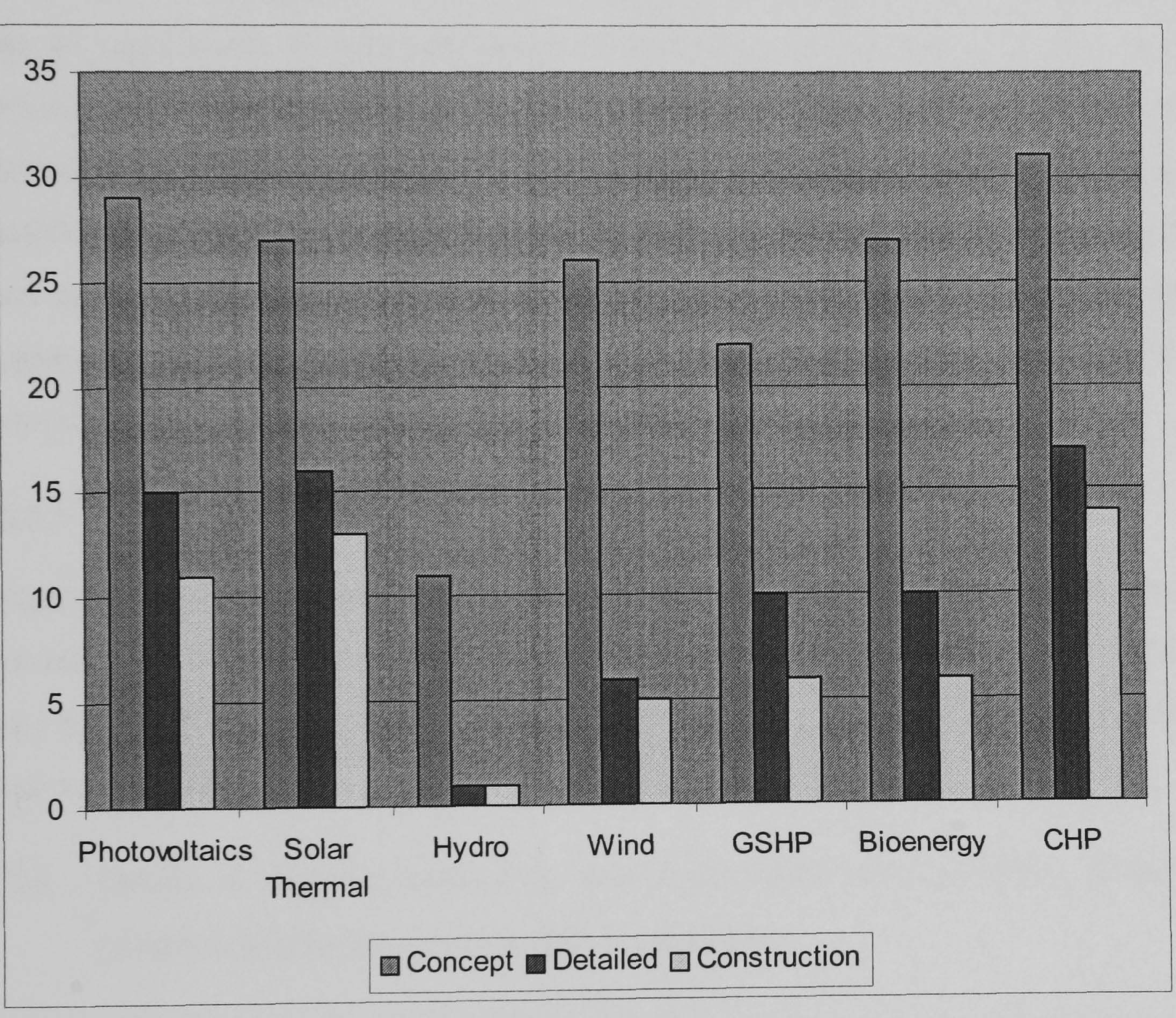


Figure 4.2 Diagrammatic representation of project involvement considering AETs

Table 4.2 and Figure 4.2 show that there is a clear disparity between the number of participants with experience of projects considering AETs as a potential option at feasibility stage and the number of projects that include them through to completion.

Hydro power is the least common of the technologies to be considered at concept design and construction stages, with less than a third of participants registering any experience. The next lowest is Ground Source Heat Pump systems, with around half of answers, and the highest is CHP with experience registered by over three-quarters of the participants.

The only participants with no experience of these technologies in practical projects were

A3, P3 & P4 (Where the codes correspond to each participant as described in section 3.3.3).

The ratio of participants who had witnessed these technologies through to construction (over just as a concept) ranged between the technologies but in total averages out at around 3 to 1. This needs more detailed and structured research but in general shows that much work needs to be conducted to help implementation of these technologies.

Of the most common was CHP; as discussed in section 4.1.3, some considered this to be not a new technology, however it was very similar in results to the other technologies. Of the 41 participants 31 had been involved with projects that had at least seen CHP as a concept, 17 of these same projects went to detailed design and then 14 to construction. Considering that the participants were generally selected with previous experience of these technologies, the ratio through to completion is surprisingly low. 14 of the participants had not seen any of these technologies through to construction, and where participants had experience of a technology at concept there was on average only a 32% chance that they would have experienced that technology at construction stage.

4.2.3 Other answer categories

Participants could also expand on their coded answers with details of project examples, or provide further insights, as they desired. The additional information given was captured and has been coded, separated, organised into headings and indexed into the following 6 main categories:

2A Details of relevant personal & project experience were provided. Either through reference to projects or technology applications.

2B An answer was given that suggested the decision to consider or use these technologies was dependent on the client or developer.

2C The potential and eventual level of success of considering these technologies varied between projects and depending on the site or type of building being proposed.

2D The decision to consider new and renewable energy technologies is influenced by the policies of government bodies, or legislation imposed.

2E Option selection is dependent on economic factors and judgement is made based on a financial assessment.

2F Other answers were given that were more in relation to Question 1, including a discussion of the technologies listed, their relevance to the heading 'new and renewable energy technologies' and details of other technologies considered relevant by the interviewee.

The responses relating to each of these categories and to additional sub-categories are shown in Appendix C and summarised in Table 4.3.

The main category of answers given were related to project experience, an example of which, from a contractor, is as follows:

T3 – "Just installed wind turbine on top of building in Manchester; and acted as a contractor for the Fibrowatt biomass power station. Developments are predominantly residential."

Table 4.3 Question 2 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
2A	**Details of personal & project experience**	**28**	**A4, B1, B2, B3, B4, B5, C2, C3, C4, O4, P1, P4, Q2, S3, T1, T3, T4,**
	Little project experience	6	A3, B6, O5, P3, Q1, T5
	Consideration at concept design	5	O3, O4, O5, Q3, T2
2B	**Depends on the client**	**5**	**A4, C1, O4, T4, T5**
2C	**Depends on the project/Site**	**4**	**Q2, T3, T4, T5**
2D	**Depends on policy/legislation**	**3**	**A4, B2, P3**
2E	**Depends on economics**	**3**	**Q3, T4, T5**
2F	**Other / Answer to Question 1**	**6**	**A5, B4, C2, P4, P5, T5**

4.2.4 Discussion

Though most of the qualitative answers highlighted project experience, there were 15 answers that referred to variable factors that influence the chances for using AETs. The answers were categorised as: client influence, project specific factors, political influence and financial considerations. These are useful to note, and will appear again in the later questions.

> Q3 – "We are using PV solely because we are getting funding, you would be a fool to use it otherwise as it is not efficient and hugely expensive."

A4 – "Most projects are for hard-nosed clients in the city with cynical views of long term paybacks… Merton council insisted that 10% of on-site energy to be from renewable sources."

O4 – "It needs to be in the clients brief to be considered at this stage. People don't understand what is involved unless it is a clear requirement of clients brief."

4.2.5 Conclusions of Question 2

The results give an insight into the level of practical experience held by participants, a comparison between the different technologies considered and some perception into the chances of a technology being included at different stages of the design process through to construction.

Although participants were selected for interviews because of previous involvement within building projects that had considered using AETs, the number of responses relating to these technologies being constructed is very low. The most common technology to be considered through to construction is CHP, but this only received 14 responses, approximately a third of all 41 participants; the other common technologies are solar thermal collectors and photovoltaics, with 13 and 11 responses.

There is a noticeable disparity between consideration at concept stage and through to construction, especially with options such as micro-hydro, wind and biomass energy. The ratio between experience of consideration at concept and at construction for these technologies is 10:1 for micro-hydro and around 5:1 for wind and biomass. This may be due to local restrictions that influence the viability of these technologies, especially with micro-hydro. It may also be because these technologies are less familiar to key decision makers who may be more at ease with (or educated toward) the use of CHP and solar technologies.

A number of additional answers, not key to the core question, were given that may shed some light on the reasons why these technologies are not often taken through to construction in projects. These points will be expanded on in later questions but there is important reference to some of the influences, such as client demands, financial constraints, politics and the suitability of the site.

An extension of this research question could be to investigate the exact number of projects having included consideration of these technologies and the ratio those eventually taken to completion; this could even be extended to try to understand the actual reasons for each failure or success.

4.3 Importance of considering AETs in building projects

This section presents the results generated from Question 3 in the interviews, which asked:

How much of a part does the consideration of these technologies have to play in building projects? How does this compare with other aspects of the design?

4.3.1 Introduction

Question 3 is an open question that tries to identify how important AETs are as a part of the building design process. Question 3 is designed to challenge whether the consideration of AETs is an important part of building projects. It should help to affirm whether there is any justification for assessing these technologies in detail. Its aim is to investigate whether or not AETs are considered to be central to the design of buildings or perceived to be an additional extra.

4.3.2 Categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 10 main categories:

3A The relevance of AETs in a project depends on the values and demands of the client or developer

3B The consideration of these technologies, and the importance attached to considering them depends on the client sector.

3C The procurement route chosen will influence the importance of considering these options

3D The validity of considering these technologies will be influenced by aspects specific to each site and other project variables.

3E The question was not considered applicable by the participant, because of their role or lack of direct experience.

3F For these technologies to be considered as an important factor in the building design they need to be a core part of the initial plan/brief.

3G These technologies do not have a large part to play in building projects.

3H These technologies are an important aspect in new building projects.

3I When decisions are made on the consideration of these technologies they are based on economic considerations.

3J Other answers which are not in direct response to the question and were not mentioned by many respondents.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.4 and summarised in diagrammatical form in Figure 4.3.

Table 4.4 Question 3 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
3A	**Relevance depends on the client**	**18**	**A1, A2, A5, B1, B2, B5, C2, C5, O2, 03, P4, Q1, Q2, Q3, Q4, S1, T1, T2.**
	Confidence/awareness	4	A1, A2, B2, O3
	Criteria/policy	9	B1, B5, C2, C5, O2, P4, Q2 Q4, T1
3B	**Depends on the client sector**	**8**	**A1, A3, B4, O3, O5, P4, T2, T5**
3C	**Depends on the Procurement route**	**3**	**A3, C5, T5**
3D	**Depends on the Project/Site**	**5**	**A5, B1, C4, T3, T4**
	Depends on the project size	2	T3, T4
3E	**Not applicable**	**2**	**O1, S5**
3F	**Needs to be a core part of the initial plan/brief**	**9**	**A3, B3, O4, P1, Q2, Q5, S2, S3, T5**
	Even if included early on they are only used if crucial	1	T1
3G	**Not a large amount**	**12**	**A1, A2, A4, B6, O3, O5, P1, P3, P5, Q1, S3, T3**
	Becoming more of a consideration	9	A4, B4, O3, O5, P2, P5, S3, S4, T3
	Cautious industry	2	A4, C3
	Not consistent	1	P1
	Only as an add-on/status symbol	2	Q1, S3
3H	**An important aspect**	**7**	B1, C4, P2, S5, T1, T3, T5
	Considered as part of sustainability	1	B4
	Considered after low energy design	3	B1, O2, T3
3I	**Decisions are made based on economic considerations**	**16**	A3, B2, B4, B5, C1, C4, C5, O3, P5, Q1, Q3, Q4, Q5, T2, T4, T5

	Consideration of capital costs	6	A3, B2, B4, O3, Q3, T2
	Consideration of running costs	4	C5, P5, Q3, T4
	Consideration of life costs	2	C4, T5
	Depends on the willingness to pay	1	B5
	Consideration of externalities should be made	1	Q1
3J	**OTHERS**	**7**	A1, Q1, Q2, B3, P1, O1, P1
	There is an important role for designers and consultants	3	A1, Q1, Q2
	The benefits of these technologies are not obvious	2	B3, P1
	Influenced by social factors	1	O1
	The process for design is unclear and inconsistent	1	P1

The full details of the responses that correspond to these categories and sub-categories are provided for reference in Appendix D. It can be noted from viewing each section of text that some statements are used more than once because they are relevant to more than one category or sub-category. Additionally comments within the sub-categories may not be represented in their respective main category.

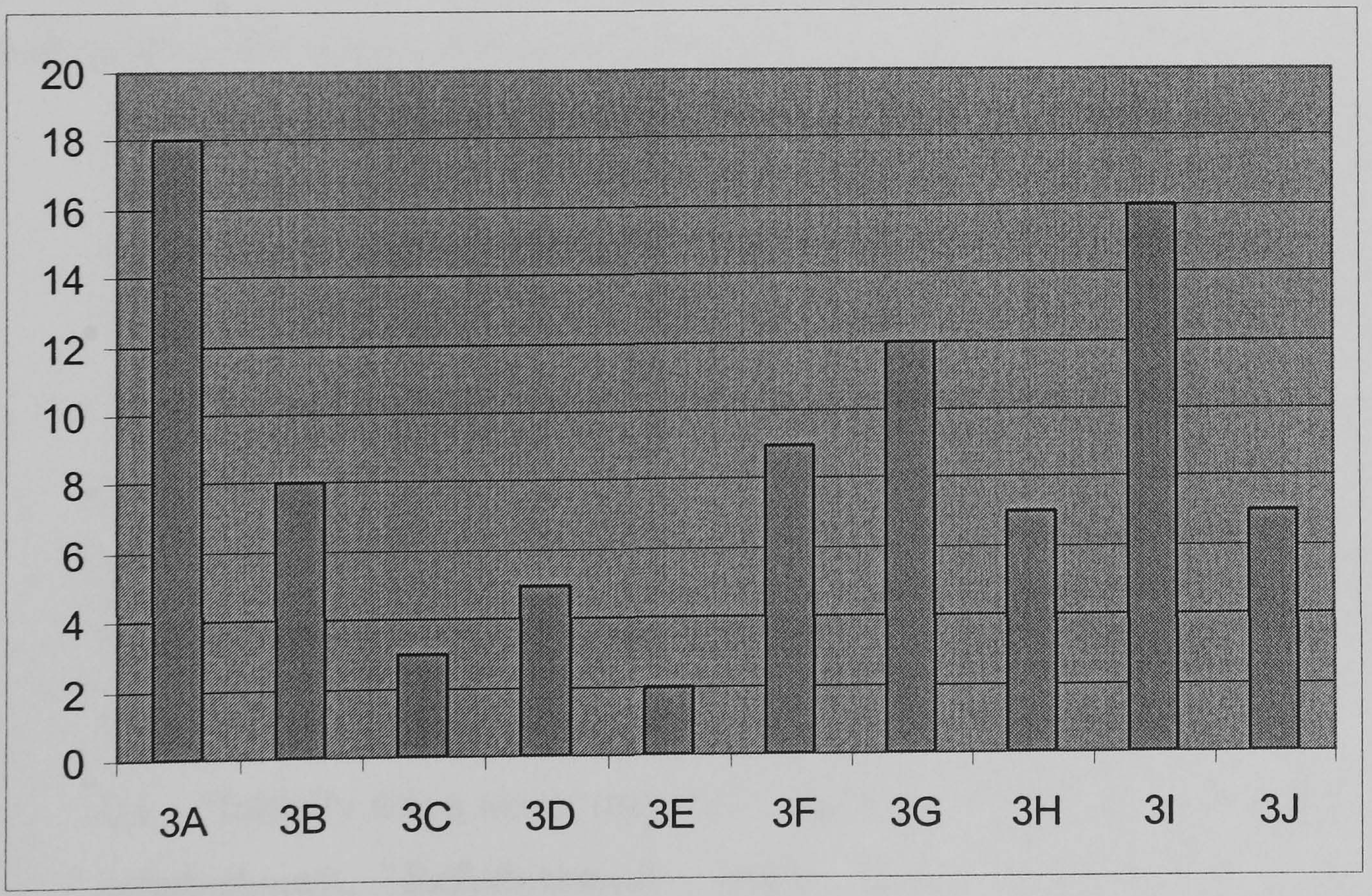


Figure 4.3 Summary of responses to Question 3

4.3.3 Discussion

From the results presented in Figure 4.3 it can be seen that the most common answer categories are:

1. [A] Relevance depends on the client (18)
2. [I] Decisions are made based on economic considerations (16)
3. [G] They do not play a large part (12)
4. [F] They need to be a core part of the initial plan/brief (9)
5. [B] Relevance depends on the client sector (8)
6. [H] They can be an important aspect (7)
7. [D] Depends on the project/site (5)

No single answer is common enough to obtain a majority though some of the categories used are very similar. It must be realised from this that because answers are not given by a participant it does not mean that they do not agree with them. Other answers relevant to this question may also occur in later questions, and so the results, and categories, used may change with further analysis.

There are 34 responses (A, B, C, D) that suggest the importance of considering AETs is variable and dependent on the individual client, the client sector, the procurement method and nature of the project. Some examples are:

> A2 – "Depends on the client, some are more receptive than others."
>
> A3 – "The UK is only interested in quick returns for their money, part of the system of financing. The best buildings are in the academic world; people that want the long-term gains from ultra-efficient buildings."
>
> B4 – "More emphasis on public sector government funded projects. There is a greater interest from private clients as result of the Climate change levy and through general environmental pressures from shareholders and potential customers."
>
> C4 – "Initially it is a major part, but it depends on whether it is a new build or refurbishment. Refurbishment limits things dramatically, and most development is refurbishment. A recent new building has had more opportunity for including renewables, and has included PV. Another new build is forthcoming and some will be considered. Part of my duty is to evaluate these

schemes."

O2 – "Depends on the client, only important if the client wants to show some commitment to sustainability"

The building consultant obviously cannot influence such factors, but it would be useful for them to understand which aspects had a positive and negative influence and how they can affect the viability of using AETs. To determine the impact of each of these variable factors further project-specific research would be required, using a large sample of case studies.

16 of the responses suggest that the consideration of AETs depends primarily on economic factors. To be considered worthwhile in a project, these technologies have to prove themselves financially. In some cases the capital cost is imperative, while other people call for the use of life cycle approaches and one answer refers to the inclusion of externalities. Thus there is variation from the use of practical and simplistic methods (Capital costs) through to the idealistic prediction of life cycle and external costs. Some examples are:

B5 – "Fancy engineering is all well and good but if it don't pay it don't go. The best technology will not survive if there is not the right economic environment to support it."

Q1 – "All goes back to the understanding of costs. Need to look at renewables in a different way, with greater consideration of externalities."

Q3 – "Most clients want to know about lowest capital cost and operating cost. No client has ever been interested just in energy innovation, they are always keen to get long term costs down."

Q5 – "There are a lot of projects where it would be nice to have these technologies but when the client realises there is no useful payback periods they are removed."

In direct response to the question, 12 answers suggest that AETs are of little importance or are considered only infrequently.

P3 – "Very little it seems to me. Obviously the exception is wind turbines and a few token Photovoltaics here and there."

In contrast, 9 responses suggest that these technologies are an important consideration, whilst two participants felt that they could not respond due to a lack of involvement in building project design.

S5 – "I could say I don't know and I don't care. As a supplier I am really only the receiver of the phone call saying we want a GSHP. I don't ask them how much of a part it plays."

T5 – "Will play a big part in the schools projects because schools looking for 30 yr life span so we're thinking of 30 year efficiency."

These results seem to show that there are inconsistencies and that in some projects these technologies will be more relevant than in others. However, the results of this question may be slanted due to the nature of the participants. All of the interviewees were selected because they had previous knowledge and experience of trying to assess or apply AETs in building projects. Therefore the answers may tend toward the positive aspect.

A significant subgroup of the category 3G is the answer that the situation is changing and that these technologies are increasingly being considered, which received 9 responses.

A4 – "Not something we'd have looked at 10 years ago, but certainly a feature now."

T3 – "Cautious industry but is gradually changing, e.g. The British Council for Offices have published a guide for obtaining grants for renewable energy."

In general the answers suggest that the consideration of AETs is highly dependent on client motivations and the particular constraints of projects. In most projects it is not an important aspect within the building design process, but it is becoming more important with time. There is also the insight that the initial assessment is made on cost, which dictates whether further consideration will be given. It seems that this is not consistent and some projects consider aspects other than just cost alone.

Another response of note is 3F, which suggests that if the technology can be seen as a core part of the design then it has a better chance of being carried through to detailed design and construction.

O4 – "It should play a big part but doesn't if it is not a mandatory part of the design. The only reason Ashton green and the development in Milton Keynes considered these technologies was that the land sale was only allowed if they considered them. The landowner has the power to insist that it is a condition of sale. Where it is not a condition the developer will find a way of not doing it. Developers will find their way round things to do what they've always done. Got to tie the developer in over a longer period of time so they have a commitment."

Though T1 indicates that inclusion from the beginning does not guarantee application:

> T1 – "They are a part of the brief but not getting implemented. If they are crucial then they get pushed through."

4.3.4 Conclusions to Question 3

The objective of Question 3 was to challenge whether the consideration of AETs is an important part of building projects and affirm whether there is any justification for assessing these technologies in detail.

The direct responses to the question are not consistent, tending both to the positive and negative. However the responses suggesting that the consideration of AETs is becoming more important is encouraging. There is also a lack of direct responses to the question, with the most common response suggesting that the importance varies between projects depending on client, project, political and financial factors.

For AETs to be integrated into more building projects they must become considered as more important by the project design team. We must try to recognise the factors that make or break their use and then shift the balance toward the negative. A key part of this is knowledge. Each project is different, but they share similarities. The use of informative case studies showing practical application are not a holy grail, but do help to show that these are not the first time barriers have been faced, and that they can be broken down. Knowing and understanding constraints is the first step generating a solution.

There is potential for further research into investigating a number of projects, documenting all the different client types, approaches, political factors, etc. and understanding the influence they have. The present interviews have only made general inquiries into participant experience but there is an opportunity to explore from a project-specific perspective, which may produce more informative results. This is partly addressed in Phase II of this research, the results of which are presented in Chapter 5.

4.4 Drivers and Barriers to using AETs in building projects

This section presents the results from questions 4 and 5. These results are presented together because they are the two quantitative questions and it is interesting to compare the scores attributed to the drivers with the scores for the barriers. These questions asked:

Based on your experience, what have been the drivers for using these technologies in building projects? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies		Image		Planning	
Environment, e.g. Climate change		Long-term economics		Lack of infrastructure	
Politics		Corporate social responsibility		Plant space	

And:

Based on your experience, what are the main barriers for using these technologies in building projects? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee		Proximity to resource		Cost (High capital and slow payback)	
Climate (variable)		Ignorance and lack of understanding		Perceived risk	
Stubbornness of energy industry		Incoherent Policy and Planning constraints		Unsuitable site	
Maintenance		Complexity		Unproven	
Lead time in construction		Environmental and Ecological impacts		Communication and common language	

4.4.1 Introduction

Question 4 and 5 are closed and quantitative questions. The categories used were generated from the focus group research held prior to the program of interviews (see Section 3.2). It is noticeable that fewer drivers (9) were listed than barriers (15). This may indicate that there is an imbalance between drivers and barriers, in favour of the latter. If this were so then it would seem to fit with present practice in light of the low proportion of buildings constructed that embrace AETs. Within the interviews each participant was asked to provide a score for each of the headings out of ten, in terms of the drivers & barriers for the use of AETs in building projects. The use of quantitative scoring allows the options to be compared and developed into a hierarchy. This judgement is used to justify whether existing methods or other decision making approaches would reflect these drivers and barriers more adequately. It can also allow reflection of which areas can be influenced by the work of the building consultant, and so help to focus future study.

It is clear that not all projects have the same drivers & barriers associated with them. Indeed it was suggested that each technology will be affected differently by the various drivers. The use of a 10 point scale was used to try to allow for some of this variation, where a 10 could represent a mark of always very important and 1 never important at all. Medium scores may be used to represent a high importance infrequently, or always of some importance.

Not all of the participants provided scores for the categories. The first 3 interviews followed the same format as the focus group questions and used an open-question format without any scoring. Participants were asked what they felt the main drivers & barriers were and to highlight which they felt most important. One other participant refused to give answers in number format and three did not provide answers for every one of the headings. The qualitative answers cannot be included with the analysis of the quantitative scoring but are included as a context along with any comments made by participants whilst attributing scores.

Figures 4.4 and 4.5 show the range of scores given for each of the drivers and barriers listed, along with the median, upper-quartile and lower-quartile scores.

The results from Questions 4 and 5 show that financial considerations are the primary barrier to using AETs in buildings and are also a substantial driver for using them. Considerations depend on financial calculations; however there are also a large number of other important influences, which tend to vary in significance between projects. The range of scores given for each of the headings reflects this variation between the participants and the importance of project specific factors from their experiences. The drivers and barriers responses are discussed in more detail in the following sections.

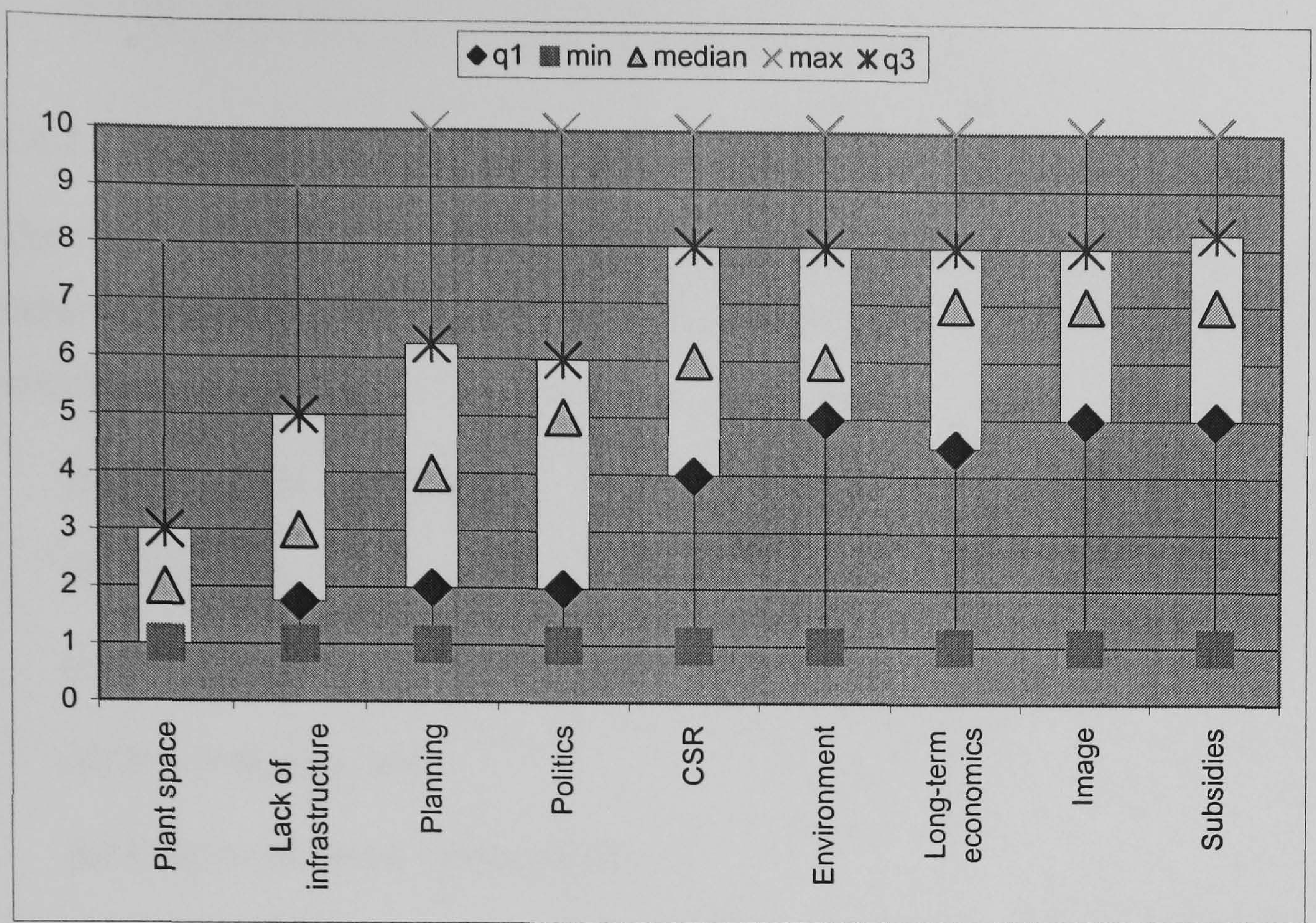


Figure 4.4 The perceived importance of drivers for the use of AETs in buildings

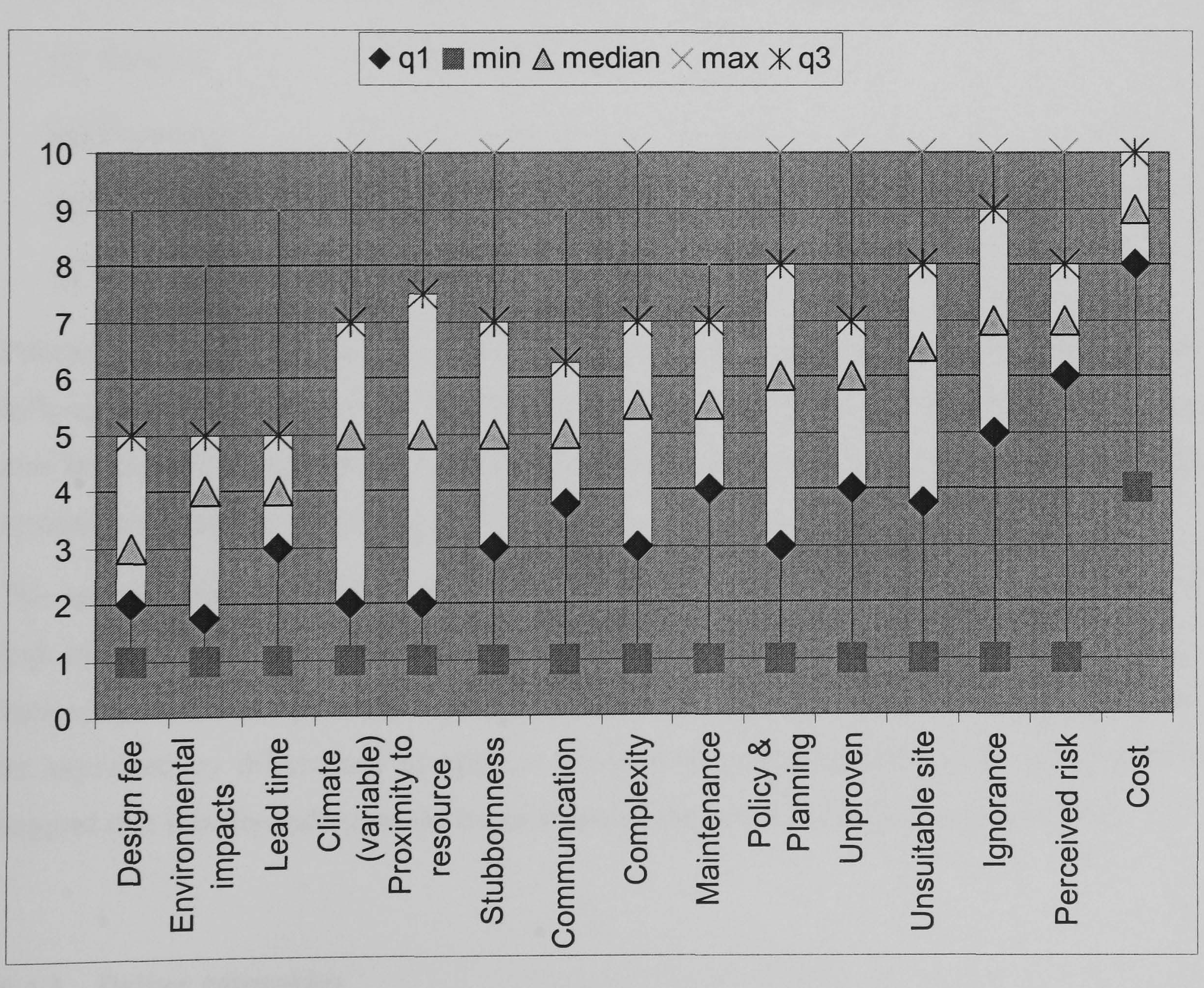


Figure 4.5 The perceived importance of barriers to the use of AETs in buildings

4.4.2 Drivers

The results from Figure 4.4 suggest that there is no single outstanding driver for the use of these technologies, but that there are 5 headings that stand out as consistently more important. These are:

(a) Long-term economics,

(b) Subsidies,

(c) Image,

(d) Environment, and

(e) Corporate social responsibility.

The first two of these are financial aspects, whereas the other three leading drivers are largely qualitative, personal factors dependent on the perceived 'values' of the client.

Beyond these there are 4 other drivers that obtained lower scores on average:

(f) Politics,

(g) Planning,

(h) Lack of infrastructure, and

(i) A lack of plant space.

Politics is variable dependent on the client, with local authority projects more heavily influenced by political drivers. The other factors are very project and site specific and may also be technology specific; for instance a lack of plant space may be a driver for GSHP systems and a barrier for bioenergy.

The inter-quartile range results in Figure 4.4 show that all of the categories, other than 'a lack of plant space', were attributed a large range of scores, showing the large variation between projects and personal experiences. However from the results, this variation cannot be explained by differences of opinion between the different stakeholder groups. They suggest that it is dependent on the experiences of the individual rather than their role.

4.4.3 Driver categories

Along with providing ratings for each of the headings many participants provided further information with details of project examples, or reasons for the scores given. Where this additional information was captured it has been coded, separated, organised into headings and indexed into the following 6 main categories:

4A The answer is directly related to the number score attributed to the drivers listed, for instance: P3 – *"With enlightened thinking long-term economics can become important"*.

4B An answer was given that suggested the drivers toward considering or using these technologies are dependent on the client or developer.

4C The drivers toward considering these technologies vary between projects and depending on the site or type of building being proposed.

4D The drivers to considering AETs are dependent on the technology being considered, as some are influenced by the drivers more than others.

4E The importance of drivers is viewed differently by each of the building project stakeholders, depending on their role.

4F Other answers were given that were more in relation to other questions, such as regarding the role of building consultants or recognising a lack of direct project experience.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.5.

Table 4.5 Question 4 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
4A	**Directly related to titles given**	**47**	
	Subsidies	10	B5, B6, C1, C2, P1, P4, Q4, S4, T2, T5
	Environment, e.g. climate change	6	A1, B6, P4, Q3, S1, S5
	Politics	2	C4, O1
	Image	7	A3, A4, C2, C4, O3, P3, Q3
	Long-term economics	6	A3, B2, B4, O1, P3, T5
	Corporate Social Responsibility	6	C1, C2, O1, O2, Q3, T5
	Planning	7	A5, B2, B6, C1, O3, P1, Q5
	Lack of infrastructure	2	B4, B6

	Plant space	0	
4B	**Depends on the client**	6	**A4, B3, Q2, Q3, S2, S4**
4C	**Depends on the project/Site**	11	**A3, B1, B4, B6, C4, O2, O3, P3, Q5, S3, T3**
4D	**Depends on technology**	4	**A5, C2, P2, T4**
4E	**Views can vary**	5	**B4, C5, O3, P4, T5**
4F	**Others**	4	**A3, B2, P3, S4,**

The full details of the responses that correspond to these categories and sub-categories are provided for reference in Appendix B. It can be noted from viewing each section of text that some statements are used more than once because they are relevant to more than one category or sub-category.

4.4.4 Discussion of drivers

Question 4 specifically relates to participant's perceived drivers for considering AETs in building projects. It is requested that answers are given in a numerical form, a score out of ten, for each of the headings given. However, participants do not always give answers in the form that they are strictly requested, either through refusal or digression from the subject.

There were 4 responses (A3, O1, S1, S2) that did not include numerical answers and 3 others (A1, Q1, T5) that did not provide numerical answers to all of the headings. In addition many participants wished to digress and discuss the score given to each heading, talk about the subject in more detail or cite a project where the issue was apparent.

The qualitative results of Question 4 are similar to some of the points made in the earlier questions. In particular, there are 26 responses (B, C, D, E) that make the point that the drivers are variable and dependent on a number of factors: including the client, the project and the different technologies.

> A3 – "Every project has its own array of drivers and problems."
>
> T3 – "For us it is simple, the issue is we consider them where there is a driver upon [us], such as from the land seller or planning authority when they would like us to look at these issues."
>
> P4 – "From our perspective the environment is a key driver but not for developers."

These variables are mentioned in each of the questions and so analysis of their significance is covered further in the cross-question analysis at the end of this report.

As described in Section 4.4.2 there is no single outstanding driver for the use of these technologies, with "long-term economics", "subsidies", "image", "environment" and "corporate social responsibility" having the highest median scores. Though these are the highest rated drivers there is large variation in the scores attributed, some of the reasons for this variation are as follows:

The impact of subsidies depends on awareness, applicability and project time constraints. In particular this varies with the nature of the client and the technologies being considered. For instance a large proportion of the government funding in the UK is applicable only to public sector or not-for-profit organisations. Awareness of the subsidies and being able to obtain them within the time constraints of a building project may also prove to be a restriction to the assistance they provide. If subsidies were equally available to all building projects and provided in a simple and timely manner then they would score more highly as a driver for these technologies. There are many quirks, inconsistencies and variables in the design and construction of a building; that the pursuit of subsidies adds to this reduces their appeal.

Long term economics are seen as a significant driver as these technologies tend to incur higher capital cost and lower operational costs than traditional systems. However the reason it is not rated higher may be that the long-term savings are not sufficient enough, there is little demand for considering them and that they are difficult to predict due to uncertainties over future markets and performance.

The relevance of long term economics depends on the client as many building developers are not concerned about operational costs. This lack of use of life cycle thinking is also shown in the results of Question 6 & 7 (to be discussed in Section 4.5). Each of the AETs offer different levels of economic viability, which varies between projects, for instance in some cases ground source heat pump systems are no more expensive than traditional systems whereas it is not uncommon for a solar photovoltaic system to have a financial payback in excess of 50 years. Long-term savings are not seen as a benefit to many building developers, especially speculative commercial developers; who do not always pay the operational costs:

> A4 – "These drivers are more important to owner-occupiers, in London most are speculative developers not occupying the buildings."

Financial costs and returns are generally seen to be tangible numbers, however with AETs there is not a lot of case experience in the industry to be able to closely predict capital costs or future performance. There are also a large number of variables that can affect future performance, such as changes in building use, and also future financial returns, such as oil, gas and electricity prices.

The image portrayed by using these technologies is an important driver for their use. However, the importance of image benefit is very project specific and dependent on human perception; so it is difficult to quantify and changeable with time. The level of importance is influenced by the type of building project and role of the client/developer in the community, by the perceived value that this image might bring, trends in the industry and future changes in public awareness.

For example, a highly public building, such as a school, or an organisation that may have a high profile and a history of environmental performance, such as an oil company, may see greater benefit in showing commitment in the form of the visible use of AETs. In comparison, a small service or component supplier may see less benefit unless there was direct customer pressure to act. However the perceived value that this improved image might bring is very difficult to quantify, and may depend on the personal perspective of the client. It is very difficult to provide a tangible value to image and so it is hard to compare it against a more quantifiable aspect such as capital cost. Without knowing the potential value the image would bring it is very difficult to make any comparison and hence any decision in its favour. This value of image may also change in time. For instance if other schools, office developments, industrial competitors, etc. begin to implement these technologies due to changes in public perception then the image value may become a primary factor.

There is also considerable value in being the first to implement these technologies. For example, the president of Ford Motor Company stated that the additional publicity from installing solar photovoltaic panels on the roof of a factory in Bridgend was instantly worth millions of pounds (Scoones, 2001). This development has now been superseded by the installation of a large 'Ecotricity' wind turbine at another factory in Dagenham, alongside the River Thames.

Image has strong parallels with two other significant drivers: environmental benefits and corporate social responsibility. Both of these aspects could be the determining reason behind an image improvement. A key factor that limits the importance of these as a driver is the difficulty in measuring tangible benefit. Social and environmental benefits are difficult to bound and measure, though there are some scoring methodologies that can allow for comparison, such as BREEAM (BRE, 1998) and ExternE (CEC, 1997). The value attributed to these factors is dependent on the level of accurate information and expertise available and on the needs and desires of the client.

4.4.5 Barriers

The results presented in Figure 4.5 show that there is one single outstanding barrier for the use of these technologies; this is the additional capital cost compared with traditional technologies. It is of no surprise that this is perceived as the main barrier, because in general AETs are cheaper in operation than traditional energy supplies. However these are more expensive to install than linking to existing energy supply networks. From the role of the building consultant it is not possible to address cost as a barrier, other than to consider the techniques to compare it against the drivers for using these technologies.

The relative high capital cost of AETs is a constant problem. Other barriers are clearly more variable, though still important and need to be addressed. Two barriers that received high median scores are 'unsuitable site' and 'incoherent policy and planning constraints'. These are site-specific issues that, along with budget constraints, need to be recognised and understood at a very early stage, as they can be crucial but also very difficult to influence in the project design process. Three other barriers that received high median scores are: 'ignorance and lack of understanding', 'perceived risk' and 'unproven'. These are 'social' factors, dependent on the experience and skills of project team members.

Compared with the drivers listed, these points are much less about client 'values' and more about stakeholder perception and the availability of reliable information.

> C5 – "I do think people have always done it one way and don't want to change."
>
> P4 – "The clients don't know in the long term if the government will put the necessary fiscal policies in place. One of the real problems in planning terms is there is no one coherent strategy for renewable energy."

The variation in importance between projects and technologies is represented by the inter-quartile range results in Figure 4.5. These results show that 'cost (high capital and slow payback)'; 'perceived risk'; 'lack of communication and common language' and 'long lead times' varied little between participants. However there were very large variations for the categories: 'the proximity to resource', 'the effect of climate variations', 'incoherent policy and planning constraints' and 'unsuitable site'. This variation is because these headings are project and technology specific. For instance:

C1 – "Proximity depends on the project."

O2 – "Planning most appropriate for wind."

S2 – "Building suitability, lack of summer load in schools,"

4.4.6 Barrier categories

Participants could also expand on their coded answers with details of project examples, or provide further insights as they desired. The additional information given was captured and has been coded, separated, organised into headings and indexed into the following 6 main categories:

5A The answer is directly related to the number score attributed to the barriers listed, for instance: P4 – *"I think there is a fear it is a lot more complex than it is."*.

5B An answer was given that suggested the barriers toward considering or using these technologies are dependent on the client or developer.

5C The barriers toward considering these technologies vary between projects and depending on the site or type of building being proposed.

5D The barriers to considering AETs are dependent on the technology being considered, as some are influenced by the drivers more than others.

5E The importance of barriers is viewed differently by each of the building project stakeholders, depending on their role.

5F Other answers were given that were more in relation to other questions, such as regarding the role of building consultants or recognising a lack of direct project experience.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.6.

Table 4.6 Question 5 response categories and sub-categories

	Category (sub-category) description	Total	Participant index
5A	**Directly related to titles given**	**73**	
	Design fee	3	A1, A3, T5
	Climate (variable)	4	B4, B6, O3, P4
	Stubbornness of energy industry	8	B4, C1, C4, P3, S1, S3, S4, S5
	Maintenance	2	B4, P4
	Lead time in construction	4	B3, C1, C3, P4
	Proximity to resource	2	C1, P2
	Ignorance and lack of understanding	11	A5, B3, B4, C1, C3, C5, P4, Q2, S2, S5, T5
	Incoherent Policy and Planning constraints	6	B4, O2, P4, S1, S2, T5
	Complexity	6	B6, C4, O5, P1, P4, S4
	Environmental and Ecological impacts	2	A1, P3, P4
	Cost (High capital and slow payback)	12	A1, A2, A3, A5, B3, B6, C3, O1, O3, Q2, S2, T3
	Perceived risk	2	C3, T5
	Unsuitable site	2	A5, S2
	Unproven	4	B3, B4, B6, C1
	Lack of communication and common language	5	A4, B3, P4, P5, T5
5B	**Depends on the client**	6	**A2, B1, B3, O2, P4, Q5**
5C	**Depends on the project/Site**	4	**B3, C1, S2, S4**
5D	**Depends on technology**	7	**A1, B4, B6, O2, P2, P3, S4**
5E	**Views can vary**	2	**A4, P4**
5F	**Others**	6	**A4, C3, C5, O5, S5, T5**

4.4.7 Discussion of barriers

Question 5 specifically relates to participant's perceived barriers to considering AETs in building projects. As described in Section 4.4.4 not all of the responses were in the form requested. There were 4 responses (A3, O1, S1, S2) that did not include numerical answers and 4 others (A4, P4, Q3, T5) that did not provide numerical answers to all of the headings.

There are also cases where participants are quite sweeping in their answers. T4 gave a score of 1 to all headings other than lead time and cost which scored highly (8 and 9 respectively) and 'maintenance', 'environment' and 'unproven', which were given medium scores of 5. This is an extreme form of numbering and clearly the participant holds strong views on these points. There is also the case of A1 who gave more than one score to some of the headings in Question 5, for instance "7 or 8", "2 or 3", "8 or 9". In this case the first score given was used, for consistency. The scores are given based on the perspective and experience of each participant and it is not right to argue with any results given, but this shows that the scoring method used will not bring forth accurate averages, but merely a general reflection of feeling.

In addition many participants wished to digress and discuss the score given to each heading, talk about the subject in more detail or cite a project where the issue was apparent.

The qualitative results of question 5 are similar to some of the points made in the earlier questions. In particular, there are 19 responses (B, C, D, E) that make the point that these barriers are variable and these responses are considered fully in the cross-question analysis section later in this chapter.

Though there is variation between the scores given for each barrier, Figure 4.5 shows that there is one single outstanding barrier for the use of these technologies; this is the additional capital cost of AETs compared with traditional technologies.

In commercial developments the required payback times can be very short, and often only minimum capital cost is seen as reasonable. Public sector projects are also very limited by capital cost, though they may have desires and policies for the consideration of long-term economics. This is because all projects are subject to limited budgets and there are always pressures to keep costs to a minimum. Even outstanding environmentally-conscious projects such as 'The Eden project' in the UK did not include AETs in the initial construction, though some have been added in later phases.

In the present economic status the AETs will not be available at a lower capital cost than traditional options, other than in special cases. To have a chance of being used, the many benefits brought by these technologies need to be considered as opposed to just short-term, direct financial returns. However, the measurement and communication of these benefits is not as easy, reliable or well known as the measurement of simple payback. This is reflected in some of the other barriers that scored highly in the interviews, in particular: 'ignorance and lack of understanding', 'perceived risk' and 'unproven'. These are social factors and highly dependent on the project team, their knowledge and experiences.

Two other barriers that received high average scores are 'unsuitable site' and 'incoherent policy and planning constraints'. These are site-specific technical and political factors that are normally outside of the control of the project team.

The social factors are variable between projects, dependent on the project team members. They are also very difficult to measure and compare between projects. When trying to understand the main barriers to using a technology it is easier to relate to cost figures but very difficult to show, for instance, that the client perceived the risk too great, the consultant felt uncertain about their use due to a lack of experience or the architect was unaware of relevant case studies. Another problem is that the personnel in a project team, their understanding and the approach they use will vary between projects, and even during a project. If a reliable and consistent source of information was available together with an accepted approach that allowed the team to voice and break down concerns, then these social barriers may not be as influential.

The technical and political issues are site specific, and therefore variable in terms of their importance as a potential barrier. These are two aspects that are very difficult to influence from within the project team, but can be crucial to the potential for using AETs. It is important for these barriers to be recognised at a very early stage, this then prevents the team from spending unnecessary time considering technologies that will not prove viable. For instance, if there is a history of opposition to wind turbines or if the wind regime is not suitable then the option of wind energy is not worth considering.

Compared with the drivers listed these points are much less about client 'values' and more about perception and the availability of reliable information. Some quotations articulate this further:

> C5 – "I do think people have always done it one way and don't want to change."

> P4 – "The clients don't know in the long term if the government will put the necessary fiscal policies in place. One of the real problems in planning terms is there is no one coherent strategy for renewable energy."

The variation in importance between projects and technologies is represented by the inter-quartile range results in Figure 4.5. These results show that 'cost (high capital and slow payback)'; 'perceived risk'; 'lack of communication and common language' and 'long lead times' varied little between participants. However there were very large variations for the categories: 'proximity to resource', 'the effect of climate variations', 'incoherent policy and planning constraints' and 'unsuitable site'. This variation is because these headings are project and technology specific. For instance:

> B4 – "The energy industry tend to be supportive, we have a biomass project in South Wales where Transco are providing the funding for it."
>
> C1 – "Proximity depends on the project."
>
> O2 – "Planning most appropriate for wind."
>
> S2 – "Building suitability, lack of summer load in schools,"
>
> S5 – "One major utility is now moving but others aren't."

It is clear that not all projects have the same drivers and barriers associated with them, indeed it was suggested that each technology will be affected differently by the various factors.

4.4.8 Conclusions to Questions 4 and 5

The results from Questions 4 and 5 are very important. They demonstrate that the factors affecting the viability of the integration of these technologies into buildings are diverse and large in number. The opinions and experiences of the application of these technologies are varied. There is a hierarchy of importance, in which cost is at the top of, but that other non-monetary and non-technical factors are also important to recognise and address.

It is essential for further development that the barriers are minimised and drivers are exploited as far as possible.

The exploitation of drivers is reliant on a better understanding and effective modes of communication of the potential benefits. These drivers are based on estimations of future markets and performance, and on human values.

Reducing the impact of barriers is reliant on technical developments, political decisions and influencing human perception within the project team.

From the perspective of the building industry, and particularly the building consultant, they have control over understanding, communication and human perception. They have a key role in interacting with the client and other team members from an early stage of project conception.

The use of AETs is not solely in the hands of the technology developers or the governments who are supporting their use. Buildings are responsible for a large proportion of energy use in the UK, they play a fundamental part in our lives and can indirectly influence the way we live outside of buildings. For a technology to be integrated into a building it needs to be supported and understood by the building consultant, and this support reiterated to the client.

4.5 Comparison methods used for selecting energy technologies

This section presents the results from Question 6 and Question 7. These questions are analysed together because they address the same objective and have similar answer categories. These questions asked:

In the building design process how are the negative and positive aspects of these technologies considered and compared?

And

In the selection of energy technologies how are quantifiable factors compared against some of the less tangible factors?

4.5.1 Introduction

Question 6 and Question 7 are open questions that try to investigate how different energy technology options are compared in building projects. They build upon the drivers and barriers discussed in earlier questions to address how AETs are compared against traditional technologies in practice. Question 6 works in tandem with Question 7, asking how are pros and cons weighed up and then what techniques are used to compare the less tangible factors with quantifiable factors such as capital cost; if any at all. The results should reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.

4.5.2 Question 6 categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 8 main categories:

6A The decision to proceed with examining these technologies as a valid option is based on economic considerations, in the form of capital cost, simple payback or life cycle cost terms.

6B The decision making process is based on a comparison of different options and the balance of pros and cons. This may be as part of the design report produced by the building consultant and presented to the client.

6C Other techniques are used or considerations made. These techniques include cost-benefit analysis, multiple-criteria analysis, life cycle assessment of environmental impacts and other environmental assessment tools such as BREEAM. Other considerations are architectural aspects, image, noise, environmental impacts, etc.

6D The respondent was not aware of any formal methods for considering these AETs in building projects.

6E The approach used to compare these technologies, if at all, depends on the values and demands of the client or developer.

6F Formal methods may be required as a planning constraint or a government policy, for instance the completion of an Environmental Impact Assessment.

6G Different considerations need to be made depending on the technology being assessed.

6H Other answers which are not in direct response to the question and were not mentioned by many respondents.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.7 and summarised in diagrammatical form in Figure 4.6.

Table 4.7 Question 6 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
6A	**Decisions made on a monetary/financial basis**	**23**	**A3, A4, A5, B2, B3, B6, C1, C5, O2, O3, P2, Q1, Q2, Q3, Q4, Q5, S1, S2, S4, T2, T3,**
	Life cycle considerations	9	A5, B2, B4, C5, P2, Q1, Q5 S4, T5
6B	**Balance of pros and cons.**	**18**	**A1, A2, A4, B1, B2, C1, C4, C5, O3, O5, P4, P5, Q3, Q4, S1, S4, T1, T2**
6C	**Other techniques used/considerations made**	**15**	**B1, B2, C1, O4, P3, P5, Q1, Q5**
	Environmental	7	B3, C5, O3, P1, P4, Q2, T4
6D	**Don't know/None**	**12**	**C3, O1, O2, O4, O5, P1, P3, P5, Q3, S2, S3, S5**
6E	**Depends on the client**	**12**	**A1, A4, B2, B5, B6, C1, C3, C4, P3, Q1, T2, T3**

6F	**Depends on planning/policies**	**4**	**B6, P1, Q2, T4**
6G	**Depends on the technology**	**2**	**A5, C2**
6H	**Other**	**9**	**A1, A3, B1, C3, O4, P5, S2, S3, S5,**

The full details of the responses that correspond to these categories and sub-categories are provided for reference in Appendix B. It can be noted from viewing each section of text that some statements are used more than once because they are relevant to more than one category or sub-category. Additionally comments within the sub-categories may not be represented in their respective main category.

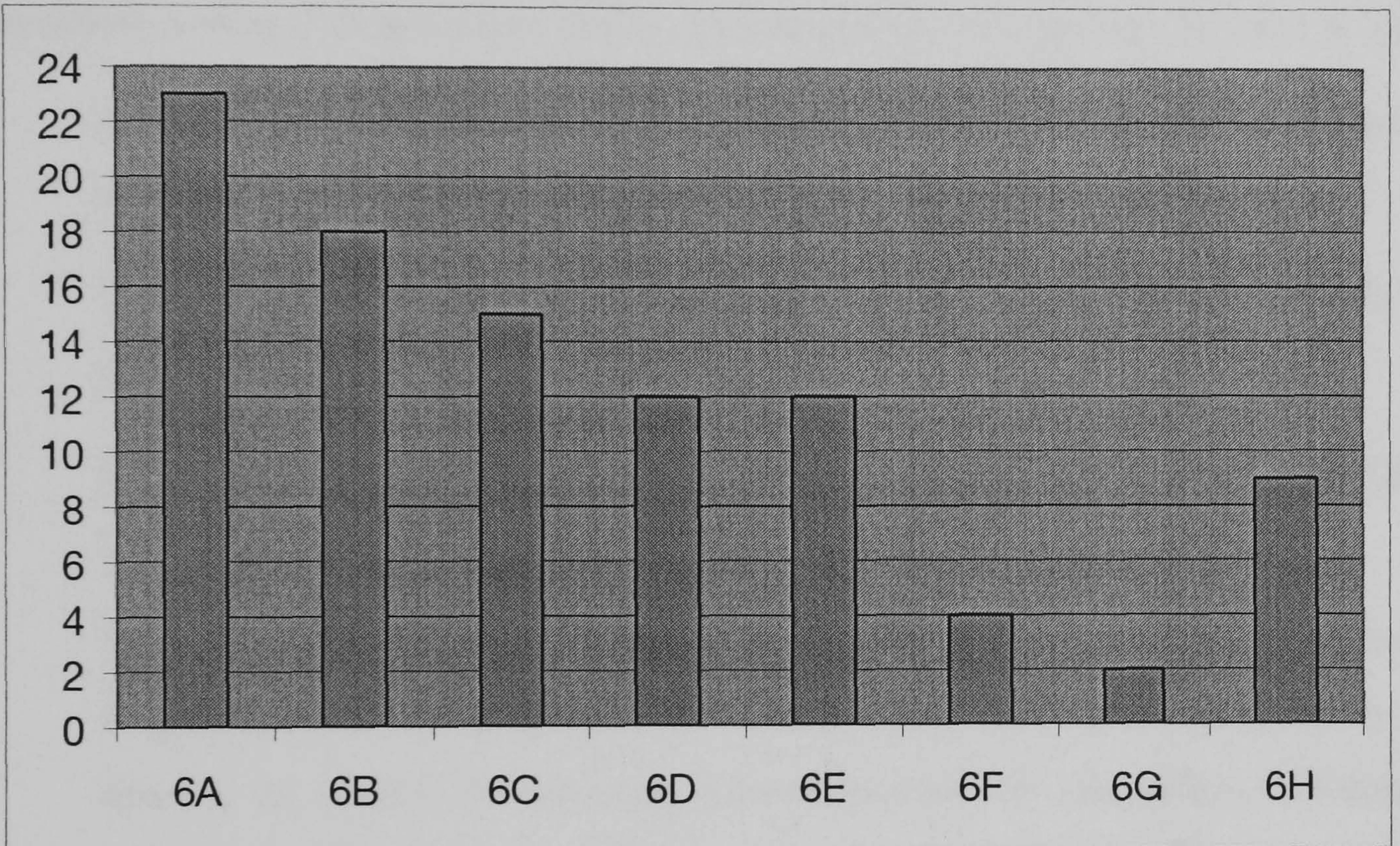


Figure 4.6 Summary of responses to Question 5 for each category

4.5.3 Question 6 discussion

From the results given in Figure 4.6 it can be seen that the most common answer categories are:

1. [A] Decisions are made on a monetary/financial basis (23)
2. [B] Decisions are made based on a balance of pros and cons. (18)
3. [C] Other techniques used/considerations made (15)
4. [D & E] Don't know/None & The process used depends on the client (12)
5. [H] Other answers (9)
6. [F] The decision process depends on planning/policies (4)

7. [G] Depends on the technology (2)

The most common response from all responses was that decisions are made based on monetary aspects; given by over 50% of the respondents and primarily by the building professionals (stakeholders ABQT, see Section 3.3.8.4). In consideration then that the results from Question 5 (Section 4.4) show that the greatest single barrier to using AETs is capital cost and slow payback, it is no wonder that the use of these technologies is low. Some of the answers given in category 6A make reference to the use of life cycle costing and net present value calculations, which can help to improve the viability of these alternatives over simple payback calculations. However, these techniques are reliant on a good understanding of future demands, costs and prices – which may not be readily available seeing that ignorance and perceived risk are seen as high barriers in Question 5.

> A5 – "Concerned with basic economic equations, payback the most significant discussion you have and then what is the life cycle costs of the system."

> B2 – "Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life cycle costs (3rd)."

> Q4 – "Weighed up normally from a report a perspective, but the last page that covers the costs is the main part that influences the clients decision."

> T3 – "Lowest capital cost issue is paramount in building design, a developer doesn't have to spend heavily on infrastructure and they're not going to unless there is an immediate payback, like an increase in sale value. Problem with higher capital cost is that developers are not getting any payback so they will not pursue it."

18 responses refer to the use of a written design report comparing options, or the use of tools such as a decision matrix or simple cost vs. benefit comparisons. These responses often refer to the consultant using their judgement/intuition/perception when writing these reports and giving their recommendations. This may lead to a high level of inconsistency between projects, which can have a major influence over the likelihood of AETs being used.

> A4 – "No formal format was used for [named project], matrices were used to compare different technologies, decisions were mostly intuitive."

> B2 – "Design team input and discussions. We had cases in the past where we showed options with low payback, but any misgivings within the team by one

party may introduce the feeling of risk and uncertainty. So the next step might be tackling peoples perceptions."

C1 – "In our consultants brief we have a requirement that the consultant considers a list of alternative technologies that I prepare for them. Also a requirement is that the consultant adds ideas added by themselves or anyone else. They then need to assess and prepare a paper on each of these ideas. Depth depends on how good the idea is. If clearly doolally I expect one sentence. If anything looks like it has a chance a comprehensive assessment of quantitative factors such as carbon emission and cost and less tangible such as visual aspects, benefits to public view and education. I expect to see reports bringing out relative benefits."

T1 – "PowerPoint presentations with graphs and tables. Scoring against the different options for pros and cons. Presented to the client so that they can make more informed decisions."

There are 15 responses that make reference to techniques or considerations that do not have a financial basis; these techniques range from structured approaches such as environmental impact assessments, to only mentioning them as a consideration, though not all answers are positive about the consideration of non-monetary aspects.

B1 – "Make simple assumptions present to the client as energy output vs. cost. Beyond that there is the consideration of architectural aspects, visual aspects and noise impacts; comparing these can be extremely complicated."

P1 – "Formal environmental impact processes are in the form of Environmental appraisals and EIAs, scheme specific appraisals, such as CHP emissions under environmental health clean air regulations."

Q5 – "Lead in times and the familiarity with the technology (has it been tried and tested)."

T4 – "The clients are not concerned about the environment."

At least 18 of the responses (E, F, G) suggest that the approach used and the considerations made are variable between projects depending on project team and external legislative influences or based on the technologies being assessed; this is a common theme throughout the questions.

A1 – "Depends on the organisation whether they can consider renewables cost-effective. If the building is to be built and occupied by the client then they have much greater benefit."

A5 – "With bioenergy there is a concern about the fuel availability, with GSHP the cost of boreholes to match supply. As regards considering anything else you can find reasonably good data now, with PV accurate costs/outputs and budget prices are available."

T2 – "If a client absolute sacred cow is to get a high BREAM rating then there is a better chance."

T4 – "Planning is a key thing because a lot of our projects are in city centres, so a lot have planning problems. Not interested in embracing these technologies, unless there are planning constraints they won't bother. Unless legislation that restricts them they won't bother. There is a lot of complacency."

12 responses suggested that there is no formal method for making these decisions, or that any method that is used was unknown to the participant. 11 of these 12 responses were made by participants from the 'COPS' grouping (see Section 3.3.8.4), who may not be directly involved in a large number of projects.

O4 – "Not really any method, people find it very difficult to compare and difficult to find the information to do so. Designers like to put one technology in as opposed to a combination of technologies, whereas a combination may be more appropriate. There is a need for different professional experiences to use a combination of technologies, which is a barrier."

P1 – "Not sure I know how architects do their designs! I suspect a lot is done by familiarity with particular systems or particular groups of expertise, not necessarily a broadening of horizon. Isn't one respect the assessment framework, locked away in different specialist areas of interest."

S3 – "I wish that I knew! There is not enough knowledge within the building profession. The methods of consideration and comparison are not mature; each project is a fresh start."

Every participant gave an answer to Question 6, though the detail of response varied from a short answer of "I don't know" (O1) to a number of paragraphs (C1, C4, Q3).

Q3 – "Normally in the form of design report recommendations from the consultant, and then the QS looks at the money.

In considering these questions I wonder whether the comparison of costs go far enough for traditional energy sources. Engineers' perceptions are based on a single piece of kit vs. a single piece of kit, which is not sufficiently inclusive of other costs. Cost in use has also got to include infrastructure costs, plant space, future fuel cost levies, capital allowances for engineering plant and lots of other factors. There is a huge amount of potential for research into producing a template for comparing the larger scale costs of comparing electricity driven by traditional X vs. alternative Y.

There is one thing to have the technology and another thing to have the information with which to make the decisions, we need the whole picture, everything. Clients do not often get the information that they require, consultants do not give the full side of the cost equations, the right questions are not being asked."

4.5.4 Question 7 categories

As before, the results from the interviews have been coded, separated, organised into headings and indexed into the following 8 main categories:

7A The decision to proceed with examining these technologies as a valid option is based on economic considerations, in the form of capital cost, simple payback or life cycle cost terms.

7B The decision making process is based on a comparison of different options and the balance of quantitative pros and cons.

7C Approaches are used that try to take into account some of the qualitative aspects. These may be single aspects, such as image, or general approaches that account for all issues.

7D The respondent was not aware of any formal methods for comparing the less tangible factors associated with these AETs in building projects.

7E The approach used to compare these technologies, if at all, depends on the values and demands of the client or developer.

7F Formal methods may be required as a planning constraint or a government policy, for instance the completion of an Environmental Impact Assessment.

7G Different considerations need to be made depending on the specific project.

7H Other answers which are not in direct response to the question, do not fit in with the other categories and were not mentioned by many respondents.

The responses relating to each of these categories and to additional sub-categories are shown in Table 4.8 and summarised in diagrammatical form in Figure 4.7.

Table 4.8 Question 7 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
7A	**Monetary aspects are considered**	**19**	**A3, A5, B4, B6, C2, C3, O1, O3, Q1, Q4, S1, S3, T1, T3, T4**
	Life cycle considerations	4	A1, C4, P1, Q2
7B	**Other quantitative costs vs. benefits**	**13**	**A1, A4, A5, B1, C4, C5, O1, O3, Q2, S2, S4 T1, T5**
7C	**Qualitative considerations made**	**18**	**A5, B1, B4, B5, B6, C2, C5, O2, O3, P1, P2, Q1, Q4, Q5, S1, S3, S4, T2**
7D	**None / New methods required**	**20**	**A1, A2, A3, A4, A5, B2, B6, C4, C5, O2, O4, P2, P3, P5, Q1, Q5, S3, S5, T2, T5**
7E	**Depends on the client**	**11**	**A1, A2, A3, B3, B6, C4, O2, P1, Q1, Q4, Q5**
7F	**Politics**	**3**	**P4, Q2, T5**
7G	**Depends on the project**	**2**	**A2, O1,**
7H	**Other**	**7**	**A1, A4, A5, O1, O3, P4, T3**

The full details of the responses that correspond to these categories and sub-categories are provided for reference in Appendix B. It can be noted from viewing each section of text that some statements are used more than once because they are relevant to more than one category or sub-category. Additionally comments within the sub-categories may not be represented in their respective main category.

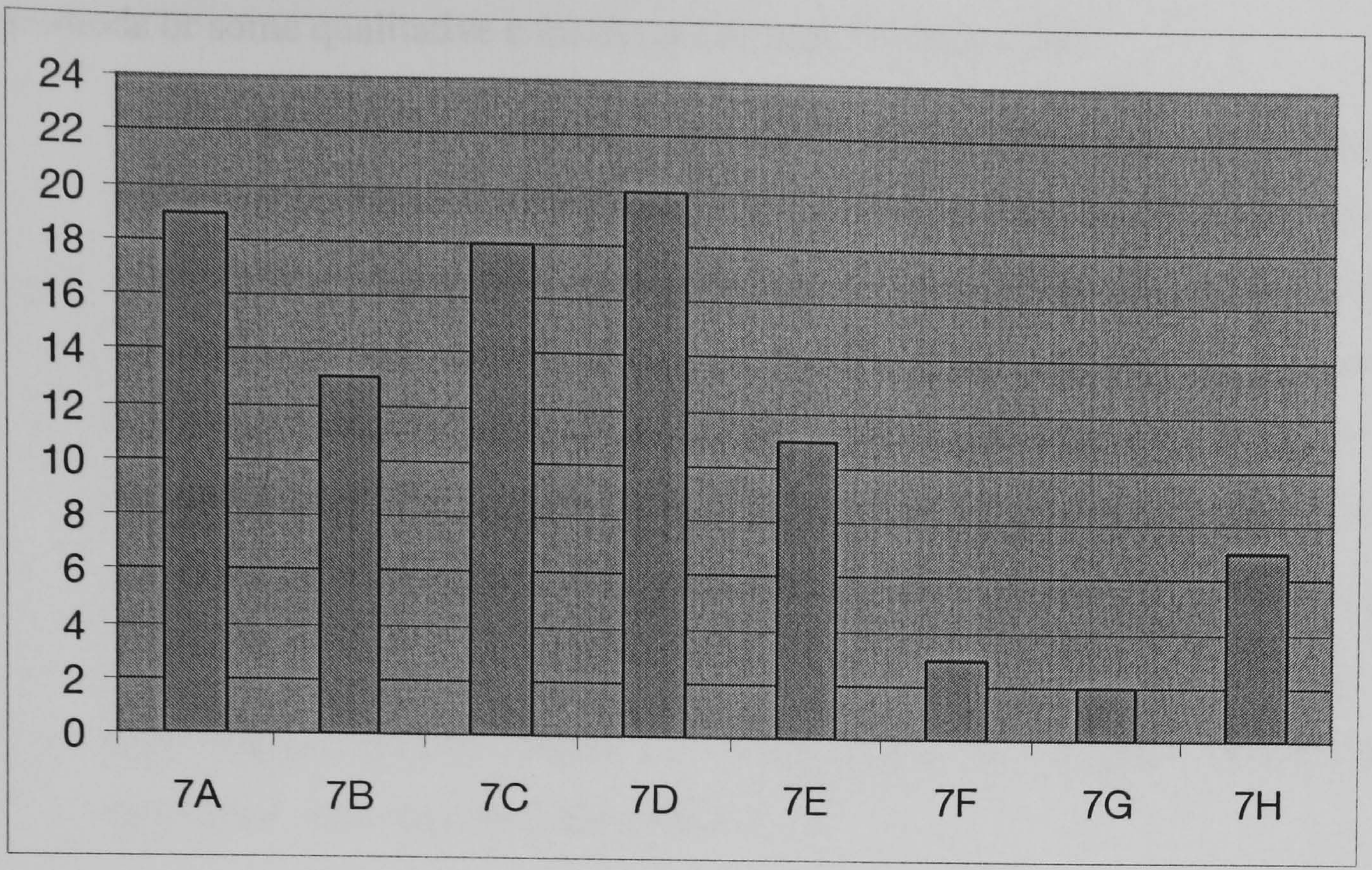


Figure 4.7 Summary of responses to Question 7 for each category

4.5.5 Question 7 discussion

From the results given in Figure 4.7 it can be seen that the most common answer categories are:

8. [D] None / New methods required (20)
9. [A] Monetary aspects are considered (19)
10. [C] Some qualitative considerations are made (18)
11. [B] Other quantitative costs vs. benefits comparisons other than financial (13)
12. [E] The process used depends on the client (11)
13. [H] Other answers (7)
14. [F] The decision process used depends on political influences (3)
15. [G] Depends on the project specifics (2)

The question "how are quantifiable factors compared against some of the less tangible factors?" is not readily answered in all of the responses. Most of the answers digress to talk about the nature of the less tangible factors, but do not discuss how they are compared in practice.

It has been determined that 20 responses are made that suggest there is no formal method used for comparing these aspects or that it is not necessary to do so. Some of the answers that fit within this category also fit within the other categories, for instance quantitative methods or some qualitative considerations may be mentioned.

A1 – "Not really, it is more of a case that they are considered complementarily, driven by resource availability. Consideration of life cycle costs and discount cash flow analysis, cost per kWh, though not always cost driven. With biofuels there are issues with fuel cost and storage, etc, which are much more of a factor, so hassle factor... Sometimes it is also a question of scale, so down to our experience."

B2 – "Very difficult to do. I don't think there is a method really. It needs a selection tool for use by the engineers. Engineers can quantify things but I don't know if there is any way of comparing the less tangible, the only way is to discuss and reflect on case studies."

C5 – "Looking for a balance, no specific quantitative vs. non quantitative comparison, but do include targets for the EMS (Environmental Management System)."

O2 – "Produce a written report that explains quantifiable and less tangible aspects. State factors for each technology and draw conclusions. No proper procedure. Usually a selection comes clear from initial study. Present it to the client and they usually have a preference toward one technology."

P3 – "I suspect there is a still a long way to go on this especially with the less tangible factors, social, aesthetical and environmental benefits have always been a problem comparing them with quantifiable factors. If not careful you get spurious science coming through, when trying to quantify the unquantifiable."

19 of the responses given made reference to the use of financial comparisons. Some of the participants suggest that money outweighs the other aspects and so there is very little need for considering the intangible aspects. There is also the position that this is a simple measure to use, which is why it is commonly the foremost approach to assessment.

Q2 – "You take into account capital cost, the life costs compared with the carbon production and try to level out the financial elements, on the back of that the authority's policies come into it. Is the council prepared to pay for reduction in carbon?"

Q4 – "Cost takes precedence because it can be quantified easily, it easily understandable. Money is a common language. Have seen people do comparisons of less tangible, which helps give an indication of priority, work out the clients priorities and see if the perception meets with these priorities. Then can compare against cost, and see if interpreted what client has said correctly."

S3 – "There is no structured method of comparison. New projects are more concerned with image than before and there is a balance between image and financial cost, but not sure how this is judged."

T4 – "All they count is money. They far out weigh less tangible."

Various qualitative considerations are mentioned throughout the responses (18 in total), and a number of these have already been illustrated in the quotes given above. Examples of the points mentioned are environmental impacts, social factors, risk and image.

B4 – "As a general summary I think that in the early stages it is the less tangible factors that get the ideas on the Table and get considered. It is not until the detailed design stage that you compare against quant factors. These quantifiable factors will commonly put the client off. Additional maintenance can put the client off. We do some network review of quantifiable and intangible aspects and rate the options out of ten, so including environmental score, but at the end of the day it is the physical cost factors that are decisive factors. Though some accept additional cost."

C5 – "We are moving away from environmental efficiency and toward sustainable development, trying to demonstrate a quantitative and qualitative balance. Sustainable development policy asks for a balance between social progress and to be environmentally efficient and keep within economic budgets."

P1 – "People factor in risk and after-management costs of running a system, probably seen as barriers rather than money-making opportunities."

The use of balanced judgement using quantitative value judgements or scoring systems is mentioned by 13 of the respondents to Question 7. For the comparison of environmental issues there is reference to the cost of CO_2 savings and the use of Environmental Impact Assessments.

A4 – "We compared each technology using annual CO_2 calculations, so you can quantify and compare. How this is related to aesthetics is highly intuitive and opinionated. It is a black hole, we deal with it all our lives."

B1 – "It depends on how far the design goes. At concept the options are discussed. It also depends on the client and architect and the considerations of the planners and local public. Environmental Impact Analysis is used for some projects. Quantify as far as you can and try to gain an idea about intangible aspects from dialogue with other parties. Some aspects are noise, environmental aspects. Early discussions are important and should be based on the best information available and common sense."

S2 – "Try to emphasise CO_2 payback & energy saving"

Once again there were a large number of references to the variation between projects due to site specific, political or client influences, 16 in total.

B6 – "Depends on the clients understanding and commitment to environmental issues if going for IPPC or ISO14001 or if they are a large company with an image or possibly with pressure from a client like ASDA for example, wanting proof of an environmental commitment of some kind."

Q1 – "Need to understand individual client objectives rather than use standard approaches, this will involve considering social benefits of options and tailoring the intangibles to the project needs."

The outstanding result from analysing the answers given to Question 7 is that there is a great variety of different approaches being used. The participants have all had different experiences of the use of techniques and of the availability of supporting information. There are many good ideas, and some very strong ideas that some approaches are more suitable than others, particularly those preferring reference to monetary values.

4.5.6 Conclusions from Questions 6 and 7

The objectives of Questions 6 and 7 were to investigate the methods used for addressing drivers and barriers and making system selections in practice. With an aspiration to reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.

The answers to these questions were more detailed than previously, which is useful, but is also difficult to summarise. A large range of views were aired and each participant has differing experiences, there was also a tendency for participants to digress from the question and begin talking about the nature of intangible factors rather than the assessment of them. However there are some general key points that can be made:

- The common factor in present approaches to decision-making is financial cost, principally in the aim of minimising capital outlay. Being that traditional systems often have economies of scale and a highly developed industry behind them AETs will always struggle on this consideration apart from for where existing infrastructure is not sufficient. If all projects were assessed this way then the use of AETs would be minimal. There are a number of reasons given for using cost as a form of comparison. Financial cost can be considered as the most important factor in decision-making, but this is over-simplification. If this were always the case then architects would be chosen based on their ability to produce the lowest-cost building, and decision-making would be relatively simple! Other reasons given are that economics is a common language (that we deal with every day) and that financial cost can be easily quantified and understood. This may be true, but there must always be room for other factors in decision-making and for generating an understanding of these factors.
- Consideration of non-financial aspects is commonly in the form of a written report or presentation, given to the client and based on the perceptions and experiences of consultants. There is no consistent approach used, or way of guaranteeing that the consultant is providing the best advice. This reliance on experience and discussion is part of decision-making, but is probably more relevant where the building stakeholders have a relatively consistent and thorough understanding of the technologies and design considerations. Due, perhaps, to the immaturity of the industry and the difference between each of the AETs, there is not a common approach to comparing these technologies or a single known source for design data.
- Some of the responses refer to use of more detailed cost comparisons and application of judgement toward future energy prices and technology performance. To do this significant financial assumptions need to be made, and decision-makers need to be aware of the impact of these. Other approaches are the use of environmental measurements through carbon accounting (£ spent vs. kg CO_2 saved) and Environmental Impact Assessment (EIA) techniques. The use of an EIA is generally only practical for large or contentious schemes, such as major planning applications, due to the cost, time and complexity associated with them; whilst carbon accounting is a very simplified approach to considering the environment.
- The most common method of comparing intangible aspects with quantifiable figures

(and balancing pros and cons) is to list out each of the options, discuss the issues based on previous experience and apply some judgement over relative benefits, possibly using a scoring matrix, before selecting a favourite option. Of the systems mentioned this seems the most reasoned, and can include the output of other approaches to add further weight to priorities. The problem is that it is susceptible to uninformed assumptions and prejudice, and still decisions can be made within the favour of the quantified points over the less formulated.

In summary there is no single approach that is identified as being an open and consistent method of selecting a technology through consideration of all benefits and drawbacks. The next step is to consider whether this is at all possible and even worthwhile attempting, as challenged in some of the responses; and if so to what extent is this practical considering the number of variables between projects and technologies. When trying to consider AETs it will always be more work than a traditional system, it will involve more thought, less certainty and more convincing. But as with any innovation, this needs to be overcome, and perhaps a new, more informed and consistent method of comparing technologies can help reduce the influence of these barriers and so help them to be used more universally.

4.5.7 Conclusions from Questions 6 & 7 Combined

The results of combining the answers provided for Question 6 and Question 7 give a different perspective on the approaches being used to decide between energy technologies. The results for each question have been combined and any double counting of similar answers provided by each participant removed. These are shown in Table 4.9 and Figure 4.8.

Table 4.9 Category results from questions 6 & 7

	Category (sub-category) **description**	**Total**	**Participant index**
A	**Monetary aspects are considered**	**30**	**A3, A4, A5, B2, B3, B4, B6, C1, C2, C3, C5, O1, O2, O3, P1, P2, Q1, Q2, Q3, Q4, Q5, S1, S2, S3, S4, T1, T2, T3, T4, T5**
	Life cycle considerations	12	A1, A5, B2, B4, C4, C5, P2, Q1, Q2, Q5, S4, T5
B	**Balance of pros and cons.**	**18**	**A1, A2, A4, B1, B2, B5, C1, C4, C5, O2, P4, P5, Q3, Q4, S4, S5,**

			T1, T2
C	Other qualitative techniques used/considerations made	25	A1, A5, B1, B2, B4, B5, B6, C1, C2, C5, O2, O3, O4, O5, P2, P3, P5, Q1, Q4, Q5, S1, S2, S3, S4, T2,
D	Other quantitative costs vs benefits	12	A4, B1, B3, C4, C5, O3, P1, P4, Q2, S2, S4, T5
E	None / New methods required	26	A1, A2, A3, A4, B2, B6, C3, C4, C5, O1, O2, O3, O4, O5, P1, P2, P3, P5, Q1, Q3, Q5, S3, S5, T2, T4, T5
F	Depends on the client	21	A1, A2, A3, A4, B1, B3, B5, B6, C1, C3, C4, O2, P1, P3, Q1, Q2, Q4, Q5, S1, T2, T3
G	Politics	6	B6, P1, P4, Q2, T4, T5
H	Depends on the project	5	A2, C2, O1, O3, P4
I	Depends on the technology	3	A1, A5, P5
J	Other	5	A1, A4, B1, B4, T2

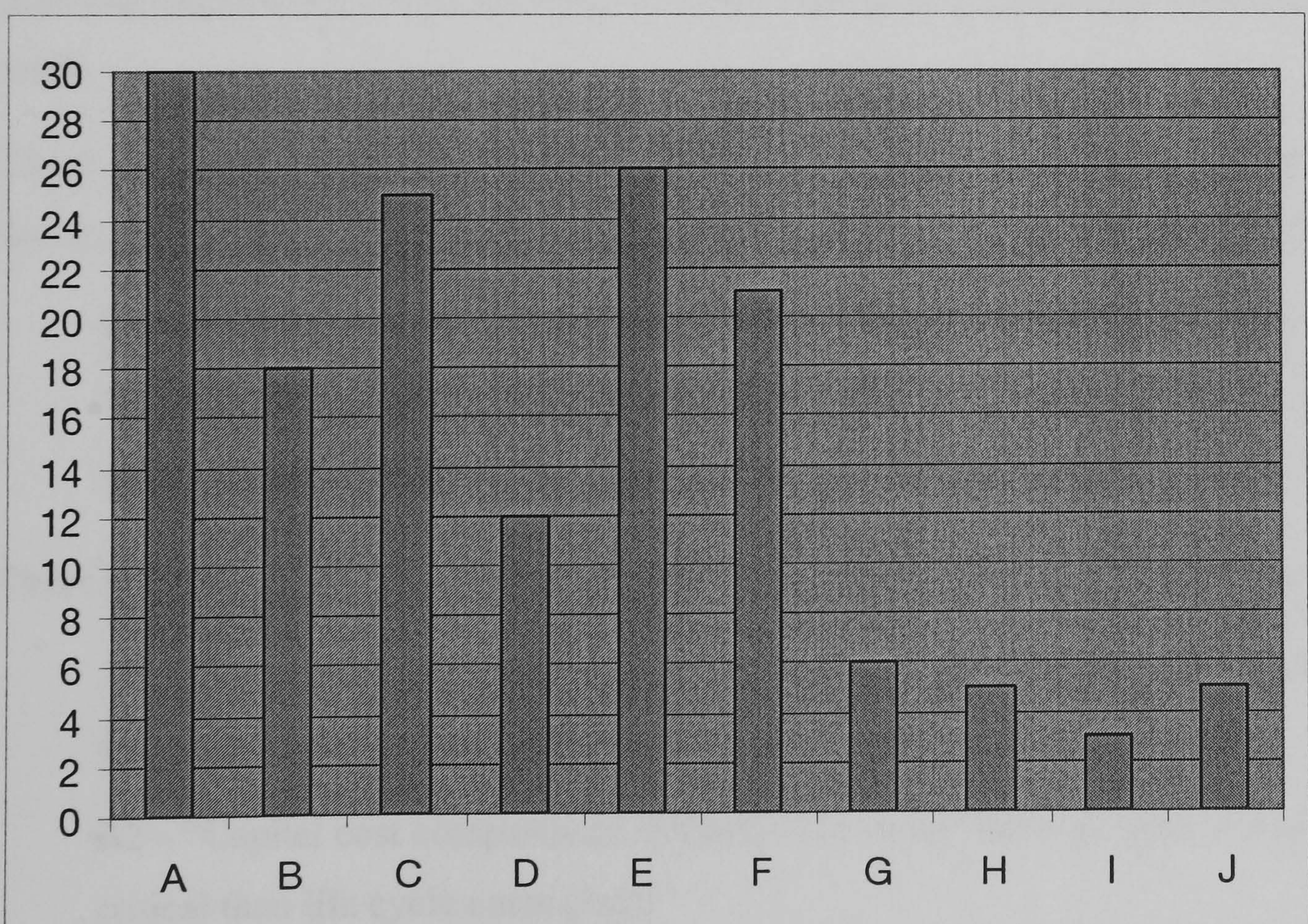


Figure 4.8 Category answers for Questions 6 & 7 combined

From the results given in Table 4.9 and Figure 4.8 it can be seen that the most common answer categories are:

1. [A] Monetary aspects are considered (30)
2. [E] None / New methods required (26)
3. [C] Other qualitative techniques are used / considerations are made (25)
4. [F] The process used depends on the client (21)
5. [B] A balance of pros and cons is used, often summarised in a report (18)
6. [D] Other quantitative costs vs. benefits comparisons other than financial & [A2] Life cycle economics are considered (12)
7. [G] The decision process used depends on political influences (6)
8. [J] Other answers & [G] Depends on the project specifics (5)
9. Depends on the technology (2)

Previous questions have shown that a number of considerations (quantitative and qualitative) need to be made for a fair selection of energy technologies. The results of Questions 6 and 7 show that such considerations are not being made and that there is no common format for assessment available. Assessments are based on financial criteria and practical engineering considerations, with few examples of qualitative considerations being made.

There is a strong emphasis on the comparison of energy options using money as the main factor, with 30 answers, suggesting that economics is the key and should remain the key.

> Q4 – "Cost takes precedence because it can be quantified easily, it easily understandable. Money is a common language."
>
> T4 – "All they count is money. They far out weigh less tangible."

There is a mention of life cycle considerations, though they are not predominant:

> A5 – "Concerned with basic economic equations, payback the most significant discussion you have and then what is the life cycle costs of the system."
>
> B2 – "Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life cycle costs (3rd)."

There are 25 responses illustrating that some qualitative aspects are considered but there is a lack of a clear and consistent approach:

> B2 – "Very difficult to do. I don't think there is a method really. It needs a

selection tool for use by the engineers. Engineers can quantify things but I don't know if there is any way of comparing the less tangible"

O4 – "Not really any method, people find it very difficult to compare and difficult to find the information to do so."

P3 – "I suspect there is a still a long way to go on this especially with the less tangible factors. If not careful you get spurious science coming through, when trying to quantify the unquantifiable."

Q3 – "Clients do not often get the information that they require, consultants do not give the full side of the cost equations, the right questions are not being asked."

S3 – "I wish that I knew! There is not enough knowledge within the building profession. The methods of consideration and comparison are not mature; each project is a fresh start."

Ignoring the qualitative aspects of decisions largely reduces the probability of AETs being used, as many of them are driving factors. Therefore, there is a clear need for new methods to be developed and used that will allow comparison of qualitative and quantitative considerations in the building design process.

4.6 How building consultants can make a difference

This section presents from the results of Question 8, which asked:

How can the building industry help to improve the effective implementation of new and renewable energy technologies?

- With reference to Question 3, how can these technologies be made to play a greater part within the building design?
- With reference to Question 7, what approaches should be used for comparison of quantifiable and less tangible aspects?
- How important is the building consultants role in the selection of these technologies and how they can best influence their integration into buildings?

4.6.1 Introduction

Question 8 and the three sub-questions that stem from it are open questions. This is a summary question that turns the central question to the participant; namely 'how can the building consultant best influence the drivers and barriers to using AETs, if at all'. This allows earlier points to be revisited and expanded upon. It should help summarise whether or not it is important that the building consultant influence the decision making approaches being used, or another route is more worthwhile.

Question 8 was originally asked using only the headline question above. It is intended as a concluding question to the interview process, where earlier questions had asked 'what is happening'. This final question would ask 'how can we make things better?'. This question was modified after the first sixteen interviews had been completed to include the three other points. It was intended that this would allow participants to reflect on the issues raised through questions one to seven in more depth.

4.6.2 Question 8 categories

The results provided for each of these questions have been grouped into identical categories, with the exception of category 8H, which is changed for Question 8.3 from 'no way' to 'consultants role is important'; other than this slight variation the results can be considered as from independent questions or combined. This Section looks at each question in turn, before discussing the relevance of the combined results. These questions are labelled, Question 8, 8.1, 8.2 and 8.3.

The results from these questions have been grouped into the following categories:

A There is a need for more education and willingness from within the building industry for people to learn how to assess and use these technologies.

B There is a need for more detailed and practical information, possibly in the form of detailed case studies that highlight where these technologies have proven to be feasible.

C Communication is a key factor

D New techniques or approaches need to be developed and used

E Political influences are required to push these technologies into use.

F Capital cost must be reduced

G The client needs to want these technologies

H There is nothing that can be done / The building consultant has an important role to play in the helping to improve the chances of using these technologies.

I Other answers

The responses to each of the questions related to these categories are summarised in the Tables 4.10 through to 4.14.

Q8. How can the building industry help to improve the effective implementation of new and renewable energy technologies?

Table 4.10 Question 8 response categories and sub-categories

	Category description	Total	Participant index
8A	Education	15	A1, A2, A3, A5, B1, B2, C1, C3, O1, O3, O5, S1, S3, S5, T1
8B	Information/Case Studies	6	A2, B3, C1, C5, S5, T2
8C	Communication	4	A3, B1, B3, O2
8D	New Techniques/Approaches	6	A4, O2, O5, P1, S2, S4
8E	Political	11	A2, B2, B3, B4, C1, O2, O3, O4, P3, Q1, S2
8F	Cost	3	C1, O2, T5
8G	Client	7	B5, O1, O3, O5, S3, T1, T5

8H	**No way**	**3**	**B2, P4, Q1**
8I	**Other**	**6**	**A1, A2, B3, C2, P3, S3**

The dominant responses from the original question asking how the building industry can help to further the implementation of these technologies are as follows:

- Education of the building industry is crucial for the use of AETs in building projects.

A3 – "Exterminate the whole industry and start again! Education and training is a starter, for all aspects of the construction industry. Increasing the number in the design industry holding to environmental ideals. Training, the education of training operatives through technical colleges has been lost but is essential. Need for an apprenticeships scheme. Specialist operatives and training required, especially for retrofits for upgrading existing housing stock. Architects and services engineers need to be up to speed and understand the benefits of these things."

C3 – "Education is the key, somebody has to educate the architects and consultants, these technologies are well worth considering openly without bias. Have met so many M&E consultants that are blinkered. Many opinions raised when all they've done is read one article, need people to really understand what can be done. I've found it very difficult."

S3 – "Wake up! The industry needs to start learning, even the use of passive solar is not commonly used."

- Other factors in the hands of the industry are the promotion of design and performance information, the development of new approaches to technology assessment and clearer communication. These received 16 responses between them.

A2 – "They need to do follow-up research and produce statistics of actual costs/benefits. Product supplier promises need to be challenged and tested and the results disseminated. Performance measurement and monitoring, with government grants for this R&D."

B1 – "Educate clients, explain things well. Create a bridge between clients and suppliers. Use appropriate technology for buildings, not power stations or token efforts. Liase with manufacturers."

O5 – "Start by adopting a whole life cost methodology for investments in these technologies."

T2 – "Proof of the pudding is in the eating. When sat in a design team meeting with the client there is nothing better than to go to and visit a similar project and talk to the energy manager."

- Beyond the control of the building industry there is also strong reference to the role of political influence, with 11 responses, and the demands of the client, receiving 7 responses.

B5 – "Unless the client has a strong green agenda I fear they will decide against paying the extra cost."

C1 – "With regard to this I think that the first thing is government. Only way to get payback down is push cost energy up and hardware down."

P3 – "I think that the intent in development policies as expressed through the planning system should be translated into a stronger action on the ground. Sustainable Development comes up all the time in the last few years. But we need firmer planning and development policies. My impression is the market will respond if the playing field is level. If the policies are consistently applied I don't think the market objects too much."

<u>8.1. With reference to Question 3, how can these technologies be made to play a greater part within the building design?</u>

Table 4.11 Question 8.1 response categories and sub-categories

	Category description	**Total**	**Participant index**
81A	**Education/Willingness**	**10**	**A5, B3, B6, C4, O4, P2, Q3, S5, T2, T5**
81B	**Information/Case Studies**	**0**	
81C	**Communication**	**2**	**B3, P2**
81D	**New Techniques/Approaches**	**5**	**B3, C5,Q3, Q4, Q5**
81E	**Political**	**9**	**B6, C1, P5, Q3, Q5, T2, T3, T4, T5**
81F	**Cost**	**10**	**B5, B6, C1, C3, P2, P5, Q3, Q4, T2, T3**
81G	**Client**	**4**	**A5, C3, P2, T4**

81H	**No way**	**0**	
81I	**Other**	**6**	**A5, C2, C5, Q2, Q5, S5**

The dominant answers to Question 8.1 are that to play a larger part in building projects, there is a need for external influences such as the use of political purchasing power, legislation or market prices to become more favourable.

> B6 – "Only through legislation I think, don't think there is any real willingness in the building industry to voluntarily doing it. Conventional legislation through Part L or alternative legislation with the emphasis more on the government 'stick'."

> C1 – "The main thing is get payback down. Once it becomes normal they get their own momentum. Make it so attractive that people want to do it."

> Q3 – "The only way to change the behaviour of clients is to force them; this could be done by the government forcing things to change. There needs to be penalties on the use of fuel."

> T4 – "The only way is through legislation, unless the government gives greater incentives to embrace this technology. You will always get an innovative client but they are always just minorities, so unless there is legislation it is going to be a long uphill struggle."

Second to this, there are calls for a stronger education and willingness within the building industry and for the use of standard approaches that will make the decision-making process clearer and more consistent.

> B3 – "More use of user friendly viability techniques, want to be able to see that it is a viable investment. It is not immediately obvious they're getting benefit. Closer cooperation with manufacturers and utilities. If more people trying to encourage it, it would help. We end up calling manufacturers."

> P2 – "The building industry need to get trained up and want to do it. Talking with the client and understanding the environmental drivers and where sustainability fits with the client, if the client doesn't give a damn then there is nothing you can do. You can only do what the client wants, but they can only do that if they have a full understanding of their drivers."

S5 – "Only by the professionals, architects and M&E engineers, by becoming aware of where they can be used in the design."

Q8.2. With reference to Question 7, what approaches should be used for comparison of quantifiable and less tangible aspects?

Table 4.12 Question 8.2 response categories and sub-categories

	Category description	Total	Participant index
82A	Education/Willingness	5	A5, B3, B6, C1, C4
82B	Information/Case Studies	4	Q4, Q5, S5, T2,
82C	Communication	2	C5, T2
82D	New Techniques/Approaches	13	B5, B6, C1, C2, C3, P2, P4, P5, Q2, Q5, S5, T3, T5
82E	Political	5	B6, P2, P3, P4, T4
82F	Cost	5	A5, B6, C3, C4, C5
82G	Client	2	C4, C5
82H	No way	3	O4, Q4, T5
82I	Other	1	B6

For the comparison of quantifiable and less tangible aspects the largest amount of responses (13 in total) mentioned the need for new appraisal techniques and approaches. The answers are dominated by references to further education, information, communication and assessment approaches, which indicate a critical role for building consultants.

C1 – "Provided you've a competent consultant. In the building services industry there is a lack of properly qualified and experienced people. Important more education."

C3 – "I think if people are open to real feasibility analysis then they would be surprised at what comes out."

Q4 – "Until you get a lot of systems with feedback, people want hardcore estimates don't want guesstimates. Once you can show it is proven then you are on a roll. Until you can say that it is intangible and unusable."

Q5 – "Whole life value approach. Need much better historical data on running costs, efficiencies etc. of various systems, and more research into long-term life expectancy."

S5 – "The data is not there for making a quantifiable comparison, designers do not have simple comparisons of value vs. renewable energy production or CO2 savings. With visual impact, I don't know at that point. How are they normally weighed up and dealt with for other design aspects rather than just in comparison of new and renewable energy technologies?"

T5 – "Don't know what tools you can use to measure. Approaches I could not tell you."

Q8.3 How important is the building consultants role in the selection of these technologies and how they can best influence their integration into buildings?

Table 4.13 Question 8.3 response categories

	Category description	Total	Participant index
83A	Education/Willingness	12	B3, B5, B6, C1, C3, O4, P2, P3, Q4, T2, T3, T5
83B	Information/Case Studies	3	Q3, Q4, T3
83C	Communication	5	B3, B4, C4, Q3, Q5
83D	New Techniques/Approaches	5	B4, C4, P3, Q5, S5
83E	Political	1	T3
83F	Cost	7	B6, P2, Q3, Q4, Q5, T3, T4
83G	Client	9	B3, B4, B6, O4, P4, P5, Q5, T3, T4
83H	Consultants role important	20	A5, B3, B4, B6, C1, C2, C3, O4, P2, P3, P4, P5, Q2, Q3, Q5, S5, T2, T3, T4, T5
83I	Other	3	B4, B6, Q4

Table 4.13 indicates that the building consultant has a very important role to play in order to further the use of AETs in building projects, with 20 answers (of 25) suggesting thus. Crucial, in them playing a positive role, is the advancement of education of building consultants.

A5 – "Is very important, the client would not go for them unless the architect and consultant pushed it."

B4 – "Through design we can actively promote passive energy design solutions and renewables at the initial concept design stage but after that it is up to the client."

C1 – "Absolutely vital at the end of day, the contractor builds what he is told to build and the client is advised by the consultant."

O4 – "If you get a decent consultant, fine. If not then they will not be used. The client role is more crucial though, they have to insist on it first. If then the consultant understands it then there is a chance it could go through."

P2 – "Very important if brought on board, they can either be good or bad, but always expensive!"

T3 – "the consultants job is to have good quality whole life cost information in addition to capital cost information. This is not necessarily an easy thing to put together."

Essentially the final decision to consider new and renewable technologies in a project is down to the project client or developer, and there are 9 responses that suggest sometimes the effort of a consultant can be quite lost.

B3 – "Not enough clients informed enough to ask for it and know what they want."

P5 – "More important that you have a customer committed to doing it. Architects and engineers will deliver to the brief. If you have 'though shalt integrate renewables into the building' then you can do something, it is important the client selects a team that can do the job."

T4 – "You've got a much greater chance of influencing the client, because there is a clear difference in the type of client that goes to a consultant than straight to a design and build contractor."

The answers from Questions 8, 8.1, 8.2 and 8.3 have been combined together to form Table 4.14 and Figure 4.9. Where respondents have given more than one answer in the same category to this group of questions the replication has not been counted again.

Table 4.14 Questions 8, 8.1, 8.2 & 8.3 summary breakdown of responses

	Total	**8**	**8.1**	**8.2**	**8.3**
Education	27	15	10	5	12

Information	**10**	6	0	4	3
Communication	**11**	4	2	2	5
New Approaches	**25**	6	5	13	5
Political	**21**	11	9	5	1
Cost	**17**	3	10	5	7
Client	**21**	7	4	2	9
No way	**6**	3	0	3	
Consultants role important	**20**				20
Other	**16**	6	6	1	3

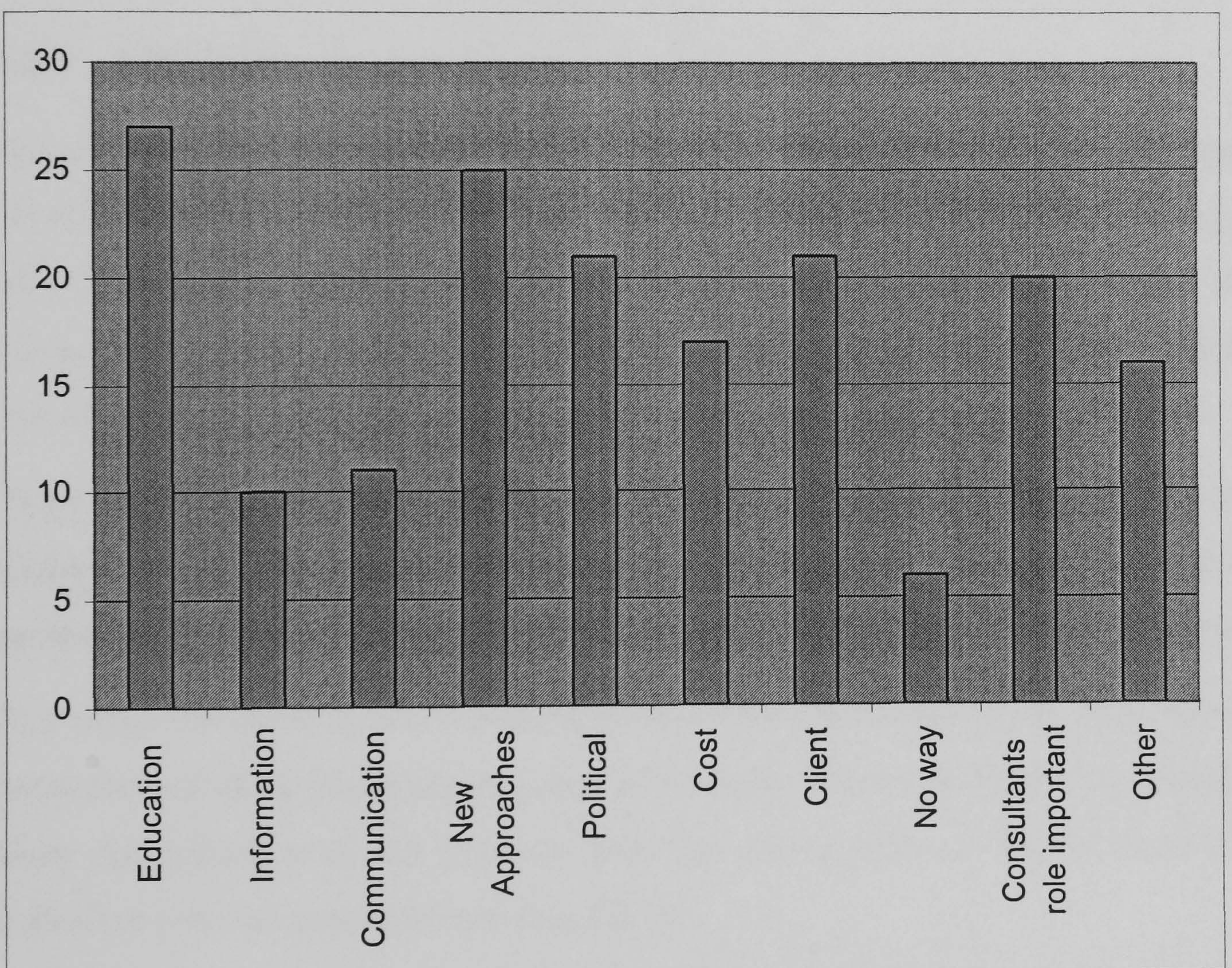


Figure 4.9 Summary of responses to Question 8 for each category

4.6.3 Question 8 Discussion

From the results given in Table 4.14 and Figure 4.9 it can be seen that the most common answer categories are:

1. [A] Education (27)
2. [D] New approaches/techniques are required (25)
3. [E & G] Political and client influences are important (21)
4. [H2] Consultants role is important (20)
5. [F] Capital costs need to be reduced (17)
6. [I] Other (15)
7. [B] More information is required (11)
8. [C] Communication is imperative (10)
9. [H1] There is nothing that the building industry can do (7)

4.6.4 Conclusions for Question 8

Question 8 is a summary question that turns the central question to the participant; namely 'how can the building consultant best influence the drivers and barriers to using AETs, if at all'. This allows earlier points to be revisited and expanded upon and should help summarise whether or not it is worth the building consultant trying to influence the decision making approaches being used, or if another route is more worthwhile.

There were a large number of answers to Question 8 and the sub-questions with it. Many of these answers are in great detail, and because of this it is not possible to quote all of the points made, but the examples given in Section 5.6.2 provide a general reflection.

The need for more positive influence from the Government and improvements in the economics of these technologies along with a lack of demand from some clients, are all far from the influence of the building industry. These external factors have a significant influence over the potential for using AETs.

However the results from Question 8 show that the building consultant does play a key part in assessing these technologies and can sometimes prove to be the deciding factor. Each client is different, as are the needs of every project, but the consultant needs to be able to offer appropriate information, experience and advice.

At present, it is shown that the understanding shown and approaches used by building consultants toward the consideration of AETs is inconsistent and at times unqualified. The technologies themselves are each very different, which does not help, but a basic understanding and a formulated approach would be advantageous. The largest number of responses (27) to Question 8 indicated that there is a clear need for education, information, willingness and communication within the building industry. Second to this is the need for new approaches and techniques for comparing technologies (results predominantly from question 8.2), which include advanced economic approaches such as whole life costing, and standard assessment tools similar to BREEAM.

It is not clear from the study how effective changes in the approach of building consultants would be in improving the viability of these technologies. Each participant has given a different perspective on the most important drivers, barriers, influences and decision-making considerations, and these stem from different experiences. The impact on each project will be different, but this needs to be investigated further.

There are a number of barriers that need to be removed and some are external to the influence of the building industry, however if the building consultant were to be stubborn or ignorant against AETs then the likelihood of them being used in building projects is minimal. It is our role to be ahead of the game, to be educated and wise to new technologies and the benefits they bring so as to offer reasoned advice rather than offering, sometimes, blind prejudice.

This section has concluded the discussion of all questions in turn (Sections 4.1 to 4.7). The following sections (5.7 and 5.8) present a summary discussion of the main points highlighted from this analysis and some conclusions and recommendations.

4.7 Summary of analysis of Questions 1 to 8

The main findings of the analysis of each question, and from cross-question analysis are clustered under six major themes:

1. The lack of education and experience of installing AETs in buildings within design teams;
2. A variety of key factors affect the viability of AETs on each project;
3. The role of specific drivers and barriers;
4. The importance of capital cost as a major barrier and the principle factor in decision-making;
5. The low use of other assessment methods; and
6. The important role that building consultants can play.

The following sections develop these in turn.

4.7.1 Experience and education

Participants were chosen because of their previous experience of considering AETs in building projects. The process of finding people from each of the stakeholder groups with the relevant experience was very difficult and time-consuming. Even still, of the respondents interviewed, 14 had not been involved in a project where these technologies had been included at the construction stage. The participants have far more experience of considering technologies at concept stage than at construction, with a ratio of around 3 to 1. The consultants and planners interviewed had very low experience of AETs being constructed, whilst contractors had a very high level of experience and a high percentage of systems constructed of those considered at concept (this reflects on the project stage that these stakeholders are involved). There is also variation in experience between each of the technologies, with some respondents only experiencing one or two of the technologies in detail. The most common of the technologies to be included through to construction was CHP, with 14 respondents having experienced this technology in their projects.

Across the participants there was strong support for the case that ignorance in the construction industry is a problem and that further education and presentation of experiences are required. Of the 41 interviews only 9 of them didn't mention the lack of knowledge and information within the industry. Also in terms of the importance of barriers to using AETs in buildings 'ignorance and lack of understanding' was rated highly, with a median score of 7 out of 10. Participants C2, C5 and T4 were the only ones to give a score of lower than 4/10.

When asked how the building industry can help to improve the chances of using AETs in building projects three responses in particular highlighted the present level of ignorance:

> A3 – "Exterminate the whole industry and start again! Education and training is a starter, for all aspects of the construction industry. Increasing the number in the design industry holding to environmental ideals. Architects and services engineers need to be up to speed and understand the benefits of these things."

> C3 – "Education is the key, somebody has to educate architects and consultants that these technologies are well worth considering openly without bias. Have met so many M&E consultants that are blinkered. Many opinions [are] raised when all they've done is read one article, need people to really understand what can be done. I've found it very difficult."

> S3 – "Wake up! The industry needs to start learning. There is not enough knowledge within the building profession. The methods of consideration and comparison are not mature; each project is a fresh start."

There was little suggestion of where this education should come from, though a few comments were made about the role of Universities, CPD training and the need for apprenticeship schemes. There was variation on the opinion of information availability, some of the responses commented on the lack of good quality information whilst others suggested that the information was there but not being accessed.

4.7.2 Key factors

The results of these interviews show that the relevance of AETs and the significance of each driver and barrier vary a great deal between projects and different people. This variation is due to a number of key factors such as project location, contract type, building type, the client type, client motivations, planning requirements, and the technologies being considered. Each of these was mentioned throughout the interviews and stem from the experiences of each of the participants in trying to apply AETs or similar technologies.

On top of this complexity, the interview responses have shown that AETs are not consistently considered as important factors in the design of a building. This level of importance is thought to be increasing and is highly dependent on client motivations and the particular constraints of projects. Regular reference was made to the importance of the client and their background; this was highlighted by 35 out of the 41 respondents.

Some of the answers suggest that the client holds the cards and it is entirely up to them.

> B3 – "Depends on the client group, it varies a lot. If talking to developer then all interest is economics, much less interested in green issues and other good things. Government clients able to be more flexible, willing to listen to more drivers and arguments."

> O2 – "Depends on the client, only important if the client wants to show some commitment to sustainability."

> T1 – "Generally they are driven by what the client wants in their brief. Unless the client wants them there is nothing you can do."

Other responses show that clients are influenced by past experiences and the advice of members of the project team.

> B6 – "Unless they are informed clients they need to be convinced that these systems will work and will not have to be replaced with expensive traditional replacements after occupancy."

> C3 – "From the clients point of view we ask them to consider renewables in the long term to save money and save the planet. On the negative side the consultant, contractor and architect say no because it makes the projects longer and more difficult, that is how they see it. Though it doesn't always prove that way in the end."

This shows that the likelihood of using AETs in building projects is often dependent on the type of client and their perspective on the importance of reducing environmental impacts. However, other project team members also have an obligation / opportunity to inform the client of the potential role that AETs could play and also influence their perspective on the worth of the environment. This is reflected in the client responses, which showed that they were disappointed by the level of understanding and commitment shown by the project team and particularly that of the engineering consultants.

This research cannot help to define the ideal combination of project and client type and other factors that would lead to the successful deployment of AETs in buildings. What it does show is that each assessment is not straightforward; there are a number of factors that will influence the viability of each technology. How the client and project team perceive cost and value is highly important, while project specific factors will affect the actual costs and value returned by each technology.

We have already seen that there is a lack of experience of considering AETs within the building industry. The differences between projects accentuate the impact of this and also make it essential that any judgement is based on the specific characteristics of each project.

4.7.3 Drivers and barriers

Along with defining drivers and barriers to using AETs in building projects this research has sought to rank them in terms of how important they have been in practice, and to see how this ranking can vary. To do this each of the participants reflected on their own project experience and gave a score (between 1 and 10) for each of a list of common drivers and barriers. As shown in Section 4.4, the results of these scores are summarised by Figures 4.4 and 4.5, showing the maximum, minimum, inter-quartile ranges and median scores for each heading.

Based on the median scores shown in Figure 4.4, the main reasons for using AETs in building projects are perceived to be:

- Long-term economic benefits,
- The availability of subsidies,
- Image benefits,
- The desire to reduce environmental impacts and
- Corporate Social Responsibility (CSR).

The first two of these are financial aspects, whereas the other three leading drivers are largely qualitative, personal factors dependent on the perceived 'values' of the client.

In the same manner, Figure 4.5 shows that the most common barriers to using AETs are perceived to be:

- High capital costs and long payback times,
- Ignorance and a lack of understanding,
- A perception of risk,
- An unsuitable site,
- A perception that AETs are unproven and

- Incoherent policy and planning constraints.

Of these six most prominent barriers, three are social factors, two are project specific issues and one is a financial aspect.

This ranking of the headings is very loosely defined due to the large variation in scores attributed by each participant. As previously noted, there are a number of factors that influence the viability of AETs for each project in many different ways, including political, personal and practical issues. The drivers and barriers that varied the most between the experiences of respondents in this study are:

Drivers
- Planning constraints,
- Political drivers,
- Corporate Social Responsibility.

Barriers
- Proximity to the resource,
- Variable output from technologies,
- Unsuitable site,
- Stubbornness of the energy industry,
- Complexity,
- Ignorance and lack of understanding.

The variation between projects has led to a moderate median score for each of these headings, though individual perceptions were often less than moderate, with many headings attributed scores throughout the full range of 1 to 10. This shows that many of the barriers and drivers listed can have a deciding influence on the use of AETs, depending on the project. This variation is illustrated by the two following views on the impact of planning:

> A5 – "I have never met a situation where planning is a driver for renewables."
>
> T3 – "For us it is simple, the issue is we consider them where there is a driver upon [The contractor], such as from the land seller or planning authority when they would like us to look at these issues."

One notable exception to this rule is 'ignorance and lack of understanding' which, despite having a large inter-quartile range in Figure 4.5, has a high median score; this is because it received very few low scores, with all but 3 answers between 4 and 10. This again highlights that a lack of experience in the industry is a consistent and influential restriction to the use of AETs in building projects in the UK.

Figure 4.6 also shows that there is a perception that AETs provide an additional risk to building projects and that this is consistently a major factor in restricting their use, achieving a median score of 7 and a very small inter-quartile range. This perception is illustrated further by the following quotations:

> S5 – "Contractual barriers and a lack of awareness by the professionals, fear factor; it is easier to duck out of dealing with it rather than finding out. Their professional indemnity means that if they take it seriously they must investigate it as an option. Barriers are created by the contractors; in design and build projects there will be contractual implications for them and so they will try a lot to stop it from happening.
>
> T5 – "I would imagine there is a great element of risk taking these technologies on for 30 years as there is no benchmark out there. I gather there are not that many companies developing these technologies."

From the results we see that each driver and barrier considered in this study may not be of paramount importance for every project, but nearly every respondent had experienced them being crucial in the consideration of AETs in building projects at some point. Therefore any assessment method devised or used should be adaptable to the variations between projects, and should not focus on the same driver or barrier for every case.

4.7.4 The importance of economics

From these interviews the majority of the responses suggest that financial viability is considered to be the most important deciding factor in the selection of AETs in building projects. 'High capital costs and slow payback' are consistently rated as a highly important barrier to using AETs, shown in Figure 4.5. 'Long term economics' and 'subsidies' also rank highly in the list of drivers shown in Figure 4.4. These high ratings reflect many of the answers to other questions in the interview process.

When asked to consider the best way of helping to increase the use of AETs in buildings 15 respondents were resolute that unless the technologies become cheaper and traditional energy supplies more expensive that AETs will not be deployed more frequently. For instance:

> C1 – "I think that the first thing is government. Only way to get payback down

is push cost energy up and hardware down. The main thing is get payback down. Once it becomes normal they get their own momentum. Make it so attractive that people want to do it."

Q3 "Most clients want to know about lowest capital cost and operating cost. No client has ever been interested just in energy innovation, they are always keen to get long term costs down. The only way to change the behaviour of clients is to force them, this could be done by the government forcing things to change. There needs to be penalties on the use of fuel."

Together with these strong views on the importance of financial viability there is also an indication that this is the main factor being used for comparison of technologies. Most of the respondents cited that in projects simple financial payback is the most common assessment methodology, with few responses mentioning methods for comparison of less tangible factors.

Q4 – "Cost takes precedence because it can be quantified easily, it is easily understandable. Money is a common language."

T4 – "All they count is money. They far out weigh the less tangible."

In terms of more detailed assessment methods there was some mention of the way we look at costs, with calls for more consideration of life cycle costing. However fewer than a third of participants referred to using life cycle costing in practice when considering AETs.

A5 – "[They are] concerned with basic economic equations, payback is the most significant discussion you have, and then what is the life cycle costs of the system."

B2 – "Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life cycle costs (3rd)."

4.7.5 Other assessment methods

The dominance of simple payback as a comparison method reflects on the lack of detail applied to the assessment of AETs in building projects. This leads to the main emphasis of this research. If indeed decisions 'all come down to cost' and high capital cost is the biggest single barrier then there is little that the building industry can do, leaving the emphasis on suppliers to lower prices and the Government to provide financial incentives. However, the results from these interviews show this is a naive view and that there is a complex array of drivers and barriers that vary in importance between stakeholders, technologies and projects. Due to these variations it is clearly not possible to simply assume a hierarchy of technologies to fit every project. This means that any assessment approach ought to be adaptable and backed up with sufficient information to allow for these natural project variations and inform what is a complex decision to make. Very few of the interviewees could mention having experience of techniques being applied that accommodated for this complexity. A problem emphasised by the large number of answers calling for new techniques to be developed and applied.

> C5 – "In many cases this is part of the great problem that architects and engineers don't tend to take sustainable development seriously; it is always a fragmented approach. No overall building infrastructure approach. Needs to be built in from the start of the process rather than just looking at a few green alternatives."

> P1 – "Need for planning tools and guidance. Need for an overview guide of technologies available that links through to the individual players in the decision process and back to the flow chart of critical things and when."

> Q4 – "The majority of designs are focussed on payback periods and savings in the long run, nobody focuses really on other parts of the building and the other benefits of doing away with traditional systems."

Financial payback is an important consideration and a common factor in most cases. Meanwhile there are well-established means of financial assessment. However, no consistent, structured approaches are used in the assessment of AETs that take account of all the other reasons for and against using these technologies. The main considerations for decision-making mentioned in the interviews were financial viability, practical risk and calculating carbon savings. Some assessment methods such as BREEAM or Ecohomes were mentioned, but these are general approaches that inform the overall building design process rather than acting as a method of technology selection. To accommodate factors such as risk many project teams made intuitive assessments or compared pros and cons in the form of a report and presented this to the client.

> A4 – "No formal format was used, matrices were used to compare different technologies, decisions were mostly intuitive."

> B5 – "One can flag to the client the pros and cons but then you must compare solely on words. Depends on the decision process used, we often use a scoring

system which in a way is pseudo-quantification."

O2 – "Produce a written report that explains quantifiable and less tangible aspects. State factors for each technology and draw conclusions. No proper procedure. Present it to the client and they usually have a preference toward one technology."

In unravelling the role of drivers and barriers to using AETs and the techniques being used to assess their viability it is clear that the existing approaches to decision-making are primitive and ignore much of the complexity of the problem. The assessment approaches used do little to enhance the impact of drivers for AETs and to reduce the impact of barriers. There is little experience of using approaches that compare qualitative and quantitative considerations in an organised manner. In terms of comparing quantitative factors such as financial cost with less tangible factors the most common answer was that such a comparison had not been made, as follows:

B2 – "Very difficult to do. I don't think there is a method really. It needs a selection tool for use by the engineers. Engineers can quantify things but I don't know if there is any way of comparing the less tangible, the only way is to discuss and reflect on case studies."

C4 – "If it is new then difficult to compare, so it can be all guess work. There is a lot of guess work and going into the unknown. It is the job of the team preparing the case to eliminate all the improbables and be fair and accurate."

S3 – "There is no structured method of comparison."

4.7.6 Building service engineers

There are many factors that influence the viability of AETs in building projects, including financial, political, technical and non-technical factors. Building consultants are limited in the influence they can have over some of these factors. They cannot change the cost of technologies or purchasing energy, neither can they directly change government policy, the type of client or the building location. However, results from these interviews show that the building consultant still has a key role to play in advising clients and informing the decision making process. Some examples reflecting on the role of building consultants show this:

B3 – "Key, unless we propose it is unlikely to happen otherwise."

C1 – "Absolutely vital at the end of day, the contractor builds what he is told to build and the client is advised by the consultant."

Q2 – "They're key really, that is the expert you rely on to advise you on the systems, what they can do and their ramifications."

T2 – "They are the first point of contact for the client."

We have seen that the level of experience of AETs within the building industry is considered to be very poor, and engineers have a key role in the industry of understanding these technologies and advising the project team. Building services engineers need to be educated to give them a better understanding of AETs and appropriate assessment methods. With the aim of this education to allow them to bring clear and timely knowledge to inform decisions and to consider using assessment approaches that incorporate quantitative and qualitative considerations.

4.8 Conclusions of Phase 1 interviews

There are clear drivers for increasing the use of AETs in buildings within the UK, not least the environmental benefits they offer. However, to date there has been a very low level of deployment except for within demonstration or exemplar projects.

This first phase of interviews with 41 building project stakeholders has shown:

- There is a lack of experience of installing AETs in buildings in the UK, and the understanding of these technologies is variable.
- There are a number of key factors that affect the viability of implementing AETs in building projects.
- There are a number of drivers and barriers to the use of AETs in buildings, and the relevance of each of these varies between projects, with time and with the technology.
- The high capital cost and subsequently long payback period is seen as the most significant barrier, and is the main focus of existing assessment approaches.
- No structured approaches to assessment that specifically address AETs and the drivers and barriers to implementation are being used in the industry. Further education and new approaches to assessment are required, to move the emphasis away from capital cost and toward the benefits provided by AETs.
- Building services engineers play a key role in the technology selection process and also in raising awareness of AETs in the industry.

In general, it is clear that there are a large number of barriers to using AETs. Of these the non-technical and non-monetary barriers play a large part. These barriers include a lack of experience, information and structured approaches to the consideration of AETs. It is thus the conclusion that we need to focus on our approach as building consultants to informing colleagues and clients in a more open and specific manner. For each project there is a need to understand:

- The project variables influencing the selection of energy technology,
- The important issues and their relative importance,
- Client values
- Levels of risk and their sensitivity
- Upon reflection of these, client preferences between options and their reasoning.

4.9 Summary of Chapter 4

This Chapter presented the results from interviews with 41 project stakeholders. Eight questions were asked in each interview, providing a mixture of qualitative and quantitative information. The results of each question have been presented in turn. Results have been categorised and the responses that fit each category counted up and the subsequent scores represented in graphical form. A summary of the main answer categories is provided for each question, illustrated by quotations from the respondents, followed by any conclusions.

The results of this study have shown that there is a lack of experience of AETs in the building industry, and that the experience and perceptions of building project stakeholders are highly variable. The viability of AETs and the balance of drivers and barriers varies between projects, though financial considerations tend to have a high level of influence in most projects. Financial viability is also the main consideration in technology selections. There is a lack of structured approaches for considering less tangible factors in decision-making, though participants acknowledge that they are potentially very important considerations. Building consultants have a key role in influencing these decisions and they need to be better informed about AETs, their use and assessment approaches that take into account qualitative issues in a structured and consistent way and not just financial viability alone.

These Phase I interview results are based on responses from a mixture of different building project stakeholders who have been asked to reflect on their experiences of building projects where AETs have been considered during the design process. Because respondents are reflecting on more than one project and technology at a time, the responses are quite general and may not show the true impact of specific project factors. The desire for more specific and detailed responses, to allow further analysis, led to the development of the Phase II interviews. These interviews with building services engineers investigate the different approaches used in practice for a number of selected building projects and evaluates whether there is a link between specific project influences and the stage of design to which AETs are considered (i.e. a measure of their success). The results of these project-specific interviews are presented in Chapter 5.

CHAPTER 5 RESULTS FROM PROJECT INTERVIEWS

5 RESULTS FROM PROJECT REVIEWS

This chapter discusses Phase II of this research project, which focuses on the project-specific experiences of building services engineers. Twenty-four projects were investigated in this second phase of participative research (through 17 interviews), using eight questions similar to those in Phase I (as presented in Section 3.4.5). The results of each of these questions are presented in turn. The main answer categories for each question have been coded alphabetically and highlighted, with informative sub-categories also provided in normal text underneath the relevant category. Using these categories the main insights are presented and then illustrated using quotations from the interviews. The analysis of each question is then followed by cross-question analysis of key points and final conclusions.

The projects reviewed in this chapter are briefly summarised by Table 5.1, which lists the projects alongside details of the project type and the number of AETs included through to the construction stage. Further detail of each project, based on the answers provided in each interview is provided in Appendix C.

The project descriptions given in Table 5.1 can be used to provide an approximate breakdown for each function that the projects provide, as shown in Figure 5.1.

Buro Happold were employed as building services engineers on all of the projects used, and this list is close to being all of the projects that had considered AETs in detail at the time of the study within the selection criteria specified in Section 3.4.4. However, the project sample has provided a good balance of projects, which may suggest that it is not only one specific type of project that is relevant for considering AETs.

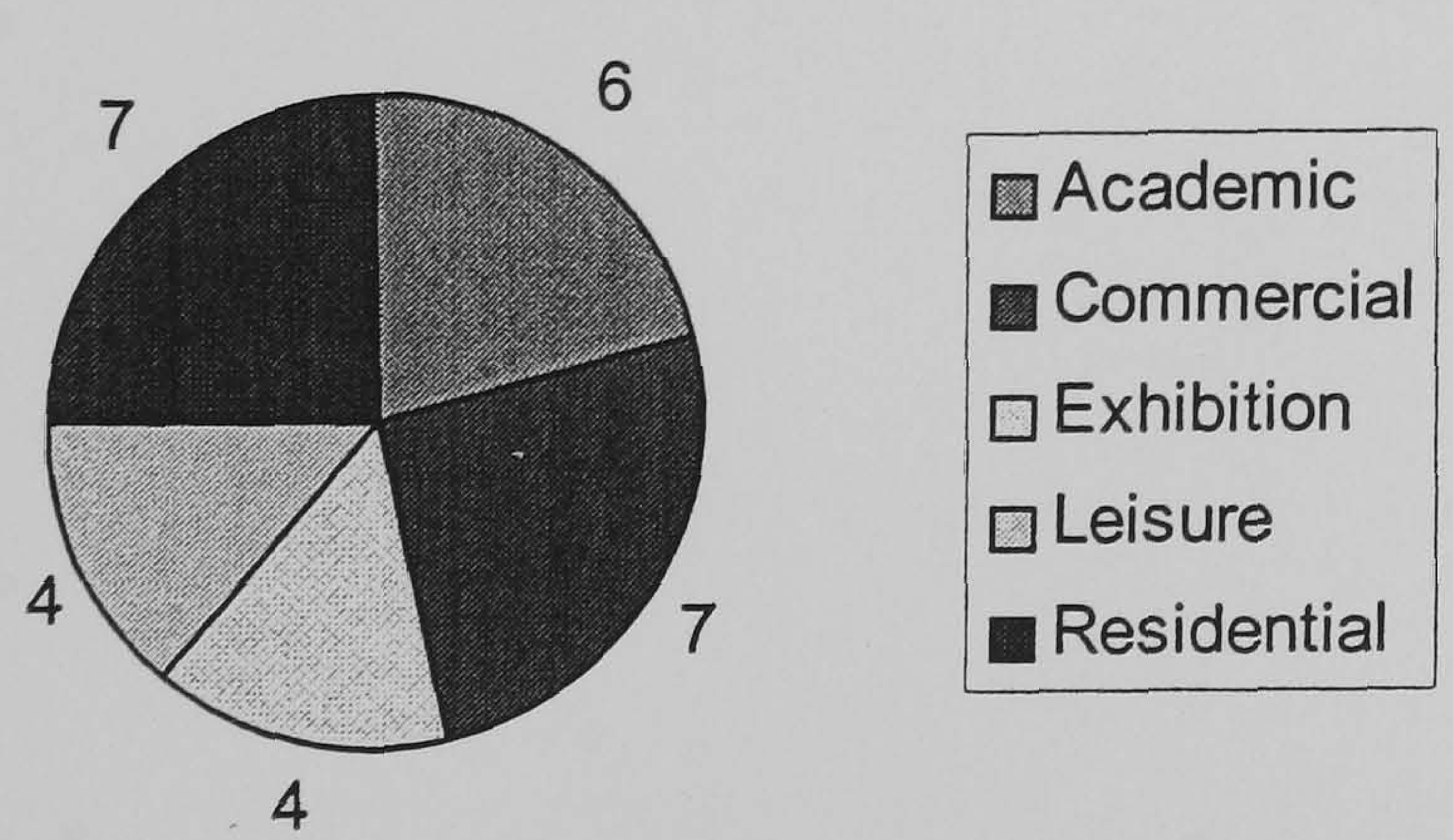


Figure 5.1 Main function of buildings referred to in Phase II interviews

Table 5.1 Details of projects reviewed in Phase II interviews

Number	Project name	Main building type	AETs considered at tender stage
2762	Techniquest	Exhibition	1
5420	Lambay island	Special residential	1
5426	Old Hall Street Liverpool	Hotel/leisure/residential	1
5538	Finglass swimming pool	Leisure	1
5671	Genzme HQ	Offices/light industry	1
5864	Portland Square, Plymouth	Academic	1
5947	Daintree	Residential/commercial	2
6076	TAG Aviation	Special commercial	0*
6108	Carterton leisure centre	Leisure	1
6915	HSE Headquarters	Offices	0
7238	Copenhagen Elephant House	Exhibition	0
7272	Nottingham Academy	Academic	0
7408	Syddansk Uni and Science Park	Academic/entertainment	0
7427	Eden - Phase 4	Exhibition	2
7439	West Tallaght swimming pool	Leisure	1
7502	Northampton city academy	Academic	0
7609	Kensington academy	Academic	2
7617	Rehan Electronics	Light industrial	1
8134	Coillte	Exhibition	2
8209	Edinburgh University	Academic	0
8285	Carlyon bay	Residential/mixed use	0*
8496	Guildford civic hall	Residential/office	0*
8869	Bermondsey Spa Sites E-U	Residential	0*
8933	New Islington Wharf	Hotel/residential	0*

5.1 Initial project aspirations

This section discusses the results from Question 1, which stated:

Please give your perception of the initial project brief and project meetings. Within these were there any references made to aspirations toward considering AETs? For instance aspirations toward innovation, low-energy design, environmental impacts, etc.

5.1.1 Introduction

The wording of Question 1 is of an open nature. This question tries to uncover if the project design brief or early meetings mentioned project aspirations that may support the use of AETs. The question is designed to make the participant think back to how the project began and so helps to uncover any changes in perspective during the design process.

5.1.2 Categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 4 main categories:

1A Yes there was mention of aspirations that support the use of AETs in the early project stages. Sub-categories provide further detail as to the nature of these aspirations, such as reducing carbon emissions.

1B There were no specific drivers for the consideration of AETs

1C Broad details of the project that provide a useful context, including the project type and practical issues

1D Other information that may have supported or restricted the use of AETs, such as the availability of external funding.

The responses relating to each of these categories and to additional sub-categories are shown in Table 5.2.

Table 5.2 Question 1 response categories and sub-categories

	Category (sub-category) description	Total	Participant index
1A	**Yes**	22	**2762, 5864, 5947, 7427, 7617, 8134**
	Special budget made	4	6108, 7502, 8134, 8496
	Running cost considerations	5	5420, 5426, 5538, 7439, 8285
	Low energy / sustainability	14	5426, 5538, 5671, 5864, 5947, 6108, 6915, 7238, 7408, 7427, 7502, 7609, 8134, 8496
	Carbon savings	3	7272, 8409, 8496
	Isolated	1	5420
	Planning incentives	2	7439, 8869
1B	**None**	7	**5426, 5671, 6076, 8933**
	Not defined	3	7238, 7427, 7502
1C	**Project background**		
	Demonstration project	2	2762, 8134
	Project constraints	6	5426, 5671, 6108, 7427, 7502, 8134
1D	**Other reasons**		
	Supply security	1	5420
	Best option	2	5420, 5538
	Grant funding	6	2762, 5420, 5538, 7439, 8134, 8209
	Dropped out	3	5864, 7502, 7609
	Token	2	6076, 7502

Of the 24 projects reviewed 22 supported the consideration of AETs through specific aspects of the project brief during initial project conception. A large proportion of these (14) had the aspiration of being a low energy or sustainable project, which drove the consideration of AETs.

7 of the projects gave negative answers to the question, of which, projects 5426, 5671, 7238, 7427 and 7502 had also given a positive answer. The categorisation used here is not exclusive. In these projects there were 3 cases where the positive aspirations were not substantiated, being more of a wish than an objective. The other 2 cases referred to a variation in aspirations within the client group.

There were also 17 responses that gave additional information, providing some context to each of the projects and other reasons for and against using AETs.

A basic summary of the breakdown of the main categories is given in Figure 5.2.

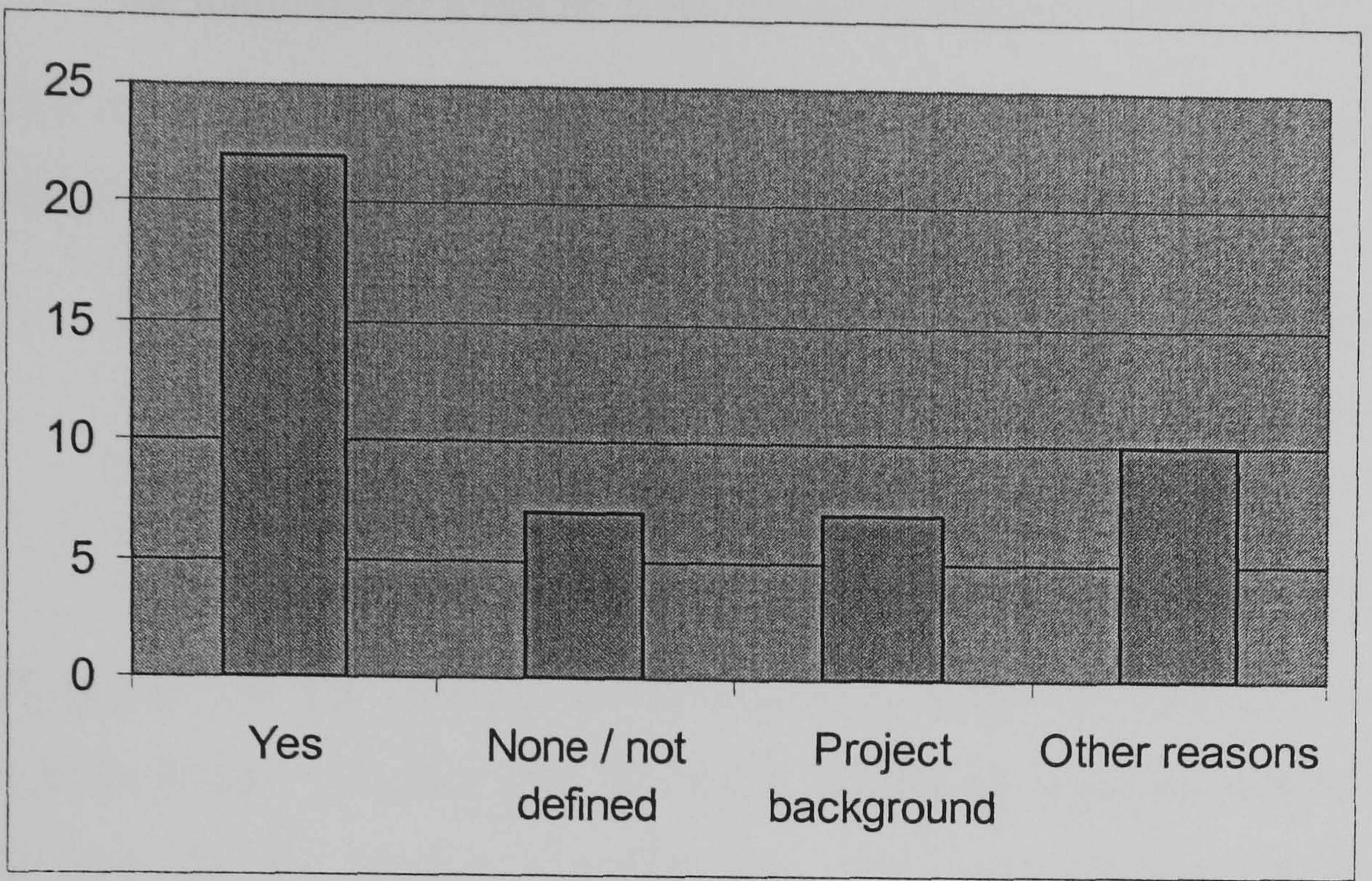


Figure 5.2 Question 1 summary of answers

5.1.3 Discussion

There are a large number of different project factors that if recognised in initial stages can clearly indicate opportunities for including AETs and distinct barriers to consideration.

The factors recognised in the projects sampled include:

- Provision of a special budget
- Desire to reduce running costs
- A requirement for a low energy or more sustainable building
- Aim for carbon dioxide emission reductions
- Lack of infrastructure
- Planning incentives

From Table 5.2 and Figure 5.2 it can be seen that the most common answer to Question 1 was that at the conceptual design stages there were aspirations for the final building that supported the consideration of AETs.

7617 – "The client was very interested in low energy and alternative energies"

Of these responses, only projects 5420, 7439 and 8496 gave the reason that the use of this technology was something of a necessity, i.e. that the site needed embedded generation due to poor energy infrastructure, or that planning conditions imposed it, for example:

5420 – "It is an island off the east coast of Ireland and it is really isolated from the mainland so it has no connectivity to main services of any kind."

The most common subcategory of this group of answers made reference to there being aspirations for a low energy or more sustainable building.

5947 – "They wanted it basically to be as sustainable as it could be for the future, and on that basis they were going to sell the apartments as low energy apartments."

6915 – "The initial brief did actually say that we should consider low energy"

However it is key that this initial support is backed up with sufficient money within the project budget. Integration of AETs into a building project can add to the capital cost of the project. In the projects sampled there was large variation in the level of financial commitment made, which affected the chance of the technologies being constructed.

6108 – "The council as a client were quite open to low energy design within the limits of the budget. The client, to be fair, was very keen that it happened and actually set-aside outside of the contract the value of the project, to pay for the CHP unit. So they were very determined to have this."

7502 – "Like a lot of schools there is a lot of interest in low energy design without there actually being any money to back it up"

Other reasons for considering AETs also came through, such as running cost and carbon reduction issues, for instance:

5538 – "Conscious of their running costs and said they were interested in energy saving devices"

8420 – "The university of Edinburgh has a carbon trading programme, that was one was of their issues in the initial brief."

Finally not all of the projects had initial aspirations for these technologies from all parties, often these drivers came through at a later stage due to changes to the project or project team.

5671 – "The client in this case was a developer, who had some hesitation as you'd imagine from an American developer, in accepting the sort of technologies we were talking about. The occupant, which was Genzyme, came into the process with a different view of life. They were interested in sustainability."

Along with these direct answers to the main question other information was given that adds context to some of the answers given and shows the nature of the projects being reviewed, and the reasons that AETs were considered, or dropped. A number of the answers referred to the importance of economics (6) and economic instruments, such as grant funding schemes (6).

> 7427 – "As we went through we hit a wall which was bringing the project into line with the budget."
>
> 7439 – "There was also the incentive for grant funding."

Other non-monetary drivers and barriers were also mentioned:

> 2762 – "keen to promote demonstration projects as part of a working display"
>
> 7609 – "But the reason why we didn't carry forward for that one is the people helping us to get the info on cost were not very proactive, when you ask them something they get back to you after a long time, and we didn't have enough time. "

5.1.4 Conclusions to Question 1

The specific question asked here is whether or not there was a clear initial driver for considering AETs. In very few cases there was not. This is not a normal set of projects, in the way that these have been selected because they included AETs in the design process at some stage. That these technologies are considered is not common in building projects, and these are an unusual group. From these results there is a clear correlation here between these technologies being included in the project and there being an initial drive for doing so.

It is not possible to say that <u>with</u> recognition of an initial driver AETs will always be considered, there are other factors that also influence that, but it is possible to suggest that <u>without</u> recognition of any driver there is a far lesser chance of this being the case.

The consideration of these technologies in building projects is very rare: this selection of 24 projects were close to being the full extent of the available sample of Buro Happold projects that had considered using AETs at the time of the study. Buro Happold have consulted on over 9000 projects since their formation in 1975, and are considered as leaders of innovation within the field of building consultancy.

For AETs to be used they need to be investigated from the very beginning. Questions need to be asked during the intial briefing process about any potential factors that may support the use of AETs for them to be used more frequently. Without being considered at the initial project conception stages it will be increasingly difficult to include AETs in the building.

Along with more informed engineers and architects to spot and make the most of the opportunities for using AETs, clients need to be driven toward developing more low energy/sustainable buildings and to value the carbon saving, supply security and green image benefits.

The reasons given for considering AETs varies greatly between each of the projects, depending on the specific project circumstances and the desires of project stakeholders. Therefore no standard answer is valid to the question: which AETs should be used in building projects? For each project the financial, technical and social viability of each technology will vary, along with the level of environmental benefit obtained.

The importance of these factors supporting or restricting the use of AETs are investigated further in later questions.

5.2 Success levels of AETs in each project

This section presents the results from Question 2, which stated:

At what stages of the design were each of the AETs considered?

5.2.1 Introduction

Question 2 is an open question that expands on the information obtained in Question 1, here the participants are asked to consider how the consideration of AETs progressed through the building design process. This question drives the participant to think about the changes in perception of the opportunity for using AETs in the project, and the factors that influenced these changes.

5.2.2 Quantitative results

Participants were asked to indicate to which stage the project had included consideration of AETs. These stages were coded as A for concept design, B for detailed design and C for construction. Given a score of 'B' it was presumed that the option had also been considered at stage 'A' and a score of 'C' that consideration was made at stages 'A' and 'B'. The results presented in Table 5.3 and Figure 5.3 represent the count of these answers. This tries to generate an understanding of a success rate; it allows some comparison of the likelihood of these technologies being constructed upon being considered at first.

Table 5.3 Number of building projects that have included AETs, and the stage to which these technologies were included.

	Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
Concept	18	15	1	9	11	4	11
Detailed	6	6	0	1	10	4	9
Construction	3	4	0	1	3	2	4
% completed	17%	27%	0%	11%	27%	50%	36%

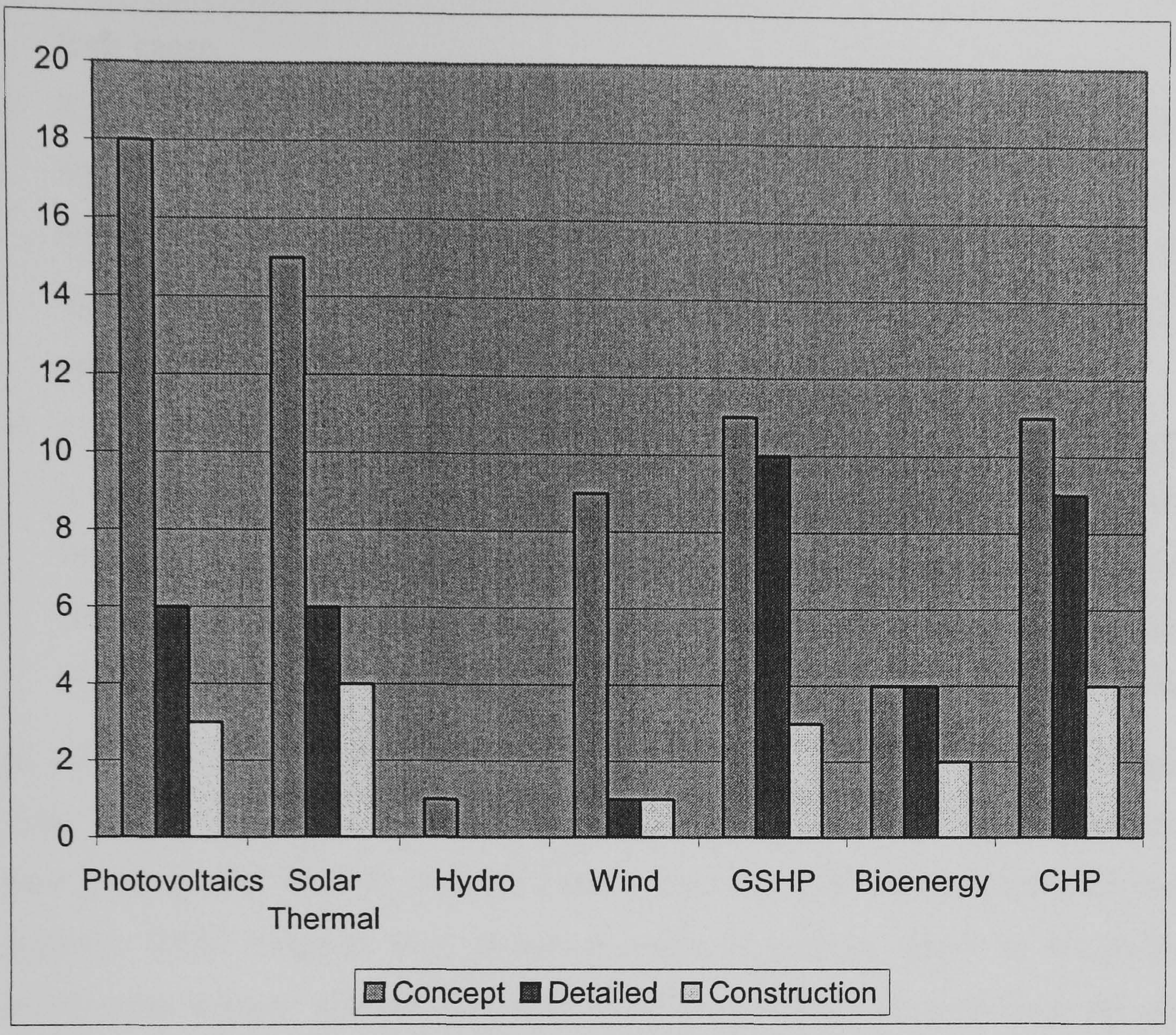


Figure 5.3 Diagrammatic representation of project involvement considering AETs

The results from this breakdown do show that there is a clear disparity between the number of these technologies considered as a potential option at feasibility stage and the number of the technologies included through to completion.

These 24 projects all considered AETs in the building design process, however only 13 of the projects have followed these designs through and into the construction phase. In four of these cases two technologies have continued through to construction, projects 5947 (Daintree), 7427 (Eden project), 7609 (Kensington academy) and 8134 (Coillte).

These are quite special projects, as follows:

- Daintree is a mixed residential and commercial development in Ireland. The client is not a speculative developer but will play the part of owner-occupier. They employed a very environment-focussed architect and had the aim of being "as sustainable as possible".
- The Eden project is an education exhibition building with very high environment friendly credentials. They specifically wanted this new extension, Phase 4, to be highly sustainable, they are also a registered charity, so could quite easily attract funding for

their cause.

- Kensington academy is a new academy funded by the DFES (Department for Education and Skills) being built in Liverpool, the first with an educational focus on the environment. For this project the architect was very keen to include sustainable design concepts and technologies and the project team convinced the client to provide a special budget for such aspects.
- Coillte is the Irish equivalent to the Forestry Commission in England. This project was an extension of their 100% timber construction headquarters and visitor centre. Again the client and the architect were committed toward using renewables because of the image and environmental benefits. In particular the client wished to support the biomass heating industry as part of its role even though they had a limited budget.

In only 2 of the projects, 6076 (TAG Aviation) and 7502 (Northampton academy), were these technologies only considered at the concept design stage. Northampton academy, a new leading-edge school, suffered from a lack of client commitment and design team support. TAG Aviation is a series of airport buildings, some of which have been constructed without any consideration of AETs, and only recently have the engineering team looked at the concept of using solar photovoltaics. This project is still in the design process, and so they still have a chance of being installed.

Some of the other projects discussed are also yet to reach the construction stage and so the percentage of technologies reaching construction figures shown above may improve. Though reaching construction stage may not lead to actual implementation as shown with project 2762, Techniquest, which faced unforeseen construction problems and failed to implement the Ground Source Heat Pump system.

Of all the technologies, small-hydro power was considered the least often, with only one consideration at concept stage. This is because of the highly location-dependent nature of hydro power, which is only rarely a suitable method of providing energy for building projects.

The most likely to be considered in the initial stages are the solar technologies, solar photovoltaics (18) and solar thermal collectors (15). These are simple technologies that are relatively easy to integrate into the building design and have a visibility potential which can be favourable with architects. The success rate of these technologies is not as high as some of the others, though they are considered more regularly.

Another technology with a poor success rate in the projects considered is that of small wind turbines, which were considered 9 times but only installed once. This single application is for Lambay island where the buildings are very remote and were suffering from fuel supply security problems, and so is quite a unique project.

The other technologies, GSHP, bioenergy and CHP systems, are each considered in less than half of the projects, though have the highest success ratios (27%, 50% and 36%). With this small sample of projects it is not possible to assume that this is a common trend

Of all the technologies considered there was on average a 25% chance of them being carried through to the construction stage.

When combined with the previous results from the same question, from the focus group and Phase I interviews, the outcome is as shown in Table 5.4.

The results of combining the answers from each phase should not be taken too literally as some projects are included more than once in this. However it does show that though there is a different spread across the technologies there is an overall chance of around 30% that if a technology is considered at concept it will reach the construction phase.

Table 5.4 Number of building projects that have included AETs, and the stage to which these technologies were included; Focus group, Phase I and Phase II results.

	Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
Concept	52	46	12	38	36	34	46
Detailed	24	25	1	8	22	16	29
Construction	16	19	1	7	11	8	19
% completed	31%	41%	8%	18%	31%	24%	41%

5.2.3 Other answer categories

Participants could also expand on their coded answers with details of the project with further insights as they desired. The additional information given was captured and has been coded, separated, organised into headings and indexed into the following 4 main categories:

2A These technologies were considered from the beginning of the project

2B They were not looked at seriously until later stages of the project

2C Broad details of the project that provide a useful context, including the project type and practical issues. Subcategories for this grouping include a range of drivers and barriers that influenced the viability of AETs through the project stages.

2D Other information was given, in this case that a design study was completed.

The responses relating to each of these categories and to additional sub-categories are shown in Table 5.5

Table 5.5 Question 2 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
2A	**From the beginning**	**15**	**2762, 5420, 5864, 5947, 6108, 6915, 7238, 7272, 7408, 7427, 7502, 8134, 8209, 8285, 8869**
2B	**Not until later stages**	**3**	**5671, 6076, 7609**
2C	**Project background**		
	Practical drivers	3	2762, 5538, 8933
	Practical barriers	8	2762, 5538, 7408, 7427, 7609, 8209, 8496, 8869
	Cost drivers	1	5426
	Cost barrier	8	5420, 5538, 7272, 7408, 7427, 7502, 8496, 8869
	Funding	4	2762, 5671, 7427, 7609,
	Client commitment	4	6108, 7427, 7609, 8933
	Needed to raise awareness	4	5426, 6076, 7408, 7502
	Environmental benefits	3	5671, 7609, 8933
	Non-technical barrier	3	7427, 7502, 7609
2D	**Other project information**		
	A design study was completed	4	5864, 6915, 8285, 8496

5.2.4 Discussion of Question 2 responses

The majority of the projects considered AETs from the beginning of the design process, with only 3 projects having a focus applied later in the project process, due to changes in client objectives or due to time considerations.

Many of the answers given to this question referred to factors that influenced the progression of the technologies, such as specific restrictions or reasons for their progress.

Of these the most common were the practical barriers and the cost barriers, each with 8 responses; examples of these are as follows:

> 2762 – "They went to a fairly cheap company who hadn't that kind of experience, and the net result was we had a lot of problems on site."
>
> 5538 – "wind generators for external lighting but again it was ruled out because of the area required for batteries and the cost so we didn't proceed any further."
>
> 8496 – "Solar thermal considered and dropped because it reduced the viability of CHP."

Some of the projects considered only one technology, often because it stood out as being a good idea from the very beginning:

> 2762 – "From the outset GSHP. As part of our scheme design report we identified this site in particular just looking at all options as a chance of promoting this, the one that kept coming up was the use of ground source."

Alternatively some approaches looked at a whole basket of technologies and then selected favourites to develop as the project progressed:

> 5947 – "PV up to scheme stage, solar thermal is still there, wind at concept, GSHP is still there, CHP at concept"

Of the three projects that only considered these technologies at later stages two of them were successful through to the construction stage. All of these projects focussed on solar technologies, which can often be easier to integrate into the building fabric at late stages than other AETs, so long as there is sufficient solar orientation.

> 7609 – "Photovoltaics [at] stage C & D, a brief paragraph in the report, but no analysis. Went through to construction. Analysed after tender. The good thing is that this is standalone item so we didn't consider that from the beginning, but as long as you have the money then you can put it in at any time."

5.2.5 Conclusions to Question 2

The results show that there is a variation in the approaches used for each project, with some projects focussing on a single technology at the early design stages and others looking at a range of technologies or making assessments at very late stages.

The variation in influence of different project factors is also apparent, with examples of economic, technical, political and social factors provided. Some of these factors vary due to the type of project, the project personnel and the technologies being considered.

There is a noticeable disparity between consideration at concept stage and through to construction. It is difficult to know how this compares with other aspects of the design, but obviously these technologies are being included in early drawings without being core to the building design ethos in most cases. Most building designs do not consider AETs at all, but of those investigated in this research that do there is only around a 30% chance of a technology being constructed upon inclusion at the concept design stage.

Though this question did not ask participants about the reasons for success or failure of AETs in each project, many factors were mentioned.

Economic factors were mentioned in 12 of the responses demonstrating the importance that economics plays in building projects. Also practical considerations were mentioned in 9 responses, and a number of non-technical and non-financial factors are highlighted. This demonstrates that there is not a monopoly of economics being the main issue, though its inclusion as an issue is common.

The spread of experience shows that projects are tending to focus on solar technologies, though with a lack of examples at detailed design stage these may not be wholly committed considerations. Solar technologies tend to be included with little forethought, for example as token elements within competition for winning work. This may be because of their high visibility and social acceptability, allowing a 'green' appearance and also because of their presumed technical simplicity.

The results of this project sample indicate that some of the other technologies have higher success rates at being considered in detail. CHP certainly benefits from a greater engineering understanding, with a better understanding of where it will and will not work, reducing the number of inappropriate considerations.

5.3 The importance of AETs and role of project team members

This section presents the results generated from Question 3 in the interviews, which asked:

How much of a part did the consideration of these technologies have to play in this project? How does this compare with other aspects of the design? Which project team members were influential in this?

5.3.1 Introduction

To be able to play a significant role in reducing the environmental impacts of building operation AETs need to be taken seriously. They need to be installed in a vast number of projects and of sufficient scale to make a difference. For this to happen they need to be considered as an important or central part of the building design, not as a token element or a distraction in the design process.

Question 3 is an open question that tries to identify how important AETs are as a part of the building design process. It should help to affirm whether there is any justification for assessing these technologies in detail. Its aim is to investigate whether or not AETs are considered to be central to the design of buildings or perceived to be an additional extra.

The final part of the question investigates the roles of project stakeholders and their impact on promoting or restricting AETs in these selected building projects.

5.3.2 Categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 5 main categories:

3A These technologies played an important part of the design.

3B They were not considered to be a core part of the design and had little impact

3C They played a small part in the design, or they were only considered for a short time

3D Background project information including the roles of project team members and their influence on the consideration of AETs

3E Other responses, including other project factors that influenced the viability of AETs

The responses relating to each of these categories and to additional sub-categories are shown in Table 5.6 and Figure 5.4.

Table 5.6 Question 3 response categories and sub-categories

	Category (sub-category) **description**	**Total**	**Participant index**
3A	**An important part**	**11**	**5420, 5671, 5947, 6108, 7238, 7408, 7427, 7617, 8134, 8496, 8869**
3B	**Not really**	**2**	**5426, 7272**
3C	**Small part / at concept**	**7**	**5538, 5864, 6915, 7427, 7502, 7609, 8209**
3D	**Project background**		
	Demonstration	5	2762, 5538, 7427, 8134, 8496
	Lack of interest / Needed to raise awareness	6	5426, 5671, 7272, 7502, 7609, 8209
	Funding	3	2762, 7439, 7609
	Client role	13	2762, 5671, 5864, 5947, 6108, 6915, 7238, 7272, 7408, 7427, 8496, 8869, 8933
	Building users	2	5671, 8496
	B.S. Engineer	11	2762, 5426, 5864, 5947, 6108, 6915, 7408, 7427, 7502, 7609, 8209
	Architect	10	5947, 6108, 6915, 7238, 7272, 7408, 7427, 7609, 8869, 8933
	Other team members	4	5864, 6915, 7427, 8933
3E	**Further information**		
	Economics important	10	5426, 5864, 6108, 6915, 7408, 7427, 7439, 7502, 7609, 8285
	Risk	2	7408, 7427
	Practical barriers	7	5538, 6108, 7238, 7427, 7502, 8496, 8869
	Straightforward	1	5538

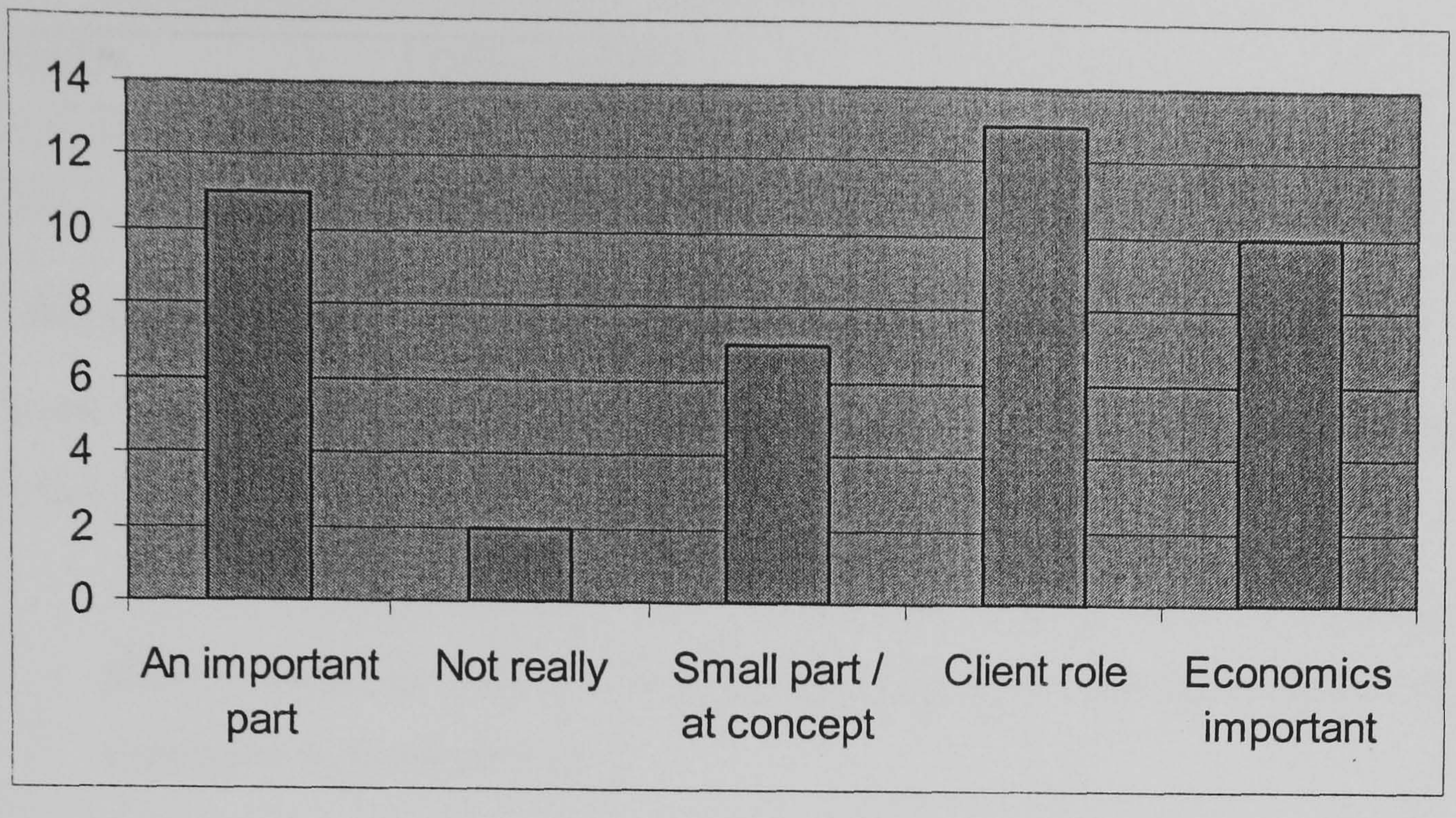


Figure 5.4 Summary of responses for each category

5.3.3 Discussion of Question 3 responses

The question that these results need to answer is "If AETs are considered in detail / as important in a building project, do they hold a better chance of deployment? From the 24 projects reviewed, eleven of them included AETs as an important part of the building design; these projects hold the following characteristics, outlined in Table 5.7:

7 of the projects are from outside of the UK. All of the projects are owner occupied or are developed by the council or a not-for-profit organisation. 7 of the projects have included 1 or more AETs through to construction, 2 of them are yet to reach construction stage and the other two (Syddansk and Copenhagen) have suffered a comprehensive change in the design team and project rationale since the concept design stage.

Table 5.7 Details of projects where AETs were judged to play an important part

Project name	Building type	Client type	AETs installed
Lambay island	Special residential	Charity	1
Genzyme HQ	Office	Occupier	1
Daintree	Residential/commercial	Occupier	2
Carterton leisure centre	Leisure	Council	1
Copenhagen zoo	Exhibit	Occupier/charity	0
Syddansk University	Academic	Occupier	0
Eden project	Exhibit	Occupier/charity	2
Rehan Electronics	Industrial	Occupier	1

Coillte	Office / exhibit	Occupier/charity	2
Guildford civic hall	Office	Council	0 *
Bermondsey Spa	Residential	Housing Association	0 *

*** this project had not reached the construction stage at the time of interview**

Some of the quotations from these project interviews illustrate the importance of these technologies:

> 5671 – "Once we decided what we were doing in terms of the environmental story, it began to impact on the project quite considerably, in terms of people wanted to understand more."

> 7617 – "They were core to the whole design"

Not all of the projects saw AETs as so important, and there were 7 responses that suggested they only made a mild or short-lived impact, for example:

> 8209 – "In terms of the competition there was an eagerness to have these included and it was right up there as a centre point. In initial meetings it quickly came apparent there was a possibility for CHP it didn't disappear off the agenda but it didn't ever rear itself as an important issue."

The two projects where AETs were not considered as important were 5426 Old Hall Street and 7272 Nottingham academy. Old Hall Street included a CHP system in construction, whereas on Nottingham academy there was consideration of solar technologies and ground source heat pumps.

Old Hall Street is a hotel with a swimming pool and a residential tower. The developer had no interest in AETs, though the hotel operator has a 10 year lease and was interested in CHP. They have installed a CHP system at zero capital cost, through a leasing agreement. CHP was considered as "not particularly important" but was included because "it showed clear cost savings". In the process "the Engineer [played a] key role, otherwise it would have quite easily have been forgotten".

From Figure 5.4 it can be seen that the role of the client, building services engineer and the architect have had a large effect on promoting or restricting the use of AETs.

> 5864 – "It depends on how green a client wants to be. It is predominantly driven by ourselves with the client."

> 7272 – "The architect was really influential on avoiding it on Nottingham"

There are mentions of other project stakeholders too, showing that there are always people that need convincing.

> 6915 – "The facilities management people were keen so it was not just the architect and ourselves that were interested."

> 7427 – "I would say from the contractor's point of view they could potentially see alternative technologies as possibly slowing down the project particularly when there was a driving programme behind it all."

5.3.4 Conclusions to Question 3

The objective of Question 3 was to challenge whether the consideration of AETs is an important part of building projects and affirm whether there is any justification for assessing these technologies in detail.

The inclusion of AETs in building design is rare, the 24 projects reviewed here all considered AETs to varying extents, and of these in only 2 were AETs not seen to be at all significant. From this it is therefore clearly very important that these technologies are considered seriously. It is also clear from the results that having buy-in from the client, architect and building services engineer is essential.

It seems from these results that to be included through to construction the client body must be strongly convinced that inclusion of AETs is the right way forward for the project, and that the subject should always remain a key point on the agenda. The buildings where these technologies have been considered as key and then applied have all had clients interested in the operation of the building and the benefits brought to occupants. They have not been primarily focussed on capital cost reductions, though there are always considerations of a limited budget. It seems the case that as these technologies are seen as important they play a key role in the building and thus are included within the budgets set, rather than being additional to the core design.

5.4 Drivers and Barriers to using AETs in each project

This section presents the results from Questions 4 and 5 which asked:

What have been the drivers for considering AETs in this project? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies	Image	Planning
Environment, e.g. Climate change	Long-term economics	Lack of infrastructure
Politics	Corporate social responsibility	Plant space

What have been the barriers for considering AETs in this project? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee	Proximity to resource	Cost (High capital and slow payback)
Climate (variable)	Ignorance and lack of understanding	Perceived risk
Stubbornness of energy industry	Incoherent Policy and Planning constraints	Unsuitable site
Maintenance	Complexity	Unproven
Lead time in construction	Environmental and Ecological impacts	Communication and common language

5.4.1 Introduction

Question 4 and 5 are closed and quantitative questions. The categories used were identical to those used in the first phase of interviews, generated from the focus group research. In the interviews each participant was asked to provide a score for each of the headings out of ten, in terms of the drivers & barriers for the use of AETs in building projects. The use of quantitative scoring allows the options to be compared and developed into a hierarchy. This judgement is used to justify whether existing methods or other decision making approaches would reflect these drivers and barriers more adequately. It can also allow reflection of which areas can be influenced by the work of the building consultant, and so help to focus future study.

It is clear that not all projects have the same drivers & barriers associated with them, indeed it was suggested that each technology will be affected differently by the various drivers. The use of a 10 point scale was used to try to allow for some of this variation where a 10 could represent a mark of always very important and 1 never important at all. Medium scores may be used to represent very important infrequently, or always of some importance.

Figures 5.5 and 5.6 show the range of scores given for each of the drivers and barriers listed, along with the median, upper-quartile and lower-quartile scores.

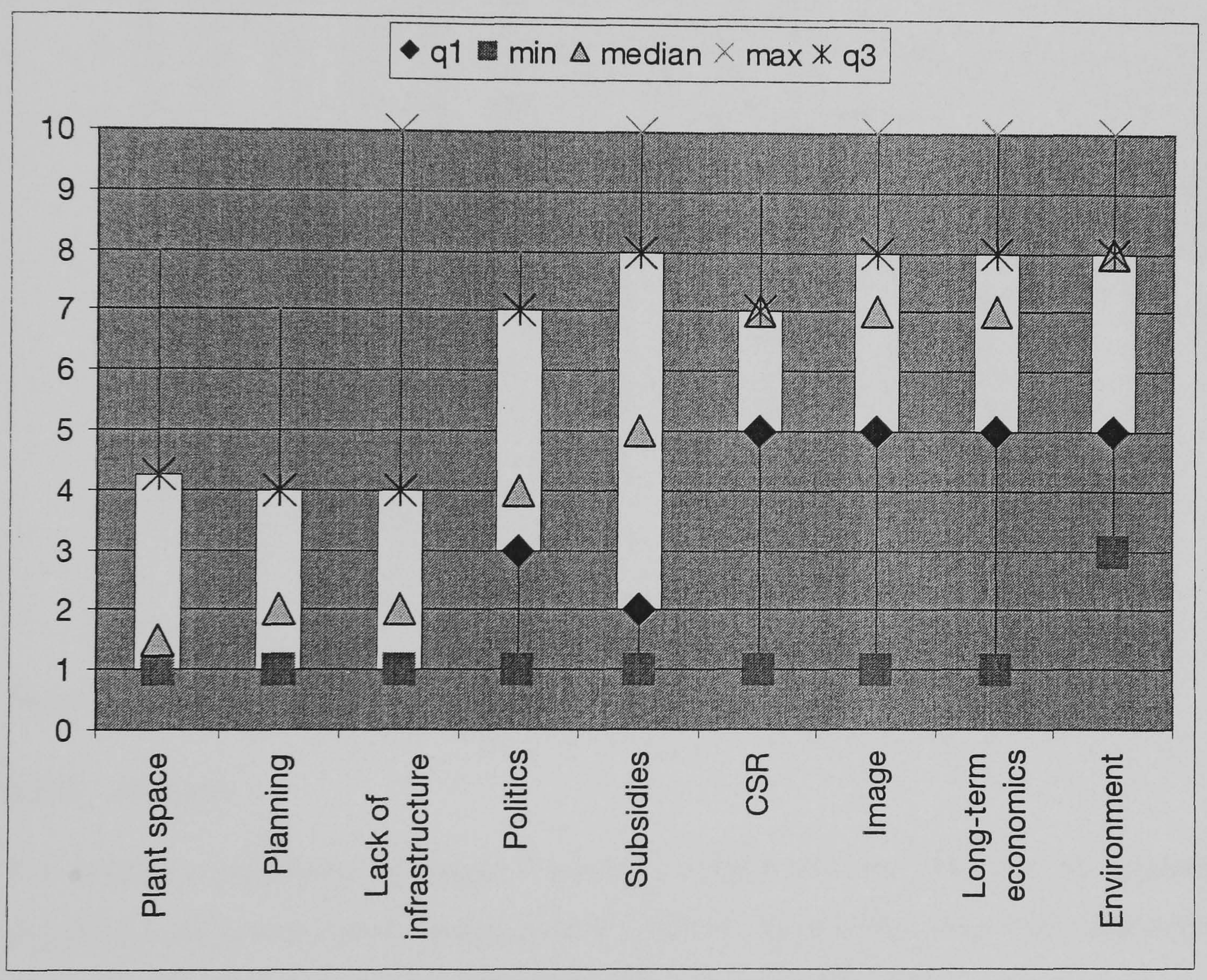


Figure 5.5 Box and whisker plots of the various drivers to using AETs

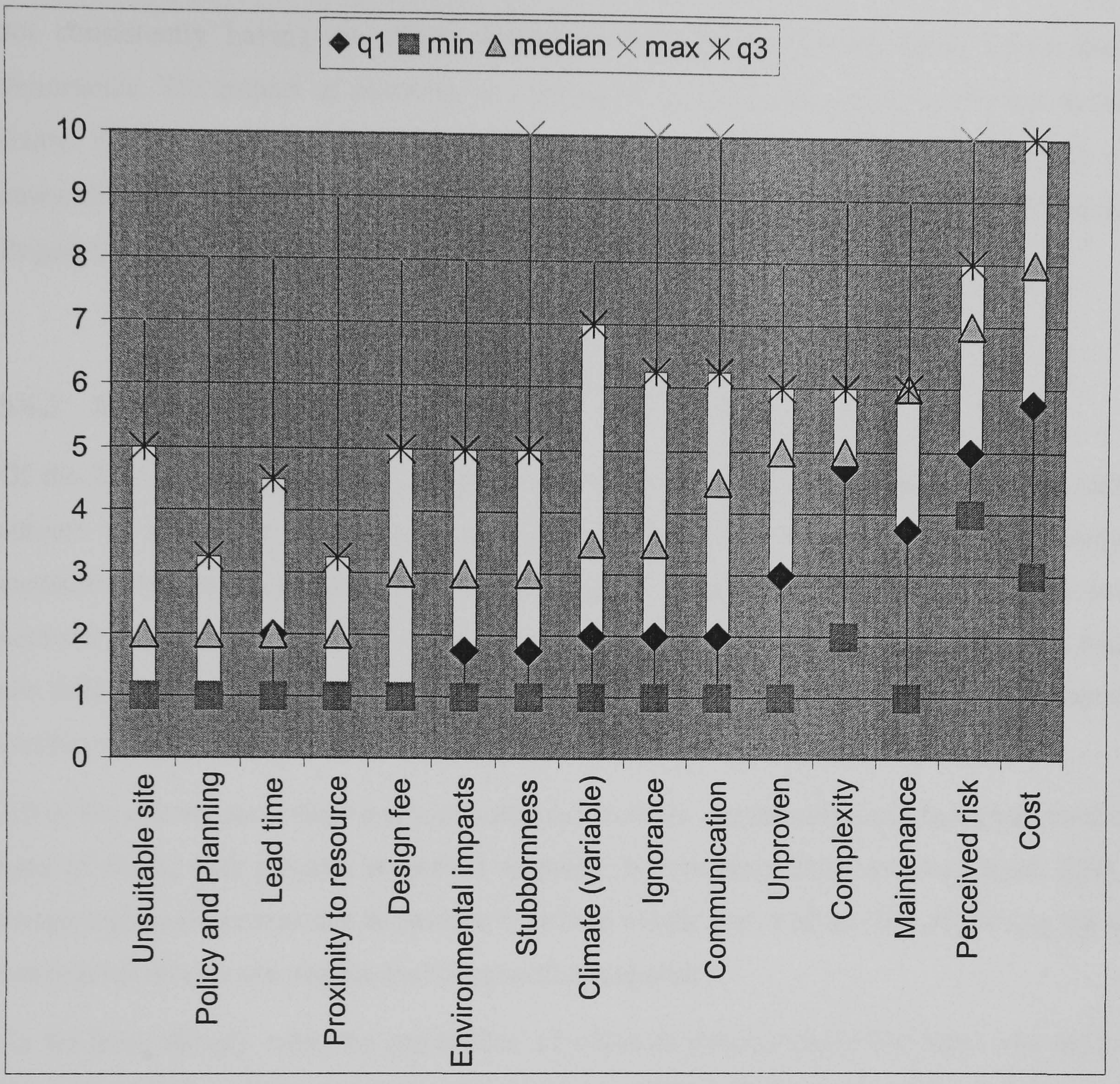


Figure 5.6 Box and whisker plots of the various barriers to using AETs

5.4.2 Drivers

The results summarised in Figure 5.5 seem to show that four factors tend to stand out as significant drivers for the consideration of AETs in the projects reviewed. These factors are the environment, image benefits, CSR and long-term economics.

Below these there are two factors that receive moderate scores, subsidies and political drivers. The scores attributed to subsidies are interesting because of their very large spread, with an inter-quartile range between 2 and 8. This shows the range of importance attributed to subsidies based on the nature of the project, the time available and the technology selected.

The three least important of the drivers are deemed to be a lack of plant space, planning requirements and a lack of infrastructure. These aspects are practical considerations inherent within particular projects. Within the majority of projects reviewed here, these are not consistently having an effect, though in specific cases they have shown their importance. The impact of planning as a driver may also become more important in the future, due to pressure being exerted by local authorities for a minimum amount of renewables on large building projects, and recent changes to Part L of the Building Regulations that promote the use of AETs.

5.4.3 Discussion of drivers

Of the four highest drivers only long-term economics is easily quantifiable, and it is still subject to a number of assumptions. The environment is becoming more commonly measured through estimates of carbon savings in decision-making, though this is not necessarily representative. The remaining two, CSR and image and qualitative factors that are difficult to judge in terms of a) the scale of the benefit gained, and b) the importance attributed to them.

All of the drivers show high levels of variation. Politics and subsidies are dependent on the type of client, with projects supported by public bodies more likely to be affected. CSR, image and environment are dependent on client values and wishes. The remaining three lower level drivers are project-specific practical variations.

As we have already seen, the application of AETs in these projects has been very much dependent on the client and their commitment to making these technologies key parts of the design. There are also cases, such as Lambay island and Techniquest where specific site considerations have played a key role in supporting a wind turbine and a GSHP system respectively.

5.4.4 Barriers

The result of scores attributed to the list of barriers, summarised in Figure 5.6, show that in these projects the impact of high capital cost and slow payback is the primary barrier to using AETs in building projects. However, there is not a monopoly on barriers, as the spread of scores attributed is quite large, with an inter-quartile range of 4 and a lowest rating of 3.

Close to cost in the scores given is ‘perceived risk’, which obtained a median rating of 7 and a lowest rating of 4. Though not such a significant factor as cost, a perception of risk within the project team is seen to be a consistently high barrier.

Four of the barrier headings receive moderate median scores of between 4.5 and 6, these are: lack of communication and common language, unproven, complexity and maintenance. The other 9 headings receive low median scores, below 4, though even with this all receive high maximum ratings at times, with the stubbornness of the energy industry registering a 10.

5.4.5 Discussion of barriers

High capital cost is a consistent factor associated with AETs. Meanwhile building projects are all constructed to a limited budget. In most cases where a client is looking to achieve a short payback, these technologies will not meet their criteria. In this selection of projects cost is seen to continue to play an important role, however the technologies have still progressed through to the construction stages.

The large spread of scores attributed to cost as a barrier, down to 3 as a minimum, proves that cost can become a secondary factor in a project where AETs can be proven to add value, either by proving to be the lowest cost option or through other means.

The building services engineers interviewed also believe that a perception of risk within the design team has proven to be a barrier throughout the project design period. This is perhaps the nature of the construction industry to be cautious but needs to be overcome through proving the ability of AETs in practice. The keys to breaking down this barrier are: further education of how they can be applied, use of standard approaches and clear and consistent communication.

Three of the moderately rated barriers, 'communication', 'unproven' and 'complexity' are related to perceived risk in that they are dependent on the knowledge and perception of the project design and the transfer of information. The other barrier of a similar level of importance is 'maintenance', which is a practical aspect related to each technology.

Therefore, beyond cost and maintenance, which are technology-related factors, there are a number of important barriers that need to be addressed, which are in the hands of the project design team. These factors can be overcome through a better supply of accurate, proven performance and design information, allowing informed and swift decision-making.

5.4.6 Conclusions to Questions 4 and 5

These two questions investigate the importance of a range of known drivers and barriers to the use of AETs in buildings. Reflecting back on the project, the engineer is asked to provide a score out of 10 for how much influence each of these factors had on the viability of keeping these technologies in the design.

The results above show the importance of long-term economics, the environment, CSR and image benefits as drivers, and of high capital costs and a perception of risk acting as barriers for the use of AETs.

To test if these insights are consistent with the views of other stakeholders a comparison has been made between the results shown in Figures 5.5 and 5.6 and the results of the Phase I interviews in Figures 4.4 and 4.5. The results of this comparison are presented in Sections 6.3 and 6.4.

A comparison can also be made within the results of the project focussed interviews by investigating the outcome of each project and separating those that included AETs through to construction, those that are incomplete and those that failed to include these technologies. This gives an insight into what factors tend to be common within projects that successfully implement AETs.

The breakdown of median scores shown in Figures 5.7 and 5.8 represent the difference between the answers given to Questions 4 and 5 depending on the success of AETs in each project. A comparison was made between the scores attributed by respondents for projects that included one or more AETs through to construction, and for projects that failed to reach construction with AETs still in the design. Projects that are yet to reach the construction stage are ignored for this comparison.

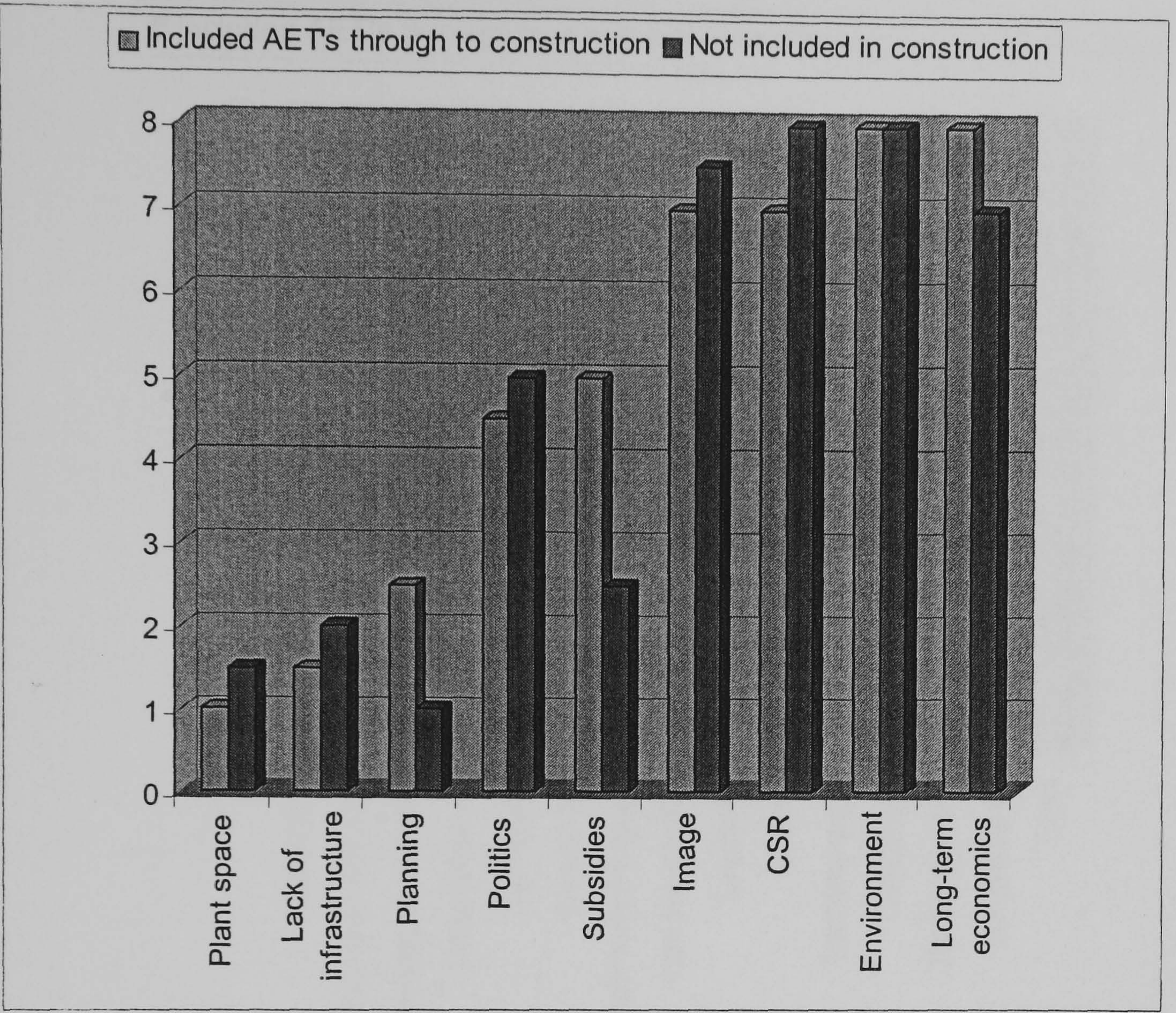


Figure 5.7 Median scores for drivers for AETs from projects with different levels of success

In terms of the drivers, the projects that considered AETs through to completion gave higher median scores by at least 1 point for 'subsidies', 'planning' and 'long-term economics', and 1 point lower for CSR. These scores tend to indicate that the more successful projects were funded through public money, as most commercial developments cannot attract government subsidies for AETs, whilst CSR would also be more relevant for commercial clients.

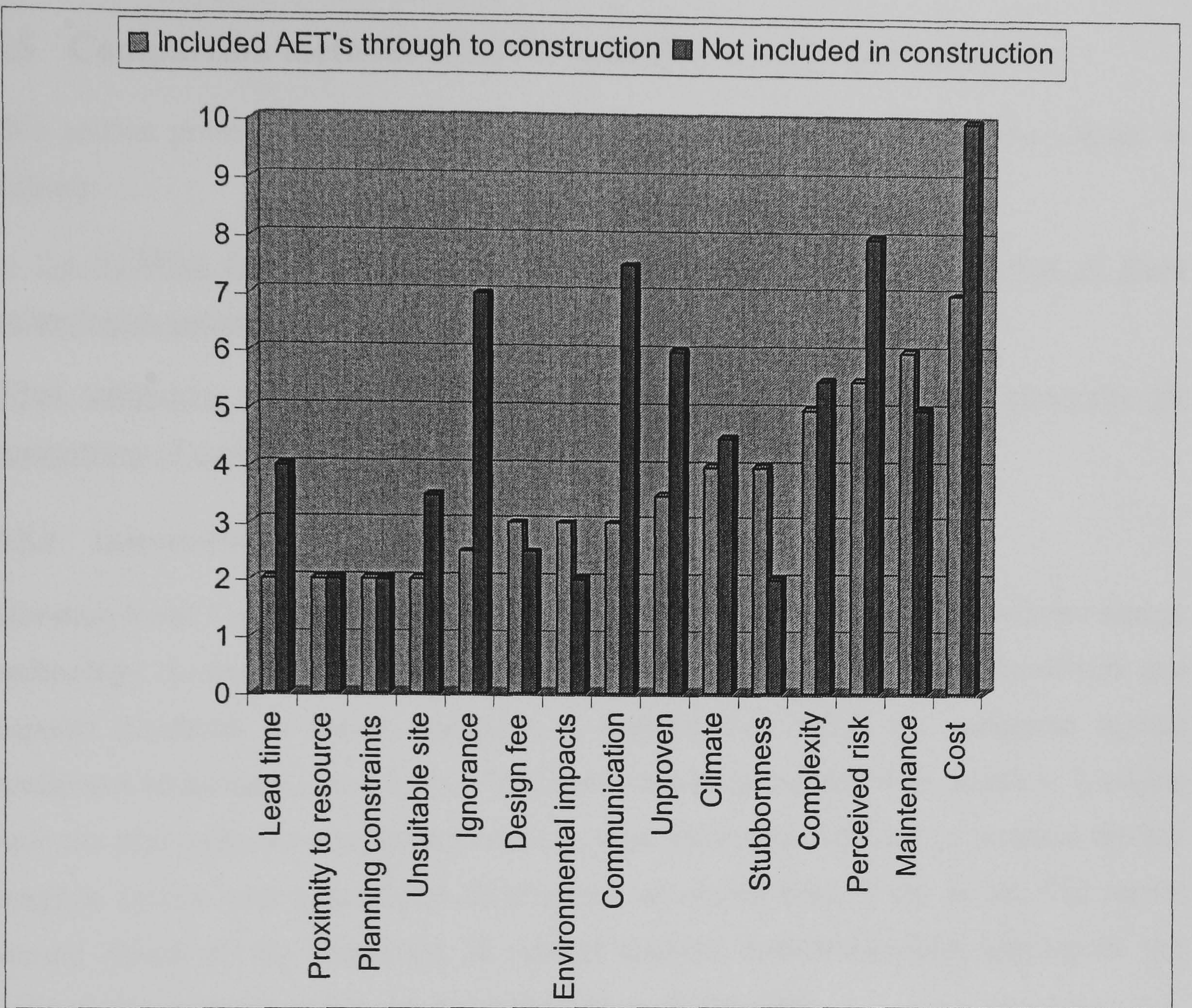


Figure 5.8 Median scores for barriers for AETs from projects with different levels of success

In terms of the barriers, the projects that considered AETs through to completion gave lower median scores by at least 1 point for ignorance (4.5), communication (4.5), cost (3), perceived risk (2.5), unproven (2.5), lead time in construction (2) and unsuitable site (1.5). Only the stubbornness of the energy industry, maintenance and adverse environmental impacts were given a higher score by at least 1 point. For the projects that succeeded to take AETs through to the construction stage the barriers were attributed much lower scores, with cost proving a much lower barrier and also ignorance, communication, perceived risk and unproven. That these four headings are much lower for successful projects is a key factor for this research. This justifies that where these barriers can be reduced there is a better chance of installing AETs.

5.5 Comparison methods used for selecting energy technologies

This section presents the results of Question 6 and Question 7, which were worded as follows:

In the building design process how were the negative and positive aspects of these technologies considered and compared?

What techniques were used for informing the decision making process, especially for comparison of quantifiable factors with some of the less tangible factors?

5.5.1 Introduction

Question 6 and Question 7 are open questions that try to investigate how different energy technology options are compared in building projects. They build upon the drivers and barriers discussed in earlier questions to address how AETs are compared against traditional technologies in practice. Question 6 works in tandem with Question 7, asking how are pros and cons weighed up and then what techniques are used to compare the less tangible factors with quantifiable factors such as capital cost; if any at all. The results should reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.

5.5.2 Question 6 and 7 categories

The results from the interviews have been coded, separated, organised into headings and indexed into the following 10 main categories:

A The decision to proceed with examining these technologies is based on economic considerations, in the form of capital cost, simple payback or life cycle cost terms.

B The decision making process is based on a comparison of different options and the balance of pros and cons. This may be as part of the design report produced by the building consultant and presented to the client.

C Qualitative considerations have been made during the decision making process, such as the consideration of risk, image or social factors.

D Other quantitative considerations were made, such as calculating the potential carbon saving.

E The respondent was not aware of any formal methods used within the project for considering AETs in building projects.

F The approach used to compare these technologies, if at all, depends on the values and demands of the client or developer.

G Formal methods may be required as a planning constraint or a government policy, for instance the completion of an Environmental Impact Assessment.

H The process used can vary between projects

I Different considerations need to be made depending on the technology being assessed.

J Other answers which are not in direct response to the question and were not mentioned by many respondents.

The responses relating to each of these categories and to additional sub-categories are shown in Table 5.8.

Table 5.8 Question 6 and 7 response categories and sub-categories

	Category (sub-category) description	Total	Participant index
A	**Decisions made on a financial basis**	**18**	**5426, 5538, 5671, 5864, 6915, 7272, 7427, 7439, 7502, 7609, 8134, 8209, 8285, 8496, 8869, 8933**
	Life cycle considerations	8	2762, 5426, 5864, 6915, 7408, 7427, 8496, 8869
B	**Balance of pros and cons**	**14**	**2762, 5426, 5864, 5947, 7238, 7272, 7408, 7427, 7439, 7502, 8209, 8285, 8496, 8933**
C	**Other qualitative techniques / considerations**	**12**	**5420, 5671, 5864, 5947, 6076, 6915, 7408, 7427, 7502, 8209, 8869, 8933**
D	**Other quantitative techniques / considerations**	**9**	**5538, 5864, 7427, 7609, 8134, 8209, 8496, 8869, 8933**
E	**Don't know / none**	**3**	**5947, 6915, 7617**
F	**Depends on the client**	**9**	**5864, 5947, 6076, 7427, 7617, 8134, 8209, 8496, 8933**

G	**Depends on politics**	2	6108, 8869
H	**Depends on the project**	5	6108, 7502, 7609, 8496, 8869
I	**Depends on the technology**	2	7609, 8869
J	**Other**	10	2762, 5671, 6108, 6915, 7238, 7272, 7427, 7502, 7609, 7617

The full details of the responses that correspond to these categories and sub-categories are provided for reference in Appendix D. It can be noted from viewing each section of text that some statements are used more than once because they are relevant to more than one category or sub-category. Additionally comments within the sub-categories may not be represented in their respective main category.

A basic summary of the breakdown of the main categories is shown in diagrammatical form in Figure 5.9.

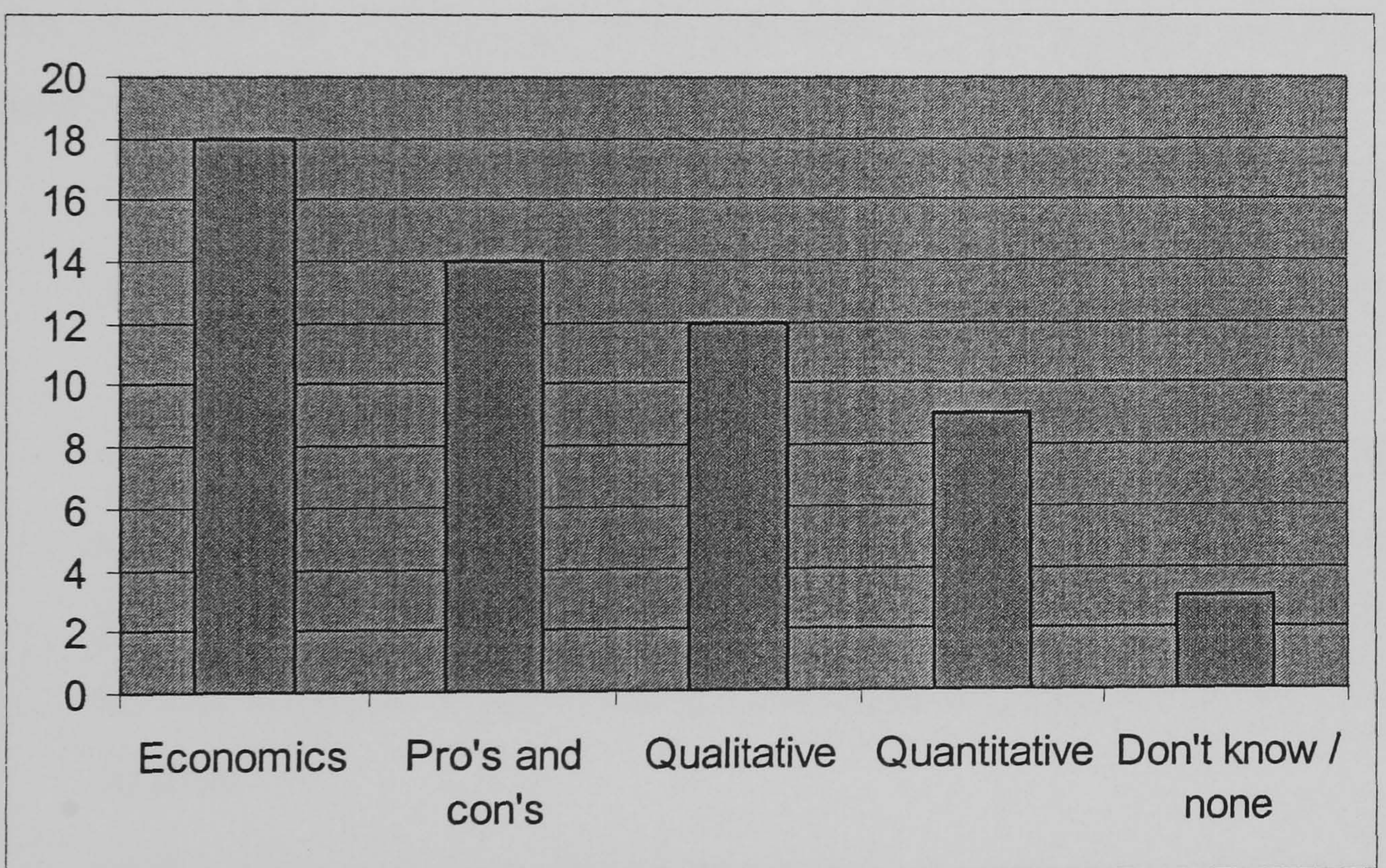


Figure 5.9 Summary of responses for each category given to Questions 6 & 7

5.5.3 Question 6 and 7 discussion

The consideration of economic viability was mentioned as the approach used more than any other, with 18 results.

> 5864 – "Often the decision making process will come down to cost, even in the early stages, whether the client wants to proceed or not. I've found that we can talk about a lot of these issues and the cost aspect is usually the one that drives

whether or not we will proceed into much detail with it, it comes back to things like payback."

8209 – "There was a cost analysis done of various different options and that was conveyed to the design team."

Of these results 8 mentioned the consideration of operational cost savings.

7408 – "In principle we would review it as almost a life-cycle come payback way and try to quantify this perhaps in money but generally to use a format where our assumptions were very transparent."

8869 – "We looked at each of the technologies, what they would cost to install, cost to run and what their payback would be, although payback was a bit of a strange concept when it is a developer, because he's not actually going to recover any of that cost necessarily."

The approach of weighing up pros and cons by the building services engineers and presentation of their recommendations to the client received 14 responses.

5947 – "Verbally and we did a report. They were discussed and then we produced a report at planning stage saying what we were intending on doing. They were discussed with the client."

7427 – "The end result would be to present to Eden more in a slide format rather than any report format to talk through what had been considered, the pros and cons and try and just give them the bottom line of what the cost would be and what the energy saving would be, and whether or not it would be suitable."

8285 – "We used a straightforward format, we did a standard report approach, where the report summary was put together, some costs in use and end use issues."

There were 12 responses that referred to the consideration of qualitative aspects in the decision making process such as consideration of construction and operating risk, image, and possible environmental and social benefits.

5671 – "We had to convince them that it was proven technology that the client wouldn't be left with a building that they couldn't maintain or operate."

8933 – "The social benefits were covered by the sustainability charter, which ran alongside an Ecohomes assessment, which had an energy section."

Along with presenting factors in a qualitative manner there were 9 responses that referred to quantitative considerations other than financial calculations. This included conducting technical performance predictions and estimating carbon savings.

> 5538 – "I think CO2 output is certainly one of the decision making factors for Dublin city council, a government body."

> 8496 – "The positive aspects have been more the image and the carbon reduction measures. We've quantified the carbon emissions and compared the carbon emissions of a standard system, boilers and chillers, against the CHP and GSHPs."

Meanwhile further reference was made to the role of the client and the perception of the factors that are important to the client.

> 6076 – "It really was personal, it was unusual in that, the architects were the same and they kind of moved the clients who were more worried about the long-term damage to the planet than he was his own cheque book."

> 8209 – "We ended up not trying to make it so much of a song and dance in case the client says 'that is bonkers'"

There were only 3 references to the use of no structured comparison technique at all, including:

> 5947 – "There was not a very direct way of assessing things, you were told that they didn't like it and that was it."

5.5.4 Conclusions of Question 6 and 7

The objectives of Question 6 and 7 were to investigate the methods used for addressing drivers and barriers and making system selections in practice. This came with an aspiration to reflect on the limitations of existing analysis methods/decision approaches and to indicate the extent to which various techniques are being used.

It is interesting to see that even with these projects, which mostly included AETs through to construction and so could be deemed to be unique; the predominant method for comparison of options is financial payback analysis. This shows that cost is not being ignored, and that these technologies are proving to be economically viable or proving that other aspects are counteracting the barrier of high capital costs. If the result had come about that cost was not being considered then an argument could be made that these were not normal or rational projects and so were irrelevant in comparison with the real world of building construction.

The important factor here is that, along with cost, other aspects are being considered, though there is still an evident lack of standard approaches to comparing qualitative and quantitative decision factors. There are still few mentions of the use of life cycle approaches, though there is consideration of running costs and maintenance. In some cases these technologies have been included at concept design without thorough consideration, delaying judgement until later project stages. This judgement may include proving reliability and past performance and quantifying the potential carbon savings to be made.

The factors affecting the final decision are dependent on the project, the previous experience of the project team and the technology being considered. For example some of the projects that considered CHP mentioned that risk and operational maintenance issues were major concerns, while for Finglass swimming pool it was seen as "a straightforward thing to deal with".

> 5538 – "CHP in a big project makes sense and you would have proper mechanical engineers maintaining the system so the complexity of it wasn't really a concern, we had it ticking over in the back of the mind but they felt it was something that people could handle."

There were also a range of client and project team attitudes, some were amazingly positive, others were nervous and the worst of all showed little commitment at all. In some of these projects the client, building user or architect were strongly in favour of using AETs and this really helped give the project team a lead. In other examples the client was willing to listen and be informed by the design team. In the cases where these technologies have been successful there has been a lack of commitment from the client and in some cases from the project team.

In summary, though cost considerations were pretty common, each project team used a different approach to informing decision making, and for each project the most important decision factors were different. With such variation between approaches there can be little consistency in ensuring that AETs are fairly judged against more traditional options. There are a large number of project variations that need to be accommodated for within any assessment procedure. The level of importance attributed to the drivers and barriers that influence the use of AETs varies between projects. These variations need to be understood at the beginning of each project with something like a weighted judgement criteria. On this criteria, which reflects the importance of each decision factor, each of the technology options need to be assessed, using the most accurate and relevant information available.

5.6 How building consultants can make a difference

This section presents from the results of Question 8, which asked:

What changes would have helped to improve the effective implementation of AETs? Specifically how could the approach of the building consultant help this?

5.6.1 Introduction

Question 8 is a summary question that turns the central question to the participant; namely 'how can the building consultant best influence the drivers and barriers to using AETs, if at all'. This allows earlier points to be revisited and expanded upon and should help summarise whether or not it is worth the building consultant trying to influence the decision making approaches being used, or if another route is more worthwhile.

5.6.2 Question 8 categories

The categorisation for the answers to these questions can be explained as follows:

A	There is a need for more education and willingness from within the building industry for people to learn how to assess and use these technologies.
B	There is a need for more detailed and practical information, possibly in the form of detailed case studies that highlight where these technologies have proven to be feasible.
C	Communication is a key factor
D	New techniques or approaches need to be developed and used
E	Political influences are required to push these technologies into use.
F	Costs need to be reduced for these technologies to be considered more often
G	The client needs to want these technologies
H	There is nothing that can be done
I	Other answers
J	The building consultant has an important role to play in the helping to improve the

	chances of using AETs.

The responses to each of the questions related to these categories are summarised in Table 5.9 and Figure 5.10.

Table 5.9 Question 8 response categories and sub-categories

	Category (sub-category) description	Total	Participant index
8A	**Education**	**14**	**2762, 5426, 5864, 5947, 6108, 6915, 7408, 7427, 7502, 7609, 8134, 8209, 8285, 8869**
8B	**Information**	**11**	**2762, 5671, 6108, 6915, 7427, 7502, 8134, 8209, 8285, 8496, 8869**
8C	**Communication**	**8**	**5426, 5671, 7238, 7272, 7407, 7427, 8285, 8933**
8D	**New techniques**	**9**	**2762, 5947, 6915, 7427, 7502, 7609, 8209, 8285, 8869**
8E	**Political**	**10**	**5426, 5864, 5947, 6915, 7272, 7427, 7502, 8134, 8209, 8869**
8F	**Cost**	**8**	**5426, 5864, 5947, 7502, 7609, 8134, 8496, 8869**
8G	**Client role**	**7**	**5426, 5671, 5864, 7272, 7408, 7427, 8134**
8H	**No way**	**1**	**7427**
8I	**Other**	**10**	**2762, 8764, 5947, 7238, 7408, 7609, 8209, 8496, 8869, 8933**
8J	**Consultants role**	**8**	**2762, 5671, 5947, 6108, 7427, 7502, 7609, 8134**

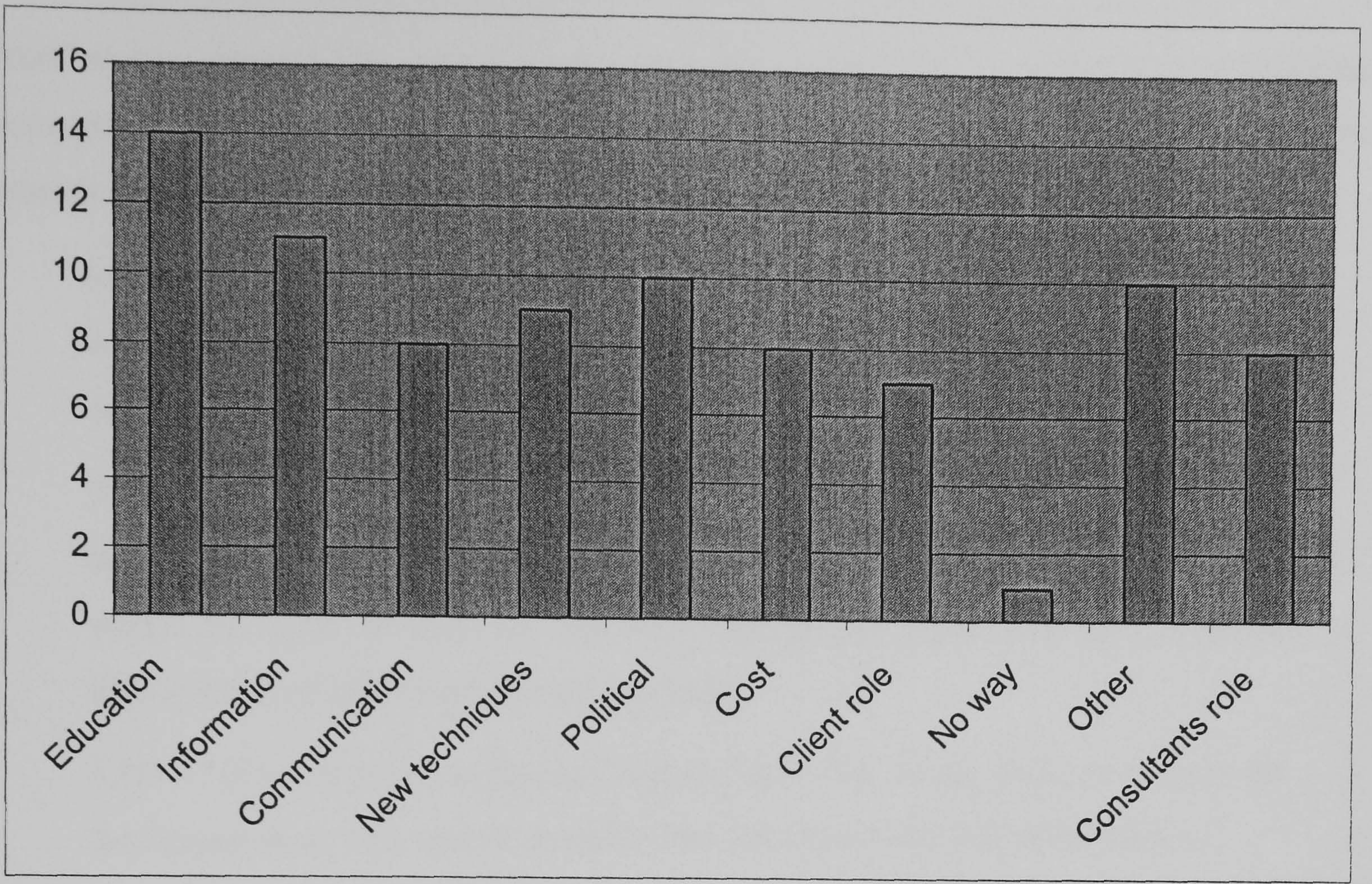


Figure 5.10 Summary of responses to Question 8 for each category

5.6.3 Question 8 discussion

Of the direct responses to this question, the most common answers referred to the need for education and willingness in the industry and the availability of accurate information. These two categories were mentioned in 14 and 11 project responses respectively.

> 2762 – "Fundamentally what stopped this was having the appropriate contractor with the experience of drilling these type of boreholes."

> 5426 – "Generally there is a lack of awareness out there."

> 5671 – "What we do need is more feedback from actual installations rather than the theoretical feelings of the design team. So the more and more projects that get built and we can get positive feedback, finished installations, then I think that will help us make design decisions, it will help the client make design decisions."

> 7609 – "I think the real barrier now is that the industry is still quite conservative."

> 8285 – "If you're putting anything in that they didn't do on their last job it is going to cost money and you're only an engineer, unless you can demonstrate a

thorough, professional, full holistic approach to it you'll never get anywhere."

Another two aspects that scored highly and are highly relevant to the role of building consultants are the need for new approaches to assessment (9 responses) and better communication within the project team (8 responses).

> 5947 – "I've never been able to master it in any quick and efficient fashion before, so we tend to squirm out of doing it. If we had some structured way of assessing them it would be brilliant"

> 7502 – "It would be handy to have a more structured approach to reporting these things and comparing them. Useful internal models that we can use would be good so that we can very rapidly put together project specific information on different types of buildings"

> 8209 – "If we're going to propose something I think we are going to have to hit the design team with specifics rather than talking about renewable energy,"

Two other high scoring categories, which are mostly out of the control of the building industry are the need for political intervention (10 responses) and the importance on cost considerations (8 responses).

> 5426 – "Government support not feeding through. Unless there is an incentive from planning purposes or in this instance running costs and savings in capital cost of a standby generator then the awareness not going to get better. On the advent of new Part L regulations this might make systems that much easier to sell."

> 7609 – "Again the payback capital cost for some of the renewables such as PV just doesn't make any sense to do, you just need to forget about payback just see it as an investment in new technology."

> 8134 – "I think that grant funding certainly helps, Government sponsorship helps. More legislation would certainly help"

> 8209 – "We could have shot the planners as well, that would have made it easier."

> 8869 – "Many of the technologies aren't viable at the moment, because they're just too expensive"

Other responses refer to the role of the client and their value criteria, and the relevance of the role of the building consultant.

5864 – "We should be and we do try at very early stages of projects, to get the client to agree a sum of money for sustainability or renewables in a project cost"

7427 – "Actually getting the right consultant in the first place, either the right practice or the right people, if the right people are not on the team then it is simply not going to happen in the first place."

Other miscellaneous answers also came out, often with general positive reflections on the project and project team, though this varied between projects:

7408 – "Shooting the engineering team in the back of the head twice."

5.6.4 Conclusions of Question 8

Question 8 is a summary question that reflects on what improvements could be made that would have helped to support the design and installation of AETs in each of the building projects. This question is aimed at building consultants and the role of the building industry in helping to improve the chances of implementing AETs. Therefore the answers are focussed on problems within the building industry, with less of a focus on the impact of external influences. The answers given do not represent that actions within the industry are more important or more likely to provide results than changes to external factors. The answers show that there is much within the industry that needs to be changed. However better market conditions and more political assistance, along with more moral commitment from building developers and users, can also make a major difference.

The categories that are used here to summarise the quotations given describe four ways in which the building industry can improve the likelihood of using AETs in building projects. With all market, political and moral drivers these technologies will not be successfully implemented to their potential without the compliance of professionals in the building industry. Poor or biased advice, delayed action, stubbornness and a lack of relevant proven information can prevent the application of a technology in the most viable of locations. This is demonstrated in the Techniquest project, where the deployment of a poorly experienced drilling contractor ruined the chances of using GSHPs due to mistakes made during construction. In this case project funding, engineering viability and client commitment were all 100%, however mistakes made during the drilling process lead to the threat of expensive building construction programme delays, and removed any chance of the GSHPs being used.

The approach used by the building consultant for informing the decision making process varies between projects. The assessment of technologies, the criteria of assessment and the method of presentation to the project team and client will impact on the viability of AETs. There is mention in these results of the need for new and better informed assessment methods and for building consultants to have standard assessment methodologies at their disposal. Unfortunately from the results there is no way of comparing the success of a project with the method used for comparison. In some cases very little comparison was made and technologies were deployed because that was simply the client wish or the obvious choice. In other projects the range of approaches used and lack of detail provided through interviews prevent a comparison of techniques being possible. However the results to Question 8 show a strong support for the need for new approaches to be developed, and it follows that these should be capable of adapting to project variations and client value criteria.

There is evidently a key need for building consultants to improve their knowledge levels, techniques used for obtaining, storing and communicating information and techniques for informing the client's decision-making process.

It is clear that economic drivers will help to some extent and that the Government has an important role to play in the way it shapes legislation, funding schemes and planning constraints.

There was only one response that suggested that in the project the approach was the best one and that they had performed everything in their power to assist the deployment of AETs where relevant. This project was Eden, where the client had a strong 'sustainable' agenda and were keen to see alternative forms of technology assessment to reflect this.

5.7 Summary of analysis of Questions 1 to 8

A review of the responses to each of the questions has brought out a number of important conclusions.

5.7.1 Question 1

The majority of the projects considered in this study had clear and recognisable drivers within the original project scope. If these initial drivers are not recognised and exploited there is a lesser chance of AETs proving successful. The opportunities vary greatly between projects, but it is important that engineers spot them and enhance client awareness from the beginning.

5.7.2 Question 2

Around 30% of the technologies considered in a project manage to continue through to the construction stage. The solar technologies are the most commonly considered, though had a low percentage of installations in these projects. A number of project factors that restricted the progress of AETs were discussed, including economic, practical and non-technical issues, showing that simple economics are not always the main barrier.

5.7.3 Question 3

The inclusion of AETs in building projects is very rare, and to be more successful they need to be considered as part of the core design. The support and commitment of the client, architect and engineers is a key factor. Assessment has to move from a capital cost focus, though the technologies still need to keep within the budget, as with any other design aspect.

5.7.4 Question 4 and 5

The highest scoring drivers for these projects are: 'long term economics', 'environment', 'CSR' and 'image benefits'. Meanwhile the highest barriers were: 'capital costs' and 'perceived risk'. Where projects had used AETs through to construction the barriers were given much lower scores, and lower on average than the drivers. In particular the impact of ignorance, cost, lack of communication, perceived risk, unproven and unsuitable site were given far lower scores. Hence where it is possible to reduce these barriers there will be a better chance of implementing AETs.

5.7.5 Question 6 and 7

There is no common method used for the assessment of AETs in these projects other than the use of financial payback analysis. Many of the projects considered qualitative and other quantitative factors in their decision-making, though these were mostly ad hoc. Decisions were very much affected by experience, which varies between project team, with an emphasis on the need to justify that AETs were viable and low risk.

5.7.6 Question 8

Further evidence is given to support the need for greater education, available information and the development of more holistic standard decision-making approaches. The engineers interviewed are adamant that they need to change their methods and improve their levels of understanding to allow more AETs to be installed.

5.8 Conclusions and Recommendations

The deployment of AETs into building projects in the UK is very rare. Here 24 projects where AETs were considered, in most cases through to the construction stage, have been reviewed in detail through a series of personal interviews. These interviews with senior-level building services engineers have provided an insight into the rationale, the drivers and barriers and the methods used for considering the use of AETs in building projects.

The key insights from this study are:

- AETs can be a viable option for a wide range of projects and locations and are not limited to public or specialist buildings.
- A key aspect to success is recognising and understanding any specific client aspirations or project characteristics that could support the consideration of AETs at the initial project conception stages. Without recognition and commitment to such aspirations the chances of installing AETs are reduced.
- Those projects that included more than one AET through to construction each had a very strong environmental focus.
- Solar technologies were considered most often of all the technologies, though this was not reflected in the number that reached the construction phase. Overall there was on average a 25% chance of an AET continuing through to the construction stage if included at concept stage.
- In 11 of the 24 projects AETs were seen as being an important part of the building design, in these cases the client was going to be the building occupant or had an ongoing interest in the building post completion. In only 2 of the projects were AETs considered to be not important at all by the project team.
- The most important drivers for AETs were judged to be of a social or economic nature, with an emphasis on investing in the future, wanting to be green and promoting a green image.
- The most significant barriers were financial cost and the perceived risk of using AETs, followed by maintenance issues, poor communication, unproven and complexity. The impact of most of these can be reduced through improved knowledge and understanding within the design team.
- There is a large amount of variation between projects, especially for the role of subsidies, politics, site suitability, variable output, ignorance, communication and capital cost.

- Comparing the scores from successful and unsuccessful projects has shown that the median scores for driver categories are roughly the same, whereas many of the barrier scores are lower in projects where AETs have reached the construction stage, particularly the social and economic barriers. These results justify that overcoming barriers such as poor communication and ignorance can be key to the viability of using AETs in buildings.
- The consideration of simple economics and the use of technical reports to balance pros and cons are the most common approaches to decision making. Considerations of risk and calculation of potential carbon savings are also referred to. However, there was not any reference to common assessment approaches that balanced qualitative and quantitative considerations.
- The building services engineers emphasised the need for better education and available information to help improve the chances of effective implementation of AETs in buildings. They also acknowledge the importance of external influences, such as the cost of energy and the availability of Government support.

Through this investigation of the actual approaches used by building services engineers it has been shown that in practice engineers do not have the knowledge or the techniques for implementing AETs in building projects. The lack of sufficient knowledge, information and tools for assessment and communication are one of the key barriers to using AETs in more projects. The experiences of engineers and approaches used in each project are not consistent and so there are some examples of engineers trying to understand and embrace AETs and the different benefits they bring; often these are the more successful projects in terms of AETs being implemented. However, engineers are primarily reliant on the drive of the client and architect and reactive to external planning and policy influences.

5.9 Summary of Chapter 5

This Chapter presented the results from a phase of personal interviews with building services engineers focussing on individual projects where AETs had been considered in detail. 24 projects were investigated, covering a mix of building and client types, project scales and success levels of AETs. 8 questions were asked, similar to those asked in the Phase I interviews, and have been presented in turn. Due to the project-specific nature of these interviews, the projects where AETs were carried through to the construction stage are separated from the projects where AETs were not so successful.

The results of these interviews have highlighted the importance of recognising opportunities for using AETs very early in the project, and gaining a commitment from the client to considering them as part of the building design. The factors affecting the viability of AETs are highly project variable and there is no essential formula for success. In the projects where AETs were maintained in the project through to construction many of the barriers were considered as less important than in for other projects. In particular there was further evidence of the importance of reducing ignorance and improving communication in the design team for increasing the chances of integrating AETs into building projects.

These interviews also reinforced the understanding that simple financial payback calculations are the most common form of technology assessment, and that other considerations are often presented within a written technical report summarising technical pros and cons. Many of the projects covered included AETs into the construction stage of the building process, often due to financial viability, or due to a specific driving force from the architect or client. This emphasises the absence of refined and structured decision tools that can accommodate qualitative and quantitative considerations in a holistic and transparent manner.

The comparison of results from this set of project-specific interviews (Phase II) with the previous study (Phase I) is presented in Chapter 6.

CHAPTER 6 COMPARISON OF RESULTS FROM PHASE I AND PHASE II INTERVIEWS

6 COMPARISON OF RESULTS FROM PHASE I AND PHASE II INTERVIEWS

This chapter provides a comparison of the results generated through the first phase of interviews with building project stakeholders against those from the project-specific interviews with building services engineers. The questions used for each phase varied slightly and so this chapter only considers those questions that served the same purpose, these are Questions 3 to 8 inclusive.

6.1 Question 3

How much of a part did the consideration of these technologies have to play in this project? How does this compare with other aspects of the design? Which project team members were influential in this?

The results from Question 3, for Phase I and Phase II are summarised by Figure 6.1. The key response categories have been selected and the percentage figures used for ease of comparison between the two phases. These percentage figures represent the number of answers within each category as a proportion of the total number of interviews.

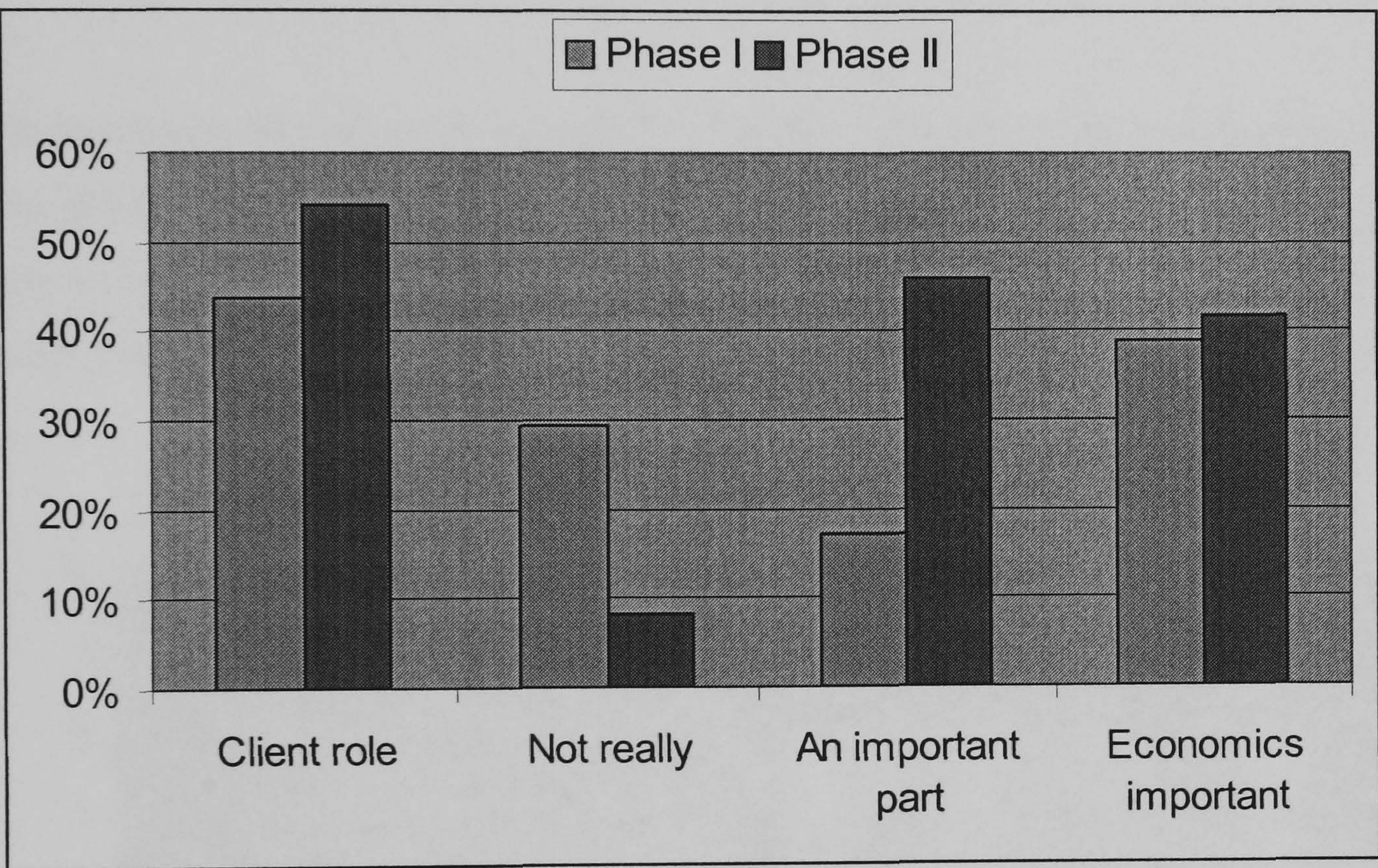


Figure 6.1 Percentage of Phase I and Phase II responses to Question 3 categories

In the project-specific interviews a greater proportion of the respondents suggested that AETs were considered as important parts of the project, with 11 from 24 answers (46%), as opposed to 7 from 41 (17%). In the same vein, far fewer responses were made suggesting that they did not play much of a part in the project, with 2 responses (8%) compared with 12 made in Phase I (29%).

There was a consistent level of responses that pointed toward the need for the client to have an aspiration for using these technologies from the initial stages of the project, as a core part of the design, for them to be successful.

6.2 Question 4

What have been the drivers for considering AETs in this project? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies	Image	Planning
Environment, e.g. Climate change	Long-term economics	Lack of infrastructure
Politics	Corporate social responsibility	Plant space

The scores attributed to the list of drivers used in Question 4 are summarised by Figure 6.2, for Phase I, and Figure 6.3, for Phase II. The headings and question used were identical for the two studies. A comparison of the two Figures is presented in Figure 6.4, which shows with more clarity the variation between the median scores from the two studies.

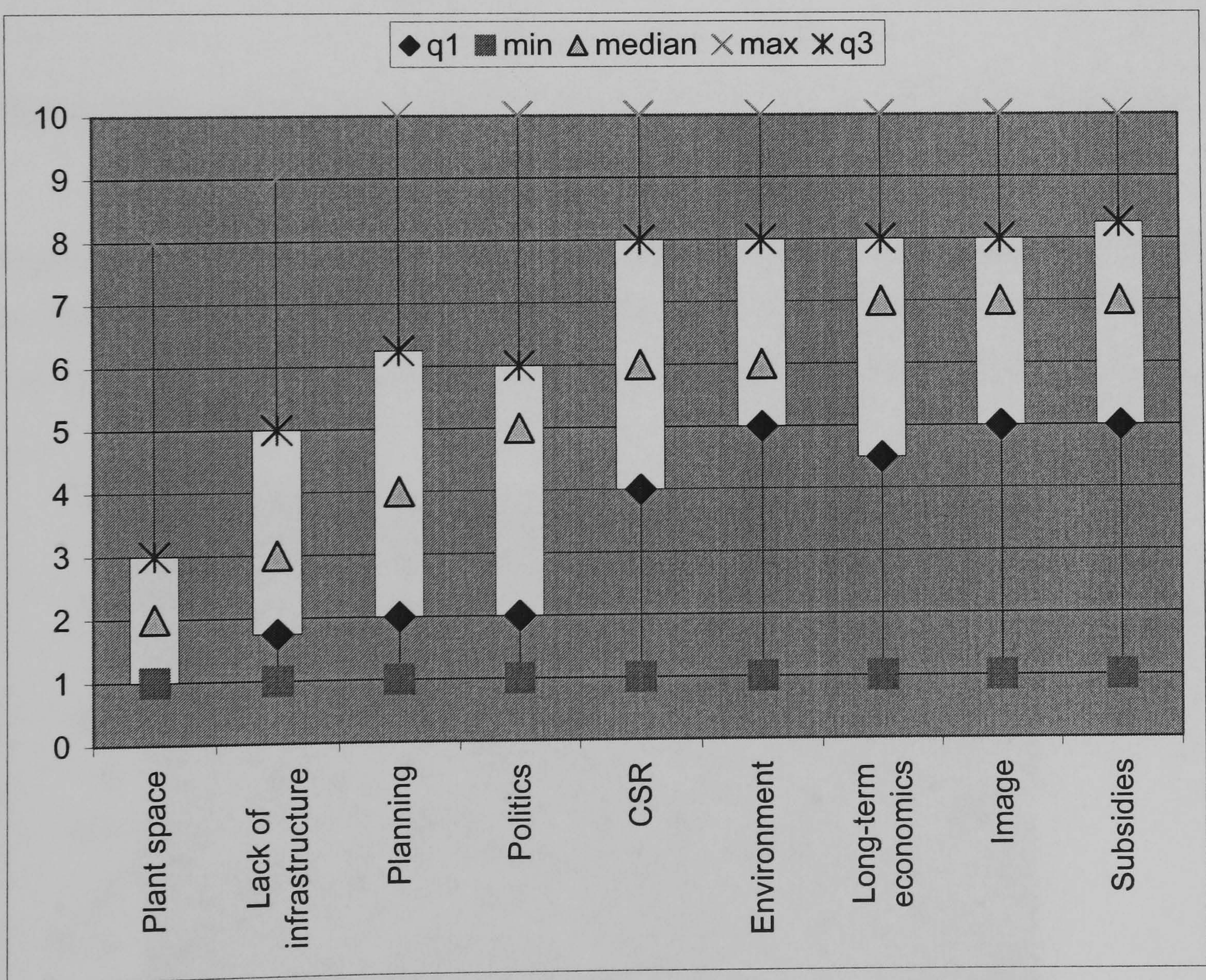


Figure 6.2 Box and whisker plots of the various drivers from Stage I interviews

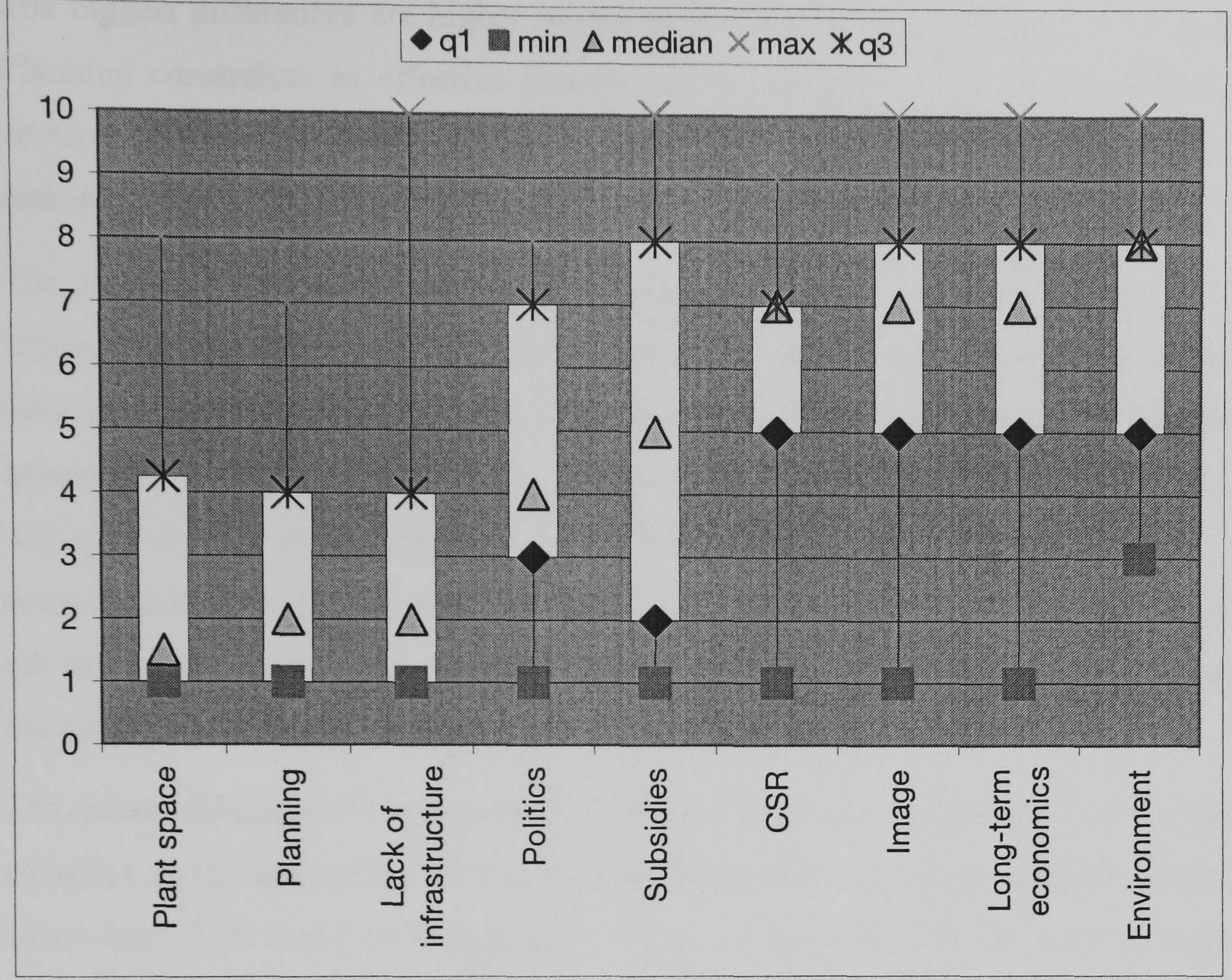


Figure 6.3 Box and whisker plots of the various drivers from project-specific interviews

Figure 6.4 shows the result of comparing Phase I median scores with those from the project specific interviews. The numbers in the chart show the difference in scores between the two studies, with a positive score representing a higher score being attributed in Phase I.

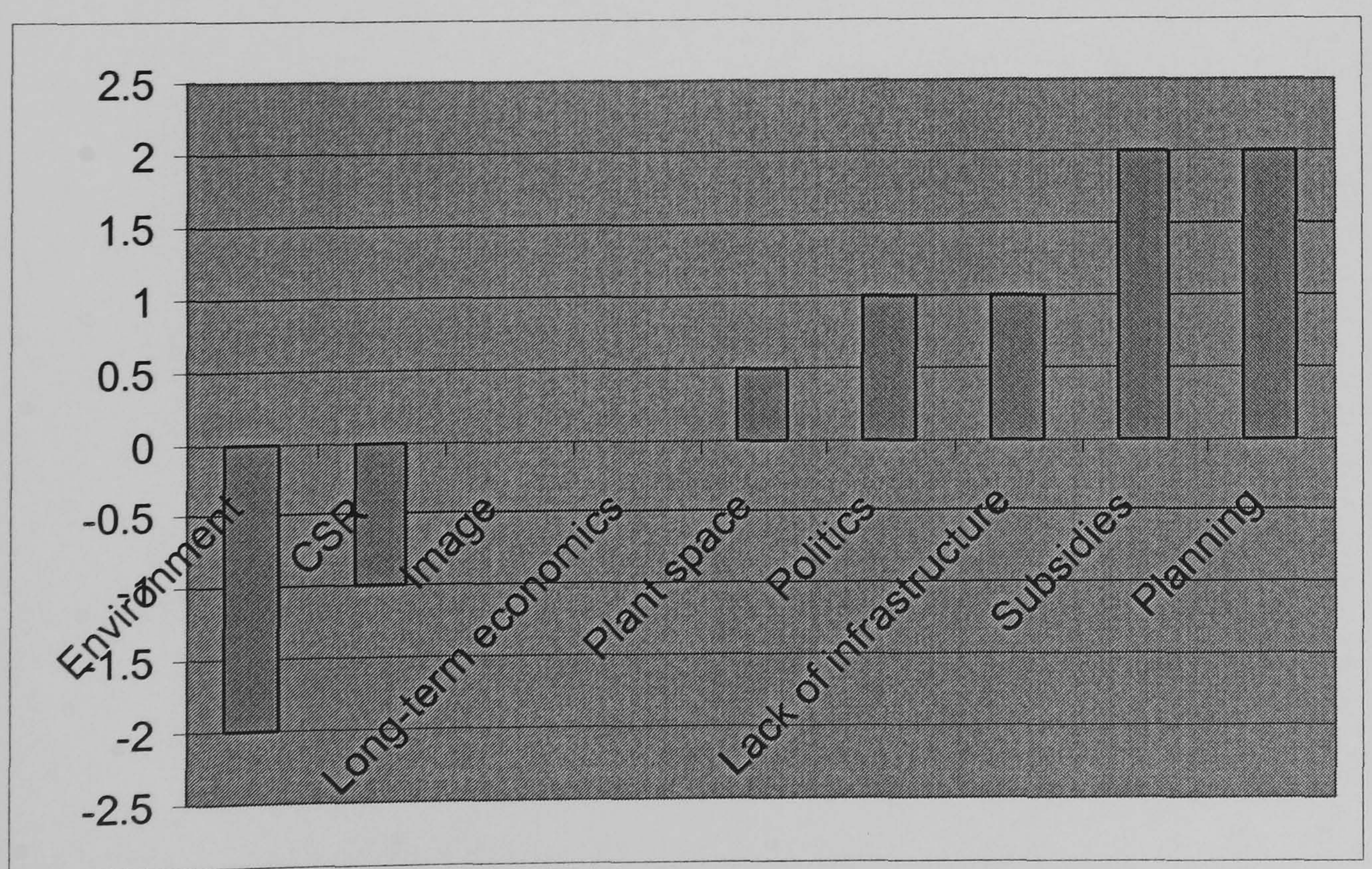


Figure 6.4 Difference between Stage I and Stage II median scores (drivers)

The biggest differences are higher scores in Phase I for the importance of Subsidies and Planning constraints as effective drivers, and a lower score for the importance of the environment as a positive influence. In general the drivers were attributed slightly higher scores in Phase I than Phase II.

The projects in Phase II were predominantly successful, these are examples of projects where in most cases one of the AETs reached the construction stage. Whereas the Phase I interviews were not specific to successful projects, but reflected on individual stakeholder experiences. In the project-specific interviews the environment is seen as a much bigger influence driving these technologies, whilst CSR also figures more highly. This shows a commitment from the client to using AETs for a good cause, rather than being reliant on the availability of subsidies or planning requirements. That these technologies are part of the ethos of the projects seem to form part of their success.

The drivers that received higher scores in Phase I interview (politics, lack of infrastructure, subsidies and planning) are very project specific factors, i.e. the building location and the client type. That these score higher for Phase I may reflect on the projects reviewed in Phase II, that they were not remote, or as reliant on Government intervention as is perceived as the norm by building project stakeholders.

6.3 Question 5

What have been the barriers for considering AETs in this project? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee	Proximity to resource	Cost (High capital and slow payback)
Climate (variable)	Ignorance and lack of understanding	Perceived risk
Stubbornness of energy industry	Incoherent Policy and Planning constraints	Unsuitable site
Maintenance	Complexity	Unproven
Lead time in construction	Environmental and Ecological impacts	Communication and common language

The scores attributed to the list of barriers used in Question 5 are summarised by Figure 6.5, for Phase I, and Figure 6.6, for Phase II. The headings and question used were identical for the two studies. A comparison of the two Figures is presented in Figure 6.7, which shows with more clarity the variation between the median scores from the two studies.

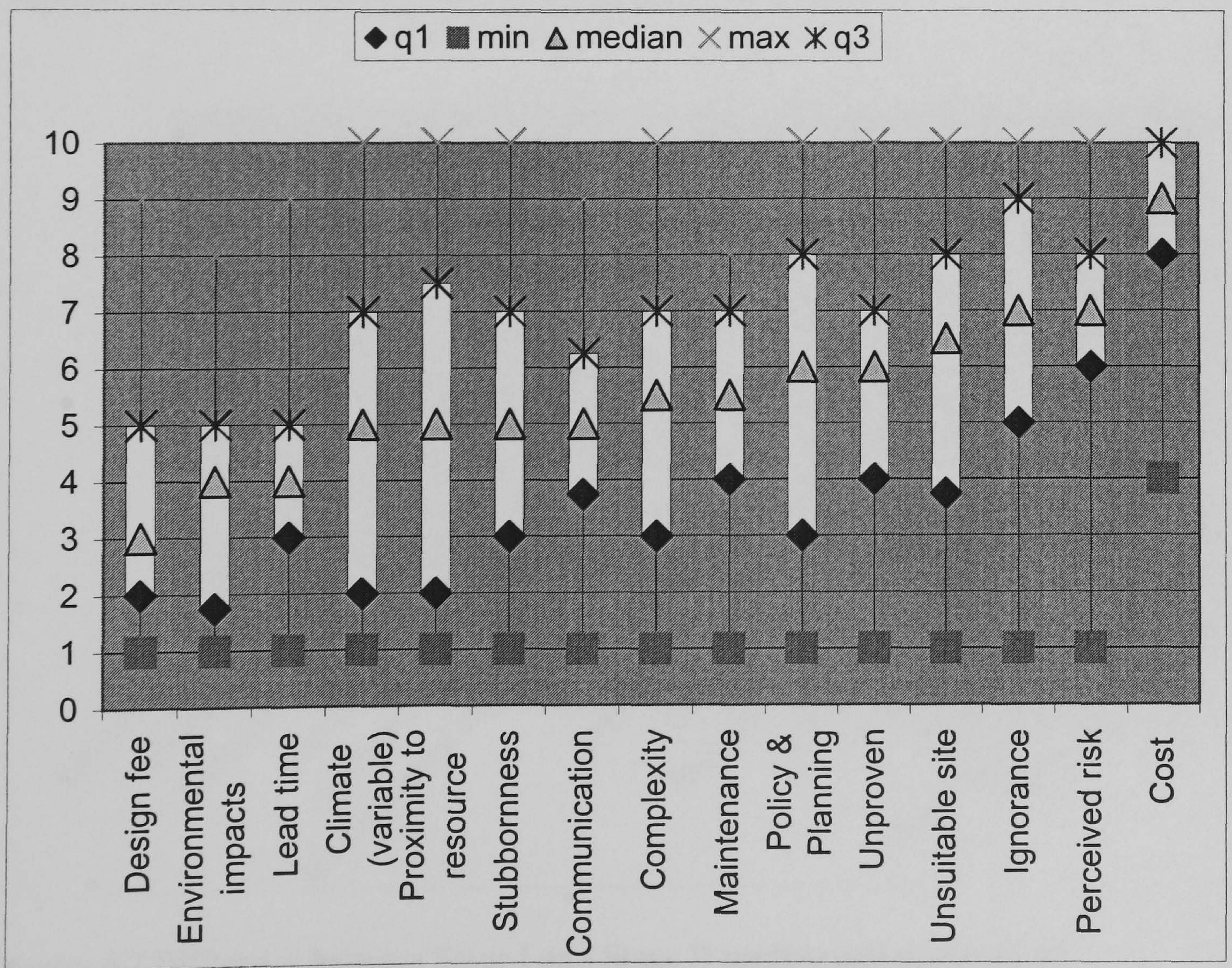


Figure 6.5 Barrier scores for Stage I

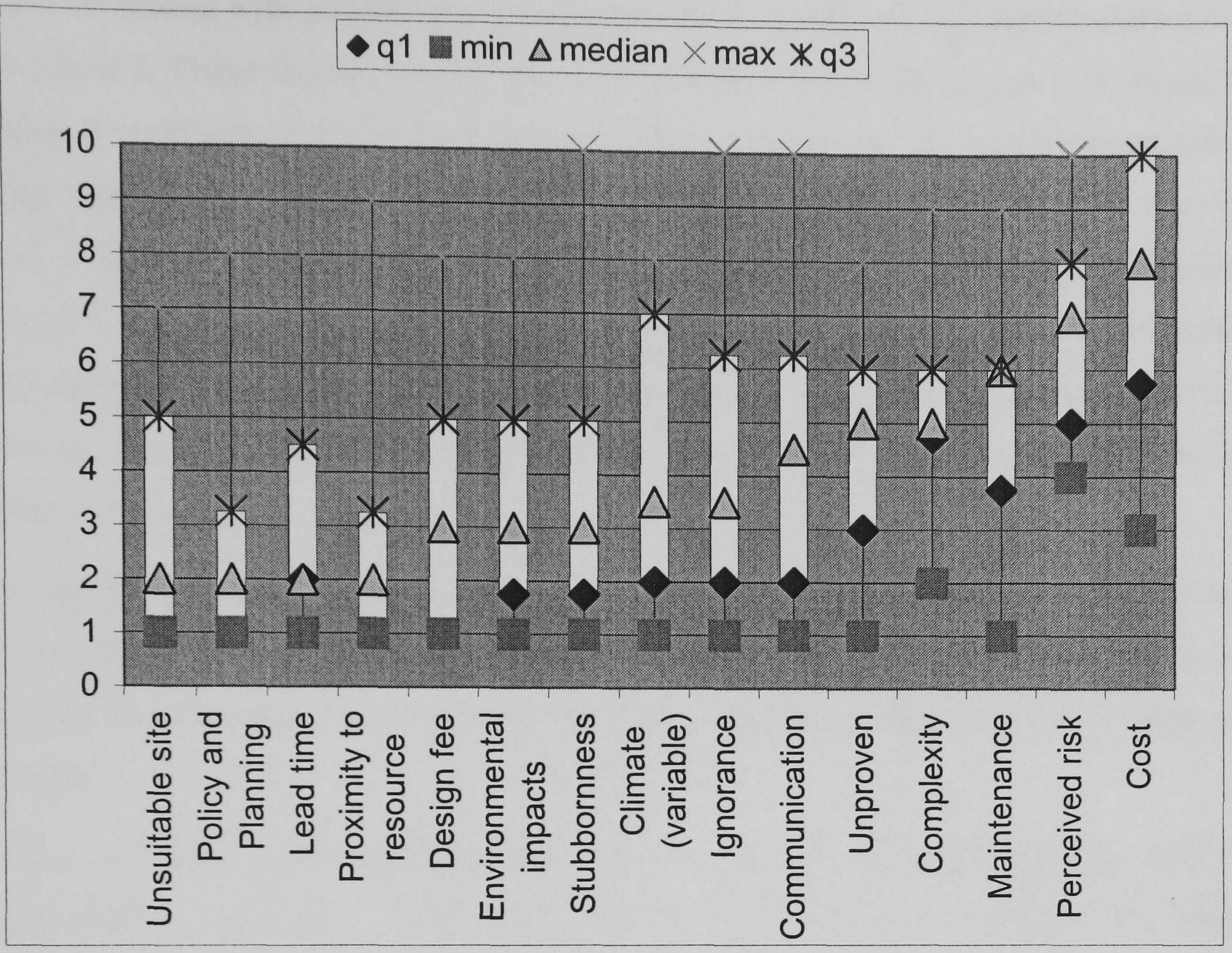


Figure 6.6 Box and whisker plots of barrier scores for Stage II

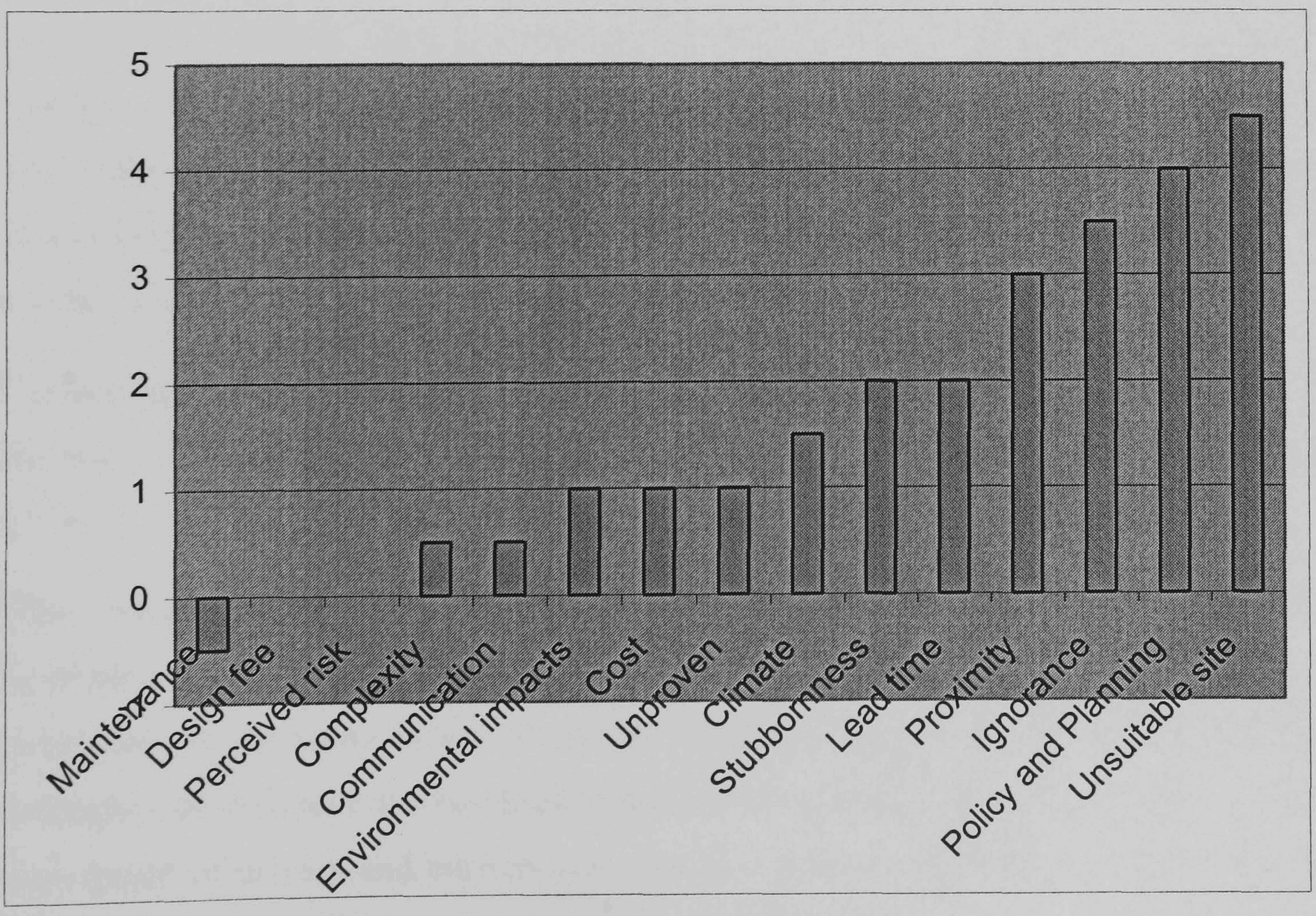


Figure 6.7 Difference between Stage I and Stage II median scores (barriers)

Figure 6.7 provides a comparison of the median ratings attributed to the list of barriers for the two studies with positive scores representing a correspondingly higher score attributed in Phase I. These figures are a result of comparing the median scores from Phase I with those from Phase II. There are important differences between the ratings attributed to the same barriers to using AETs in building projects. The scores attributed to barriers by the mixed stakeholder participants are far higher than those in the project-related interviews. The Phase I participants cited the importance of the site suitability, incoherent policy and planning constraints, ignorance and the proximity to a renewable energy resource to be far greater. Stubbornness of the energy industry and the proximity to a resource also scored higher in the Phase I interviews.

In the project-specific interviews, where success rates in general were higher the barriers were rated as being far less significant on the whole. The impact of high capital costs still scored highly, though it was not as significant and had a larger spread of inter-quartile scores.

Many of these barriers listed cannot be directly influenced through the role of the engineering consultant. Those that can be influenced the strongest are arguably: 'ignorance', 'complexity', 'perceived risk', 'unproven' and 'communication'. All of these are considered important factors in both Phase I and Phase II interviews. From this shortlist, the category 'ignorance and lack of understanding' was judged to be much less of a barrier in the Phase II interviews. Figure 5.8 in the previous Chapter shows that this issue was much less of a factor in the projects where AETs were considered through to construction. This highlights the importance that ignorance plays in influencing the viability of AETs, and the role of engineering consultants in reducing its impact.

Comparison of the highest and lowest ratings do not show as much variation as between the mean scores, with many headings having maximum scores of 9 or 10 and lowest scores of 1 or 2.

These results suggest that in individual cases any single one of the drivers and barriers can be predominant and that they are very project specific. This signifies the importance of awareness, as for many of the drivers and barriers listed a level of prior knowledge and foresight can influence the resultant impact. Hence an approach that seeks to uncover the importance of drivers and barriers early on in a project and then to address them should help to improve the viability of using AETs in each project.

In summary, compared with the Phase I interview results, the project specific results scored most of the barriers lower on average, though peak scores were still high. In terms of drivers the environment was seen as more important, while subsidies and planning were less so. Of the barriers, the impact of high capital cost was less dominant then previously and ignorance was seen as a far lesser issue.

6.3.1 Conclusions from Question 4 and 5.

The conclusions drawn from comparing Phase II with Phase I results for Questions 4 and 5 are as follows:

- The environment played a much bigger role in the projects of Phase II, with a shift in the median from 6 to 8, though the inter-quartile range was the same. Subsidies played a smaller part, dropping from 7 to 5. Planning played a smaller part and plant space was again low.
- Barriers were consistently given much lower scores in the project-focussed interviews. This may be because the answers given were not general perceptions but very specific to each individual case. So though each of the barriers received a high rating in some cases, they are evidently project specific and so not playing a part in others.
- With both sets of interviews cost and perceived risk are the highest rated barriers. Cost has a much greater spread and a lower median score. Ignorance moves from a median of 7 to one of 3.5, suggesting that the projects did not suffer from a lack of knowledge in the project team. There are other headings that received much lower ratings: unsuitable site fell by 4.5, policy constraints fell by 4 and proximity to resource fell by 3.The lower scores may indicate that by reducing these barriers the projects were able to include AETs.

6.4 Question 6 & 7

In the building design process how were the negative and positive aspects of these technologies considered and compared?

What techniques were used for informing the decision making process, especially for comparison of quantifiable factors with some of the less tangible factors?

The results provided for questions 6 and 7 for both of the studies are summarised by Figure 6.8. The responses from the 41 participants in Phase I and for the 24 projects in Phase II are similar in scale for many of the categories from Questions 6 and 7, notably the emphasis on financial comparisons and the use of technical reports for balancing pros and cons. More of the responses given in Phase I did not recognise there was any technique being used for comparing quantitative with qualitative considerations. Economic comparisons were dominant for both studies. Qualitative considerations were mentioned more often in Phase I.

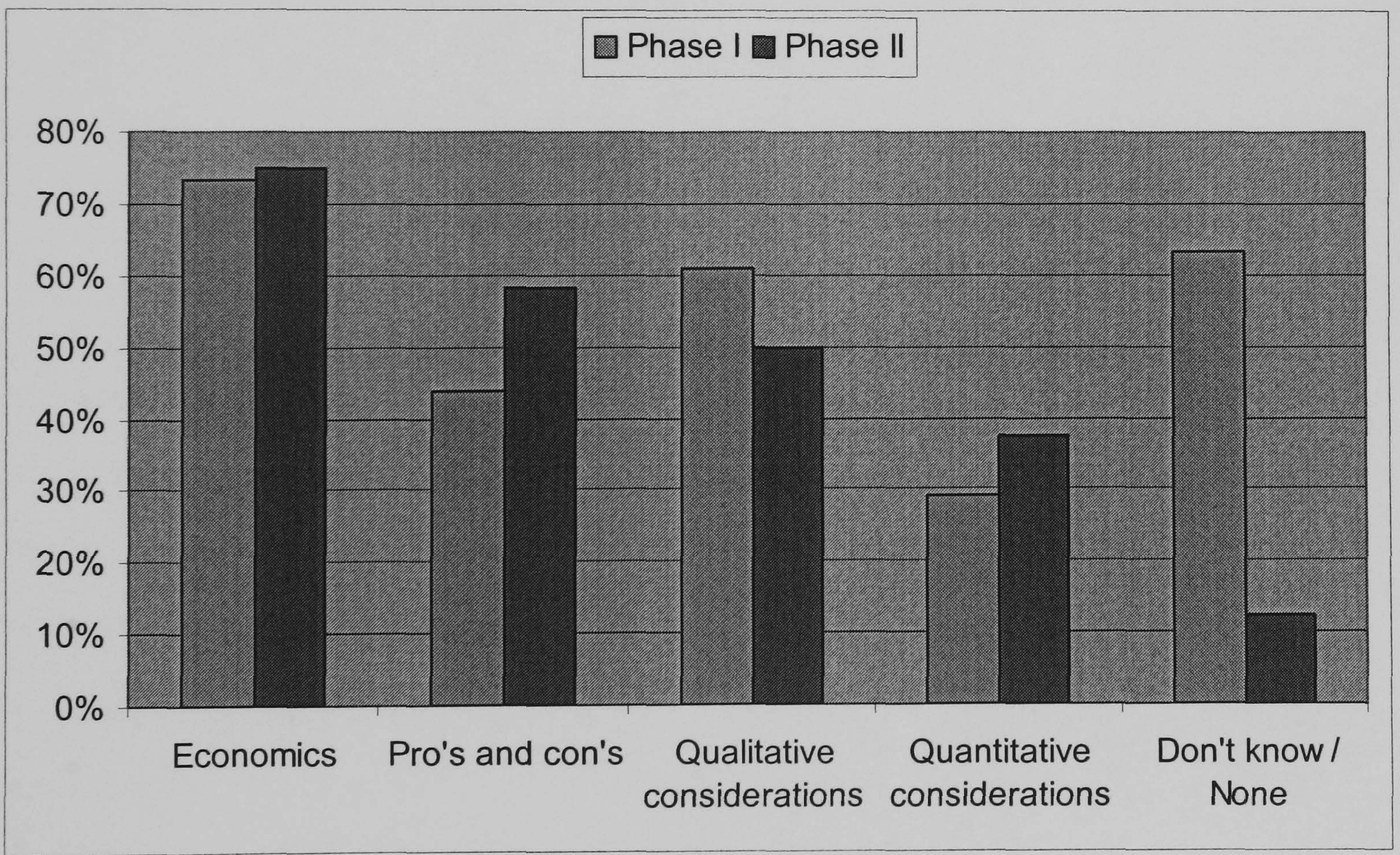


Figure 6.8 Percentage of Phase I and Phase II responses to Question 6 & 7 categories

The key difference between the responses for the two studies is that the building services engineers interviewed for Phase II very rarely gave the answer that they did not know of a method for comparing energy technologies, whereas the Phase I interviews provided a large proportion of 'don't know' answers. This difference may be because of the different roles held by participants in Phase I, where there was a mix of project stakeholders.

In nearly all of the Phase II projects the building services engineers had applied some techniques of comparing less tangible aspects with more quantifiable factor such as cost. The most common response was to recognise the production of a technical report, which would be used to summarise pros and cons, recognise technical risks and present the overall recommendations of the engineer. In many of the Phase I responses there were answers from participants suggesting that they did not know how or what assessments had been made, which reflects on the opaque nature of decision-making in most building projects.

6.5 Question 8

What changes would have helped to improve the effective implementation of AETs? Specifically how could the approach of the building consultant help this?

The responses given to Question 8 for the two studies are summarised by Figure 6.9.

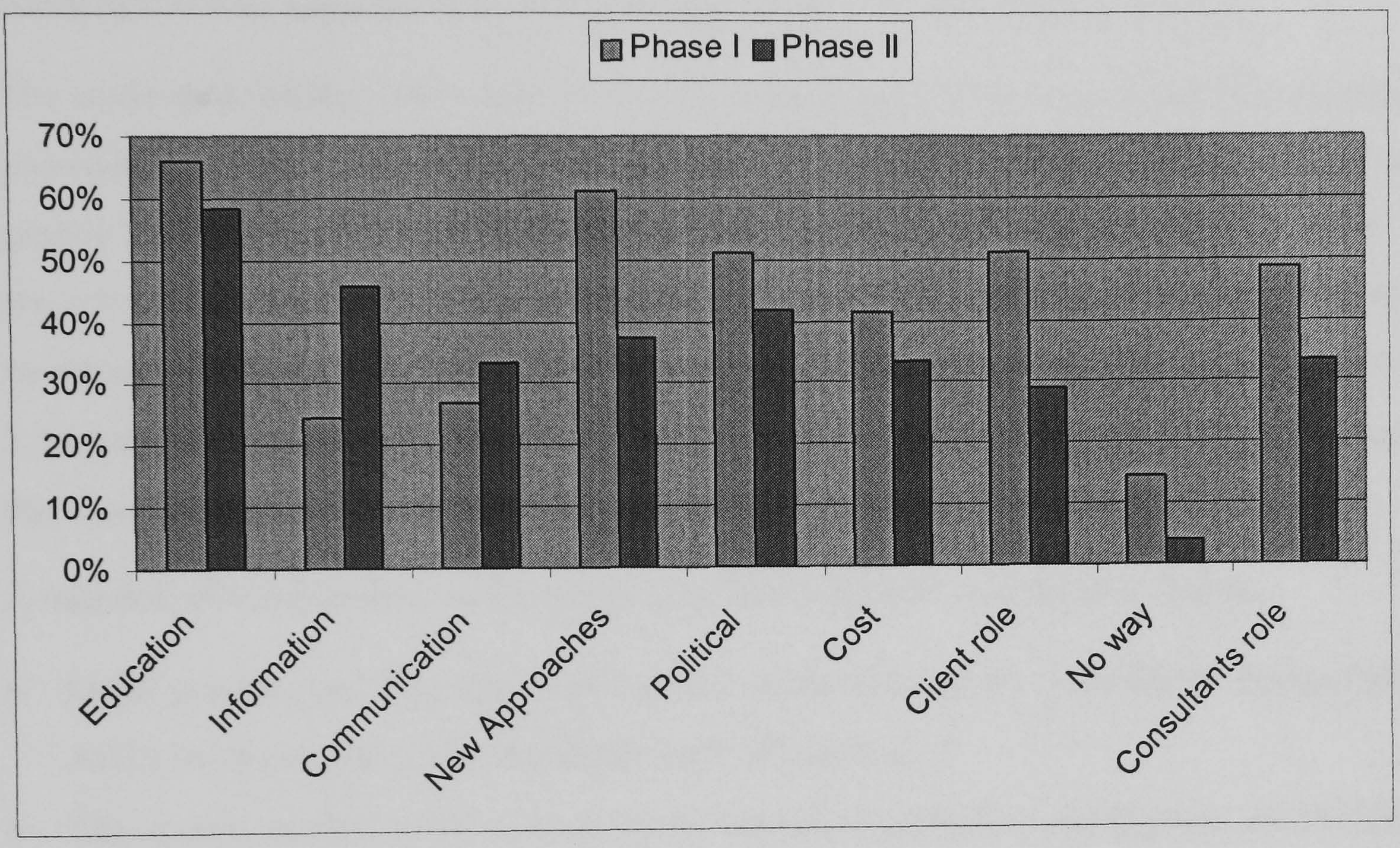


Figure 6.9 Percentage of Phase I and Phase II responses to Question 8 categories

Comparison of the results of the two interview sessions for Question 8 gives an indication of the different perceptions of where improvements are needed and who has responsibility for these changes.

There is a modest difference between the responses given to Question 8 between the two sets of interviews. The few differences of note are as follows:

- The Phase II interviews gave fewer responses to the categories than in Phase I.
- The Phase II interview results put a greater emphasis on the need for information and communication, with very few mentioning that there is nothing that can be done.
- The Phase I results have a stronger emphasis on the importance of external factors such as cost, politics and the client role.

The responses for this set of interviews are all from the perspective of the building services engineer. Previously they were from a range of different building project stakeholders, and it is these that emphasise the importance of the consulting engineer in improving the effective implementation of AETs in building projects.

6.6 Summary of Chapter 6

This Chapter presented the comparison of results from the Phase I and Phase II interviews.

The project-specific interviews (Phase II) are largely based on single situations where the consideration of AETs was a successful one. They are also all from the perspective of the building services engineer responsible for the options analysis and reporting.

The multi-stakeholder interviews (Phase I) were largely reflecting on all experiences of considering AETs in projects for each stakeholder. The level and type of experience varies greatly between each stakeholder and is very difficult to define. Responses were not project-specific and so some of the points made can be conflicting or aggregated when based on more than one instance. This may be reflected in the answers to Questions 4 and 5 that reflect on the importance of drivers and barriers. The mixed stakeholder responses to these questions tended to be in the middle-range rather than at the extents of the scale.

A number of conclusions can be drawn from the comparison of these 2 studies:

- In the project-specific interviews a greater proportion of the respondents suggested that AETs were considered as important parts of the project.
- The scores attributed to barriers by the mixed stakeholder participants are far higher than those in the project-related interviews.
- Ignorance and lack of understanding was judged to be much less of a barrier in the Phase II interviews. Figure 5.8 in the previous chapter shows that this issue was much less of a factor in the projects where AETs were considered through to construction. This highlights the importance that ignorance plays in influencing the viability of AETs, and the role of engineering consultants in reducing its impact.

These results suggest that in successful projects ways have been found to reduce barriers and to allow positive drivers to overcome them. The role that the consulting engineer has to play and the impact that they can have on reducing the impact of ignorance through obtaining and disseminating accurate information has been shown to be key.

The rationale for undertaking these interviews stemmed from project involvement in Buro Happold. From these projects a number of social barriers were recognised that restricted the use of AETs in buildings even where technologies were technically and economically viable. This prompted the need for research into the experiences of other building project stakeholders to illustrate the extent of these barriers, their effect and the methods that could be used to reduce them. This project experience is described in more detail in Chapter 7.

CHAPTER 7 PROJECT EXPERIENCE

7 PROJECT EXPERIENCE

This Chapter reflects on four years of project experience and describes the varying levels of success of trying to integrate AETs into building designs. A wide range of projects are introduced, together with a description of my involvement, the energy technology selection process and the factors that had the most influence over the final decision. These are selected projects where I have had significant involvement, spanning the entire time period of the research period. The early projects helped to resolve the research question to be addressed. The later projects helped to test out the ideas developed.

This chapter concludes with the presentation of technology fact sheets developed for use by building services engineers, formed from the experience gained through involvement in these projects.

7.1 Project experience summary

The integration of AETs into building projects requires a number of roles to be performed by the building consultant throughout the project design and construction process. Within Buro Happold it has been essential to provide specialist guidance to the project design team, and in the main to the building services engineer. Some of these roles are explained as follows:

- Planning – Devising and writing strategy documents
- Brainstorming – Initial review of options
- Selection – Advising of appropriate systems and scales
- Modelling – Analysis of energy loads, system performance, costs and carbon emissions
- Detailed technology studies – In-depth analysis of a specific system
- Guidance – Production of educational material
- Construction – Final selection, system specification and procurement
- Review – Monitoring and checking performance

Involvement in a range of Buro Happold projects during the period of the research project has meant that each of these roles have been fulfilled on a number of occasions, as detailed in Table 7.1.

Table 7.1 A summary of roles performed in example projects

Role	Detail	Example Projects
Planning	Strategy documents	Convoy's Wharf; Lower Lea Valley; The Village; The Calyx
Brainstorming	Initial review of options	Halley VI; Kuwait University
Selection	Advising of appropriate systems and scales	Eden project; Royal Mills; Queens University Library Belfast
Modelling	Analysis of energy loads, system performance, costs and carbon emissions	Bermondsey Spa; Schools for the future; Corby Academy
Technology study	In-depth analysis of a specific system	Copenhagen Elephant House; Eden Biomass Feasibility Study; CHP loads
Guidance	Production of educational material	Biomass Procurement Guidelines
Construction	Final selection, system specification and procurement	Eden Biomass; Kensington Academy
Review	Monitoring and checking performance	Carterton leisure centre

7.2 Project examples

This section provides a background to each of the projects listed in Table 7.1 and further details of the role employed.

7.2.1 Carterton leisure centre

This new leisure centre in Oxfordshire includes a 25m competition pool, a fitness studio and multi-use area used for aerobics and crèche facilities. A 60kWe 90kWth CHP engine was installed in July 2004 to act as the leader boiler alongside 2 gas boilers sized to accommodate the phase II extension providing a gymnastic facility aimed at becoming a 'centre of excellence'.

On the basis of performance estimates made by the building services engineer, the client agreed to installing a CHP unit. However, during the construction process and again after 6 months of trial operation the facilities manager challenged these performance estimates, with the aim of removing the CHP unit from the project.

My role was to review the projections of the engineer, facilities manager and the unit supplier (Ener.G Combined Power) using the recorded data available and industry rules of thumb. The results of the study showed that the engine was operating according to the engineering projections, though the financial performance was lower due to changes in energy prices.

7.2.2 Royal Mills, Ancoats

The Royal Mills project is a mixed-use development, involving the regeneration of an old mill building and installation of a community heating system and small CHP engine. The development is to be made up of 178 apartments in existing 19th Century mill buildings and 3700m^2 of bar, restaurant, retail and business space, all presently under construction. An additional 119 apartments, business and retail space will be included in phase 2.

Through the various stages of the design, I assisted the building services engineers through reviewing the sizing and design of the CHP unit and community heating scheme, providing design advice and contacting potential system suppliers. The design of this system was also compared against another system being proposed for the Bermondsey Spa project (see section 7.2.13) to help improve both designs.

7.2.3 Convoy's Wharf

Buro Happold were employed to help develop a master plan for the redevelopment of a 40-acre site in Deptford on the south bank of the River Thames in London. The site is a formerly active wharf, and prior to that was in various uses (naval yard, slaughter house and munitions depot). Currently the client envisages a development of around 3,000 residential units plus leisure and commercial space.

An "Energy Assessment & Strategy" report was included in the planning submission. This report quantified the projected energy usage and carbon emissions resulting from the site wide development utilising standard solutions, and suggested methods by which these can be reduced, for the site as a whole, whilst also addressing the GLA's "The London Plan" and the "Green Light for Clean Power" policy documents. The strategy was well received by all parties and was a key part of the successful planning application, obtained June 2005.

From the building layouts and energy consumption estimates produced by the other members of the project team, I completed an assessment of the viability of AETs, comparing them against traditional energy options in practical, economic, social and environmental terms. Basic cost and CO_2 savings were calculated and practical considerations made for each viable option. Other factors considered were occupant energy use, the use of low energy design, barriers to development, Government policy and the availability of financial and legal incentives.

Some of the barriers to considering the use of AETs were as follows:

- A lack of accurate and available energy use data for mixed-use developments;
- Lack of technology awareness and of a pre-defined selection or comparison methodology;
- Limits to the time and resource available for research and assessment;
- Lack of awareness and technical and procedural uncertainty.

Because of these factors the energy strategy issued was initially undervalued by the project team, however it became a critical issue later in the process due to changes in planning policies.

7.2.4 Copenhagen Elephant House

This project involved the design of a new elephant house for Copenhagen zoo, replacing the existing facility and providing greater levels of comfort and utility for the animals, keepers and visitors alike. A review of alternative technologies was completed and the building was proposed to include facilities for rainwater harvesting, grey water recycling and the anaerobic digestion of elephant residues.

After informing this initial review, my role was to conduct a detailed study into the use of elephant and other zoo wastes for providing energy and reducing problems of waste disposal. The detailed analysis included a large amount of research into the nature of anaerobic digestion of different wastes and of the design of these biogas plants. Though there were problems with obtaining relevant information, the final submission to the client included estimated sizes and outputs from the digestion of the elephant dung and a mix of dung with human effluent.

There were problems with obtaining information, due to a lack of previous experience; there were also clear organisational barriers in terms of team members having different perspectives of the original objectives. Knowledge sharing was very difficult and it was hard to co-ordinate the design of a novel technology within the normal project design process. In this project the client was very enthusiastic but there were difficulties convincing the architect and other engineers that it was worthwhile.

A paper was presented that detailed this study at the 2003 Conference for the Engineering Doctorate in Environmental Technology at Brunel University (see Appendix E).

7.2.5 Eden project

Buro Happold provided building services design consultancy for Phase 4 of the Eden project development, which includes a new "Education and Resource Centre" (constructed September 2005) and a Dry Tropics Biome (on hold). This included a review of the rainwater recycling systems and of the potential for using AETs.

After completing the initial review of AETs for the Phase 4 development my role included involvement with further development phases, a detailed biomass feasibility study and the specification of a waste digestion system.

7.2.5.1 Biomass energy crop feasibility study (Jul – Nov 03)

This detailed study considered the feasibility of using locally grown energy crops and wood fuel as an alternative fuel for Eden and for providing support to local economies. Eden had been offered various biomass energy systems in the past but they wanted to be clear about the social, environmental and commercial risks and benefits associated with the different biomass supply options. With the provision of funding from the European Agricultural Grant Guarantee Fund (EAGGF) I led a team that investigated many of these issues related to the supply and use of biomass fuels, and presented the results to Eden in November 2003. Two important factors for the viability of a system at Eden were found to be the need for creating a stable supply system for these fuels and also allaying local fears about increased emissions and transport movements.

Based on the results of this study a paper was presented at the 3rd International Conference on Sustainable Energy Technologies, held at Nottingham University in June 2004 entitled "Eden project Biomass Energy Crop Feasibility Study". This paper was selected to be peer reviewed and was subsequently published in the International Journal of Low Carbon Technologies (see Appendix F).

7.2.5.2 Biodigester specification (Sep 03 – Jan 04)

A waste digestion system has been built as part of a quest by Eden to become 'Waste neutral' forming part of the new "Waste Recycling Centre" for sorting and treating waste whilst also being a new educational exhibit. With the support of other project team members I oversaw the design, construction and commissioning of a digester that would produce a useful compost, and possibly a source of renewable energy from organic restaurant and garden wastes. This included responsibility for producing a specification for, procuring and monitoring the installation of this potential first for the UK.

This project has been subject to considerable time delays due to its innovative nature and problems with defining the precise requirements of the client. There were issues of uncertainty in terms of the potential system performance and the needs of the client, which were somewhat allayed through our advice and open approach to decision-making.

7.2.6 Kensington Academy

The Anglican Diocese of Liverpool and the Roman Catholic Archdiocese have come together to pursue the aspiration of a new school, due for completion in 2005. For this project a number of alternative technologies were reviewed, with the use of green roofs, integrated solar PV panels and solar thermal collectors taken through to construction. In support of this a grant of £67,000 was obtained from the Energy Saving Trust for the solar PV roof.

The solar thermal collectors and solar PV panels were only considered in any detail at the tender stage of the project. The client had secured £100,000 of the budget to be spent on these technologies and my role was to quickly design the solar PV and solar thermal systems within the constraints of the building design and fit within this budget. This involved an initial review of potential system suppliers and subsequent meetings with architects, engineers and specialist contractors. Once the designs were agreed, I helped to compile applications for grant funding and advised on any installation issues.

The solar PV was relatively simple to integrate into the design and received a grant for 55% of the installed cost. However there were problems trying to integrate the solar thermal collector system due to the design of the hot water and heating system and lack of summer occupancy. In addition to these problems the funding application to the DTI Clear Skies Programme was unsuccessful due to over-subscription.

7.2.7 The Village

The Village is a proposed sustainable 101 house Eco-Village on a community-owned 67-acre rural estate in North Tipperary, Rep of Ireland, including community, catering and commercial buildings. My role was to produce the energy section of a feasibility study funded by Sustainable Energy Ireland. This included a review of the Village "Environmental Charter", likely site energy demands, environmental impacts, the potential for using AETs and passive energy saving measures, and a cost analysis of potential options.

This project showed the importance of clear and consistent information and an understanding of the relationship between energy demand estimates and supply potential. It also showed that an enthusiastic client can be a drawback, with a need for a realistic understanding of potential system outputs and costs, and for a consideration of the design process costs.

7.2.8 Schools for the future

Buro Happold were chosen to develop an exemplar design for an inner city secondary school. This and other 'Schools for the future' designs will provide a basis for schools and Local Education Authorities (LEAs) to develop their own plans for school renewal. The output was a design that would act as a template for the design of future schools, and so was only completed to scheme design stage.

Alongside the normal design, my role was to explore the possibility of a zero fossil energy variant, based on the core design but using building integrated renewable energy sources. Four different system options were proposed and investigated and the favourite of these explored further, through analysis of the potential financial, environmental and practical considerations.

From an internal viewpoint it was disappointing to see an early enthusiasm for AETs be swamped by the realities of building design, and in particular the time spent considering ventilation strategies. It showed that the energy system must be a core component of the design and not a sideline venture, so there is a requirement for improved communication and understanding throughout the team.

7.2.9 Lower Lea Valley

This was a master planning project for the regeneration of the Lower Lea Valley in East London, with and without an Olympic proposal for 2012. An energy strategy was required for the outline planning application that outlined the potential size and layout of the energy systems required to serve the whole development.

Due to the scale and timing of this project, my role was to assist with and the study that supported the energy strategy and then later extended and assessed in more detail specifically for the London Olympics 2012 bid. Load profiles and plant size estimates for each area of the development have been made through the use of energy system modelling software. A district energy system has been proposed, consisting of small, embedded generators linked via a private wire network. This approach will help reduce capital costs, improve the potential for phasing, reduce operational costs and improve efficiencies, and includes the use of CHP and renewable energy technologies.

This project highlighted the sea-change of opinion within the planning authority and the energy supply and distribution companies. The sheer scale and importance of this project led to new perspectives of sizing and designing building energy systems. Initially the design team intended to rely on a single central power plant, sized to meet the maximum demands of the project. Experience from Woking and other recent projects in the UK has shown that the more efficient and effective approach is to phased development of embedded generators within private wire networks, each joined via public wires. This approach helps with phasing, reduces capital infrastructure costs, improves operating efficiency, favours the use of renewables and reduces energy costs.

The availability of case study knowledge, supportive planning policies and a client that was keen to champion the alternative approach were key factors in the success of this project.

7.2.10 Queens University Belfast Library

Queens University, Belfast is looking to invest in a new 'flagship' library and knowledge centre in the heart of their city campus. The building will have an approximate floor area of 18,000 m^2, over 4 stories. Its main functions will be to house 1.5 million books, the campus computer centre and some substantial network servers. Adjacent to the building will be a new 2,300m^2 maths building, replacing the building presently occupying the site.

For this project I was provided with an estimate of potential annual energy demands, from which I developed potential energy demand profiles and made an assessment of AET options. From these options the use of a Ground Source Heat Pump system was investigated further, including a site soil conductivity test. If successful the system could act as a source of heating and cooling and provide capital cost, operational and environmental benefits.

7.2.11 CHP Loads

In March 2004 I created and then supervised an internal research project to investigate and agree standard heat demand profiles and CHP system design assumptions. It included the examination of previous Buro Happold projects, notable UK project examples and published design tools and research.

Throughout the practice a range of different approaches were being used for the assessment of CHP system feasibility. These approaches used different assumptions and methods of assessment, which were having a major impact on the viability of CHP for each project. Key variations were the assumptions for electricity, gas and maintenance prices/costs and the shape and scale of hot water demand profiles.

This study brought together all the reports and spreadsheets generated in the practice, summarised the projects completed and assessed the availability and suitability of other commercial tools. It also included investigation of international research into typical hot water load profile curves for domestic properties. The study is ongoing, however the information gained has been used in a new spreadsheet tool and successfully applied for the assessment of CHP viability on a number of residential and mixed-use developments.

7.2.12 The Calyx

The Calyx is proposed to be an evolving festival of horticultural excellence that aims to create a world-class garden showcase on a 61 acre site to the south side of Perth. Initially a new 7000m2 visitor building is proposed, to form a key focal attraction complementing the gardens and demonstrating the key theme of the project, including environmental awareness.

For this project I presented to the design team a number of case study projects before conducting an initial brainstorming workshop for the energy options and using this information to guide initial decision-making. Based on these proposals the project team is seeking to attract sufficient funding to allow the building to be constructed.

7.2.13 Bermondsey Spa

This is a 600 dwelling development being built over several phases in Bermondsey Spa, consisting of a third social housing, a third key worker housing and a third for private let. My role involved providing initial technology guidance and then leading a team through a detailed option review, which included: analysis of energy use of the different phases of the development, design of a heat distribution system, analysis of CHP and renewable energy technologies, a biomass resource assessment and whole life cost modelling of the possible options.

This part of the study was supported by a grant from DEFRA through the Community Energy Programme, the result of which is that the scheme will initially incorporate district heating, with an option for incorporating CHP or biomass heating in later phases.

7.2.14 Corby Academy

This new academy for 1250 pupils will replace the existing community college and form a focal point of an extended urban regeneration for Corby. The sponsor is keen to pursue the idea of a carbon neutral development and in particular the use of locally available biomass wood-chip for heating. To inform these aspirations I completed a short study into the practicalities and additional capital costs of making the academy carbon neutral in its energy use. This included commissioning a short resource study for a biomass heating system to help assess the viability of providing local woodfuel at an economic price.

7.2.15 Halley VI competition

Buro Happold led one of three teams chosen to develop designs for a new research base for the BAS to be located on sea ice off the coast of Antarctica.

The energy challenge is to reduce the use of energy as far as possible, and then to find a solution that reduces the need for imported fuel. To help with this I was involved in an initial brainstorming process, and provided information to inform the judgement of ht team. For the final submission, which was unsuccessful, a combination of wind power, PV for the summer periods and energy storage through Hydrogen was proposed.

7.2.16 Oasis Academy

This new 1050 pupil academy to be built in Enfield is sponsored by Oasis, a Christian Trust. It is designated as having a religious character and will operate a totally inclusive admissions policy, accepting students irrespective of faith or ability. The vision is for local, multi-agency, community partnership – engaging public, voluntary and business sectors in the establishment of a centre of excellence for education and lifelong learning. Due to the Christian beliefs of the sponsor there is a strong emphasis on the role of the school in society and impacts on the environment.

For this project I had reviewed the AET options and developed a proposal for using a biomass boiler in a basement plantroom, which will help to provide significant carbon emission reductions for the school and potentially for neighbouring buildings.

7.2.17 Biomass Procurement Guidelines

Together with Andrew Russell of Mercia Energy Ltd, I co-authored a document entitled "Biomass Procurement Guidelines for Ireland" to assist architects and engineers in the specification and design of wood-fuel boiler systems. These guidelines are being published by Sustainable Energy Ireland (SEI) as part of an EU funded project. This free guide will help architects and engineers to write specifications for biomass boilers to ensure greater project success. The guidelines were written in a simple and explanatory manner summarised by a number of checkboxes, with reference to all relevant existing legislation.

7.2.18 Eden Biomass

Following the recommendations of the biomass feasibility study completed in November 2003 I was asked to asked to assist with the design and installation of a new 300kW biomass boiler, biomass store and distribution system to be connected to the existing site heating system. This biomass boiler is designed to provide the base load heating needs, improve the efficiency of the present system, reduce reliance on the natural gas supply and significantly reduce carbon emissions.

Due to changes in the development of the infrastructure from the plans in 2003 there were additional technical constraints not foreseen during the completion of the feasibility study. Meanwhile, the time constraints of the funding being provided for the installation of the boiler did not allow for obtaining planning permission for a separate boilerhouse. This left the design team with massive technical challenges, trying to retrofit a biomass boiler into the existing building, which posed a number of logistical problems.

Despite these problems the biomass boiler is to be installed in spring 2006, along with a custom-made wood-chip storage and delivery facility.

7.3 Project experience observations

From the case studies, there are a number of observations that can be made, with many common lessons between projects.

The number of projects studied, and in particular the short studies, shows that there is great interest in AETs for various project types, locations and scales. To meet this demand engineers need a simple tool to allow them to perform quick but informed analysis of the various options brought forward from early brainstorming. Such a tool should help to inform the technology selection process and to provide appropriate information that can be used as required.

The lack of a detailed awareness and understanding of renewable energy design information was a common barrier within each of the projects. However, through research and project involvement more detailed and concise information has been gained, so improving the chances of using renewables in more recent projects such as the Eden project.

Another advantage held by the Eden project, and a factor that limited the Convoy's Wharf, Village and Schools for the future projects, was the availability of reliable energy use data. The Eden project has been subject to data collection and computational energy modelling. This allows potential systems to be sized appropriately to different aspects of demand and adds greater certainty to utilisation and economic payback calculations.

Along with a lack of technology awareness many of the attempts to consider AETs within the projects suffered due to a lack of co-ordination between the technology design process and the building design process. For a technology to be integrated in a building these processes must be co-ordinated so as to inform each other. It is important to provide the right detail of information at the right time and not to be too sparse in detail nor to overload a design with complications. A demonstration of this is the scarcity of information that restricted the design of an anaerobic digester for Copenhagen zoo, whereas the Eden digester design was clouded by an excess of information in the early project stages. There is thus a clear case for understanding the level, type, format and method for obtaining information required by the design team at each stage.

The understanding of the design process and necessary information flows, developed through this practical experience, has informed the generation of Figure 7.1. This flowchart outlines the role of the AET consultant and their relationship with the building services engineer and project team throughout the initial project design stages.

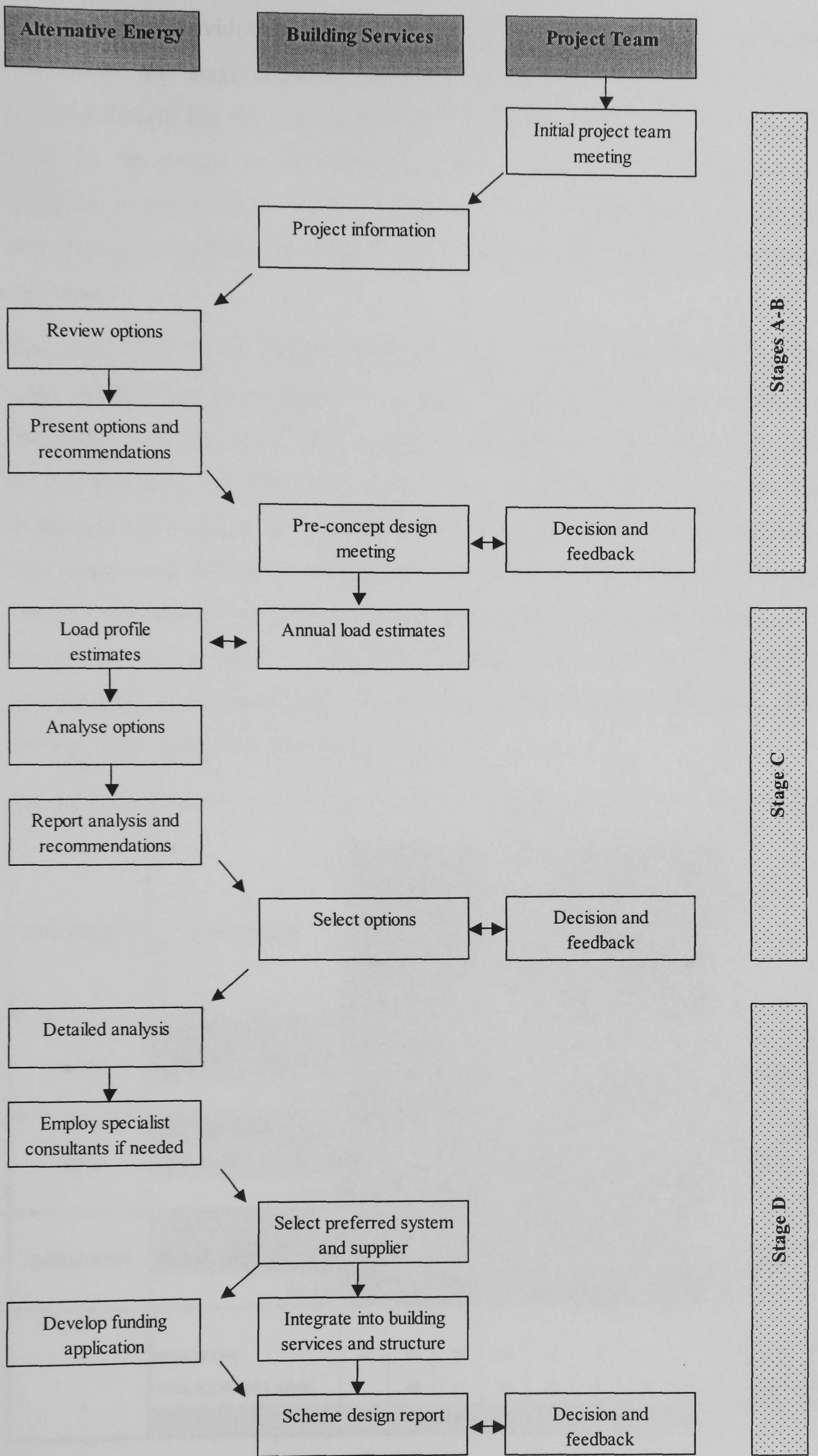
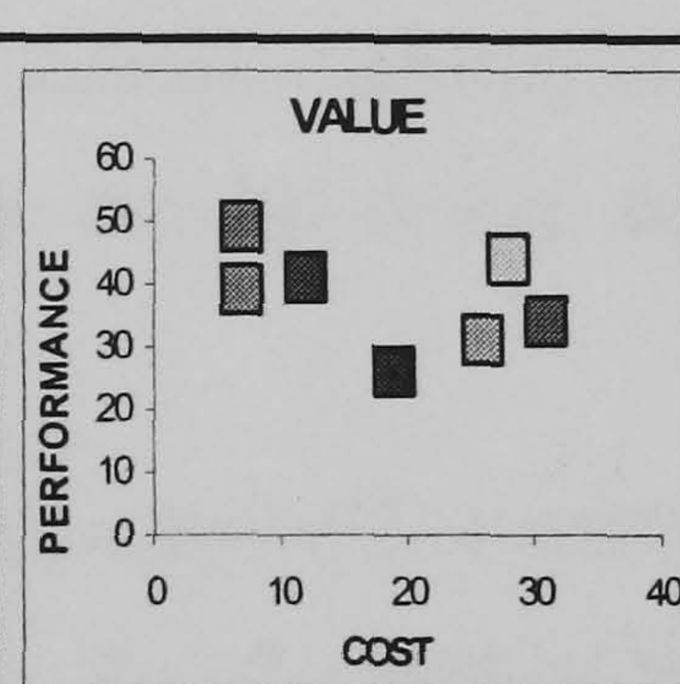


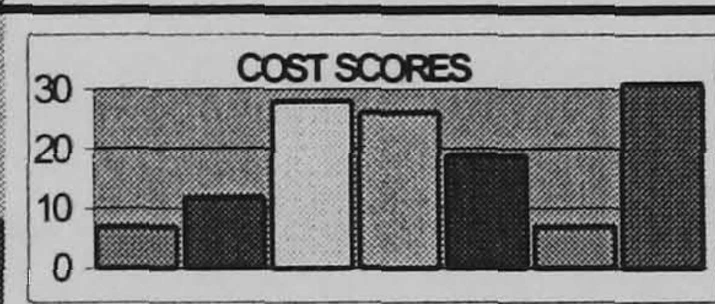
Figure 7.1 Alternative Energy Technology design process

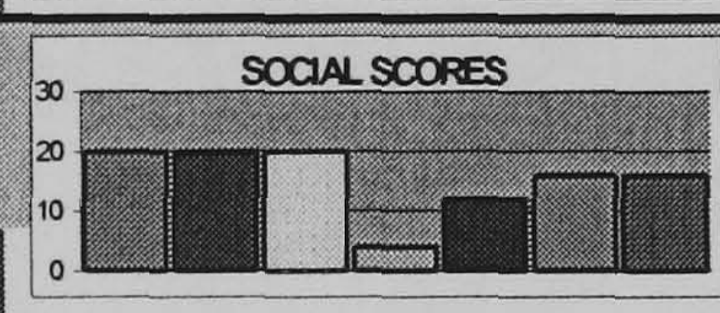
This flowchart provides the important illustration that the design and assessment of AETs need to be one stage ahead of the building services design. For instance, at stage D (scheme design) the AET is analysed and designed in detail, whereas the detailed design stage for the project on the whole is not until stage E. This advancement in detail is necessary because of the lack of familiarity of these technologies and the problems faced with trying to convince the design team that sufficient rigour has been applied to the assessment.

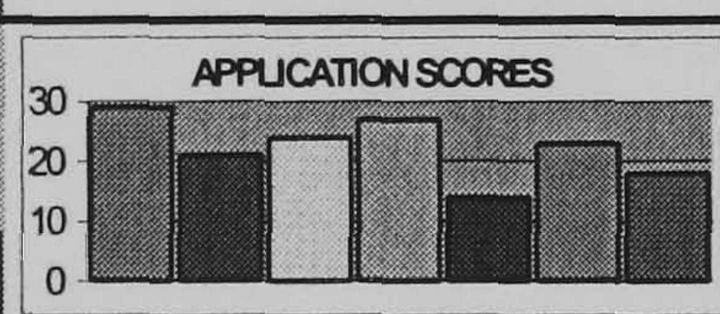
This knowledge of the design process also extends to communication within the design team and the need for an agreement of objectives at an early stage. Different members of the design team will have their own personal reservations and drivers for various options. So it is important that these are voiced and understood early on so as not to slow progress at more detailed stages. If a system is to prove unsuitable then this needs to be realised very early on to prevent wasting time and reducing the chance of other systems being viable. With Eden, a decision matrix was used at an early stage, as shown in Figure 7.2, combined with a visual presentation of each of the options. Following a discussion involving all of the stakeholders it was possible to progress with a more informed agreed strategy, increasing the chances of success.

KEY CATEGORY	SUB-CATEGORY	Score Weighting	Photovoltaics	Solar Thermal	Wind Turbine	Heat Pumps	CHP	Hydrogen Fuel Cell	Biomass
			OPTIONS						
COSTS	LOWEST CAPITAL COST	5	1	2	4	4	3	1	5
	RETURN ON INVESTMENT	2	1	1	4	3	2	1	3
	Sub-total	7	7	12	28	26	19	7	31
SOCIAL	VISUAL AWARENESS	4	5	5	5	1	3	4	4
	CURRICULUM	4	0	0	0	0	0	0	0
	Sub-total	8	20	20	20	4	12	16	16
APPLICATION	SPACE	3	3	3	4	5	2	1	2
	FUNDING POTENTIAL	4	5	3	3	3	2	5	3
	Sub-total	7	29	21	24	27	14	23	18
	TOTAL SCORE	22	56	53	72	57	45	46	65
	TOTAL SCORE EXCL COST		49	41	44	31	26	39	34
	RANKING		4	5	1	3	7	6	2









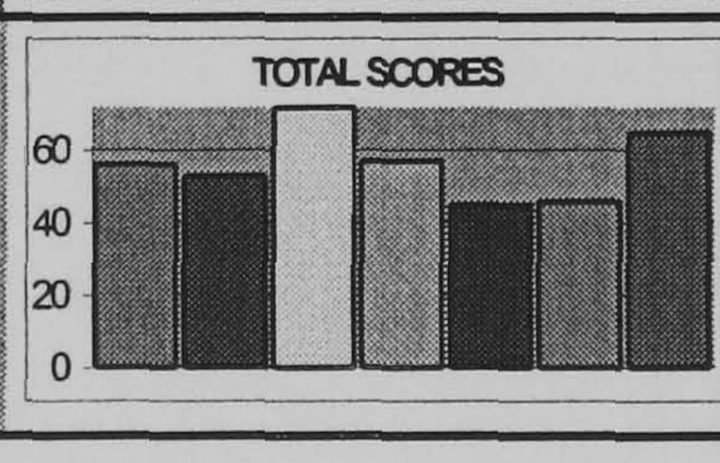


Figure 7-2 An example of a decision matrix

Beyond these, four other conclusions can be made, based primarily on the detailed biomass feasibility study at Eden. These issues are as follows:

- Selecting AETs, and specifically biomass systems, entails additional time and cost demands due to the added complexity and uncertainty associated with them.
- There is a lack of readily available operational examples of similar scale and location, with some case study data available but from various sources and of varying quality.
- The necessary involvement of many stakeholders, in particular local renewable energy suppliers and residents, who each have their own views on which technologies should be used.
- The need for an understanding of external benefits that AETs like biomass heating systems provide. These include the benefits to the local community in the form of support for local economies and environmental biodiversity whilst increasing local awareness of energy use.

From this practical experience, it seemed that there were no simple standard assessment tools or process guidance notes available in the public domain for engineers wanting to consider AETs in building projects. There also seemed to be no commonly used procedure for comparing ethical or environmental benefits against simple financial payback calculations. So in conclusion AETs were not being compared with traditional options in a fair manner, and so the chances of them being included within the detailed design and construction stages were being reduced.

To challenge this conclusion an investigation into the experiences of stakeholders within the building and renewable energy industries was proposed, which formed the basis of the participative research study (See Chapters 4, 5 and 6). This would capture the experience of practitioners with different perspectives of the building design process and of varying levels of success with the consideration of AETs and test if they were consistent with my findings.

7.4 Technology guidance

Based on the practical experience gained from this research programme and from reading around the subject of AETs and buildings a fact sheet has been developed for each of the technologies, and presented in Appendix G. These fact sheets are designed for use by engineers without a detailed knowledge of AETs, to allow them easy access to guidance and information. Though the technology fact sheets are not identical typical headings include:

- Introduction – a brief explanation of the technology.
- System options – any technology type or scale options within the core theme.
- Advantages – a list of some common advantages of that technology over other AETs and traditional forms of energy supply.
- Disadvantages – a list of common disadvantages.
- Site considerations – project characteristics that may help or hinder the technology.
- Diagram – a typical diagram and/or photograph of the technology.
- Size and output – some scale guidance, to assist with initial space considerations.
- Costs – Typical scale costs.
- Funding – Existing opportunities to obtain financial support.
- Legislation – Specific legislation that needs to be referred to.
- UK suppliers – Names of useful system suppliers in the UK.
- Books and documents – Details of other sources of information.
- BH projects – Names of projects where this technology has been applied before.
- Other points – Any other outstanding issues that need highlighting.
- Summary – A brief summary of considerations that need to be made.

It is expected that these fact sheets would be used to inform discussions in design team meetings and the production of simple reports or presentations. Hence the information is provided in a simplified and easily accessible form. This tool is useful where an engineer has been educated in the use of AETs at a basic level but needs pointers in meetings to help jog the memory when issues arise; they are not a learning tool, but an information source.

7.5 Summary of Chapter 7

This chapter has presented details of 18 different projects that have informed this research. There is great variation in the type, size and timescale of each project, so requiring differing levels and forms of input. The roles required have been explained for each project in turn and also categorised under 8 simple headings: planning, brainstorming, selection, modelling, technology study, guidance, construction and review.

There are a number of observations made through this experience, namely:

- The importance of being able to provide accurate energy use and technology performance information predictions on demand;
- The benefits brought from experience of considering the technologies for a range of projects, including the knowledge of practical shortfalls, benefits and opportunities for each technology;
- Need for coordination with the building design process and communication with the design team to provide the appropriate level and form of assistance at each stage;
- A lack of structured decision-making approaches for assessment of AETs that take account of the complexity and variation common with in each project.

This project experience has allowed for the development of selection techniques and the gathering of up-to-date technology information. This information was used to inform later projects, making the process easier, quicker and more reliable each time. Much of this information has also led to the development of a group of fact sheets, designed to provide a simple and accurate source of reference for building services engineers.

CHAPTER 8 CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

8 CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This chapter draws conclusions from the previous work, reflects on the contributions to knowledge made during this research project and provides recommendations for further research.

AETs have an important role to play in reducing the environmental impacts from energy used within buildings. There are many factors that restrict the use of AETs in building projects, including technical, social, political and economic factors. This research project is a culmination of participative research, practical project experience and a review of published research, focussing on the factors that can be influenced through the role of the consulting engineer to improve the frequency of integration of AETs into UK building projects.

8.1 Project aims

The main aims of this research programme have been to:

- Develop an understanding of AETs and how they can be integrated into building projects.
- Understand the process of delivery of building projects and how the consideration of AETs can form a part of this.
- Understand how the work of engineering consultants can increase the chance of uptake of AETs in building projects.
- Understand what the key factors are that lead to successful use of AETs in building projects.
- Use this combined understanding to help improve the delivery of AETs.

These aims have been met through a combination of involvement in building projects and a period of participative research.

8.2 Research methods

Experience of considering the use of AETs in building projects has developed throughout the research project through involvement with a wide range of Buro Happold projects. Observations from this practical work led to the development of the aims of this research, which were met through a combination of participative research and further project involvement. The subsequent project work has provided further insight into the design process and added to the development of useful case studies, guidance for the assessment of technologies and a source of design information.

Participative research approaches have been employed to investigate the experiences of senior actors within the building industry. The first phase of the participative research process began with a series of focus groups, used to develop a set of questions that could then be used for personal interviews. The focus groups were quickly followed by interviews with a selection of building project stakeholders, broadly representing 8 different stakeholder groups. The conclusions from these interviews led to the development of a second phase of interviews, with the objective of highlighting specific project experiences.

The first phase of interviews was a qualitative and partly quantitative investigation of building project stakeholders in the UK. It was conducted between October 2003 and May 2004 to explore the approaches used in assessing AETs and how actions and perceptions vary in the industry. 41 telephone and one-to-one interviews were conducted in all with participants chosen because of previous experience of considering AETs in building projects. These interviews provide an insight into the perceptions of a small group of stakeholders that do not constitute a statistically relevant sample, but provide detailed opinions based on their personal experiences.

The second phase of personal interviews was held with building services engineers from within Buro Happold. This phase looked more closely at 24 relevant projects in turn, forming case studies that were compared against the more general insights and conclusions generated in Phase I. This project-specific study investigated in more detail the decision-making approaches used and the influence of factors throughout the design process.

8.3 Conclusions from results generated

This section brings together the conclusions generated from each element of the research project.

The use of AETs in building projects is recognised as being important for reducing the environmental impact of buildings during their operational life. There are few examples of buildings in the UK that use AETs; however the interest in these technologies is increasing. It is becoming increasingly common for building projects to consider the use of AETs, and this demand is coming from all building sectors. The examples given in this research project prove that projects of varying size, building type and location are capable of using AETs.

8.3.1 Important factors

The specific factors affecting the viability of the integration of AETs into buildings in the UK are diverse and large in number. The opinions and experiences of applying these technologies are varied, and the potential for use of AETs is heavily influenced by the client, the project brief, specific project considerations and the motivations and approach of the design team used.

The variation between building projects makes the assessment and selection of energy technologies a complicated process. There are a number of key factors that influence the viability of the various AETs, including the client type, project location, building purpose, construction timescale, etc. These natural project variations are a hindrance to the integration of AETs. There is a lack of suitable operational examples in the UK that cover the extents of these variations and in enough detail. Such case studies are useful in the design process, they reduce the level of uncertainty and the perception of risk within the design team because they show that the technology has been applied in a similar case before and remains a success.

This lack of project examples for engineers to use adds to the impact of the overall lack of detailed awareness, design experience and understanding of the principles of using AETs, which is common throughout the building industry. This overall ignorance, lack of common understanding, perception of undue risk, feeling that AETs are unproven and fear of complexity are restricting the use of AETs in UK building projects. Through the project experience gained during this research project, information has been obtained and put into practice, spreadsheets and assessment approaches have been developed and refined, and eventually technologies have been designed into buildings and built. With each project this process becomes easier and quicker and the technologies are considered in more detail, and then installed more frequently. The benefits of reducing ignorance in the design team are also shown in Phase II of the interviews; here the most successful projects were those where ignorance was a far smaller barrier than in the projects where AETs were not used.

8.3.2 Drivers and barriers

The project variations also have an impact on the importance of drivers and barriers to the use of AETs. There are many defined lists of drivers and barriers for the use of renewable energy, energy efficiency, sustainable construction approaches, etc. These lists vary depending on the context of the research, the technology in focus and the definitions of the researcher. For this research a list of important drivers and barriers to using AETs in building projects was produced through focus group research and then scores were attributed to each heading in terms of their importance during each interview.

Building project stakeholders have experienced that each project has its own hierarchy of drivers and barriers; of these financial cost is consistently a major barrier, though other factors can be equally significant. Beyond the capital cost and technical constraints that cannot be influenced through the role of the building services engineer there are other significant barriers, such as ignorance, perceived risks and the view that these technologies are unproven. This is supported by other research showing the large number of factors restricting distributed generation (Lovins et al., 2002), uptake of renewables in developing countries (Painuly, 2001) and more sustainable construction (Gann, 2003), the common emphasis on cost alone (Horsley, 2003) and the need to consider social and environmental factors (Bartlett and Howard, 2000; Elliott, 2003; Reddy and Painuly, 2004).

A hierarchy of drivers and barriers to the use of AETs has been produced for each of the interview phases. Despite the variation between projects, 'high capital costs' stands out as being rated as a consistently major barrier. In nearly all of the projects reviewed capital cost was seen to be a major barrier. The capital cost of AETs is a factor that is not directly influenced through the role of engineer.

8.3.3 Overcoming barriers

It is essential for further development of AETs that for each project the key drivers and barriers are recognised, barriers minimised and drivers exploited as far as possible. This progress is reliant on technical developments, political decisions and influencing human perception within the project team. The exploitation of drivers is reliant on a better understanding and effective modes of communication of the potential benefits, as found by Charters (2001). The building consultant has a key role in interacting with the client and other team members from an early stage of project conception (Bordass, 2001) along with influencing their understanding, perceptions and eventual decision-making.

We have seen that in most cases high capital cost is a major barrier to using AETs, but that other drivers and barriers also play significant roles in determining their viability in building projects. Despite this variation between projects the approach to decision-making is often based on monetary and technical considerations. This research has highlighted that there are no commonly used methods for comparing quantitative factors, such as cost, with less tangible factors such as environmental benefits. In the Phase II interviews the environment and long-term economics were the highest rated drivers, and capital cost the highest rated barrier. However no method is used for comparing these important factors in a holistic manner. Without methods that can openly compare qualitative and quantitative considerations, particularly as many of the drivers are difficult to quantify, it will be difficult to justify using AETs in building projects.

8.3.4 Role of the engineer

The results of interviews with a variety of building stakeholders showed that consulting engineers have a key role to play in helping to increase the integration of AETs in building projects. The project-specific interviews show that the work of the engineer can reduce the impact of barriers such as: Ignorance, Lack of communication and common language, the perception AETs are unproven, Complexity and Perceived risk. Also through applying more holistic approaches to decision making they can shift the emphasis for making assessments away from some of the barriers and toward the drivers.

8.3.5 Key factors to the success of AETs in building projects

Key factors for integrating AETs into building projects have been shown to be:

- High levels of awareness and understanding of AETs,
- A high level of importance attributed to the environment and to green image benefits.
- An early and sustained commitment from the client.
- The client having an ongoing interest in the building.

Other key factors to the successful integration of AETs in buildings are highlighted through the project experience. These are as follows:

- The availability of reliable energy consumption data and technology design, cost and performance data. To do this a large database of projects needs to be amassed, and the details made available publicly.
- Co-ordination with the design process, being one stage ahead of the main design and being prepared to provide the right level of information at the right time
- Agreed project priorities and objectives from an early stage, the use of a decision matrix can help to inform this process.
- Ensuring that the client is aware of potential additional risks, design time and costs, but also of the external benefits such as identity, local economy and local energy awareness. This includes providing an insight into the risk and sensitivity of future fuel price changes, which have become very topical due to the sudden changes in recent months.
- Necessary involvement of other stakeholders such as renewable energy suppliers, local residents, funding bodies, etc. Who can have a significant influence on the viability of AETs at the later project design stages.

8.4 Recommendations for action

The perspectives of motivations, barriers and approaches for considering alternative energy technologies has been reviewed under the context of UK building projects. The recommendations for change are specific to this context but are generated from interviewing a broad perspective of building industry stakeholders.

Building professionals, and particularly building consultants have a key role to play in integrating AETs into building projects. To do so, they need to be more educated and enthusiastic, to use detailed case study information and use more informed 'holistic' approaches to decision making. These approaches must be based on a better understanding of qualitative and quantitative aspects such as whole life financial, environmental and social impacts and clearly defined client value criteria. They must also guide the engineer through the decision process and be designed to provide the right level of information at the right time. Such methods will help to improve the chances of integrating alternative energy technologies into building projects, beyond the use of subsidies and legislation to reduce the up-front financial burden of investment.

Buildings should also be designed to be future-ready so that if where AETs are considered to be not viable in the present climate, the building should be able to accommodate them in the future without significant alterations. This takes account of future changes in energy prices, public perception and technology developments.

The conclusions from this study can be verified in practice. A holistic decision making approach could be developed, perhaps based on a multiple-criteria decision analysis model, and deployed in a number of projects. The tool should be used by the building services engineer to inform selection of technologies at the concept stage, it should then provide sufficient information and case studies to allow system sizing, positioning, costing and integration advice at scheme and detailed design stages. At each stage the engineer will need to be able to justify the inclusion of the AET in the building design. To do this it is key that the selection value criteria are agreed at the project conception and referred to through the project. The tool and supporting information should be designed to provide a strong argument for using AETs and sufficient guidance for allowing integration to be easily achieved.

A similar investigation to that undertaken here should be completed focussing on each individual technology to probe the specific factors that influence the viability of each technology. Other improvements that may improve the consistency of results and make it easier to obtain a statistically significant sample are: use of a smaller set of stakeholders, similar to Phase II of the study. The answer categories generated from the qualitative study can be used again in a more quantitative study, such as a survey, to obtain a larger sample and so provide a more statistically relevant set of results.

8.5 Contribution to knowledge

The particular facets of the work that are original are listed below:

- The presentation of results from an investigation of the experiences of a range of stakeholders within the UK building industry of integrating AETs into buildings.
- Presentation of a hierarchy of drivers and barriers to the use of AETs in UK building projects.
- Development of an understanding of the role of engineers and how they can make a difference in trying to increase the use of AETs in building projects.
- Provided an insight into what makes for successful integration of AETs into a building.

The main findings of this research project have been that the most important barriers that the building services engineer can address are:

- Ignorance and a lack of understanding within the project design team;
- The importance of providing the right level of information, in the right form at the right time;
- The need for proven examples of systems for ease of comparison.

This work has helped to address all three of these barriers through:

- Project input and development of fact sheets
- Collection, storage and dissemination of case study and technology performance information
- The development and application of a more holistic selection approach

More work is required in the future to develop the selection approach as recommended, potentially culminating in a decision tool. Continual development of information collection and storage is also required to help with the application of any such decision tool.

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APPENDICES

Appendix A Phase I Sample Details

APPENDIX A Phase I Sample Details

This section provides some context to the results from the Phase I interviews presented in Chapter 4 of the report. Based on notes taken during each interview the following details of the various participants were developed. These notes have been grouped in terms of the 8 stakeholder definitions used.

There are a number of variable factors for the 41 interviews completed and this chapter aims to highlight some of these. Each of the participants' acts individually, holds individual experiences and responds to the interview questions in different ways. This chapter tries to reflect these individual reactions, based on the interviewers' recollection. Each case is not presented here in turn, but the results are summarised in terms of the stakeholder groups introduced in Section 3.3.3.

A for Architects

The architects interviewed were made up of senior partners from large and small specialist practices and two with considerable academic experience. It was not a problem finding architects who would profess to considering AET's and be happy to discuss their experiences. Of the sample chosen it was common to be invited to the practice for a personal interview, rather than to conduct a telephone interview. It was also noted that the views given were generally strongly put and forthright. There were often a lot of references to past projects, which is useful. The participants also had a tendency to draw and sketch during the personal interviews; these would either be in the form of doodles or illustrations.

Of the interviews held the architects came across as the more aggressive and tended to answer some of the questions before they were asked. The retired academic (A3) was more relaxed with his manner than the others, but had a tendency to talk for a long time and digress from the subject.

The architects generally had previous experience of considering solar energy technologies, and also referred to the use of passive solar design and natural 'alternative' building products such as timber. It was important to stress to these participants that this research is restricted to the AET's as defined in Question 2 of the interview (see section 3.3.4).

B for Building Services Engineers

Four of the interviews were completed via the telephone and two in the form of a personal interview. The majority of the interviews with Building Services Engineers were relaxed and clear, with the exception of participants B1 and B5. B1 seemed to be uncertain how to approach the questions, or whether to answer the questions; this may have been due to the company being in competition with Buro Happold. B5 was a more aggressive interview; the participant was eager to complete the interview as quickly as possible and tended to answer the questions before they were asked! For instance, during the introductions he made the insight "It's the economics stupid!".

The reason for completing six interviews was that the last participant returned a call after the fifth interview had taken place. To reduce the sample to five it would have been necessary to reject the chance of the interview or to delete the results of one already completed. Neither of these options was deemed to be beneficial to the consistency of this investigation, so the interview was completed and documented.

Of the six building services engineers one focussed on building simulation, one was involved with refurbishment and problem solving in existing buildings, two were mostly engaged in large commercial master planning projects and two were involved with day-to-day building services systems design. All were of a senior level.

C for Clients

Of the client sample all were from within the public sector industry, though people from the private sector were approached it was not possible to conduct any interviews. Three of the clients were from an engineering background acting as mechanical services managers at UK Universities. One of the clients was previously an architect and worked within a council planning department, with the client status focussed around the recently constructed department building. The last of the clients was responsible for a large Government estate, with 99% of the buildings managed on their behalf through the PFI scheme.

Contact with four of the clients was generated through leads given by other participants and the fifth through a chance meeting at a CHP conference. The university-based clients had considered a number of projects all within one site, whereas the council planning department client had a detailed knowledge of a single building and the client responsible for the government estate had responsibility for a large number of buildings but very little hands-on experience.

O for Consultants

Four of these interviews were telephone interviews other than for O1 which was completed at a conference. One of the consultants was academically based; three of the consultants focussed more on strategic consulting. Only two had regular contact within building projects and even then a lot of the work was theoretical studies.

The first of these studies was conducted face-to-face, but was one of the first interviews completed and not a great deal of information was gained, this may have been due to uncertainty and a lack of experience. However, this participant also held very little experience of the building industry with most experience conducting wind and biomass feasibility studies from a resource availability point of view. This was a similar case for O5 who acts mostly as a promoter for CHP. These consultants had a very focussed position within their industry without branching into other areas such as the building industry.

In contrast to this, participants O2 and O3 had the majority of their experience in the building industry, and trying to apply sustainable building methods in practice.

P for Planners

The planners are generally similar in their strategic outlook; most have not been involved with individual building projects considering AET's.

P1. Is involved with the INREB Faraday partnership and has experience of integration of renewables in planning.

P2. Previously worked for Future Energy Solutions in a consultancy role and now works within a county council planning department advising on sustainability issues.

P3. Was self-employed having previously been a local authority head of department and had spent two years heading up the engineering department.

P4. Has not had a huge practical experience with individual projects, though has been involved with making planning applications for wind farms and biomass plants.

P5. Is a highly experienced Planner/Architect/Management consultant, who produced a guide to energy planning for the Royal Town Planning Institute.

Each of these were telephone interviews and were consistently lengthy and detailed. They all offered a large amount of time and thought to the interview and often mentioned regret that they had not had more hands on experience with finished projects.

Q for Quantity Surveyors and Project Managers

Four of these were telephone interviews and the other (Q1) conducted within the premises of the participant.

Q2, Q3 and Q4 were all involved in practical building projects and had experience of applying these technologies in practice. Q1 and Q5 had been involved in more of a strategical position. Q1 has spent a large amount of time considering the options for assessing various sustainable building technologies, and covered each of the questions in great detail, so taking the total interview time in excess of 90 minutes.

Q1. Not involved with specific project work, more assisting projects with planning guidance, implementing government policy, and advising industry and trade bodies.

Q2. Mainly focussed around leisure centre projects. Very interested in how these technologies could be used. The interview was an easy process.

Q3. Not a lot of experience other than based on the work at Eden project since 1996. Most clients have been based in the private sector. Had scripted some answers on paper before speaking. Very articulate, but difficult to keep up with. Made key points a number of times.

Q4. Affable, chatty and joking, a simple process.

Q5. Problems at first as he did not have the questions visible, this was a distraction, but once we had the questions open it was a smooth process.

S for Suppliers

The first two were personal interviews at a conference, they were representing their companies and so there were seats available for talking. These were the first interviews completed after the focus group study and they did not tend to capture as much detail as some of the later interviews.

S1 answered questions at a conference alongside colleagues and was happy to converse because there were few visitors to the stand. The focus for answers was CHP, and particularly with respect to energy recovery from waste materials.

S2 was happy to sit down and discuss the different questions in a relaxed manner; he was very open to talking about the various experiences, mostly focussed toward heat pumps, solar thermal and PV technologies.

S3 is involved in the design, manufacture, research, installation and consultancy of renewable energy technologies. This was a very open, informative and enjoyable interview.

S4 works for a company who supply and design biomass energy systems. The participant had been involved in promoting biomass energy systems for a number of years and was happy to offer his experiences. This was completed in a relaxed manner at the end of the day.

S5 supplies ground source heat pump systems. The interview was very open and the participant was happy to be able to comment on past experiences.

T for Contractors

The contractors all had vast experience within the building industry, apart from T5, but had very little experience of considering AET's, and mostly their answers were focussed on involvement with a single unique project. T5 was a special case because the contracting organisation had employed him because he would offer a view different to other people in the organisation.

All were telephone interviews. The first was a relaxed interview, mainly focussed on the experiences gained from involvement with the Eden Project.

T2 was a very informative interview, however it was difficult to find a time to complete it so time was a bit tight and answers were slightly rushed.

T3 held a role within a company whose business was split as follows: House builder/developer 80% and contractor 20%. The developments they complete are predominantly residential and so there was a strong tendency to focus on the housing industry. Also some of the points made were more general in terms of sustainability rather than energy supply.

T4 provided open and direct answers. He was actively interested but frustrated by the lack of opportunities provided within the industry. Happy to partake, though time limited. They had considered CHP properly in a number of cases but as most of their work is design and build, where budgets are tight. Most of their clients are in the health and fitness industry. Opportunities have proven few and far between because they are generally too financially driven.

T5 held a Doctorate in Glacial geology and was employed because of his broad environmental background to provide a fresh approach to the company. Involvement in construction for one year, specially employed to consider the potential for using alternative technologies in PFI projects.

Appendix BPhase I interview results

APPENDIX B Phase I interview results

Q1. What technologies do you consider are covered by the heading 'new and renewable energy technologies'?

1A	**Reference to the technologies given in Q. 2**
A2	Fuel cells, micro-CHP
A5	Anything solar, wind, wave power, hydro – anything renewable. Would include borehole/geothermal/ground source energy for heat and coolth, and biomass
B5	wind, wave, biomass,
C3	pv panels, wind, solar thermal and hydro.
P2	Fuel cells, sun and geothermal.
P4	In terms of our role: Mainly biomass, PV, wind and I think we would like to get involved in district heating systems.
Q3	Biomass and similar, GSHP Wind, solar, hydrogen fuel cells for the future.
Q4	Providing you with energy PV, not geothermals to be new they've been around a long time, wind, all the solar energy, solar thermal. I don't see CHP as renewable energy just using existing in a different way. Not solving green problems, get power cheaper.
Q5	PV, wind, biomass, CHP is an alternative. Difficult to label. Combine generation of power with heat is alternative to traditional.
S5	What I understand by new and renewables. I believe some are not relevant for buildings solar, wind, wave, tidal, new biomass, micro-chp, micro-hydro, fusion, heat pumps.
T3	PV, solar thermal, hydro, etc. CHP a maybe depending on the fuel source. Gas-fired CHP is not renewable, alternative to conventional.
T4	new and renewable is alternative technologies wind, wave, bioenergy, geothermal.
T5	new material would include pv and solar panels, also looking at the idea of small wind turbines. I doubt we will look at bioenergy, very expensive. Most significant the solar thermal and the wind.
	Direct reference
B3	some are new and some are renewable. Using the list below as an index, renewables everything except CHP.
B6	All listed below. Including fuel cell,
C4	Looking through the answers listed below, Solar, wind, biomass, (including methane), geothermal. The CHP systems on our site is a new type of CHP using gas fired micro-turbines.
P3	Those listed below
P5	Those listed in question 2, active solar, biomass, geothermal, fuel cells, shifting towards

	hydrogen.

1B	**Additional technologies**
A2	Thermal storage
B5	landfill gas, coal-mine methane.
Q3	and hot rocks, tidal,
Q5	Wave, tidal, timber,
S5	Solar, wind, wave, tidal, new biomass, micro-chp, micro-hydro, fusion, heat pumps.

1C	**Exclusion of technologies**
A5	Would not include nuclear,
Q4	not geothermals to be new they've been around a long time,
	CHP
B1	CHP is considered old and established, though micro-CHP and fuel cells are new.
B3	Renewables everything except CHP.
B6	CHP not new technology it's been around for a long time.
C3	Don't consider CHP as a renewable, maybe new but not a renewable.
C4	I do not include CHP as new and renewable.
P1	CHP is an unusual one, if waste not necessarily renewable.
Q1	CHP quite old.
Q4	I don't see CHP as renewable energy just using existing in a different way. Not solving green problems, get power cheaper.
S4	Should gas CHP be included?
T3	Gas-fired CHP is not renewable, alternative to conventional.

1D	**Reference to other spheres of thought**
O4	I consider that Energy efficiency measures should be applied before renewable energy is considered. This study will focus on the supply side, though I find it difficult to separate the two.
O5	Sustainable energy (sustainability has three elements social, financial and environmental). The technologies considered have got to incorporate these three elements.
P3	plus of course I would add to that land use planning for transport and energy efficiency but

	not technologies they're policies. We did some work previously relating land use to public transport potential.
P5	and also passive solar. I would regard energy efficiency as a new energy technology, negawatts.
Q3	Recycling and capturing of energy, the avoidance of waste seems to be where the industry has been most concentrated in the past, though this may change.

1E	Other answers Q5, S4, S5, T5
Q5	Not sure how you can renew energy,
S4	Biomass heating specification supplier and installation.
S5	What I understand by new and renewables. I believe some are not relevant for buildings
T5	I would also like to see a system that harnesses the natural environment depending on where the project is built, some will be suited to wind or solar.
	Project experience
C4	The CHP systems on our site is a new type of CHP using gas fired micro-turbines.
C5	99% is managed on our behalf by land securities under a PFI scheme. Answer from the point of view of the department. Our department is different from other Government departments, but others are coming into it, they don't want to be in the building game so are going toward PFI. Of all our energy use, over 1800 buildings, 50% is from a renewable energy supplier, through the grid. We have 1 CHP about to be implemented and there is current consideration of biomass.
Q3	Not a lot of experience other than based on the work at Eden project since 1996. Most of my clients have been based in the private sector.

<u>Q2. From the definition used for the purposes of this research please indicate at which stage you have considered these technologies in building projects. The options for this are: (A) concept design, (B) detailed design and (C) construction. Please also list any projects of significance.</u>

Photovoltaics Solar Thermal Hydro Wind GSHP Bioenergy CHP

2A	Details of personal & project experience

A4	Most projects are for hard-nosed clients in the city with cynical views of long term paybacks. This project is an office for CIPD in Wimbledon and is presently under construction, the engineers were RIBCA.
B1	Welsh Assembly project
B2	Solar thermal – 2 schemes Longley Park College (Sheffield), Royal Mills (Manchester residential) CHP – Royal Mills (Manchester residential) 250 apartments with district heating scheme fed by CHP. 4MW heating feeding some commercial, bars and restaurants. Only penthouse properties have solar thermal collectors – so that they could meet SAP requirements. HSE building in Bootle has solar thermal.
B3	CHP detailed design Paper Mill, previous company.
B4	National aquarium Plymouth (PV). Paignton zoo (solar thermal), Plymouth college of further education (Wind, GSHP), Exeter schools PFI. Porthleven harbour (hydro) Trevoll business park (bioenergy). Esso research centre (CHP), Plymouth university (CHP).
B5	10MW biomass system built. Tend to deal with larger power projects but also hotel/hospital schemes.
C2	New offices. Elmfield New Yatt Road, Witney OX28 1PB. Trying in this building to be exemplary, issues about alignment and form all had things to do with using renewables, so that these components were implicit in the process, as the building envelope involved these. We have a BMS computer that learns from weather experiences, some of the sensing relates to wind so wind sensors rather than wind energy. Operation of a building as an environment, heated and cooled, integrated design.
C3	Coventry University campus
C4	University of Plymouth (10 years). Previous position in consultancy.
O4	Working with Ian Lindley on Ashton Green, and locally on other smaller developments.
P1	Ashton Green, Leicester.
P4	We have a wind farm currently at planning application stage. With PV we are just at the early feasibility study stage for an office block for ourselves and would like to consider that.
Q2	Wind for leisure centre, ruled out due to close proximity to RAF airfield.
S3	500 systems installed worldwide. Research into Building integrated wind.
T1	Experience of these technologies for the Eden project only.
T3	Just installed wind turbine on top of building in Manchester. And acted as a contractor for the Fibrowatt biomass power station. Developments are predominantly residential
T4	We have considered properly CHP, most of our work is design and build,
	Little project experience
A3	Mostly provided academic advice and produced literature on sustainable architecture, including the use of AET's.

B6	Have completed maintenance of GSHP
O5	Promoter for CHP.
P3	Never in an actual scheme only CHP as a potential investigation into city-wide CHP. CHP as a city-wide scheme, formal study.
Q1	Not specific project work, more assisting projects with planning guidance, implementing government policy, and advising industry and trade bodies.
T5	No. not looked at yet, for the simple reason that Laing O'Rourke have never had a need to look at it, never had consultants or architects specify it.
	Consideration at concept design
O3	All at concept except than hydro. Work at early stages of the design process
O4	Trying to get these considerations involved at concept design in all cases. It needs to be in the clients brief to be considered at this stage. People don't understand what's involved unless it is a clear requirement of clients brief.
O5	Wind considered at concept, but not integrated into a building.
Q3	All technologies have to be introduced at the concept stage to prove viable.
T2	Involvement typically begins between concept and detailed design generally Design and Build.

2B	**Depends on the client**
A4	the client (owner/occupier) wanted a building that would be environmentally and people friendly
C1	It is written in the consultants brief that an assessment is made of all appropriate technologies to provide environmental benefit. Report given and used to influence later stages.
O4	It needs to be in the clients brief to be considered at this stage. People don't understand what's involved unless it is a clear requirement of clients brief.
T4	most of our clients are in the health and fitness industry. Many of them their priority is money and time, they don't give a monkeys about energy or anything else. Just want a fast-track programme, the opportunities are few and far between.
T5	either because the client has not asked for it or is not aware of it

2C	**Depends on the project/Site**
Q2	Wind for leisure centre, ruled out due to close proximity to RAF airfield.
T3	In certain schemes they are considered but not in the vast majority, used on flagship, special

	projects.
T4	Leisure centres with swimming pools are more receptive.
T5	With new schools project we are looking at the concept of renewables for the first time. We are starting to look at renewables because they are PFI projects, it's funded by a consortium of which we are one significant element. The finance and control is there with the consortium and not the architect. In a traditional build the buildings are already designed when we tender so we can only suggest minor changes. With PFI it's a blank canvas.

2D	Depends on policy/legislation
A4	Merton council insisted that 10% of on-site energy to be from renewable sources.
B2	Only penthouse properties have solar thermal collectors – so that they could meet SAP requirements.
P3	But the investigations in the 1980's were dropped due to the privatisation of the electricity supply companies, then it was no longer practical to plan tariff rates. Before I left the Local Authority, about 10 years ago, we left a concept of the competitive release of land where energy conservation and efficiency was to be a major concept, combined with biodiversity. It is now known as Ashton Green, and finally went to tender last year.

2E	Depends on economics
Q3	We are using PV solely because we are getting funding, you would be a fool to use it otherwise as it's not efficient and hugely expensive.
T4	budgets are tight Projects are generally too financially driven. Not my personal opinion but it's the nature of the market we are in.
T5	We are trying to build in life cycle costs perspectives. Looking to use these experiences to learn how we can use alternatives to reduce life costs.

2F	Other
A5	CHP not renewable unless fed with a renewable source, it is more of an interesting energy conserving technology.
B4	The other one that we consider is geothermal direct.
C2	Agree with those. Others are architectural design using PV, solar thermal, local materials and techniques; using a philosophical approach to design. We used wool insulation, which is a low-tech renewable.
P4	I don't know a lot about GSHP.
P5	Buildings integrated renewables. Whole built environment.

T5	With [the present company] for 1 year, and there has never been a renewable technology built into the fabric of the buildings, either because the client has not asked for it or is not aware of it. 99% of engineers and construction managers here maybe don't know they exist, but even if we do it's not our role. We get a list of specifications and build the building to them, will give advice where we think it would improve but ultimately it's up to the architect and consultant. With new schools project we are looking at the concept of renewables for the first time. We are starting to look at renewables because they are PFI projects, it's funded by a consortium of which we are one significant element. The finance and control is there with the consortium and not the architect. In a traditional build the buildings are already designed when we tender so we can only suggest minor changes. With PFI it's a blank canvas. We are trying to build in life cycle costs perspectives. Looking to use these experiences to learn how we can use alternatives to reduce life costs.

Q3. How much of a part does the consideration of these technologies have to play in building projects? How does this compare with other aspects of the design?

3A	**Relevance depends on the client**
A5	Depends on the client and the project; sometimes it is dominant and sometimes it is only a minor aspect, for instance the Earth Centre we built a PV array, where the whole structure acted as a solar collector, in this project it was dominant.
Q1	Client lead.
Q3	Depends on the client. Eden are receptive up to a point.
S1	Depends on customer
T2	Largely dependent on the client and the sector he works; if you take speculative office development developers are not receptive to new ideas, they like to take the safe route, BCO standard office is what the industry wants.
	Client Confidence/Awareness
A1	Generally it depends on how confident in the technologies the clients are
A2	Depends on the client, some are more receptive than others.
B2	It depends, a huge part personally but 80% of clients are not interested. In most instances not want the client is looking for and we could go down the wrong track if client does not give a damn.
O3	Local authorities and Regional Development Agencies are becoming more aware of the issues and more confident.
	Client Design criteria/policy

B1	It needs to be appropriate to the site and developers criteria.
B5	Depends on the client, it's very much client led, they often have a strong lead until they see how much of a price premium they have to pay.
C2	It was implicit, but part of a larger philosophical programme. We wanted to be exemplary.
C5	More around considering the potential for the department to meet the governments expectations. Land securities, who operate our buildings, have an interest in marketing themselves to potential customers and to support ISO14001. On a PFI contract as a partner, we developed a policy statement that land securities are signed up to and the contract follows the same lines as the Government's targets.
O2	Depends on the client, only important if the client wants to show some commitment to sustainability.
P4	With most of developments in the area the designers look to meet building regulations as a maximum, we don't see a lot of innovative design for renewable energy in projects. Don't think there is any way we can force building developers to go down that route. Planning policy number 22 draft is out at present, and is in the right direction.
Q2	These technologies tend to be driven by what policies the council has in place with regards renewable energy sources and environmental impacts. Some councils have a taken a strong stance but many others haven't, every council should have an agenda 21 policy but it tends to sit on the shelf and not do a lot. Others have a key aim to reduce Carbon output.
Q4	Don't think they've really been considered, more the client wants it so fit it in.
T1	Generally they are driven by what the client wants in their brief

3B	**Depends on the client sector**
A1	depends on sectors
A3	The UK is only interested in quick returns for their money, part of the system of financing. The best buildings are in the academic world; people that want the long-term gains from ultra-efficient buildings.
B4	More emphasis on public sector government funded projects. There's a greater interest from private clients as result of the Climate change levy and through general environmental pressures from shareholders and potential customers.
O3	Local authorities and Regional Development Agencies are becoming more aware of the issues and more confident.
O5	White collar CO2 report from Association for the Conservation for Energy identifies that in the commercial sector energy consumption is going in the wrong direction. In the domestic sector increasingly people are considering these things due to the drivers that are emerging.
P4	I think the key is that it's very dependent on who the land owner and developer and designer is. Don't have builders/developers with new innovative ideas on renewable energy and

	energy efficiency.
T2	Largely dependent on the client and the sector he works; if you take speculative office development developers are not receptive to new ideas, they like to take the safe route, BCO standard office is what the industry wants.
T5	Will play a big part in the schools projects because schools looking for 30 yr life span so we're thinking of 30 year efficiency. So consideration of the technologies from our point of view came even before the contracts were signed, we had the project managers and directors thinking "what are the alternative technologies and processes we can use to reduce life costs".

3C	**Depends on the Procurement route**
A3	However the ECD building at East Anglia was seriously compromised under PFI.
C5	Land securities, who operate our buildings, have an interest in marketing themselves to potential customers and to support ISO14001. On a PFI contract as a partner, we developed a policy statement that land securities are signed up to and the contract follows the same lines as the Government's targets.
T5	Will play a big part in the schools projects because schools looking for 30 yr life span so we're thinking of 30 year efficiency. So consideration of the technologies from our point of view came even before the contracts were signed, we had the project managers and directors thinking "what are the alternative technologies and processes we can use to reduce life costs".

3D	**Depends on the Project/Site**
A5	Depends on the client and the project; sometimes it is dominant and sometimes it is only a minor aspect, for instance the Earth Centre we built a PV array, where the whole structure acted as a solar collector, in this project it was dominant.
B1	It needs to be appropriate to the site
C4	Initially it's a major part, but it depends on whether it's a new build or refurbishment. Refurbishment limits things dramatically, and most development is refurbishment. A recent new building has had more opportunity for including renewables, and has included PV. Another new build is forthcoming and some will be considered. Part of my duty is to evaluate these schemes.
	Depends on the project size
T3	On major schemes they are of importance
T4	Some of the larger, more educated clients do consider CHP

3E	**Not applicable**

O1	Not involved in other aspects.
S5	Interesting sitting where I sit as [a supplier]. I could say I don't know and I don't care. As a supplier I am really only the receiver of the phone call saying we want a GSHP. I don't ask them how much of a part it plays.

3F	**Needs to be a core part of the initial plan/brief**
A3	The first things that tend to go are the add-ons.
B3	If they are to be included there is dramatic importance that you plan to accommodate them.
O4	It should play a big part but doesn't if it is not a mandatory part of the design. The only reason Ashton green and the development in Milton Keynes considered these technologies was that the land sale was only allowed if they considered them. The landowner has the power to insist that it is a condition of sale. Where it's not a condition the developer will find a way of not doing it. Developers will find their way round things to do what they've always done. Got to tie the developer in over a longer period of time so they have a commitment.
P1	Not seen as an important aspect early enough
Q2	It tends to be very much dependent on the design brief, usually there is a paragraph to investigate renewable energy sources and the potential for lessening environmental impacts.
Q5	Depends whether it affects the business viability of the project, some may be critical to the project, as a fundamental aspect.
S2	They need to be considered before the design takes shape to be useful – orientation is an important factor, low flow temperatures are important, and heat losses should be minimised.
S3	In the past they have only really been considered toward the tail-end of a building project, as a last-minute add-on. This is beginning to change so that the use of renewable energy is considered early on and can influence the building design.
T5	Then we can look at the technology first and build the buildings around it. One example we have one building on a sea loch, the building is on steep slope 5 to 10 degrees so a lot of water coming down. We will use a cut and fill approach to level the ground, but then we alter the water course, if we can capture that we have got a hydro situation, or look to capture it and use in the building. We are looking at these ideas from the concept design stage.
	Even if included early on they are only used if crucial
T1	They are a part of the brief but not getting implemented. If they are crucial then they get pushed through.

3G	**Not a large amount**
A1	We have decided not to work on any buildings that do not incorporate these. Hence we are not doing very many.
A2	Most practices are based on architectural design alone, others focus on environmental design.

	Bere try to incorporate the two, environmentally sound and architecturally interesting. Only when disaster strikes will these technologies be widely adopted.
B6	Quite small in our experience, probably 5% I would think.
P3	Very little it seems to me. Obviously the exception is wind turbines and a few token Photovoltaics here and there.
	Becoming more of a consideration
A4	Cautious industry but is gradually changing, e.g. The British Council for Offices have published a guide for obtaining grants for renewable energy.
B4	More so these days with the emphasis on low energy and sustainability.
O3	An Increasing part, not important enough but changing
O5	Think that they have a low priority because the cost of energy use during building occupation accounts for 5% of a company's operating costs. The management of the organisation and occupancy accounts for 40-60% so achieving savings in those areas is far more important to the designer. This is primarily the reason CCL was introduced, to focus more attention on energy use.
P2	All I am concerned about is new and renewable energy so it's important to me. It is becoming an increasingly important aspect, reducing carbon emissions means that practical steps are required.
P5	You can see it gradually happen but in no way a commonplace
S3	This is beginning to change so that the use of renewable energy is considered early on and can influence the building design.
S4	Since the clear skies and biomass capital grants schemes have begun the demand for these has been much more widespread. There has been considerable change over the past 18 months.
T3	Not something we'd have looked at 10years ago, but certainly a feature now.
	Cautious industry
A4	Cautious industry but is gradually changing, e.g. The British Council for Offices have published a guide for obtaining grants for renewable energy.
C3	The problem I found with any new technologies is that you're batting on a sticky wicket trying to force in something new and different. Total uphill struggle. A classic example is something simple as lighting controls, consultants don't want to consider it, contractors don't want to install it and architects don't want to include in their designs because it causes trouble.
	Not consistent
P1	Not seen as an important aspect early enough and not consistent.
	Only as an add-on/status symbol
Q1	It's an add-on.

S3	In the past they have only really been considered toward the tail-end of a building project, as a last-minute add-on. However renewables are still more of a status symbol than a serious intent to be more sustainable.

3H	**An important aspect**
C4	It's a very important consideration
P2	All I am concerned about is new and renewable energy so it's important to me.
S5	In some projects it plays a very significant role and in all projects you see at the moment it does play a significant role. Because we are novel in the UK we are a significant part. Not in value but in the attention given, it might change as it becomes more common. Depends on what other novel features are being considered. At the current stage only considered in novel buildings.
T1	They are a part of the brief
T5	Will play a big part in the schools projects because schools looking for 30 yr life span so we're thinking of 30 year efficiency.
	Considered as part of sustainability
B4	Generally most people look for sustainability or environmental awareness in the design of their buildings, new and renewables are just one possibility we look at.
	Considered after low energy design
B1	Important role to play in building design but it is important to reduce energy demand first
O2	Priority should be given to low energy design. PV you spend a lot of money on. They are additional to a really energy efficient design
T3	On major schemes they are of importance and should be not that far behind consideration of additional insulation, etc. energy efficiency coupled with renewable energy.

3I	**Decisions are made based on economic considerations**
C1	Anything to do with environmental issues are low on the agenda, form the university as a whole. They have to be able to stand on their own two feet. If it gets to capital cost cutting these things get chopped first. If it is between fancy door knobs or heat reclaim it will be the heat reclaim that goes.
Q4	Not because the system would be highly beneficial to the scheme, but if the client thinks he can sell it for more money with green credentials.
Q5	There are a lot of projects where it would be nice to have these technologies but when the client realises there's no useful payback periods they are removed.
	Consideration of capital costs
A3	this is gradually eroded by the client when the costs come in. The first things that tend to go are the add-ons. It is the up-front cost rather than revenue savings that matter to the client.

	The UK is only interested in quick returns for their money, part of the system of financing. The best buildings are in the academic world; people that want the long-term gains from ultra-efficient buildings. However the ECD building at East Anglia was seriously compromised under PFI.
B2	there is a capital cost issue. All of the above have extra costs.
B4	Large part in concept design stage, at detailed design a lot get taken out due to cost savings. Either cost not economically viable.
O3	still driven by cost. Renewables prove to be an extra cost so are not a priority, but this is changing. The sustainability debate has matured
Q3	Most clients want to know about lowest capital cost and operating cost. No client has ever been interested just in energy innovation, they are always keen to get long term costs down.
T2	If it doesn't result in more £/ft not interested.
	Consideration of running costs
C5	As an incentive to them we put them on a shared savings scheme so they focus on environmental efficiency. Operational savings are shared. Land securities would supply capital. Effectively we are a tenant.
P5	Apart from a few demo projects doesn't really get considered at all as there's no economic driver so projects use gas and meet building regulations. Basically energy price signals do not really drive the market for buildings integrated solutions.
Q3	Most clients want to know about lowest capital cost and operating cost. No client has ever been interested just in energy innovation, they are always keen to get long term costs down.
T4	Our clients would all go for it if they felt it was not impacting the capital cost, closely followed by more space. Cost and space constraints are primary. David Lloyd have retrofitted CHP into projects because of high running costs. It is disappointing that we can spend half a million pounds on a big night club and the moment we hand over they will neglect it. It seems criminal that they will run it into the ground.
	Consideration of life costs
C4	Life cycle costing is important. There is no point doing renewables if it needs replacing in five years, it needs to stand its corner. It's a very important consideration but you have to evaluate all life costs and the capital costs as a comparison.
T5	Will play a big part in the schools projects because schools looking for 30 yr life span so we're thinking of 30 year efficiency. So consideration of the technologies from our point of view came even before the contracts were signed, we had the project managers and directors thinking "what are the alternative technologies and processes we can use to reduce life costs".
	Depends on the willingness to pay
B5	Fancy engineering is all well and good but if it don't pay it don't go. The best technology

	will not survive if there is not the right economic environment to support it.
	Consideration of externalities should be made
Q1	All goes back to the understanding of costs. Need to look at renewables in a different way, with greater consideration of externalities.

3J	**OTHERS**
	There's an important role for designers and consultants
A1	It is an important aspect for us to try to produce zero energy and CO2 buildings.
Q1	Consultants have a role for promoting sustainability more widely.
Q2	We rely on consultants to advise on these aspects.
	The benefits of using these technologies are not obvious
B3	Tangible benefits to the users/investors are not obvious unless some follow-up monitoring is carried out. We're offering POE of the building if there were renewables will look to monitor. For CHP have to monitor to get the QI proven for Good Quality CHP.
P1	There is a lot of top-level information, we should be thinking about these things down to sub-regional potential info.
	Influenced by social factors
O1	Driven by social factors
	The process for design is unclear and inconsistent
P1	At the other end there is advice and info for architects. No information on process, where these decisions need to be made, when, and by whom. When something more complicated than an individual client and individual site, so into the realm of new communities, urban extensions, etc. The process is unclear at that scale. They tend to use processes they are familiar with. Estimate loads, provide in normal way, from grid. They do not think through energy saving or renewables from the outset design costing stage, and then the process goes to pot. Unless you're clear on that process, decision gets foreclosed by decisions made by other people earlier in the loop. Community level process for planners to follow are not available. People make it up as they go along.

Q.4 Based on your experience, what have been the drivers for using these technologies in building projects? Please rate each of the following drivers out of 10 for relative importance (10 being most important and 1 the least) and any other drivers you wish to add.

Subsidies		**Image**		**Planning**	
Environment, e.g. Climate change		**Long-term economics**		**Lack of infrastructure**	

Politics		**Corporate social responsibility**		**Plant space**	

4A	**Directly related to titles given**
	Subsidies
B5	If subsidies available.
B6	Subsidies are the most important commercial consideration.
C1	Subsidies has been the key in the CHP project.
C2	Subsidies were a major driver in achieving PV.
P1	Subsidies help some.
P4	If subsidies were good that would be huge driver, but they aren't at the moment. From our perspective the environment is a key driver but not for developers.
Q4	Subsidies tend to be the main reason that tends to make it happen, more an enabler than a driver.
S4	Public sector wants to have any subsidy if there is one available. Clear skies scheme has brought a lot more interest from local authorities.
T2	Link with the local grant structure for residential projects, we managed to hang on to CHP, because it is tied into the grant provision.
T5	Cant judge subsidies, not seen at the early stages.
	Environment, e.g. climate change
A1	Wanting to have an environmental agenda, Ecological building rather just climate change
B6	Clients save climate change conscience with buying green energy.
P4	From our perspective the environment is a key driver but not for developers.
Q3	For eden environment hugely important.
S1	Public perception of other benefits, e.g. waste minimisation
S5	Under environment, CO2 is the factor.
	Politics
C4	Politics important in our area.
O1	*Legislation (most significant driver),
	Image
A3	Building may well attract a large amount of publicity.
A4	Current image is modern and fashionable.
C2	Image overlaps with CSR. We are traditionally a Conservative authority, and there was a desire to change the image.

C4	Image is not everything but CHP in our building did raise our profile.
O3	Image frighteningly high, wants to be seen to be green.
P3	Image is getting higher.
Q3	Clients not concerned with image.
	Long-term economics
A3	The add-on cost for sustainably advanced design. Higher re-sale price.
B2	Most clients look at long term economics over 3 years.
B4	They often start as a cheap way of generating electricity and sometimes they find that its not.
O1	project specific cost drivers, long term economics,
P3	With enlightened thinking long-term economics can become important.
T5	LTE probably the most important.
	Corporate social responsibility
C1	Social responsibility is taken by the university.
C2	Image overlaps with CSR
O1	CSR
O2	Mostly work for the public sector so CSR not such a big issue.
Q3	Most clients not social responsible.
T5	SR not serious in the past but becoming.
	Planning
A5	Wind power is the most cost-effective renewable energy technology wanted without appropriate pro-active planning. I have never met a situation where planning is a driver for renewables, though quite often planners are interested. The Regional Development Agencies have got an obligation to support renewable energy, so where they are working it's in the agenda but they are not the planning authority, more there to promote good design.
B2	Building regs included in planning.
B6	Planning can be important if they have to consider it.
C1	In planning an environmental statement is produced but not looked at.
O3	Planning varies a lot, big issue in London
P1	Planning helps when you have a local authority with an interest in renewables. Scottish hebrides…
Q5	Planning varies tremendously
	Lack of infrastructure
B4	If there's no infrastructure then it can be a major driver.
B6	Lack of infrastructure abroad has been a very large factor, especially in developing nations.

4B	**Depends on the client**
A4	These drivers are more important to owner-occupiers, in London most are speculative developers not occupying the buildings.
B3	The relevance of the score is dictated by who the client is, government funded client is dramatically different compared with commercial developer. Have tried to give an overview globally, an average of clients. Found that government funded agencies where there are directives to be green the desire for LTE is not so strong a factor. On Aberdeen factor did not want to substantiate the economic payback, interest was in affordable warmth, investment cost not an issue.
Q2	Relates to the aims and objectives of the council, how green they want to be.
Q3	Clients not concerned with image. For eden environment hugely important. Most clients not social responsible.
S2	Domestic consumers have ethical and 'greenism' demands above money.
S4	Public sector wants to have any subsidy if there is one available. Clear skies scheme has brought a lot more interest from local authorities.
4C	**Depends on the project/site**
A3	Every project has its own array of drivers and problems.
B1	Depends on the location
B4	If there's no infrastructure then it can be a major driver.
B6	Lack of infrastructure abroad has been a very large factor, especially in developing nations.
C4	Politics important in our area.
O2	Specific to each project
O3	Planning varies a lot, big issue in London
P3	These things can vary from place to place and based on potential.
Q5	Planning varies tremendously
S3	These factors vary depending on the location
T3	For us it's simple, the issue is we consider them where there is a driver upon Taylor Woodrow, such as from the land seller or planning authority when they would like us to look at these issues.
4D	**Depends on technology**
A5	Wind power is the most cost-effective renewable energy technology
C2	Subsidies were a major driver in achieving PV
P2	Varies from technology to technology.

T4	Related only to CHP.
4E	**Views can vary**
B4	They often start as a cheap way of generating electricity and sometimes they find that its not.
C5	Could give number of land securities, they would give a different perspective.
O3	Clients drivers are usually different to the advisors anticipated drivers
P4	From our perspective the environment is a key driver but not for developers.
T5	These are my opinion, not necessarily the company's.
4F	**Other**
A3	The drivers should come from the designers initially. Inspire the client. Should emphasise that it has genuine payback advantages, real cost-benefits.
B2	Other – SAP ratings. Solar thermal as a means of winning back the requirements when dealing with glass box residential buildings.
P3	[Reservations that experience would not be detailed enough.]
S4	We mostly get involved in public sector and visitor centre work, forestry sector and large country houses.

Q.5 Based on your experience, what are the main barriers for using these technologies in building projects? Please rate each of the following barriers out of 10 for relative importance (10 being most important and 1 the least) and any other barriers you wish to add.

Design fee		**Proximity to resource**		**Cost (High capital and slow payback)**	
Climate (variable)		**Ignorance and lack of understanding**		**Perceived risk**	
Stubbornness of energy industry		**Incoherent Policy and Planning constraints**		**Unsuitable site**	
Maintenance		**Complexity**		**Unproven**	
Lead time in construction		**Environmental and Ecological impacts**		**Communication and common language**	

5A	**Directly related to titles given**

	Design fee
A1	Require a lot more design effort. Some technologies are more complex than others.
A3	Extra professional costs.
T5	Design fee a reason:
	Climate (variable)
B4	Variable climate has killed a few of our schemes.
B6	Climate important for solar.
O3	Clients worry about variability, but need reassuring.
P4	The issue is not the variable output.
	Stubbornness of energy industry
B4	The energy industry tend to be supportive, we have a Biomass project in South Wales where Transco are providing the funding for it.
C1	Stubbornness has been a problem in the past, is getting less so and has largely gone away.
C4	Energy industry do not give you support you need at times.
P3	I think the construction industry is stubborn rather than the energy industry.
S1	connection cost for power
S3	Stubbornness is related to grid connection and utility companies. Good utility companies and changes to G81 regulations can help reduce cost, time and risk.
S4	Stubborness very site specific, if a council engineer does not want it then give up!
S5	One major utility is now moving but others aren't.
	Maintenance
B4	Maintenance in terms of biomass systems: there is a lack of expertise in terms of supply and maintenance for biomass power generating equipment, not a proper infrastructure, there are some companies but they're scattered over country.
P4	Maintenance may be an issue to occupiers and owners.
	Lead time in construction
B3	Some of the things have long lead times, depends on type of building, a large prestigious building you will make the time to happen.
C1	Lead time is a barrier in some instances.
C3	Other than cost lead time is a primary factor, followed by risk
P4	Lead time in planning is an issue.
	Proximity to resource
C1	Proximity depends on the project.
P2	Proximity depends on the technology.
	Ignorance and lack of understanding
A5	ignorance is less of a barrier now.
B3	Go to most clients, most are not well informed in renewables

B4	There is a lack of expertise in terms of supply and maintenance for biomass power generating equipment, not a proper infrastructure, there are some companies but they're scattered over country.
C1	Ignorance is important; I have trouble persuading colleagues what we are getting at.
C3	And a lack of understanding. If the main contractor on a project sees something he doesn't fully understand he assumes he can't get it. People are anti-change.
C5	I do think people have always done it one way and don't want to change.
P4	Think there is enough people with the right knowledge out there. There's a complete lack of understanding across the whole industry, planners and developers.
Q2	Don't tend to have a very detailed cost breakdown at the outset,
S2	Lack of training in installers, and expertise & awareness of consultants.
S5	In addition contractual barriers and a lack of awareness by the professionals, fear factor; it's easier to duck out of dealing with it rather than finding out. Their professional indemnity means that if they take it seriously they must investigate it as an option. There is no training for the professionals, building consultants and architects. And also barriers are created by the contractors; in design and build projects there will be contractual implications for them and so they will try a lot to stop it from happening.
T5	Ignorance less of a problem, there are a lot more information and experts coming to the fore.
	Incoherent Policy and Planning constraints
B4	The Government pushes these things but all sorts of problems arise when pushing them through planning.
O2	Planning most appropriate for wind.
P4	The clients don't know in the long term if the government will put the necessary fiscal policies in place. One of the real problems in planning terms is there's no one coherent strategy for renewable energy.
B4	Planning stopped the North Devon Hydro scheme.
S1	Legislation, and future changes to legislation, waste licensing issues
S2	Attention of grant rules & specs,
T5	Not come across planning constraints yet, though white paper has indicated that it will become more important in the future.
	Complexity
B6	These are comparatively simple technologies.
C4	Complexity can be overcome by using consultants.
O5	More complex to do. People want to take the tech and strap them onto buildings rather than decide which is most appropriate,
P1	Complexity of process important
P4	I think there's a fear it's a lot more complex than it is.

S4	Infrastructure for biofuels is a major barrier in the UK.
	Environmental and Ecological impacts
A1	Waste to energy can have a local ecological impact.
P3	We explored the potential for tyre burning but the supply of all tyres coming in meant that environmental impacts were the major constraint. A classic one is the burning of farmyard slurry.
P4	People are not convinced about the environmental impacts of renewable energy, which goes back to uncertainty.
	Cost (High capital and slow payback)
A1	Cost is perceived as a barrier though I don't think it should be. People do not worry about the payback for a kitchen or a BMW.
A2	usually people do not use them for financial reasons. If they do then these technologies are usually unrealistic in the medium term. People in the UK do not think of the long term for house/work facilities. They care about themselves rather than next generation.
A3	Need to identify additional costs from a truly sustainable building. There's a perceived extra cost. Appearance/Aesthetics, Intrusiveness cost extra, poor-rate of return from the grid. Extra professional costs.
A5	Most barriers are cost and unsuitability,
B3	Everything has to pay for itself at the end of the day.
B6	Generally quite high in costs.
C3	Down to cost, a lot we have lost because we could not prove a case economically.
O1	Cost
O3	More worried about costs rather than the complexity of nuts and bolts.
Q2	Most barriers are financial. Don't tend to have a very detailed cost breakdown at the outset,
S2	Price, *Payback (important)
T3	Definitely when looking at putting together a development the developments are generally sold on, so the major driver is lowest capital cost.
	Perceived risk
C3	Other than cost lead time is a primary factor, followed by risk
T5	I would imagine there's a great element of risk taking these technologies on for 30 years as there is no benchmark out there. I gather there are not that many companies developing these technologies.
	Unsuitable site
A5	Most barriers are cost and unsuitability,
S2	Building Suitability, Lack of summer load in schools,
	Unproven
B3	Amongst a lot of lay people these still seem unproven.

B4	We would not recommend it if it's unproven.
B6	Most technologies pretty well proven.
C1	The University likes unproven technologies.
	Communication and common language
A4	Working with different consultants causes communication problems, people have different opinions of renewables, difficult to give consistent factual evidence.
B3	Have to be careful how you put the messages across
P4	There's as much miss information as good information.
P5	Common language is important as you get enthusiasts blabbering on about things that nobody understands.
T5	The common language problem I liken to PC and Apple computers, they make the same function but the language is different.
5B	**Depends on the client**
A2	It all comes down to the clients motivations, usually people do not use them for financial reasons. If they do then these technologies are usually unrealistic in the medium term. People in the UK do not think of the long term for house/work facilities. They care about themselves rather than next generation.
B1	It depends on the clients view.
B3	Scores different with a different client base. Go to most clients, most are not well informed in renewables, have to be careful how you put the messages across.
O2	Most important to get the client on board.
P4	Maintenance may be an issue to occupiers and owners.
Q5	depends on who the nature of the client, on the commercial reasons for the development. If commercial office not likely you will be looking at long term. One of the barriers is the client developing speculatively. They will not be interested in long term.
5C	**Depends on the project/Site**
B3	Some of the things have long lead times, depends on type of building, a large prestigious building you will make the time to happen.
C1	Lead time is a barrier in some instances. Proximity depends on the project.
S2	Lack of summer load in schools
S4	Stubborness very site specific, if a council engineer does not want it then give up!
5D	**Depends on technology**
A1	Some technologies are more complex than others.
B4	Depends on the technology. Planning stopped the North Devon Hydro scheme. Maintenance

	in terms of biomass systems
B6	Climate important for solar.
O2	Planning most appropriate for wind.
P2	Proximity depends on the technology.
P3	Depends on the technology
S4	Infrastructure for biofuels is a major barrier in the UK
5E	**Views can vary**
A4	Working with different consultants causes communication problems, people have different opinions of renewables, difficult to give consistent factual evidence.
P4	There's as much miss information as good information.
5F	**Others**
A4	Jonathan Porrit lecture stated that environmental awareness takes a lot of work.
C3	If the main contractor on a project sees something he doesn't fully understand he assumes he can't get it. People are anti-change.
C5	Many cases it's because I have a series of targets that come from government and I am responsible to get land securities signed up, then it's up to them to implement.
O5	People want to take the tech and strap them onto buildings rather than decide which is most appropriate, there is a basket of technologies; no one is a panacea.
S5	And also barriers are created by the contractors; in design and build projects there will be contractual implications for them and so they will try a lot to stop it from happening.
T5	I was at the NEMEX conference, spoke to several companies selling PV and solar, price and payback, what is technology going to be in 2 years? Payback time of over a decade, if buying a laptop would want an upgrade. Would supplier offer an upgrade to make sure that the newest technology will be provided and the system is not going to be out of date? No. In 5 years the payback time maybe 2 years, so may as well wait.

Q.6 In the building design process how are the negative and positive aspects of these technologies considered and compared?

Q.7 In the selection of energy technologies how are quantifiable factors compared against some of the less tangible factors?

	Category (sub-category) **description**
A	**Monetary aspects are considered**

A3	Intrusiveness cost extra, poor-rate of return from the grid. Extra professional costs.
A4	Generally clients are business clients and business works with money, there is a budget and there are priorities, and environmental things tend to be marginal, hence not essential.
A5	Concerned with basic economic equations, payback the most significant discussion you have and then what's the Life Cycle Costs of the system.
A5	Solar Century do a Cost Benefit Analysis of solar installations and agree with the client to see how the Figures can be made to look rosier. Starts with 100 year payback, with grants of 50% available and ROC's doubling the value of the electricity generated and the payback has gone down to a 25 year payback.
B2	Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life cycle costs (3rd).
B3	Cost, running savings, simple payback and carbon savings.
B4	but at the end of the day it's the physical cost factors that are decisive factors. Though some accept additional cost.
B6	Generally when compared the primary function is finance, capital implications, then planning implications, which are quite serious if putting in wind turbines.
B6	Internally driven from financial perspective if subsidies, paybacks.
C1	If anything looks like it has a chance a comprehensive assessment of quantitative factors such as carbon emission and cost and less tangible such as visual aspects, benefits to public view and education.
C2	Subsidies were a major driver in achieving PV.
C3	We've just been considering GSHP and we had to go to a great deal of trouble to do feasibility study and people have decided that not a budget. Budget gets fixed early on in project and if you want to use something expensive capital cost and not lower in revenue it's difficult to get it.
C5	Land securities often have to go and borrow the money so if payback in excess of 3 years it wont happen.
O1	Cost – availability & security.
O2	This often depends if you can get funding.
O3	It's a balance between risk and finance.
O3	adapt simple formula based on CO_2 (crude) value for money.
P1	People obviously look at up-front cost, site preparation and installation. Tend to discount long term costs, this is a broader issue.
P2	Financial analysis, whole life time costs, cost comparison with the conventional approach.
Q1	Simple cost analysis.
Q1	Cost dominates.
Q2	You take into account capital cost, the life costs compared with the carbon production and

	try to level out the financial elements,
Q3	Normally in the form of design report recommendations from the consultant, and then the QS looks at the money.
Q4	Weighed up normally from a report a perspective, but the last page that covers the costs is the main part that influences the clients decision.
Q4	Cost takes precedence because it can be quantified easily, it easily understandable. Money is a common language. Have seen people do comparisons of less tangible, which helps give an indication of priority, work out the clients priorities and see if the perception meets with these priorities. Then can compare against cost, and see if interpreted what client has said correctly.
Q5	Probably based on a comparison of the economics, WLC, Basically a viability study, how much will it cost to install and run compared with alternatives.
S1	Generally a commercial decision
S2	Payback.
S3	there is a balance between image and financial cost, but not sure how this is judged.
S4	Also a simple financial analysis, including a 15 year NPV analysis. Typically, we would offer an initial budget price and we would detail an outline of running requirements.
T1	They should all be compared back to money to get a real understanding of the commitment. You can put anything into monetary terms. Set yourself a benchmark and you can score it. But a pound sign makes people focus.
T2	It is basically cost.
T3	Quantifiable aspects are cost and how much energy you can deliver.
T3	Lowest capital cost issue is paramount in building design, a developer doesn't have to spend heavily on infrastructure and they're not going to unless there is an immediate payback, like an increase in sale value. Problem with higher capital cost is that developers are not getting any payback so they will not pursue it.
T4	All they count is money. They far out weigh less tangible.
T4	The clients are not concerned about the environment.
T5	Negative is the opposite, if you are not willing to look at Life Cycle Costs, or if you want instant gain then you will always go for traditional.
	Life cycle considerations
A1	Consideration of life cycle costs and discount cash flow analysis. Cost per kWh. Not always cost driven.
A5	Concerned with basic economic equations, payback the most significant discussion you have and then what's the Life Cycle Costs of the system.
B2	Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life

	cycle costs (3rd).
B4	Normally do a LCC on all alternative technologies and compare them with conventional systems and then review payback. That's it in terms of comparisons. Each technology is unique but the main method is LCC.
C4	Whole Life Costing could be used as a method. But there are options on that, depends on how much you use the system and the maintenance needs, all part of the business case. Sometimes, people forget maintenance costs.
C5	Basically look for cost benefit appraisal and then look to put life cycle technologies into it. We are developing with land securities a method for looking at life cycle returns, looking for recovery over time with projects. As a converse to this we still do a simple internal rate of return assessment.
P2	Financial analysis, whole life time costs, cost comparison with the conventional approach.
Q1	Some projects (around 7%) consider Whole life costing, a smaller proportion consider Life cycle costs and around 0.1% ask for Multi-criteria analysis, comparing costs with other factors.
Q2	You take into account capital cost, the life costs compared with the carbon production and try to level out the financial elements,
Q5	Probably based on a comparison of the economics, WLC,
S4	Also a simple financial analysis, including a 15 year NPV analysis.
T5	Positive, look at life cycle costs, renewable will always beat traditional technologies over their life, but very rare for a client to perceive a payback time in 5 or 10 years.
B	**Balance of pro's and con's.**
A1	In the process of building design I would concentrate on the positive aspects. The negative aspects would be designed out in the process. Negative aspects can be forced out in early design through a Renewable energy feasibility study.
A2	Put the positive aspects first, the client and project manager will always offer the negative side.
A4	No formal format was used for CIPD, matrices were used to compare different technologies, decisions were mostly intuitive.
B1	Make simple assumptions present to the client as energy output vs cost. Beyond that there is the consideration of architectural aspects, visual aspects and noise impacts; comparing these can be extremely complicated.
B2	Design team input and discussions. We had cases in the past where we showed options with low payback, but any misgivings within the team by one party may introduce the feeling of risk and uncertainty. So the next step might be tackling peoples perceptions.
B5	One can flag to the client the pro's and con's but then you must compare solely on words.

	Depends on the decision process used, we often use a scoring system which in a way is pseudo-quantification.
C1	They then need to assess and prepare a paper on each of these ideas. Depth depends on how good the idea is. If clearly doolally I expect one sentence. If anything looks like it has a chance a comprehensive assessment of quantitative factors such as carbon emission and cost and less tangible such as visual aspects, benefits to public view and education. Bringing the technology to people. Expect to see reports bringing out relative benefits.
C4	Before this you need to prepare a fair and honest case. In the building design process, if putting a CHP scheme forward it needs to be fully evaluated, so look at all parameters, prepare and present to the right people. Target at the right people. Both the negative and positive aspects. CHP grant scheme should get them involved, all needs to be fully evaluated and has to have a good business case. Target at the decision maker, might be the one that holds the purse strings, but prepare right beforehand.
C5	Basically look for cost benefit appraisal and then look to put life cycle technologies into it. Need a balanced approach to assessment.
C5	Looking for a balance, no specific quantitative vs. non quantitative comparison, but do include targets for EMS. Consider quality as well as quantity. We are moving away from environmental efficiency and toward sustainable development, trying to demonstrate a quantitative and qualitative balance. Sustainable development policy asks for a balance between social progress and to be environmentally efficient and keep within economic budgets.
O2	Arbitrarily. Try to convince the client they want to pay for it and then go for a feasibility study.
O2	Produce a written report that explains quantifiable and less tangible aspects. State factors for each technology and draw conclusions. No proper procedure. Usually a selection comes clear from initial study. Present it to the client and they usually have a preference toward one technology.
P4	Normally we would in terms of plan applications start from a position that proposals should conform to national and local plan policies. Then we look at material planning considerations such as noise, pollution, vehicle movements, health issues, etc. We weigh up the pro's and con's.
P4	We look for demonstrable harm when we look at any planning application, we weigh it up in the balance as a matter of judgement, if schemes where we do not have a lot of experience then we seek advice from colleagues. I think it's different with the planning process than building design, by the time the project gets to us the debate and discussion by the design team has already taken place so we are not in a position to really drive the new and innovative ideas.
P5	You would use an agreed system like BREAM it captures various issues you can compare.

	It's a system for comparing pro's and con's.
Q3	Normally in the form of design report recommendations from the consultant, and then the QS looks at the money.
Q4	Weighed up normally from a report a perspective, but the last page that covers the costs is the main part that influences the clients decision.
Q4	Have seen people do comparisons of less tangible, which helps give an indication of priority, work out the clients priorities and see if the perception meets with these priorities. Then can compare against cost, and see if interpreted what client has said correctly.
S4	A design study of how it might fit is important so consideration of physical practical issues.
S5	My worry is that they're not compared on a like for like or objective basis. Our suspicion is that the negative and positive aspects are not laid out. People are not asked "what are their objectives", we see what we feel are quite arbitrary decisions, architects pet systems. Not compared on a rational basis.
T1	Powerpoint presentations with graphs and tables. Scoring against the different options for pros and cons. Presented to the client so that they can make more informed decisions.
T2	90% of comparison is all about cost and what value will it add to the job. If cost outweighs value then unless there's a really strong driver from the client it's not going to happen.
C	**Other qualitative techniques used/considerations made**
A1	With biofuels there are issues with fuel cost and storage, etc, which are much more of a factor, so hassle factor. Hiring of caretaker or use of contracts. Sometimes it is also a question of scale, so down to our experience.
A5	People are undoubtedly interested in the image of being green, it's worth a lot in terms of publicity. Then what's it worth to the client or company in terms of publicity value? £10-20,000 worth of first year publicity for the National Trust, a small publicity cost. Quantifying PR value is very difficult.
B1	Quantify as far as you can and try to gain an idea about intangible aspects from dialogue with other parties. Some aspects are noise, environmental aspects.
B1	Beyond that there is the consideration of architectural aspects, visual aspects and noise impacts; comparing these can be extremely complicated.
B2	Design team input and discussions. We had cases in the past where we showed options with low payback, but any misgivings within the team by one party may introduce the feeling of risk and uncertainty. So the next step might be tackling peoples perceptions.
B4	As a general summary I think that in the early stages it's the less tangible factors that get the ideas on the Table and get considered. It's not until the detailed design stage that you compare against quant factors. These quantifiable factors will commonly put the client off. Additional maintenance can put the client off. We do some network review of quantifiable

	and intangible aspects and rate the options out of ten, so including environmental score, but at the end of the day it's the physical cost factors that are decisive factors. Though some accept additional cost.
B5	One can flag to the client the pro's and con's but then you must compare solely on words. Depends on the decision process used, we often use a scoring system which in a way is pseudo-quantification.
B6	Less tangible factors tend to be externally driven. For example a lot of companies they consider they can't do anything about energy consumption but can be 10-15% better through buying power from renewable sources or incorporating renewables into individual processes, so they can say to the client or public that they are a green company. Quantifiable aspects are cost and CO2, less tangible are image, environmental commitment, one is internally driven and the other is externally driven.
C1	If anything looks like it has a chance a comprehensive assessment of quantitative factors such as carbon emission and cost and less tangible such as visual aspects, benefits to public view and education. Bringing the tech to people. Expect to see reports bringing out relative benefits.
C2	Image overlaps with CSR. We are traditionally a Conservative authority, and there was a desire to change the image.
C5	Looking for a balance, no specific quantitative vs. non quantitative comparison, but do include targets for EMS. Consider quality as well as quantity. We are moving away from environmental efficiency and toward sustainable development, trying to demonstrate a quantitative and qualitative balance. Sustainable development policy asks for a balance between social progress and to be environmentally efficient and keep within economic budgets.
O2	Produce a written report that explains quantifiable and less tangible aspects.
O3	It's a balance between risk and finance.
O4	People feel they can't trust them after past bad experience.
O5	They are given priorities, social equity, carbon are not compared with money.
P2	Trying to get those included because you need them when trying to justify. Need them but difficult to do. Need some guidance. There is a 'Social costs of carbon' report by the DTI treasury. Helps to justify going for a lower carbon measure.
P3	For some of the sites using advanced technologies and techniques there's a prior agreement between planning authority, land owners and developers and they decide the most appropriate planning policies and technologies at the initial design concept. But I don't think that's typical.
P5	You would use an agreed system like BREAM it captures various issues you can compare. It's a system for comparing pro's and con's.
Q1	around 0.1% ask for Multi-criteria analysis, comparing costs with other factors.

Q1	Need to understand individual client objectives rather than use standard approaches, this will involve considering social benefits of options and tailoring the intangibles to the project needs. MCA is good for capturing social drivers. LCA tools, e.g. ENVEST, can be used to capture environmental drivers.
Q4	Have seen people do comparisons of less tangible, which helps give an indication of priority, work out the clients priorities and see if the perception meets with these priorities. Then can compare against cost, and see if interpreted what client has said correctly.
Q5	Lead in times and the familiarity with the technology (has it been tried and tested).
Q5	Generally compared based on the clients perceived value, things like the value of the projection of a particular corporate image of environment responsibility, how much value they attribute to running costs of the development, compared with capital costs. Need to put a value on them to be able to assess the non tangibles comparatively. Value is benefit over cost. Benefit is sometimes not so tangible, the value they place on corporate image, etc.
S1	Element of risk, risk exposure, reflect risk in monetary terms
S2	Consideration of 'fashion'
S3	New projects are more concerned with image than before and there is a balance between image and financial cost, but not sure how this is judged.
S4	Sell local employment and forestry benefits, as a generic.
T2	We would look at published data and demonstration projects somewhere, it's up to the individual to turn less tangible things into something that can be understood and compared with the more tangible.
D	**Other quantitative costs vs benefits**
A4	We compared each technology using annual CO_2 calculations, so you can quantify and compare.
B1	Environmental Impact Analysis is used for some projects.
B3	Cost, running savings, simple payback and carbon savings.
C4	Methods as laid down in business law and through CIBSE for comparing systems. If it's new then difficult to compare, so it can be all guess work. There's a lot of guess work and going into the unknown. It's the job of the team preparing the case to eliminate all the improbables and be fair and accurate, avoid bullshit.
C5	Developing ISO14001 Environmental Management System for government that covers all 1800 buildings, so always looking for potential for meeting targets set for this.
O3	A common comparison method is Tonnes of CO_2 saved per £ spent.
O3	adapt simple formula based on CO_2 (crude) value for money.
P1	Formal environmental impact processes are in the form of Environmental appraisals and EIA's, scheme specific appraisals, such as CHP emissions under environmental health clean

	air regulations.
P4	we look at material planning considerations such as noise, pollution, vehicle movements, health issues, etc. We weigh up the pro's and con's. Bigger schemes need EI Assessments. Have to show the Environmental Impacts. We get a consultant to look at them, this is a specialist field.
Q2	You take into account capital cost, the life costs compared with the carbon production and try to level out the financial elements, on the back of that the authorities policies come into it. Is the council prepared to pay for reduction in carbon?
S2	Try to emphasise Co2 payback & energy saving
S4	Assessment of the net CO2 reduction, using the IEA methodology for life cycle emission factors, so equating the annual CO2 emissions offset.
T5	If I was a client then I would want to quantify everything. If you cant quantify it then give a damn good try. Quantifiable will always win against the less tangible.
E	**None / New methods required**
A1	Not really, it is more of a case that they are considered complementarily, driven by resource availability.
A2	Generally people are spending considerable amounts of money on PV because they find it easy to specify PV rather than actually giving thought to other technologies. These other technologies need a sympathetic understanding and sympathetic occupants/users to be successful.
A3	Less tangible should become more tangible, comfort and health. The quantifiable factors are right up front.
A4	How this is related to aesthetics is highly intuitive and opinionated. It's a black hole, we deal with it all our lives.
B2	Very difficult to do. I don't think there is a method really. It needs a selection tool for use by the engineers. Engineers can quantify things but I don't know if there is any way of comparing the less tangible, the only way is to discuss and reflect on case studies.
B6	Not sure how those decisions are reached. Quantifiable aspects are cost and CO2, less tangible are image, environmental commitment, one is internally driven and the other is externally driven.
C3	Very difficult to quantify it to be honest,
C4	If it's new then difficult to compare, so it can be all guess work. There's a lot of guess work and going into the unknown. It's the job of the team preparing the case to eliminate all the improbables and be fair and accurate, avoid bullshit. Some of the problems dealing with consultants is getting them to buy in to our methods, they need a greater understanding of the client needs and of the system.

C5	Looking for a balance, no specific quantitative vs. non quantitative comparison, but do include targets for EMS
O1	Don't know
O2	Arbritarily
O2	No proper procedure. Usually a selection comes clear from initial study. Present it to the client and they usually have a preference toward one technology.
O3	Amount of data and case studies getting better
O4	People have not got techniques to describe social benefits. Though there is evidence out there if you go and look for it. Generally the less tangible factors are not considered.
O4	Not really any method, people find it very difficult to compare and difficult to find the information to do so. Designers like to put one technology in as opposed to a combination of technologies, whereas a combination may be more appropriate. There is a need for different professional experiences to use a combination of technologies, which is a barrier.
O5	Don't think things are really appropriately considered, need to take the bigger picture.
P1	Not sure I know how architects do their designs! I suspect a lot is done by familiarity with particular systems or particular groups of expertise, not necessarily a broadening of horizon. Isn't one respect the assessment framework, locked away in different specialist areas of interest.
P2	Trying to get those included because you need them when trying to justify. Need them but difficult to do. Need some guidance.
P3	I suspect there's a still a long way to go on this especially with the less tangible factors, social, aesthetical and environmental benefits have always been a problem comparing them with quantifiable factors. If not careful you get spurious science coming through, when trying to quantify the unquantifiable.
P3	In a routine development I don't think they are.
P5	I wouldn't know how to measure social impact, there is no agreed measuring system for them, an opinion survey might tell you something but usually NIMBY.
Q1	Need to understand individual client objectives rather than use standard approaches, this will involve considering social benefits of options and tailoring the intangibles to the project needs.
Q3	There is a huge amount of potential for research into producing a template for comparing the larger scale costs of comparing electricity driven by traditional X vs. alternative Y. There is one thing to have the technology and another thing to have the information with which to make the decisions, we need the whole picture, everything. Clients do not often get the information that they require, consultants do not give the full side of the cost equations, the right questions are not being asked.
Q5	Need to put a value on them to be able to assess the non tangibles comparatively. Value is

	benefit over cost. Benefit is sometimes not so tangible, the value they place on corporate image, etc.
S3	There is no structured method of comparison.
S3	I wish that I knew! There's not enough knowledge within the building profession. The methods of consideration and comparison are not mature; each project is a fresh start.
S5	With difficulty due to lack of information. I sympathise with the people who have to make the selections, they probably find it difficult to find the information to make the decision.
S5	Sitting here I don't know, given my role as a supplier.
T2	It goes back to communication and common language. If you have a couple of believers on the team they can really champion the course and they can really sell it to the team. We would look at published data and demonstration projects somewhere, it's up to the individual to turn less tangible things into something that can be understood and compared with the more tangible.
T4	Planning is a key thing because a lot of our projects are in city centres, so a lot have planning problems. The clients are not concerned about the environment. Not interested in embracing these technologies unless there are planning constraints they wont bother. Unless legislation that restricts them they won't bother. There is a lot of complacency.
T5	It is difficult to quantify the future operational output of renewables compared with the supply of traditional which is always dependable.
F	**Depends on the client**
A1	Depends on the organisation whether they can consider renewables cost-effective. If the building is to be built and occupied by the client then they have much greater benefit.
A1	Sometimes the client has gone for a different technology than we have recommended. They have to have the final say.
A2	Either the client has a conscience or they do not!
A3	I have the cynical view that only few people invest money for the greater good. They are only concerned about a good return in the next 5 years within the UK.
A4	Generally clients are business clients and business works with money, there is a budget and there are priorities, and environmental things tend to be marginal, hence not essential.
B1	It depends on how far the design goes. At concept the options are discussed. It also depends on the client and architect and the considerations of the planners and local public. Early discussions are important and should be based on the best information available and common sense.
B3	Depends on the client group, it varies a lot. If talking to developer then all interest is economics, much less interested in green issues and other good things. Government clients able to be more flexible, willing to listen to more drivers and arguments.

B5	Client led, dependent on whether they want to consider simple payback or NPV, depends on what decision criteria the client wants to use.
B6	Depends on the clients understanding and commitment to environmental issues if going for IPPC or ISO14001 or if they are a large company with an image or possibly with pressure from a client like ASDA for example, wanting proof of an environmental commitment of some kind. All of those depend on the market position of the company involved.
B6	Certainly [cost is] a major factor in modern business where they never generally look beyond 2 financial years, this is due to a lack of stability in industry, changing demands from their clients.
C1	In our consultants brief we have a requirement that the consultant considers a list of alternative technologies that I prepare for them. Also a requirement is that the consultant adds ideas added by themselves or anyone else. First it is judged by 'me' then it goes to a project sub-committee that oversees the project. They will get the paper with comments from 'me', with technologies we consider as worthy. Then it's down to the committee to decide yes or no. We have a small budget that can subsidise some of these technologies. When this money is used most get incorporated. Then it gets reviewed at detailed design stage to ensure the capital cost and anticipated environmental and cost benefits still in line.
C3	They don't have an open mind, as a client you can dictate, which can have negative implications, difficult to get them to look at it objectively.
C4	The client has a different emphasis than consultants
C4	Target at the right people. Both the negative and positive aspects. Target at the decision maker, might be the one that holds the purse strings, but prepare right beforehand.
O2	Usually a selection comes clear from initial study. Present it to the client and they usually have a preference toward one technology.
P1	House developers have no relationship with the house once it is sold. Housing associations have a long term concern for the performance of the building. Buyers and mortgage companies and builders only care about reducing up-front cost. People factor in risk and after-management costs of running a system, probably seen as barriers rather than money-making opportunities. Most volume builders are not interested in after-management issues. No longer term interest in the buildings they are specifying.
P3	Well considered in this case, but on the other side there has been a developer led approach to site-release with this. In a routine development I don't think they are. For some of the sites using advanced technologies and techniques there's a prior agreement between planning authority, land owners and developers and they decide the most appropriate planning policies and technologies at the initial design concept. But I don't think that's typical.
Q1	Need to understand individual client objectives rather than use standard approaches, this will involve considering social benefits of options and tailoring the intangibles to the project

	needs.
Q1	It depends on getting the right client. Oxfam used MCA, BP used LCC and public sector procurement uses WLC.
Q2	In this project there wasn't a lot of detail in it to be honest, touch and go whether we got CHP, it put the project over the budget! The only way we got it installed was to use up the contingency with agreement from director of finance.
Q4	work out the clients priorities and see if the perception meets with these priorities. Then can compare against cost, and see if interpreted what client has said correctly.
Q5	Generally compared based on the clients perceived value, things like the value of the projection of a particular corporate image of environment responsibility, how much value they attribute to running costs of the development, compared with capital costs. Need to put a value on them to be able to assess the non tangibles comparatively. Value is benefit over cost. Benefit is sometimes not so tangible, the value they place on corporate image, etc.
S1	Integrated in early project decision making. Generally a commercial decision
T2	If a clients absolute sacred cow is to get a high BREAM rating then there's a better chance.
T3	If it was an office development where the client is living in the building for the next 25years then may have longer term perspective, but a speculative developer needs to maximise short term return.
G	**Politics**
B6	then planning implications, which are quite serious if putting in wind turbines.
P1	Formal environmental impact processes are in the form of Environmental appraisals and EIA's, scheme specific appraisals, such as CHP emissions under environmental health clean air regulations.
P4	We look for demonstrable harm when we look at any planning application, we weigh it up in the balance as a matter of judgement, if schemes where we do not have a lot of experience then we seek advice from colleagues.
Q2	on the back of that the authorities policies come into it. Is the council prepared to pay for reduction in carbon?
T4	Planning is a key thing because a lot of our projects are in city centres, so a lot have planning problems. Not interested in embracing these technologies unless there are planning constraints they wont bother. Unless legislation that restricts them they won't bother. There is a lot of complacency.
T5	But environmental planning and CSR may come to the fore in the next few years, maybe 2 years time.
H	**Depends on the project**
A2	We try to push towards the use of solar thermal and other technologies according to the

	specific location.
C2	There is an issue of how effective they are at being integrated into the other elements of the design. For example no wind because it could not be integrated into the design of the building. Our vision was not about technology but about overall credentials as a part of the building.
O1	Resource availability.
O3	Then the second phase Is what can we do with the site, anything clever with renewables and what that will cost. After that it's project specific.
P4	Bigger schemes need EI Assessments.
I	**Depends on the technology**
A1	With biofuels there are issues with fuel cost and storage, etc, which are much more of a factor, so hassle factor. Hiring of caretaker or use of contracts. Sometimes it is also a question of scale, so down to our experience.
A5	With bioenergy there is a concern about the fuel availability, with GSHP the cost of boreholes to match supply. As regards considering anything else you can reasonably good data now, with PV accurate costs/outputs and budget prices are available.
P5	With a building project, unless you were specifically setting out to, I would avoid putting wind turbine in because you are giving yourself more problems than you are solving.
J	**Other**
A1	A factor in the design process is demand reduction, size of technologies can be reduced, this is often termed holistic design.
A4	Try to argue for long term thinking as opposed to the short term. Because we can throw buildings up quickly and we are very short termist, we used to envisage a building lasting 100 years; people are now trying to design and build buildings within a year.
B1	There would be a review of the site including an energy demand assessment and building orientation.
B4	As a general summary I think that in the early stages it's the less tangible factors that get the ideas on the Table and get considered. It's not until the detailed design stage that you compare against quant factors. These quantifiable factors will commonly put the client off. Additional maintenance can put the client off. We do some network review of quantifiable and intangible aspects and rate the options out of ten, so including environmental score, but at the end of the day it's the physical cost factors that are decisive factors. Though some accept additional cost.
T2	We would look at published data and demonstration projects somewhere, it's up to the individual to turn less tangible things into something that can be understood and compared with the more tangible.

Q.8 How can the building industry help to improve the effective implementation of new and renewable energy technologies?

With reference to Question 3, how can these technologies be made to play a greater part within the building design?

With reference to Question 7, what approaches should be used for comparison of quantifiable and less tangible aspects?

How important is the building consultants role in the selection of these technologies and how they can best influence their integration into buildings?

8A	Education
A1	Need education and training of consultants and architects and trades people.
A2	Tradesmanship is poor. People fall back to the 'easy' position. With renewables you have rely on a lot of other factors, they can be complicated. People are not motivated enough.
A3	Education and training is a starter, for all aspects of the construction industry. Training, the education of training operatives through technical colleges has been lost but is essential. Need for an apprenticeships scheme. Specialist operatives and training required, especially for retrofits for upgrading existing housing stock. Architects and services engineers need to be up to speed and understand the benefits of these things.
A5	With solar it's very important to have an understanding of detailing requirements and to have a feel for the area needed for decent electricity generation.
B1	Better understanding of technologies and implications. Educate clients, explain things well. Create a bridge between clients and suppliers. Use appropriate technology for buildings, not power stations or token efforts. Liase with manufacturers.
B2	Education of the building industry, across the board.
C1	There is a lot of wishful thinking from people who write these documents.
C3	Education is the key, somebody has to educate the architects and consultants, these technologies are well worth considering openly without bias. Have met so many ME consultants that are blinkered. Many opinions raised when all they've done is read one article, need people to really understand what can be done.
O1	Education of the client – Awareness.
O3	Lack of awareness in the construction industry, increase knowledge and education. Starts in universities. Drip, drip over time. CPD training is often just a free lunch, but is one way to move current thinking in 90% of staff.
O5	A greater understanding of carbon issues and emerging things such as emissions trading will contribute as well as understanding the benefits to end-users. A greater understanding

	of these benefits would help.
S1	More awareness of technologies & products but not application. Product knowledge.
S3	Wake up! The industry needs to start learning, even the use of passive solar is not commonly used.
S5	Internal training and awareness, the industry need to recognise how much they need to know and in what form. We give training to architects, disseminating and promoting the practice of using GSHP.
T1	Need to understand the technologies and where they can be applied. Understanding where the grants are. Sponsor people to become experts. Drive and motivation.
8B	**Information/Case Studies**
A2	They need to do follow-up research and produce statistics of actual costs/benefits. Product supplier promises need to be challenged and tested and the results disseminated. Performance measurement and monitoring, with government grants for this R&D.
B3	Post occupancy Evaluation would provide more of a record of success stories in a more tangible way, and see the benefits gained.
C1	Get some real prices and see how it really works out.
C5	My point is that they need to be interested in building in information on investment cost and expected returns. Want to see tried and tested and proof of cost and return. Land securities want ease of installation and to see monitoring of outcomes, it needs to prove itself.
S5	By dissemination of successful implementations; people need to know the results. Traditionally this was a role for the BRE for example, through the best practice program they would analyse, monitor and publicise information; this needs to be independent if possible. Certification – should GSHP be accredited by the agreement board? This gives confidence that they can use that product. Need the respectability and trust of the industry.
T2	Proof of the pudding is in the eating. When sat in a design team meeting with the client there's nothing better than to go to and visit a similar project and talk to the energy manager.
8C	**Communication**
A3	Absolutely essential that they have to work together from day one, from the inception. Architects need to understand that it's is a partnership and not a hierarchy.
B1	Create a bridge between clients and suppliers. Liase with manufacturers.
B3	if we want to really push renewables need to develop closer alliances with utilities, manufacturers and grant funders. We want to see renewables as part of the build, not enough assistance and help, we do not liaise enough with utilities and manufacturers,

	some utilities seem to be being less than helpful particularly with CHP.
O2	Helps if the whole team is all together.
8D	**New Techniques/Approaches**
A4	Somehow get an agreed way of evaluating environmental impact so you can rate buildings across the board. Possibly use the environmental footprint idea. Things that have been a success in the past have a non-technical understanding. We tried to use the green guide to specification as a guide. It is difficult when you have different criteria to work to, domestic buildings have a SAP rating using an index is useful for comparison.
O2	Presentation to the client and selling the advantages is important. Make renewables cool and popular.
O5	Start by adopting a WLC methodology for investments in these technologies.
P1	Need for planning tools/guidance – highlighting the processesNeed for an overview guide of techs available that links through to the individual players in the decision process and back to the flow chart of critical things and when.
S2	Be more proactive offering alternatives. Design for low heat loss & low temp systems
S4	There needs to be thinking at the concept stage to integrating renewables and stay committed to it. It is more work but you need to carry it through.
8E	**Political**
A2	The oil companies lobbied government for funding into PV. Performance measurement and monitoring, with government grants for this R&D.
B2	A lot more could be done through government promotion. Could be driven by the professional institutes. Quite a bit different in other countries. Scandinavian building regulations are more qualitative, trying to focus people toward going beyond building regulations.
B3	Utilities, if the government had not given the RO if that not in place utilities wouldn't bother. More interested now in meeting own target that encouraging them as a general policy. Issue of a lot of things will only be moved ahead through govt regulation, utilities and other bodies, there's no champion to move these things on. A cluster of little groups with no real power without govt initiatives. The building industry will have a positive effect if the talk of giving buildings to have energy performance certificates is true.
B4	I feel the problem is the lack of government support, they give a lot of verbal support but I think there are various grants available to help in the early stages, but don't give long term commitment in terms of energy subsidies. They give a grant to install Wind Turbines, but the client's worry is in 5 years time if the electricity price drops and they're left with a

	white elephant. Austria and Denmark offer energy subsidies that promote these technologies in their countries. It's more of a role for central government, in England they give you a grant and tax fuel they don't want you to use, we need to encourage the use of alternative fuels by making them cheaper. They tend to think around a big city concept.
C1	With regard to this I think that the first thing is government. Only way to get payback down is push cost energy up and hardware down.
O2	Put it on the building regulations. This could be in the form of Carbon emission standards, or planning constraints to guarantee the use of renewables.
O3	Planning policies to set targets for using renewables and CHP.
O4	The only way is if the government regulates the industry to do so. The industry will not do it unless told to do so.
P3	I think that the intent in development policies as expressed through the planning system should be translated into a stronger action on the ground. Sustainable Development comes up all the time in the last few years. But we need firmer planning and development policies. My impression is the market will respond if the playing field is level. If the policies are consistently applied I don't think the market objects too much.
Q1	Developers look to the government to distort the market to make things viable, through regulation and planning control implementation.
S2	Legislation is useful.
8F	**Cost**
C1	Payback periods must come down. There is a lot of wishful thinking from people who write these documents. Only way to get payback down is push cost energy up and hardware down.
O2	Dependent on the financials.
T5	Make energy more expensive. Energy is so cheap is not worth our while to make energy efficient. Need to make energy more expensive, by ten times then renewables will come to the fore, what they did with the landfill tax to reduce use of primary materials. Need to make it cost effective. Justify these products saving the client money or contractor money, that's what I have to do at the moment. Business is based on making profit.
8G	**Client**
B5	Unless the client has a strong green agenda I fear they will decide against paying the extra cost.
O1	Education of the client
O3	Instil confidence in clients and other stakeholders.
O5	In big commercial operation where people have long-term landlord it's not so competitive.

S3	There is a need for an inspired developer who can push for the brief to be environmentally friendly and so allow these technologies to be looked at from scratch.
T1	Unless the client wants them there is nothing you can do.
T5	Justify these products saving the client money or contractor money, that's what I have to do at the moment. Business is based on making profit.
8H	**No way**
B2	Renewables are treated as alternative rather than a main stream technology. Not really viable, only for greenies.
P4	I think the building industry if they wanted to could drive innovation. They will say they cant due to the bottom line and cost, but could do a huge amount in best practice. A lot of time the design goes into default mode, a lot of it is run of mill. Designers do the minimum they can get away with. Very good example is house building, it's not particularly difficult to make them much more energy efficient and have more recognition of renewable energy, but mass house builders say that the market/people are not ready for it. I don't believe that. They have efficient ways of putting up houses and don't want to change. We are beginning to see such things as grey water but it's still very unusual.
Q1	Demistify. Principally the mainstream of designers think it is not up to them to do it. Simplify the procurement process. Some suppliers do not want to open up the market, they want control over a niche market rather than having to compete on a large scale.
8I	**Other**
A1	Hire Altechnica. You have to hire the expertise.
A2	Controls is a big problem, maybe biggest. Controls (BMS) systems try to control solar thermal and cause enormous problems.
B3	Looking at renewables alone is a serious mistake much more energy can be saved through reducing current consumption through improving efficiency of energy consumption. Not enough emphasis is given to that.
C2	The materials need to be integrated as building components. The control systems need to work better. We have a BMS that works on the basis of the PV generating electricity, the solar water heaters warming water, rainwater harvesting collecting water and convection ventilation systems that opens and closes windows automatically. However the control of the technology has lots of problems, at the start it worked very badly. There was a perceived lack of ability for personal intervention, no override facility people could not open or close own windows.
P3	They can play a huge part in build design and it seems that they are developing in many ways.

S3	Timescale is a problem; the building project timescales do not allow development time for tuning the technology to the project.
81A	**Education/Willingness**
A5	Solar is a driver for the building design, but you have to be interested
B3	If more people trying to encourage it it would help. We end up calling manufacturers.
B6	don't think there is any real willingness in the building industry to voluntarily do it
C4	Up to our industry to decide that, it's fundamental that it starts in schools. If you get it going in schools you get the drivers, young people interested and people talk about things positively, in the right area. Our industry is dying because we are not getting the message across.
O4	By becoming a mandatory requirement for architects and design team to be trained to have more knowledge than currently.
P2	The building industry need to get trained up and want to do it.
Q3	Until people discover the benefits of alternatives then they will only consider traditional. Design teams could be a little bit more innovative. Once there is an interest for the technologies the suppliers will develop new solutions.
S5	Only by the professionals, architects and M&E engineers, by becoming aware of where they can be used in the design.
T2	The construction industry isn't known for its leadership, it tends to be more reactive.
T5	We are trying to predict what happens in the future, I am the social conscience for the designers.
81B	Information/Case Studies
81C	**Communication**
B3	Closer cooperation with manufacturers and utilities.
P2	Talking with the client and understanding the environmental drivers and where sustainability fits with the client. If the client doesn't give a damn then there's nothing you can do. You can only do what the client wants, but they can only do that if they have a full understanding of their drivers.
81D	**New Techniques/Approaches**
B3	More use of user friendly viability techniques, want to be able to see that it's a viable investment. It's not immediately obvious they're getting benefit.
C5	In many cases this is part of the great problem that architects and engineers don't tend to take sustainable development seriously; it's always a fragmented approach. No overall building infrastructure approach. Needs to be built in from the start of the process rather

	than just looking at a few green alternatives.
Q3	Need to advise on the costs of non-implementation of AET's, what are the additional costs of not doing it?
Q4	Majority of designs are focussed on payback periods and savings in the long run, nobody focuses really on other parts of the building and the other benefits of doing away with traditional systems.
Q5	We could perhaps make it easier for clients to understand the benefits of these technologies. The building industry needs to get its act together on Whole life value advice, attributing a value to less tangible aspects, such as the image they are projecting by using renewables.
81E	**Political**
B6	Only through legislation I think, don't think there is any real willingness in the building industry to voluntarily doing it. Conventional legislation through Part L or alternative legislation with the emphasis more on the government 'stick'.
C1	Part L and building regulations changes, but they also start to constrain you, rather than allowing you to choose the most appropriate approach for the situation.
P5	To me this is in the governments hands, they can either regulate for it or use procurement power, the public sector is 40% of the market. They just have to demand it, in schools, hospitals, etc. and put their money where their mouth is. Problem is if a public sector organisation says they want to do it, it could run foul of the audit commission, have to make a case to say it is actually the best value and against current energy prices they might not be able to say that. If they're serious about integrating renewables they can regulate it or demand it as a customer.
Q3	The only way to change the behaviour of clients is to force them, this could be done by the government forcing things to change. There needs to be penalties on the use of fuel.
Q5	Through legislation. The building industry could lobby government for better legislation and better subsidies. Introduction of a carbon tax will also help.
T2	Taxation – At the moment it's seen as a financial disincentive due to high capital cost. Needs to be disincentive to use traditional technologies.
T3	Regulation is the obvious one, and improved financial incentives through capital allowances or whatever.
T4	The only way is through legislation, unless the government gives greater incentives to embrace this technology. You will always get an innovative client but they are always just minorities, so unless there's legislation it's going to be a long uphill struggle.
T5	If it comes to a stage that planning states it should be considered because of government initiatives then it may become a consideration.

81F	**Cost**
B5	If economic they will promote themselves.
B6	Unless there are tangible benefits it's not going to work - conventional energy is far too cheap
C1	The main thing is get payback down. Once it becomes normal they get their own momentum. Make it so attractive that people want to do it.
C3	Perhaps we're picking wrong ME consultants, choose based on a certain fee structure, choose on price. To use new tech probably need a little more money in the design process.
P2	In the private sector clients are trying to make money and anything that led them from the conventional approach will cost money. If the client did not specify it I had to look at low carbon because it would make it more complicated and there is a perspective that it makes it more expensive.
P5	At the end of the day it comes down to money.
Q3	Need to advise on the costs of non-implementation of AET's, what are the additional costs of not doing it? It is important that the consultant identifies and secures grants, these are key to using the technologies.
Q4	Majority of designs are focussed on payback periods and savings in the long run, nobody focuses really on other parts of the building and the other benefits of doing away with traditional systems. Trouble is you can't get rid of replacing all of the old with all of the new. Clients will not fully appreciate all of the benefits of renewables until they've replaced all of the traditional.
T2	At the moment it's seen as a financial disincentive due to high capital cost. Needs to be disincentive to use traditional technologies.
T3	Economically it does not stand up.
81G	**Client**
A5	Depends if you are interested in providing appropriate space for energy generation/collection, this has to be driven by the client, and influenced by the architect. The University of Gloucestershire has a wave-form roof with PV collectors on the south face and north lights for natural daylight. Solar is a driver for the building design, but you have to be interested, the client must release the funds for this.
C3	Perhaps we're picking wrong ME consultants, choose based on a certain fee structure, choose on price.
P2	In the private sector clients are trying to make money and anything that led them from the conventional approach will cost money. Talking with the client and understanding the environmental drivers and where sustainability fits with the client. If the client doesn't

	give a damn then there's nothing you can do. You can only do what the client wants, but they can only do that if they have a full understanding of their drivers.
T4	You will always get an innovative client but they are always just minorities
81H	**No way**
81I	**Other**
A5	The impact of these technologies on the building design is minimal. Bioenergy needs a bigger plantroom, wind turbines need a suitable site, solar orientation is pretty forgiving. The best place for PV is a big area of flat roof, then it's easier to integrate.
C2	With the first roof-mounted systems they were seen much as retro-fit clip-ons. The way forward is to have technologies that which in addition to their technological function they also have some function as a part of the building envelope; something integral to other building functions.
C5	In many cases this is part of the great problem that architects and engineers don't tend to take sustainable development seriously; it's always a fragmented approach. No overall building infrastructure approach. Needs to be built in from the start of the process rather than just looking at a few green alternatives.
Q2	Integration with the building and its services is quite important. Keep the costs of equipment down.
Q5	If renewables become more sexy then people will use them more.
S5	Otherwise it is down to people like me knocking at the door later in the project to get it included, but then it becomes an add-on.
82A	**Education/Willingness**
A5	We do a lot of PV because we understand the fundraising process, using EU and British funding back-to-back on a project to give 100% funding, the subcontractor (Solar Century) also provides a lot of our design and installation needs; that makes the biggest difference. Other renewables do not impact on the architecture, more engineering stuff. There's nothing magic in terms of building design apart from solar technologies,
B3	Need to keep abreast of the changing market. One of the barriers to renewables being used is the market place and government initiatives changing, makes anticipating future viability difficult to assess. If your interested in investment return over a long period of time, it may not be viable in three years when rules have changed.
B6	Got instruments like BREAM in place but it's poorly understood and not widely used as it should be.
C1	Provided you've a competent consultant. In the building services industry there's a lack of

	properly qualified and experienced people. Important more education.
C4	Depends on how green consult ant is what their policies are like. If you go to the wrong consultant you don't get the right answer. All part of the approach.
82B	**Information/Case Studies**
Q4	Until you get a lot of systems with feedback, people want hardcore estimates don't want guesstimates. Once you can show it's proven then you are on a roll. Until you can say that it's intangible and unusable.
Q5	Need much better historical data on running costs, efficiencies etc. of various systems, and more research into long-term life expectancy.
S5	The data is not there for making a quantifiable comparison, designers do not have simple comparisons of value vs. renewable energy production or CO2 savings.
T2	Bit of a chicken and egg situation. It needs more people to buy into it, more demonstration projects, more publicity for it.
82C	**Communication**
C5	The Building consultant could push the client toward consideration of life cycle concerns over just project costs. Need to push clients and promote the image and importance of life cycle.
T2	As an industry we are very good at moaning about shortfalls and not good at celebrating success.
82D	**New Techniques/Approaches**
B5	Pseudo-quantification.
B6	Got instruments like BREAM in place but it's poorly understood and not widely used as it should be. It has some shortcomings, such as it could be made more user friendly. BRE should relinquish the monopoly and allow it to be awarded through other routes there also needs more emphasis on existing rather than new buildings. The value of the building's enhanced if BREAM accredited. Credits if solar oriented, natural ventilated and natural light but not for renewables. We do have these instruments available to us. Needs to be a combination of legislation, taxes and tools with which to do it, universally recognised tools, like a risk assessment really.
C1	Way we do it works well. Brief, list, reports in depth and recommendations.
C2	I think a subject of study that will look at our attitudes of the building in use, which is being monitored by Solar Century and Oxford University will help to do this. This monitoring and appraisal system was part of the provision of a grant for PV.
C3	I think if people are open to real feasibility analysis then they would be surprised at what

	comes out,
P2	Understanding impacts of local energy supply rather than using imported energy.
P4	Use of environmental assessment techniques is quite a good method. Could develop sustainable appraisal checklists which might help.
P5	If aspects are not tangible, they are not measurable, not real, just somebody's opinion. Try to come up with measuring systems for criteria that are deemed to be important, need a system of indicators and targets, BREAM is the best example of that sort of system. You've got to have a system that's widely agreed in the market place. Academics may dream up systems and models and nobody uses them, we need something that is market driven, BREAM is a good idea because it originated from BRE working with a group of developers. Very important what the Peabody trust was doing, on their estate, important thing they went and studied the potential for retrofitting renewable energy systems on their estate. They thought that in the future energy prices will be going up and wanted to avoid the future risk of tenants not being able to pay rent or bills.
Q2	Some kind of options appraisal would be useful; at the planning design stage you have a site, you know what the surrounding environmental conditions are and just need to know what the options are.
Q5	Whole life value approach. Need much better historical data on running costs, efficiencies etc. of various systems, and more research into long-term life expectancy.
S5	The data is not there for making a quantifiable comparison, designers do not have simple comparisons of value vs. renewable energy production or CO2 savings. With visual impact, I don't know at that point. How are they normally weighed up and dealt with for other design aspects rather than just in comparison of new and renewable energy technologies?
T3	There is an approach already used, ecohomes, using a building assessment scheme you can build in the quantifiable and non-quantifiable aspects. It's still a relatively new scheme, but it will become important because government or planners will latch on to it, it's a very convenient thing to hang your hat on. Renewables are built into scoring process. Compliance with Building Regulations brings no extra points, but renewables will give points. This encourages change. Developers will look to find the most cost-effective way of obtaining the relevant standards. On the commercial side you have similar schemes such as BREAM, NEAT, etc.
T5	Don't know what tools you can use to measure, need to have a lot more quantitative case study data to show how these technologies can perform in practice. Approaches I could not tell you.
82E	**Political**
B6	Needs to be a combination of legislation, taxes and tools with which to do it. Building

	regulations Part L are quite stringent but the building industry do not always understand the implications.
P2	Europe is supposed to be a level common market but sustainability acts against that. Because we purchase so much energy the projects need to be an OJEC. Caught in a paradox.
P3	The politics of it are important. In the 1970's there were huge exercises to gain objective information and huge exercises in scientific approaches for making major planning decisions. In the end the decisions made were political anyway. Decisions need to be politically informed. Politicians need to have direct access to expert opinion.
P4	I think the other thing that could be done to really drive innovation is to revise build regulations, make minimum standards, if we start to push like Scandinavian countries have then there will be a lot of interest in renewables because they would have to.
T4	There must be a legislative incentive to draw comparisons and make people think about it.
82F	**Cost**
A5	and if solar becomes cost effective people will begin farming them.
B6	The value of the building's enhanced if BREAM accredited.
C3	too much based on 3 year payback not enough on true life costs. Costs money to go through the process of in-depth study.
C4	If you go down the green route you have to accept a cost penalty, come to a half-way house in my opinion. It's inherent that new design uses part of old design, so not all new.
C5	The Building consultant could push the client toward consideration of life cycle concerns over just project costs. Need to push clients and promote the image and importance of life cycle.
82G	**Client**
C4	Depends what the client is happy to do and what is put in front of him by the consultant. Depends on how green consult ant is what their policies are like. If you go to the wrong consultant you don't get the right answer. All part of the approach.
C5	The Building consultant could push the client toward consideration of life cycle concerns over just project costs. Need to push clients and promote the image and importance of life cycle.
82H	**No way**
O4	Not convinced there is anything there yet.
Q4	Don't know that you can. In a way you have to live with it.
T5	Don't know what tools you can use to measure. Approaches I could not tell you.

82I	**Other**
B6	In new buildings these things tend to be done in the design stage and not always carried through to completion.
83A	**Education/Willingness**
B3	Not enough clients informed enough to ask for it and know what they want.
B5	We can influence it by understanding what solutions are available and what are likely to fit the building being considered, identify the technologies and work out costs and benefits of each.
B6	Need to generate motivation and awareness of the client.
C1	Vital that consulting engineer is properly educated and conversant with the practicalities of the technology and can give the client the guidance that he needs. Do feel there is a real lack of knowledge in building services, I also find that some consulting engineers use one particular thing and want to put it everywhere they go. Hell of a battle to persuade them to look at other alternatives. Spread knowledge internally in the practice is important. To provide a balanced opinion to clients.
C3	if you get people on board you can overcome prejudice. If consultant is anti then you will always struggle, rely on to come up with novel ideas and solutions.
O4	If you get a decent consultant, fine. If not then they will not be used. The client role is more crucial though, they have to insist on it first. If then the consultant understands it then there is a chance it could go through.
P2	Some building consultants are just trying to get the job done as easily as possible others want to consider green issues.
P3	certainly architects and engineers should be well informed and let the client know the options.
Q4	We have got to be informed,
T2	If the consultant is a firm believer in these technologies then he has a key role, he has to sow the seeds to start with.
T3	the consultants job is to have good quality whole life cost information in addition to capital cost information. This is not necessarily an easy thing to put together.
T5	but dependent on how well versed they are in these technologies, especially as the technologies are changing and new, depends on how up-to-date the consultants are.
83B	**Information/Case Studies**
Q3	There needs to be a collaboration between building and cost consultants to produce a cost module that identifies to clients the true costs to the client.

Q4	We have got to be informed, got to have the data to back up any decisions that we make.
T3	If the client is set out to do it then the consultants job is to have good quality whole life cost information in addition to capital cost information.
83C	**Communication**
B3	People like the association of consulting engineers and other corporate bodies in construction industry should be talking to the utilities to see if there is anything we can do.
B4	We can liaise with other members at early design stages to make allowances for such systems in design so they are sympathetic to these technologies.
C4	In my opinion they need to try to listen to what the client wants other than what their bosses want them to tell the client. Their role is to guide the client, but not to lie to him or baffle him, speak to in plain English.
Q3	There needs to be a collaboration between building and cost consultants to produce a cost module that identifies to clients the true costs to the client.
Q5	Our consultants need to talk more about the economics rather than how it will work. Client does not read the report, only summary conclusions and recommendations.
83D	**New Techniques/Approaches**
B4	We can liaise with other members at early design stages to make allowances for such systems in design so they are sympathetic to these technologies. As design consultants we should put the emphasis to making buildings flexible to using a range of sources now and in the future. At the moment gas is cheap but in the future things may change so allow for biomass energy in the future. Building can then be adapted.
C4	They need to advise not by just capital cost, and not just thinking of their fees.
P3	The decision making system which is largely buried and not well known lies behind development decisions, and should be more transparent. It is often financiers of a development who have to see a return on their investment, I don't think the background to decision making is well known. People should know who is involved and understand what they stand for, and avoid the naïve political rant about capitalists. There are complex investment decisions that lie behind major developments. The biggest developers are the house construction industry. They have a much simpler system of decision making. Access to the top of big house builders is easy, not complex. How you persuade these people to take a more environmentally enlightened line I don't know, certainly architects and engineers should be well informed and let the client know the options.
Q5	These technologies need to be designed in as soon as possible rather than as an after-thought. Our consultants need to talk more about the economics rather than how it will work. Clients are not interested in how clever it is. Less interested in how it will work than

	the benefits that they will derive through added value. Client does not read the report, only summary conclusions and recommendations. Client needs to be reassured it will not be obsolete in a few years.
S5	By appropriate selection for that particular building. None of these technologies are a panacea for one particular building.
83E	**Political**
T3	The main driver is the client or planning authority or someone else having an influence over the client.
83F	**Cost**
B6	There's a predictive requirement, energy costs are going to tend to rise, cheap gas and electricity will not be here forever.
P2	[consultants] can either be good or bad, but always expensive!
Q3	They must show the add-on costs and positive PR factors available. We have recognised that getting awards wins business. There needs to be a collaboration between building and cost consultants to produce a cost module that identifies to clients the true costs to the client.
Q4	Another problem is that CHP is always judged on current rates of electricity and gas. No-one can predict beyond 5 years, crystal ball gazing.
Q5	more about the economics rather than how it will work. Clients are not interested in how clever it is. Less interested in how it will work than the benefits that they will derive through added value. Client needs to be reassured it will not be obsolete in a few years.
T3	If the client is set out to do it then the consultants job is to have good quality whole life cost information in addition to capital cost information.
T4	they are more likely to respond favourably if the consultant can explain paybacks in a reasonable time.
83G	**Client**
B3	Not enough clients informed enough to ask for it and know what they want.
B4	Through design we can actively promote passive energy design solutions and renewables at the initial concept design stage but after that it's up to the client.
B6	The clients need some fairly strong arguments to convince them that expenditure on these technologies is worthwhile. Unless they are informed clients they need to be convinced these systems that they will work and not have to be replaced with expensive traditional replacements after occupancy.
O4	The client role is more crucial though, they have to insist on it first.

P4	It's about raising the profile, getting the client to really want it to happen.
P5	More important that you have a customer committed to doing it. Architects and engineers will deliver to the brief. If you have 'though shalt integrate renewables into the building' then you can do something, it's important the client selects a team that can do the job.
Q5	Clients are not interested in how clever it is. Less interested in how it will work than the benefits that they will derive through added value. Client needs to be reassured it will not be obsolete in a few years.
T3	The main driver is the client or planning authority or someone else having an influence over the client. If the client is interested then they will have a longer term interest in the building.
T4	You've got a much greater chance of influencing the client, because there's a clear difference in the type of client that goes to a consultant than straight to a design and build contractor. They come to us as they recognise there is an approach where they do not have to pay professional fees. There are then clients who believe you can't do a project without a professional consultant, they are more likely to respond favourably if the consultant can explain paybacks in a reasonable time. Because the type of customer that would go to a consultant is different nature to a one that goes to a design and build contractor. Irrespective of where they are in the market place.
83H	**Consultants role important**
A5	Is very important, the client would not go for them unless the architect and consultant pushed it.
B3	Key, unless we propose it is unlikely to happen otherwise.
B4	Through design we can actively promote passive energy design solutions and renewables at the initial concept design stage but after that it's up to the client.
B6	Absolutely critical really.
C1	Absolutely vital at the end of day, the contractor builds what he is told to build and the client is advised by the consultant.
C2	Building consultant selection is crucial. The contractor's were appalling, and we are still in contractual dispute. Ridge and Partners the QS were hopeless too, as they had no particular expertise.
C3	Is crucial, if you get people on board you can overcome prejudice. If consultant is anti then you will always struggle, rely on to come up with novel ideas and solutions.
O4	Think they are very important, as above.
P2	Very important if brought on board, they can either be good or bad, but always expensive!
P3	Very very important. Obviously lots they can do.
P4	As much of a role as the architects

P5	The selection of the development team and selection of technologies is important.
Q2	They're key really, that's the expert you rely on to advise you on the systems, what they can do and their ramifications.
Q3	The role of the building consultant could be considerable.
Q5	Very important because they are involved in the feasibility and concept design stages.
S5	Crucial.
T2	They are the first point of contact for the client.
T3	Is important, but not in fact the driver. They are important but not the main driver.
T4	Very important. You've got a much greater chance of influencing the client, because there's a clear difference in the type of client that goes to a consultant than straight to a design and build contractor. They come to us as they recognise there is an approach where they do not have to pay professional fees. There are then clients who believe you can't do a project without a professional consultant, they are more likely to respond favourably if the consultant can explain paybacks in a reasonable time. Because the type of customer that would go to a consultant is different nature to a one that goes to a design and build contractor. Irrespective of where they are in the market place.
T5	Do have an important role 8/10
83I	**Other**
B4	Have to consider the embodied energy in the raw product, we learnt from Austrian and Danish that no transport of biomass beyond 10-15km is economic or environmentally practical. District heating schemes in Denmark are multi heating systems and they can use any fuel as it is cost-effective. Sometimes District Heating biomass pellets come from Canada.
B6	With CHP there are specific demands, it's not viable unless year round demand for heating. There are fixed demands that need to be explained to clients and abstract concepts sometimes. Solar and PV are less understandable, certainly with heat pump technologies no body has a clue. Bioenergy are misnomers that nobody understands, need to explain very simple principles.
Q4	Otherwise so many are bolt-on's or add-ons and not an integrated part. With CHP it starts with being a good idea but ends up being a bolt-on item added to the building and looks ugly, not integrated.

Appendix C Phase II Project Details

APPENDIX C Phase II Project details

This section provides some context to the results presented in Chapter 5, based on notes taken during each of the interviews a brief summary had been produced for each project. This additional information provides context to the results given in the main section of the report, it also shows the diversity of projects that have included the consideration of AET's in the design process.

Note: Projects denoted with * had not reached the construction stage when the interview was conducted.

2762 Techniquest

It was a children's hands on science centre. It sat directly above a well established aquifer. All we had to do was sink a single borehole down, abstract water, pass it through heat exchangers and dump it into the adjacent dock. The welsh electricity board learnt about our interest in it and sponsored the desk study and appraisal and offered to pay for all of the funding over and above what we'd normally occur on a project like this and use it as a demonstration project.

Fundamentally what stopped this [GSHP] was having the appropriate contractor with the experience of drilling these type of boreholes.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A				C x		

5420 Lambay Island

Lambay are a special case. It's an island of the East coast of Ireland and it's really isolated from the mainland so it has no connectivity to main services of any kind. To generate electricity they used a diesel generator. If the weather is very bad they could be isolated for days on end and boats can't get through to them. It's a privately owned island by a charitable trust.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
			C			

5426 Old Hall Street Liverpool

Hotel, Swimming Pool and Residential tower. Carillion were appointed to secure a guaranteed maximum price for the project, they weren't necessarily interested in energy technologies or sustainability issues. They were interested in getting the job built at the right price. There was zero outlay, [the] system is leased.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
						C

5538 Finglass swimming pool

5538, is a public job for Dublin city council. [They're] conscious of their running costs of their pools. We were appointed by the city council in a fairly standard way to do the building services design for project and said they were interested in energy saving devices. They received a grant from Sustainable Energy Ireland for 50% of the cost of those technologies. I think the client probably would have proceeded with the CHP without the grant funding because it would have paid back for itself within a 5-year timescale which was their criteria.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A			C

5671 Genzme HQ

Genzyme is located in Boston MA, it was a European team that won the project so there was very much a European flavour to the way the design developed. The client in this case was a developer, who had some hesitation, as you'd imagine from an American developer, in accepting the sort of technologies we were talking about.

The project went from being very European in its approach to energy and energy systems, to something that was very American. In other words that the project cost was of importance, familiarity had to be of importance, time constraints has to be important, so we in the design team thought that we had lost the whole essence of the project. However at the same time, in a parallel operation the developer brought on board the occupant, which was Genzyme, and they came into the process with a different view of life. They were interested in sustainability, they were interested in the working environment, so they wanted to hear more.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
C						

5864 Portland Square, Plymouth University

The client came to us and was looking for a low energy design, part of the solution was a naturally ventilated building, they were into sustainability, low energy, passive systems.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	C					A

5947 Daintree

The project was a mixed development of seven apartments and a commercial space. The architect are ecological architects, they had their own agenda, but the client bought into that. They wanted it basically to be as sustainable as it could be for the future, and on that basis they were going to sell the apartments as low energy apartments.

It was an unusual project in that the best payback would not necessarily get to be the selected technology.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
B	C		A	C		A

6076 TAG Aviation*

Aviation building. It's a multi-stage project, we've constructed 2 buildings on site already the traffic control tower and a hangar and we're just on-site now with the new terminal building and then there are more buildings planned once this current building's finished.

They didn't come to us with a sustainable agenda, being an airport with million pound airplanes, kind of money no object kind of client, they are interested in it but its not part of their brief.

An opportunity has come up fairly recently with the site layout where PV might be an achievable option, it's not something the client's come to us [with], it's one of those light bulb moments 'you look at something and think that might work'.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A						

6108 Carterton Leisure Centre

It's quite a small centre, which also had the complication that it was possibly going to be built in two phases. The first phase was a swimming pool, gym and multi-use areas and the 2nd phase was likely to be a gymnasia school of excellence, which is basically a big open hall really.

The council as a client were quite open to low energy design within the limits of the budget.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
						C

6915 HSE Headquarters

This was a PFI project; the initial brief did actually say that we should consider low energy, renewable strategy and rainwater harvesting. The solar panels was a big plus at the early stages of the design because we were competing with other consultants. And the client actually said to us at one point "Those technologies set us apart"

The architect was really keen on low energy and because it's a PFI scheme running costs do actually come into the equation so that helped us to integrate some of the issues that normal clients aren't interested in it's helpful. The facilities management people were keen. The contractor really did not want these solar panels in at all, in fact at one point he told us to write a report to say that they would not be viable.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
	B					

7238 Copenhagen Elephant House Exhibition

It was the general wish of the client to be sustainable but that wasn't a defined thing. We're waiting for the funding because it's a zoo so they're waiting for the funding, we thought it was starting but it's stopped again.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
B					B	

7272 Nottingham Academy

The BB87 Carbon emission was our brief. The building bulletins tell you about carbon emissions but we don't have to try very hard to get a tick. It was definitely considered as a bolt-on, it wasn't an integral part of the architecture, even though it's quite good educational thing.

With academies the DFES pay for it all but then you have a school who's going to run it and the DFES give money to the school and that becomes a trust for the academy.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A			B		

7408 Syddansk University and Science Park

Phase 1 is 5 accommodation blocks for a university, a concert hall for 1100 people and 3 blocks of a science park. Phase 2 will be a further 2 accommodation blocks.

The brief background of this project was it a competition... and we won outright, because they were so impressed by the integration of the renewable and passive technologies. There was one throwaway comment regarding client aspirations, which was to receive a low-energy building, which could be defined in many different ways. We then found that after the project had been won there was a desire to erode this.

The client was made up of 14 different individuals of 14 different sets of aspirations, but in principle the client body that authorised the money were a risk-averse client. While academically they enjoyed the idea of a low-energy building when the implications were identified to them the cost of energy consumption per year and close controlled comfort, they chose close controlled comfort.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A	B		

7427 Eden - Phase 4

The brief was probably clearly set from the outset. In that it had to be a very highly sustainable. They wanted renewables but we didn't feel that they should be putting them in just for the sake of it. They were very much looking at the whole picture, they wanted a story for the use of this energy and if the story fitted with the project ethos then all the better. That story was to not just look at things in isolation but to look at the whole impact. That whole picture view of things was quite unusual and probably wouldn't apply to commercial [projects].

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
C	A	A	A	B	C	

7439 West Tallaght Swimming Pool

The client was a local authority, his interest I suppose was low energy so they wouldn't spend a fortune on energy bills, there was also the incentive for grant funding, and getting the project through planning the more low energy aspects you have the more easy it is to be accepted I suppose.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A	B		C

7502 Northampton City Academy

[It's a] £20 million school on site since the beginning of the year, architects Fielden Clegg. Like a lot of schools there's a lot of interest in low energy design without there actually being any money to back it up, it had a quite limited budget. We shoved solar thermal and wind in quite early on in the scheme but because we perceived that it might end up being a sacrificial lamb we didn't proceed with the full design. It was always kept as a lump of money in the cost plan and the means for plumbing it into the systems that were going to be in the building were very loosely defined. As in all of these things you get a brief such as it is that says 'oh yes we want to do an environmentally friendly, sustainable building' but people often haven got a clue what it means.

We tried to raise them as discussion points with the various bodies involved in the design, with variable success and they weren't seen as being core parts of the building in scheme design. We actually found things that were more important to the project as a whole to discuss most of the time. They weren't high enough up on anyone's agenda

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A			

7609 Liverpool Kensington Academy

The initial project brief was based around SEAM (Replaced by BREEAM for schools). The reason we can have PV is that Kensington is an environmental school specialising in environmental science. We could put a stronger case to the DFES for additional funding for the items, so we've got the money. I don't think the DFES are willing to spend more money unless the design team put the case strong enough to convince them.

The design team and QS tried to estimate the cost that would be associated with these renewable technologies. Then we obtain some money to buy these items and later on we secured grant funding through DTI so that's 50% of the cost saved.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
C	C			A		

7617 Rehan Electronics

The client was a Dutch man who was very interested in low energy and alternative energies. The client was a very hands-on client who wanted to build everything himself without having a main contractor, so he went off looking at various things and paybacks himself.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
B	B			C		B

8134 Coillte

Building built ten years ago by Duncan Stewart who was considered to have an interest in sustainable design and they built an all timber building. They are interested in timber products and marketing timber. They needed to build an extension to their office using the same architect. The architect had an interest in wood pellet and wood chip boilers and because of his sustainable hat he convinced Coiltte to have solar panels and the wood chip boiler. The whole design was around demonstrating the uses of timber and trying to build a zero Carbon Dioxide emitting building.

So before we got on board they had made decisions to go down those routes. [They had] already spoken to a boiler manufacturer in Austria and agreed to buy the boiler at that stage [We] applied for grant funding, [and as] they are a private organisation the scheme they applied for gave 25% of the cost; they saw that as a bonus, I think they wanted to proceed in any rate.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	C				C	

8209 Edinburgh University

The University has a carbon trading programme, that was one was of their issues in the initial brief. What transpired soon after that, during initial project meetings, that unbeknown to us at the initial competition stage that a campus-wide CHP was waiting for its funding decision. They were looking for something that would help their carbon emissions profile but at the same time other factors in the university that made them move toward this central CHP were dictating how the building would go forward.

I don't think we could have asked for a client who would have been more receptive. I think the biggest issue here was what scuppered things was the introduction of the CHP.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A	B		

8285 Carlyon Bay*

More a commercial affair, they were interested in considering the benefits of renewables and CHP as a site operation and we convinced the client to allow us to do a feasibility study. There was more collaboration across the company with people who've been through this.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
						B

8496 Guildford Civic Hall*

A civic hall where all the alternative energies are being considered and there is a public building which will be operated by the council, which is interested in reducing its carbon emissions and then there's a commercial element of the scheme which is funding the civic hall, which is a straightforward residential. The initial project brief stated an aspiration towards sustainability and reducing the environmental impact of the building, and the end-user has since clarified that they are Carbon led in their decision making rather than purely focussed on running cost reduction.

The initial project brief asked for a trigeneration system to be costed as an extra over against the standard mechanical and electrical systems and the developers did put in an extra sum of money for that. Subsequently we've managed to get them to agree to the extra over being a budget that could be spent against any measure, or several measures to reduce carbon emissions, not just trigeneration.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A			B		B

8869 Bermondsey Spa Sites E-U*

Initially CHP was a consideration because it was referenced in the initial planning discussions with Southwark Council who are a partner in the scheme, there was also consideration of the alternative technologies. There was a, not strictly a requirement, but there was a recommendation to have 2.5% of the sites energy needs provided by on-site renewables. The architects were quite keen on renewables, but only in a fairly academic manner.

The client themselves was interested in providing a scheme that was best for the tenants and the consideration of CHP. Benefit to the environment and overall image were actually seen to have a very little influence on the client who is a responsible developer, but the primary factor it was felt was there was a driver between what the GLA requirements were in housing and what the GLA requirements were in energy.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
A	A		A		B	B

8933 New Islington Wharf*

Phased development, Phase 1 Residential, Phase 2 Hotel.

The brief was for an all electric scheme, it wasn't until much later that started to talk to them about alternatives. The client was keen to see an alternative to electric; the architect is very into solar-efficient buildings. The project manager is doing a CHP scheme on another project so they were saying if it works on that scheme then it could work on this scheme.

The Eco-homes is a compulsory part of our project environmental charter through British Waterways. The client has said that their shareholders would be very happy if they had CHP because it fits in with their plans for a sustainable development.

It all came down to cost at the end of the day, is it cost neutral and will it get us bonus points on the sustainability chart? What did help in making us get CHP in is the fact that the cost plan has been there from day 1.

Photovoltaics	Solar Thermal	Hydro	Wind	GSHP	Bioenergy	CHP
				B		B

Appendix D Phase II interview results

APPENDIX D Phase II interview results

Q1. Please give your perception of the initial project brief and project meetings. Within these were there any references made to aspirations toward considering AET's?

1A	**Yes**
2762	keen to promote demonstration projects as part of a working display
5864	Definitely, the client was looking for a low energy design
5947	to be as sustainable as it could be for the future
7427	there very much was
7617	the client was very interested in low energy and alternative energies
8134	The architect convinced Coiltte to have solar panels and the wood chip boiler.
	Special budget made
6108	The council as a client were quite open to low energy design within the limits of the budget. The client, to be fair, was very keen that it happened and actually set-aside outside of the contract the value of the project, to pay for the CHP unit. So they were very determined to have this
7502	It was always kept as a lump of money in the cost plan
8134	Before we got on board they had made decisions to go down those routes
8496	The initial project brief asked for a trigeneration system to be costed as an extra over. Managed to get them to agree to the extra over being a budget that could be spent against any measure, or several measures to reduce carbon emissions
	Running cost considerations
5420	It's an island of the East coast of Ireland and it's really isolated from the mainland so it has no connectivity to main services of any kind. if their diesel supplies happen to run out at a time when the weather doesn't suit then there may be issues getting the oil to and from the island. We suggested it might make sense for them to have a wind turbine again to give them free power.
5426	Developer has 10 year leasing agreement and retains part of profit of hotel
5538	Conscious of their running costs and said they were interested in energy saving devices
7439	The client was a local authority, his interest I suppose was low energy so they wouldn't spend a fortune on energy bills
8285	they were interested in considering the benefits of renewables and CHP as a site operation

	Low energy /sustainability
5426	Hotel operator supported AET's
5538	they were interested in energy saving devices and have a group called CODEMA City of Dublin Energy Management Agency who advised them on energy saving aspects
5671	the occupant, which was Genzyme, came into the process with a different view of life. They were interested in sustainability; they were interested in the working environment
5864	the client was looking for a low energy design
5947	the architect are ecological architects, they had their own agenda, but the client bought into that. They wanted it basically to be as sustainable as it could be for the future, and on that basis they were going to sell the apartments as low energy apartments.
6108	The council as a client were quite open to low energy design within the limits of the budget.
6915	the initial brief did actually say that we should consider low energy
7238	it was the general wish of the client to be sustainable but that wasn't a defined thing
7408	one throwaway comment regarding client aspirations, which was to receive a low-energy building
7427	the brief was probably clearly set from the outset. In that it had to be a very highly sustainable
7502	Like a lot of schools there's a lot of interest in low energy design without there actually being any money to back it up
7609	initial project brief was based around SEAM (Replaced by BREEAM for schools). This lead to the aspiration to using some renewable or alternative energy technology
8134	The architect had an interest in wood pellet and wood chip boilers and because of his sustainable hat he convinced Coiltte to have solar panels and the wood chip boiler.
8496	And the initial project brief also stated an aspiration towards sustainability and reducing the environmental impact of the building
	Carbon savings
7272	The building bulletins tell you about carbon emissions but we don't have to try very hard to get a tick. The BB87 Carbon emission was our brief
8209	The university of Edinburgh has a carbon trading programme, that was one was of their issues in the initial brief.
8496	the end-user has since clarified that they are Carbon led in their decision making rather than purely focussed on running cost reduction.
	Isolated
5420	It's an island of the East coast of Ireland and it's really isolated from the mainland so it has

	no connectivity to main services of any kind.
	Planning incentives
7439	getting the project through planning the more low energy aspects you have the more easy it is to be accepted I suppose.
8869	Initially CHP was a consideration because it was referenced in the initial planning discussions with Southwark Council. There was a, not strictly a requirement, but there was a recommendation to have 2.5% of the sites energy needs provided by on-site renewables.

1B	**None**
5426	Carillion were appointed to secure a guaranteed maximum price for the project, they weren't necessarily interested in energy technologies or sustainability issues.
5671	the client in this case was a developer, who had some hesitation as you'd imagine from a American developer, in accepting the sort of technologies we were talking about.
6076	TAG aviation is an airport, as part of their brief they didn't come to us with aspirations for low energy or sustainability
8933	The brief was for an all electric scheme, it wasn't until much later that started to talk to them about alternatives.
	Not defined
7238	it was the general wish of the client to be sustainable but that wasn't a defined thing, most clients just say something but they don't actually know what it is so we need something like BREEAM to relate to them.
7427	Whether they had a budget was not clear.
7502	As in all of these things you get a brief such as it is that says 'oh yes we want to do an environmentally friendly, sustainable building' but people often haven got a clue what it means.

1C	**Project background**
	Demonstration project
2762	keen to promote demonstration projects as part of a working display
8134	as their industry is timber, so the wood-chip boiler was of interest to them.
	Budget constraints
5426	They were interested in getting the job built at the right price and they had to go in very, a very tight developer who wanted to maximise his profits, which is typical.
5671	The project cost was of importance,
6108	quite open to low energy design within the limits of the budget.

7427	As we went through we hit a wall which was bringing the project into line with the budget.
7502	without there actually being any money to back it up, it had a quite limited budget. We had solar thermal in there and stayed in for quite a while, as a lump of money, when the project came back over budget that was the most convenient thing to remove from the project.
8134	The client had a limited budget and was a concerned about the cost particularly the solar panels

1D	**Other reasons**
	Supply security
5420	if the weather is very bad they could be isolated for days on end and boats can't get through to them. So if their diesel supplies happen to run out at a time when the weather doesn't suit then there may be issues getting the oil to and from the island.
	Best option
5420	We suggested it might make sense for them to have a wind turbine again to give them free power dumping into heating it would make a huge difference to the fabric of the building. It would also give them more flexibility than just using the diesel.
5538	I think the client probably would have proceeded with the CHP without the grant funding because it would have paid back for itself within 5 year timescale which was their criteria.
	Grant funding
2762	The welsh electricity board learnt about our interest in it and sponsored the desk study and appraisal and offered to pay for all of the funding over and above what we'd normally occur on a project like this and use it as a demonstration project.
5420	the county council on the mainland gave £(I) 50,000, they've had various grants for upgrade and maintenance work so they treated the turbine as something that was needed for maintaining the fabric.
5538	They received a grant from Sustainable Energy Ireland for 50% of the cost of those technologies.
7439	there was also the incentive for grant funding,
8134	Applied for grant funding, though because of the money we scaled down the solar panels because we didn't think they would give the quantities they were talking about. They are a private organisation the scheme they applied for gave 25% of the cost; they saw that as a bonus, I think they wanted to proceed in any rate.
8209	a campus-wide CHP was waiting for its funding decision.
	Dropped out

5864	A lot of them dropped out at early stages.
7502	We shoved solar thermal and wind in quite early on in the scheme but because we perceived that it might end up being a sacrificial lamb we didn't proceed with the full design. [wind] was the first one to go because we thought the planners wouldn't actually take to it. We had solar thermal in there and stayed in for quite a while, as a lump of money, when the project came back over budget that was the most convenient thing to remove from the project.
7609	But the reason why we didn't carry forward for that one is the people helping us to get the info on cost were not very proactive, when you ask them something they get back to you after a long time, and we didn't have enough time.
	Token installation
6076	They didn't come to us with a sustainable agenda, being an airport with million pound airplanes, kind of money no object kind of client they are interested in it but its not part of their brief.
7502	we carried out a brief technical analysis of the benefits to the project wind in particular was a bit about 'lets have something that's very visible on the building, a signpost for the school'. It was very much a token gesture.

Q2. At what stages of the design were each of the following AET's considered?

2A	**From the beginning**
2762	From the outset GSHP. As part of our scheme design report we identified this site in particular just looking at all options as a chance of promoting this, the one that kept coming up was the use of ground source.
5420	Lambay the wind was considered from the start and we didn't consider anything else. They had a very limited budget so we couldn't consider anything else.
5864	All of those where we considered them were considered at the concept stage of the project
5947	PV up to scheme stage, sol thermal still there, wind concept, GSHP still there, CHP concept
6108	That was decided by the early stages
6915	We looked at, right at the beginning of the PFI process; we proposed that there would be solar panels on the roof to give hot water.
7238	Copenhagen definitely had bio energy, it's Danish stages so it got to roughly stage C+ but it was never dropped which is the nicest thing about it
7272	PV were considered at stage C but got dismissed quite quickly, same for solar, GSHP I

	think we did think about them especially when we went to put quite a lot of cooling, but in the end cost put people off.
7408	from the competition stage or the early conception stage where we tried to drive a higher influence of passive and renewable technologies.
7427	Eden from the very beginning with an overview we looked at all technologies and we assessed how that might fit into the project.
7502	Came in early in the project, as lumps of money to throw at these things.
8134	PV considered and ruled out, solar thermal and bio energy there from the start and constructed.
8209	PV were mentioned in the competition brief but in all honesty they were never taken forward. Solar thermal again they featured in the competition. Wind was put in the competition entry but the project team themselves decided quickly that in an urban environment where planning was sensitive for this new high building that it was not worth going down the route of. GSHP again featured in the competition
8285	Carlyon bay we took CHP up to concept and at scheme design we did a feasibility study, but it didn't get any further, it was parked basically.
8869	PV, solar and wind considered at a very initial phase

2B	**Not until later stages**
5671	When Genzyme took over the project they actually became fairly active in what they could afford to do. It was during the construction drawing stage that the PV's went in.
6076	an opportunity has come up fairly recently with the site layout where PV might be an achievable option,
7609	PV - Stage C & D, brief paragraph in the report, but no analysis. Went through to construction. Analysed after tender. The good thing is that this is standalone item so we didn't consider that from the beginning, but as long as you have the money then you can put it in at any time.

2C	**Project background**
	Practical drivers
2762	The drivers on that was given its location in Cardiff it sat directly above a well established aquifer. All we had to do was sink a single borehole down, abstract water, pass it through heat exchangers and dump it into the adjacent dock. In some senses it was a no-brainer.
5538	The CHP was there from the start, it was something that made good technical sense.
8933	We have also looked at Ground-source Heat pumps, well we haven't ruled them out, the site is owned by British Waterways.

	Practical barriers
2762	They went to a fairly cheap company who hadn't that kind of experience, and the net result was we had a lot of problems on site. The works on site was potentially hampering the main contractor building his concrete in-situ frame and a decision was taken to abort.
5538	Consideration of using wind generators for external lighting but again it was ruled out because of the area required for batteries
7408	Solar thermal collectors were considered but discarded very quickly. Within Denmark they tend to operate on fairly large district CHP schemes so they are encouraged by fairly hefty penalties to take heat from the national system rather than provide their own by other means. Wind turbines didn't work with the site, the site's very compact and a residential area.
7427	GSHP I think have been considered on numerous projects in the past but simply haven't been followed through. We looked at it again on the education building but at that time Eden did have the opportunity to follow it through, the design team was willing to assist, but at that particular point of time Eden did not make the decision quickly and the design simply progressed without developing that aspect. Eden's looked at wind generation historically around the top of the pit; I believe it was rejected on planning grounds the impact on local residents.
7609	Solar, again it was briefly mentioned in the Stage D report but it wasn't included in the tender as such. The study was done quite recently, after contract issue, it's quite late timing. We found it very hard to incorporate it because of the unknown summer no-load situation for schools.
8209	Solar thermal again they featured in the competition the CHP came along, any heat source would come counterproductive at that point. So they were immediately shelved. Wind was put in the competition entry but the project team themselves decided quickly that in an urban environment where planning was sensitive for this new high building that it was not worth going down the route of.. [GSHP] was viewed that integrating boreholes underneath the building was a risk in terms of delaying the ground works.
8496	Solar thermal considered and dropped because it reduced the viability of CHP.
8869	Bio energy was considered for some time and there was significant work done on trying to find out the implications of that on spatial requirements
	Cost a driver
5426	Zero outlay, system is leased
	Cost a barrier

5420	They had a very limited budget so we couldn't consider anything else.
5538	wind generators for external lighting but again it was ruled out because of the area required for batteries and the cost so we didn't proceed any further.
7272	GSHP I think we did think about them especially when we went to put quite a lot of cooling, but in the end cost put people off.
7408	PV were considered briefly but discarded. The reason they were discarded was partly economic. [GSHP] was again discarded by the Danish engineers purely on monetary values and risk.
7427	As we went through we hit a wall which was bringing the project into line with the budget. They wanted renewables but we didn't feel that they should be putting them in just for the sake of it.
7502	When the tender came back they got chucked out. If they'd got enough money we'd have gone through to fully design them and just utilise the provisional sum as best as we could.
8496	PV only briefly because of the long payback period.
8869	and then also running costs for bio energy.
	Funding
2762	The welsh electricity board learnt about our interest in it and sponsored the desk study and appraisal and offered to pay for all of the funding over and above what we'd normally occur on a project like this and use it as a demonstration project.
5671	When Genzyme took over the project they actually became fairly active in what they could afford to do, and were they aware, for example that they could obtain quite significant grants from Massachusetts board in terms of installing PV's.
7427	Eden have had success with PV and obviously they have had a considerable grant to incorporate a building integrated PV scheme on the education building. The PV was dead easy, they had decided themselves that they wanted this and went out and found funding for it. We didn't have to prove a thing to them. We keep pushing [Bioenergy], they came back to us and asked us to help them put together some application for funding on that from clear skies, and they've been granted the grant.
7609	The reason we can have PV is that Kensington is an environmental school specialising in environmental science. We could put a stronger case to the DFES for additional funding for the items, so we've got the money.
	Client commitment
6108	That was decided by the early stages, possibly before they decided whether they were going to do phases 1 and 2 together or just phase 1.
7427	They wanted renewables but we didn't feel that they should be putting them in just for the

	sake of it. The client even got on board other people, or other people approached the client with ideas and the client would come to us with ideas of what we considered inappropriate. Bio energy, we have done a feasibility study, it was quite an unusual approach because the client gave us quite a lot of money to do it.
7609	as long as you have the money then you can put it in at any time. The reason we can have PV is that Kensington is an environmental school specialising in environmental science.
8933	The Eco-homes is a compulsory part of our project environmental charter through British Waterways.
	Needed to raise awareness
5426	Raise client and contractor awareness.
6076	it's not something the client's come to us, it's one of those light bulb moments 'you look at something and think that might work'.
7408	from the competition stage or the early conception stage where we tried to drive a higher influence of passive and renewable technologies. We then found that after the project had been won there was a desire to erode this.
7502	there was no great enthusiasm from the other members of the team or the client or the project manager which is one of the reasons why we didn't do a full design, because we sensed they would go anyway.
	Environmental benefits
5671	when they heard that putting PV's in would also help them in their environmental rating for the building then they decided to go ahead with it.
7609	Kensington is an environmental school specialising in environmental science. We could put a stronger case to the DFES for additional funding for the items, so we've got the money.
8933	The Eco-homes is a compulsory part of our project environmental charter through British Waterways.
	Non-technical barrier
7427	Eden did have the opportunity to follow it through, the design team was willing to assist, but at that particular point of time Eden did not make the decision quickly and the design simply progressed without developing that aspect.
7502	It was quite a tight design programme which didn't help so we had to concentrate on designing the core services.
7609	The study was done quite recently, after contract issue, it's quite late timing. We found it very hard to incorporate it because of the unknown summer no-load situation for schools. GSHP was explored very briefly just before tender in an attempt to allow for some more

	money for doing that later on but it's just not enough expertise and not enough information to complete the task.

2D	**Other project information**
	A design study was completed
5864	We did a design study on them, how feasible they would be, how much plant space, solutions we'd require and what the paybacks might be, against the target energy use of the building, the site and layout of the building.
6915	We looked at, right at the beginning of the PFI process; we proposed that there would be solar panels on the roof to give hot water. We gradually had to develop it as it went through from outline proposals through to the point where we had to do a detailed payback analysis.
8285	Carlyon bay we took CHP up to concept and at scheme design we did a feasibility study
8496	PV, solar, GSHP and CHP have been considered in an energy strategy report.

Q3. How much of a part did the consideration of these technologies have to play in this project? How does this compare with other aspects of the design?

3A	**An important part**
5420	the wind turbine was the project really; it was almost a project in itself.
5671	Once we decided what we were doing in terms of the environmental story, it began to impact on the project quite considerably, in terms of people wanted to understand more.
5947	they were core to the whole design,
6108	The CHP played a significant part in the design because you have to take into account your boiler selection and how you're going to gear up your controls to ensure you get the most out of the CHP unit. And also to ensure you've got enough plant space to accommodate it and in terms of the flueing arrangements it's compatible with how we're dealing with the products of combustion from any other system. Also we have to get the electricity board on side as quickly as you possibly can to make sure they're clear that you are going to have a CHP on site, what your intentions are in terms of exporting energy.
7238	It was pretty much a big driver to be honest, there was a whole thing about the slope and all the manure, it became a part of it, that was the weird thing about it.
7408	They probably had a larger part to play in this project than most that I encounter, that was

	two-fold, one because of the fairly sustainable nature of Danish and Nordic countries but also because it was a main driver for winning the competition.
7427	With Eden it was very much a part of it, the concept designs were very focussed on renewables. The biomes we looked at allsorts having wind collectors integrated into the shape of the biome.
7617	They were core to the whole design,
8134	The whole design was around demonstrating the uses of timber and trying to build a zero Carbon Dioxide emitting building. So it was very much a key driver for the building as a whole.
8496	It's a very public part of the design, we've presented it in public meetings to the whole of the Borough Council, so it's played a major part in the pre-planning stages of the project and also, because we're considering GSHP, the builders work, the logistics of the site investigation and coordination of at an early stage because it's all ground works and foundation works is playing a major part. This probably is playing more major part than the more conventional technologies, where we are just fitting boxes into the building.
8869	The CHP had quite a big impact, as did bio energy initially. Because it influenced what we were looking at, basement sizes and looking at ecohome scores. The other renewable technologies played very little part and in fact it was decided they would be discounted.

3B	**Not really**
5426	Not particularly important.
7272	Nottingham it was definitely considered as a bolt-on it wasn't an integral part of the architecture, even though it's quite good educational thing.

3C	**Small part / at concept**
5538	For Finglass it was a small enough part, after the initial studies were done it was decided what the considerations were going to be, CHP was a very straightforward thing to deal with. Integrating with the local electricity network was probably the only thing to get right it's seen now as a fairly straightforward technology rather than anything hugely groundbreaking.
5864	They play quite a big part at concept stage but often they disappear at concept, or scheme design stage or even detailed design stage, in my personal experience.
6915	The solar panels was a big plus at the early stages of the design because we were competing with other consultants. And the client actually said to us at one point "Those technologies set us apart" and the fact we had a mixed-mode building, that set us apart from the other competitors that were air-conditioned offices and no AET's considered at

	all. So they did get us brownie points.
7427	Initially the education building considered quite close integration of PV, solar thermal and GSHP. Quite quickly into the concept design for the education building it became clear that alternative technology probably didn't ought to be considered as a fundamental part of the building.
7502	It didn't necessarily influence the design in any way, other than making sure that the systems to which they would be connected could interface or there was space to incorporate those interfaces.
7609	Relatively small part. For example PV on the roof and solar thermal systems on the roof there was area to put them on, but I wouldn't say that we need to consider them right from the beginning
8209	In terms of the competition there was an eagerness to have these included and it was right up there as a centre point. In initial meetings it quickly came apparent there was a possibility for CHP it didn't disappear off the agenda but it didn't ever rear itself as an important issue.

3D	**Project background**
	Demonstration
2762	The intention was to showcase this as part of an alternative strategy. They were more than happy to have this as an exhibit.
5538	Sustainable Energy Ireland wanted to set an example, there are other leisure centres being built and so they wanted to show that this was an appropriate way forward, a more sustainable way.
7427	They were very much a part of the whole process of Eden, integrated within the building preferably, very keen to put the right message across.
8134	The whole design was around demonstrating the uses of timber and trying to build a zero Carbon Dioxide emitting building.
8496	It's a very public part of the design
	Lack of interest / needed to raise awareness
5426	Engineer key role, otherwise it would have quite easily have been forgotten
5671	We on the European side almost had to educate the client and the contractor about what was involved.
7272	The architect wasn't really brought into the whole thing and we were slightly isolated from the trust. We couldn't get into to see the trust early enough in the design; we were kept a bit away from them by the architect, that's just how they operate. The architect was really

	influential on avoiding it on Nottingham. The client didn't have any opinion on it really on Nottingham, though the DFES has one person who is like the M&E tick off person and he's really into getting technologies in but he never helped us get it in there.
7502	Well we put them in and didn't get much support from anyone else.
7609	I don't think the DFES are willing to spend more money unless the design team put the case strong enough to convince them.
8209	the client would have been receptive if we could justify various things and say look I think this is the right way forward.
	Funding supplied
2762	SWALEC were the major funders
7439	They were not add-on but I suppose the fact that there was grant aid available there was something going to be there it was just a matter of what paid back the best
7609	For city academy the funding for the whole school was decided at Stage D so anything that we hadn't allowed at stage D we either would not be allowed in or we would have to fight for more. Is just an economic problem
	Client role
2762	The client who were happy for something from nothing. They were more than happy to have this as an exhibit.
5671	People wanted to understand more. We on the European side almost had to educate the client
5864	It depends on how green a client wants to be. It's predominantly driven by ourselves with the client. At concept and scheme stages we're driving it with the client.
5947	The client, architect and ourselves
6108	Apart from that it was driven really by the client, the client wanted to have CHP and the architect supporting him in that decision.
6915	And the client actually said to us at one point "Those technologies set us apart"
7238	The client was more into it on the elephant house
7272	The client because it's a single client there's no sponsor, so the DFES back it, also they have to keep their costs down. The client didn't have any opinion on it really on Nottingham, though the DFES has one person who is like the M&E tick off person and he's really into getting technologies in but he never helped us get it in there.
7408	The client was made up of 14 different individuals of 14 different sets of aspirations, but in principle the client body that authorised the money were a risk-averse client.
7427	very keen to put the right message across. the client was very keen on it. From the clients team as a whole there are a whole mass of people who input and comment on the design,

	but specifically there were probably only one or two. A lot of people at Eden will talk about things that they would like to have and like to see in the design but there are very few that can actually go out and get the funding and probably make a decision.
8496	It's driven by the initial development brief, and the subsequent clarification that the council is carbon led in its decision making, the developer is also supportive of the approach.
8869	The clients themselves was interested in providing a scheme that was best for the tenants and the consideration of CHP. It must be said that he was not particularly tied to CHP in this project although he was on one of his earlier sites because it was a planning condition.
8933	The client was keen to see an alternative to electric. The client has said that their shareholders would be very happy if they had CHP because it fits in with their plans for a sustainable development.
	Building users
5671	Genzyme's people were eventually the users of the building, so it was the Genzyme team that really gave the design team the instructions or encouragement to think in a low energy or renewable energy way.
8496	the council is carbon led in its decision making
	B.S Engineer role
2762	Mainly ourselves
5426	Engineer key role, otherwise it would have quite easily have been forgotten
5864	It's predominantly driven by ourselves with the client. At concept and scheme stages we're driving it with the client.
5947	The client, architect and ourselves,
6108	There was support from me because I was the mechanical engineer on the job. Apart from that it was driven really by the client, the client wanted to have CHP and the architect supporting him in that decision. I was interested, I'd not done one before, to get one through and with there being two swimming pools it seemed an ideal opportunity to do it
6915	it was not just the architect and ourselves that were interested.
7408	The reasons they were eventually eroded and discarded were political reasons between the architect the Danish engineer and the client
7427	From BH's point of view I would say that probably Steve Williamson and Grimshaw's Michael Pawlyn looked at a number of options and suggested options with a view of either trying to bring a fresh light on the brief of the project or even try to bring in more work either of which are justifiable reasons for looking at the alternative technologies.
7502	Well we put them in and didn't get much support from anyone else. We had a substantial saving to achieve and we ended up being fairly involved in the process of actually taking

	them out because we couldn't see any way of actually achieving the savings that we needed.
7609	Mainly us, building services, and then the architect, who was convinced by us, so then the design team was in a much stronger position from stage D towards tender for asking for more money.
8209	I think a lot of the decisions were taken by BH themselves as to how we go forward with the future of these. I feel learning from other projects that the client would have been receptive if we could justify various things and say look I think this is the right way forward.
	Architect role
5947	The client, architect and ourselves
6108	Apart from that it was driven really by the client, the client wanted to have CHP and the architect supporting him in that decision.
6915	The architect was really keen on low energy
7238	The architect was really influential of including it on the elephant house, but that's because of the individuals, they were different architects totally although it's the same practice.
7272	The architect was really influential on avoiding it on Nottingham
7408	The reasons they were eventually eroded and discarded were political reasons between the architect the Danish engineer and the client
7427	Well certainly the architect
7609	Mainly us, building services, and then the architect, who was convinced by us, so then the design team was in a much stronger position from stage D towards tender for asking for more money.
8869	The architects were quite keen on renewables, but only in a fairly academic manner.
8933	the architect is very into solar-efficient buildings.
	Other team members
5864	I suppose the QS's are involved on the periphery as well, as to the cost of those elements, price up the costs, that type of input.
6915	The facilities management people were keen so it was not just the architect and ourselves that were interested.
7427	From the contractor's side of things, they need direction; they understand the Eden philosophy and their desires for alternative technology. But I don't particularly think they proactively go about trying to influence decisions. As with a typical contractor they'll provide the minimum that's needed to meet the brief of the project and if the brief quite a loose brief it leaves a lot of flexibility for the contractor to go off working with their

	architectural team and engineering team to provide any number of solutions. I would say from the contractor's point of view they could potentially see alternative technologies as possibly slowing down the project particularly when there was a driving programme behind it all.
8933	The project manager is doing a CHP scheme on another project so they were saying if it works on that scheme then it could work on this scheme.

3E	**Further information**
	Economics important
5426	Showed clear cost savings.
5864	Whether that's because the paybacks aren't short enough for clients or whether the project costs and value engineering drive some of the aspects out.
6108	with there being two swimming pools it seemed an ideal opportunity to do it, and the numbers appeared to stack up.
6915	because it's a PFI scheme running costs do actually come into the equation so that helped us to integrate some of the issues that normal clients aren't interested in it's helpful.
7408	The client was made up of 14 different individuals of 14 different sets of aspirations, but in principle the client body that authorised the money were a risk-averse client.
7427	Through the erratic way that Eden seems to acquire funding, although the will is there the demands of the programme and financially, simply meant that without any really agreed way forward the design should consider more conventional technologies just with the option to integrate alternative energies in the future. Everybody was aware of the cost issue; unless this thing was proven to be viable it was never going to happen.
7439	it was just a matter of what paid back the best
7502	We had a substantial saving to achieve and we ended up being fairly involved in the process of actually taking them out because we couldn't see any way of actually achieving the savings that we needed.
7609	Is just an economic problem, I don't think the DFES are willing to spend more money unless the design team put the case strong enough to convince them.
8285	if there's any value in the scheme in the use of renewables or CHP then we'll have it but otherwise no thank you
	Risk
7408	The client effectively became financially driven and risk averse design driven.
7427	from the contractor's point of view they could potentially see alternative technologies as possibly slowing down the project particularly when there was a driving programme behind

	it all.
	Practical barriers
5538	Integrating with the local electricity network was probably the only thing to get right
6108	The CHP played a significant part in the design because you have to take into account your boiler selection and how you're going to gear up your controls to ensure you get the most out of the CHP unit. And also to ensure you've got enough plant space to accommodate it and in terms of the flueing arrangements it's compatible with how we're dealing with the products of combustion from any other system. Also we have to get the electricity board on side as quickly as you possibly can to make sure they're clear that you are going to have a CHP on site, what your intentions are in terms of exporting energy.
7238	there was a whole thing about the slope and all the manure
7427	although the will is there the demands of the programme and financially, simply meant that without any really agreed way forward the design should consider more conventional technologies
7502	other than making sure that the systems to which they would be connected could interface or there was space to incorporate those interfaces
8496	because we're considering GSHP, the builders work, the logistics of the site investigation and coordination of at an early stage because it's all ground works and foundation works is playing a major part.
8869	Because it influenced what we were looking at, basement sizes
	Straightforward
5538	CHP was a very straightforward thing to deal with

6. In the building design process how were the negative and positive aspects of these technologies considered and compared?

7. What techniques were used for informing the decision making process, especially for comparison of quantifiable factors with some of the less tangible factors?

6A	**Decisions made on a financial basis**
5426	Decision based on capital and running cost savings.
5538	the cost-benefit drove the decision on the PV and the solar thermal
5671	we did have to make comparisons between other types of systems so they could form a value judgement of whether the design and the process was the right thing to do. We did

	that really by looking back at standard examples using cost in dollars per square foot and very crude.
5864	Often the decision making process will come down to cost, even in the early stages, whether the client wants to proceed or not. I've found that we can talk about a lot of these issues and the cost aspect is usually the one that drives whether or not we will proceed into much detail with it, it comes back to things like payback. Estates guys are around for a relatively short period of time and are only really interested in capital cost and the outturn costs of the project as opposed to long-term costs. That doesn't apply to all clients. With Plymouth the capital cost of the project was a big driver, probably the main driver, it's both driver and barrier.
6915	We had to compare the solar panels with an electric scheme and look at capital cost, running costs, there was no consideration of carbon savings or anything like that, which would have helped out. Perhaps in future we could do it that way.
7272	We did some on cost; in the stage C report I think that's when we discussed it.
7427	We did some cost benefit assessment but we did a matrix actually where we analysed the impact on energy, the environment and cost, and actual practical issues as well. One of the things about Eden is it's not just the physical costs that are the success it's quite often the stories, that adds to the whole Eden Project image. That whole picture view of things was quite unusual and probably wouldn't apply to commercial developments. It was down to Eden to go away and agree amongst themselves whether it could be afforded within the budgets or whether it would need additional funding or whether they had anything else that they could contribute, any other grant they thought that they could acquire.
7439	We did a feasibility submission to Sustainable Energy Ireland for the various technologies and we were looking there for a definite payback. Was very straight down the line grant-funding – no grant funding, no we don't want that.
7502	We put forward indicative costs and indicative payback periods. One of the problems we have with these schools is that they are given a fixed sum of capital funding and they don't have extra money to spend up front to actually give them payback.
7609	The design team and QS tried to estimate the cost that would be associated with these renewable technologies. Then we obtain some money to buy these items and later on we secure grant funding through DTI so that's 50% of the cost saved.
8134	Generally there is some sort of a cost-benefit analysis, on coiltte trying to size the solar thermal panels there was a cost benefit set against things like PV. Very much considered from that point of view. I think a lot of the time it was about trying to get to a sensible payback. Particularly if grant funding wasn't available for things such as the PV and solar thermal it did come down to a straightforward cost benefit really.
8209	There was a cost analysis done of various different options and that was conveyed to the

	design team.
8285	We used a straightforward format, we did a standard report approach, where the report summary was put together, some costs in use and end use issues. when there is a good case you need to put on your client head and try and think 'it's my money I'm spending is this really going to be of benefit to me?'.
8496	We've done a qualitative comparison of the different technologies available to the site and given indicative payback periods based on a couple of scenarios of reducing capital cost of equipment, increasing energy tariff costs. The building it's replacing gas bills are something like £30,000 a year, so in absolute terms it's difficult to justify the payback Techniques are load analysis and energy consumption modelling and spreadsheets to compare different scenarios of how capital cost might fall and how energy tariffs might increase to give a range of more achievable payback periods.
8869	The main issue that had to be considered was cost. It's not just capital cost, it's overall cost to tenants, anything that adds a cost to the project adds a cost to the rent. The cost of the effect on rental and on service charges of these technologies was a big influence and probably had a negative aspect to us doing it. Positively there is actually very little that can be said for it, CHP cannot be proven to be financially viable because nobody knows what the spark-gap is going to be in 5 years time. The basic premise with a lot of them was fairly easy to determine that they wouldn't be viable; it was obvious they were not possible when looking at very high paybacks. We looked at each of the technologies, what they would cost to install, cost to run and what their payback would be, although payback was a bit of a strange concept when it's a developer, because he's not actually going to recover any of that cost necessarily. And what the added value was to use those technologies, which actually was advised by the estate agent to be zero.
8933	It all came down to cost at the end of the day, is it cost neutral and will it get us bonus points on the sustainability chart?
	Life cycle considerations
2762	What the client saw was a more environmentally acceptable alternative innovation and with cheaper running bills.
5426	capital and running cost savings. running cost evaluation sheet, Figures from suppliers and retrospective projects.
5864	Things like cost modelling is looking reasonable. It's useful to take clients to see existing clients that have taken on or embraced these technologies and used them in their buildings to get their feedback, get their views on maintenance, reliability of the systems, complexity of the technology for them to maintain it.
6915	We had to compare the solar panels with an electric scheme and look at capital cost,

	running costs
7238	we did life cycle costs
7408	In principle we would review it as almost a life-cycle come payback way and try to quantify this perhaps in money but generally to use a format where our assumptions were very transparent.
7427	You do it in a number of phases; the first job is convincing them that it's worth spending their money to look at, because effectively they're paying your fee. In doing that we went through the process and reported the benefit. Behind that I think that the project managers and cost consultants, Davis Langdon, would have been giving it all a little bit in the ear of the client to hurry things along because they probably take a view that they've looked at this on countless number of projects and it never stacks up. So there's one aspect that if you are to get your scheme then you need to get those kind of people on board as quick as you can. To do that you need to demonstrate a whole project view of life, the costings considered the builders work the aggravation to the project programme
8496	indicative payback periods based on a couple of scenarios of reducing capital cost of equipment, increasing energy tariff costs. Techniques are load analysis and energy consumption modelling and spreadsheets to compare different scenarios of how capital cost might fall and how energy tariffs might increase to give a range of more achievable payback periods.
8869	It's not just capital cost, it's overall cost to tenants, anything that adds a cost to the project adds a cost to the rent. The cost of the effect on rental and on service charges of these technologies was a big influence. We looked at each of the technologies, what they would cost to install, cost to run and what their payback would be, although payback was a bit of a strange concept when it's a developer, because he's not actually going to recover any of that cost necessarily.

B	Balance of Pro's and Con's
2762	We did a separate feasibility study that proved the viability of it that was then substantiated by the hydro geologist desk study sponsored by SWALEC.
5426	Evaluation report.
5864	We as a practice will consider all of the aspects of a particular technology. At concept studies we will do design studies of various technologies, but often the decision making process will come down to cost
5947	Verbally and we did a report. They were discussed and then we produced a report at planning stage saying what we were intending on doing. They were discussed with the client.
7238	On the elephant house it was a lot clearer because we had a bit more help and that was a

	thing on the bio stuff and quite a good thing on the PV, so actually it was a bit more of a concise comparison, we did life cycle costs, it was a better report really I think that was more convincing, and the time we spent on it made it keep in the scheme. It was our report which was without doubt was the biggest technique, partly because of the language thing and also the distance to go to Copenhagen.
7272	in the stage C report I think that's when we discussed it. Nottingham we used our report and workshops, the workshops were probably the most important, but you have to have something prepared.
7408	it was reviewed and communicated in report format and PowerPoint presentation, but was generally devalued based on the experience of the engineer and the architect regardless of what supporting evidence we provided.
7427	Most of the technologies started off with sketch ideas or concept ideas that were talked about at design team meetings or sketched them onto architects drawings just to initially trying to explore what could be possible. That quite often led onto comments from Eden and then as a design team we would then go off and look at pro's and con's I suppose. Sometimes the calculation and the work we had to carry out ourselves, sometimes it was possible to go to manufactures. The end result would be to present to Eden more in a slide format rather than any report format to talk through what had been considered, the pros and cons and try and just give them the bottom line of what the cost would be and what the energy saving would be, and whether or not it would be suitable. We did some cost benefit assessment but we did a matrix actually where we analysed the impact on energy, the environment and cost, and actual practical issues as well. We clearly showed benefits that were mentioned in sort of a pro's and con's summary, but only if we felt it was a key driver for the client was it flagged.
7439	We did a feasibility submission to Sustainable Energy Ireland for the various technologies
7502	We put forward suggestions for how renewable energies might be incorporated in the various design reports at stage C and stage D. We tried to raise them as discussion points with the various bodies involved in the design, with variable success and they weren't seen as being core parts of the building in scheme design.
8209	Mostly that was an internal process, that would have been informal discussions. And a way we were proposing to compare that risk with the benefits was a pro's and con's matrix.
8285	We used a straightforward format, we did a standard report approach, where the report summary was put together, some costs in use and end use issues.
8496	The main method for comparison was an energy strategy report and presentation to the council.
8933	we looked at the impact on façade performance, cost, new part L, acoustics and did an option report and tried to rate on sustainability but it all came down to cost at the end of the

	day, is it cost neutral and will it get us bonus points on the sustainability chart? The client wanted a report to be carried out.

C	**Other qualitative techniques used / considerations made**
5420	On Lambay there were lots of less tangible decision factors in terms of them being in isolation, there are different types of drivers.
5671	we had to convince them that it was proven technology that the client wouldn't be left with a building that they couldn't maintain or operate. We the design team had an awful lot of responsibility to ensure that the client and contractor understood what we were doing and why we were doing it.
5864	It's useful to take clients to see existing clients that have taken on or embraced these technologies and used them in their buildings to get their feedback, get their views on maintenance, reliability of the systems, complexity of the technology for them to maintain it.
5947	So we were trying to explain to them that a GSHP might not have been the best payback time in the world, and we did demonstrate that to them, but they still wanted GSHP. So image was a lot of their thing. The client wanted, I suppose, the bottom line, but when you showed it to them the architect would say that's all very well but gas is going to run out some day so maybe CHP isn't such a good idea, so on Daintree it was very tricky. It was an unusual project in that the best payback would not necessarily get to be the selected technology.
6076	It really was personal, it was unusual in that, the architects were the same and they kind of moved the clients who were more worried about the long-term damage to the planet than he was his own cheque book.
6915	Anything negative would have more weight and the contractor, we were working for the contractor, really did not want these solar panels in at all, in fact at one point he told us to write a report to say that they would not be viable.
7408	It was reviewed and communicated in report format and PowerPoint presentation, but was generally devalued based on the experience of the engineer and the architect regardless of what supporting evidence we provided. Part of the disadvantage was the engineers that we were related with were a small company and not very experienced at a large project and non-air conditioned boxes. The value placed on the less tangible factors such as social responsibility and moral obligation were positive at meetings but again discarded when the decision came. Effectively it came to flat cost and risk and that was disappointing.
7427	That story was to not just look at things in isolation but to look at the whole impact, very sort of sustainable focussed client. We did some cost benefit assessment but we did a

	matrix actually where we analysed the impact on energy, the environment and cost, and actual practical issues as well. One of the things about Eden is it's not just the physical costs that are the success it's quite often the stories, that adds to the whole Eden Project image. For example the PV is very much part of the story that stuck and that's why it's still in there, whereas in terms of cost and energy produced it was way off the scale. That whole picture view of things was quite unusual and probably wouldn't apply to commercial developments. If you can actually inspire people to change the way they think you'll have a greater impact than running the building along low energy, if you can inspire people to turn their lights off once or twice the overall impact of that completely swamps, that's the value of the non-engineering side. To do that you need to demonstrate a whole project view of life, the costings considered the builders work the aggravation to the project programme, a critique of the risk I suppose trying to quantify less tangible factors is always going to be difficult, it's always very subjective but I believe we tried a simple scoring a weighting matrix. And just try to list out all possible factors, try to put a weighting against their importance and then just try to put a score.
7502	So we did have a discussion about payback periods, investment and image,
8209	They almost fell away as BH realised the various implications of the risk of the perceived reaction from the client it was viewed we don't even want to be going down this path. It wasn't about pushing the client. I think a quote that someone said from one of our design workshops was "the client would think we were mad talking about this", and I think that was a shame.
8869	And also the requirements on bio energy the physical size required is a big influence that is not practical and the fuel's not available. Of the less tangible items benefit to the environment and overall image were actually seen to have a very little influence on the client who is a responsible developer. These intangibles about image and long-term benefits, fuel security, had not been considered because they are secondary concerns so are borderline.
8933	we looked at the impact on façade performance, cost, new part L, acoustics and did an option report and tried to rate on sustainability but it all came down to cost at the end of the day, is it cost neutral and will it get us bonus points on the sustainability chart? The social benefits were covered by the sustainability charter which ran alongside an Ecohomes assessment, which had an energy section.

D	Other quantitative techniques used / considerations made
5538	On finglass the cost-benefit drove the decision on the PV and the solar thermal, beyond that

	things like the CHP in a big project makes sense and you would have proper mechanical engineers maintaining the system so the complexity of it wasn't really a concern, we had it ticking over in the back of the mind but they felt it was something that people could handle. I think CO2 output is certainly one of the decision making factors for Dublin city council, a government body.
5864	It also can involve specialist manufacturers, get some input from them, factors related to the system, its design life, maintenance cycle, again I suppose more practical feedback.
7427	Another thing that we did try to do was make better use of thermodynamic models to try and better predict the energy consumption of a building and how it would match up with the availability of resources, to try to come up with an optimum size of either biomass boiler or GSHP.
7609	GSHP are not possible because of either technical aspects and also space and coordination with other stuff in the ground.
8134	maintenance certainly factors into it and availability.
8209	Part of the issue with the boreholes was the risk of construction, period.
8496	The positive aspects have been more the image and the carbon reduction measures. The building it's replacing gas bills are something like £30,000 a year, so in absolute terms it's difficult to justify the payback, it's more the 33% reduction in carbon emissions for heating and cooling that's being sought. We've quantified the carbon emissions and compared the carbon emissions of a standard system, boilers and chillers, against the CHP and GSHP's.
8869	And what the added value was to use those technologies, which actually was advised by the estate agent to be zero. From the point of view of biomass, the only other one that was considered, the main item for that was, the factors that were considered were what was the cost of fuel and how do we get the fuel?
8933	it all came down to the carbon emission reduction.

E	**Don't know / None**
5947	There was not a very direct way of assessing things, you were told that they didn't like it and that was it.
6915	It was sold as a bolt-on goodie and then we had to try and make it work, in hindsight we came about it from the wrong direction, we should have checked its grounding first before we sold it.
7617	There was not a very direct way of assessing things, you were told that they didn't like it and that was it.

F	Depends on the client
5864	Estates guys are around for a relatively short period of time and are only really interested in capital cost and the outturn costs of the project as opposed to long-term costs. That doesn't apply to all clients.
5947	In a lot of cases people have preferences and you can show the payback for CHP to be perfect for something, and if they don't want it that's it. You were told that they didn't like it and that was it.
6076	It really was personal, it was unusual in that, the architects were the same and they kind of moved the clients who were more worried about the long-term damage to the planet than he was his own cheque book.
7427	only if we felt it was a key driver for the client was it flagged the first job is convincing them that it's worth spending their money to look at, because effectively they're paying your fee.
7617	The client was a very hands-on client who wanted to build everything himself without having a main contractor, so he went off looking at various things and paybacks himself. He made the client decision really, we weren't really called upon, he made his own decisions and we told him how to build it, or how to install the technology, how to design the technology. It really was personal, it was unusual in that, the architects kind of moved the clients who were environmentally conscious clients.
8134	It was a client decision, they wanted it, they definitely decided they wanted the wood-chip boiler and in a way looking forward to maybe developing an industry. They made a very clear decision.
8209	We ended up not trying to make it so much of a song and dance in case the client says 'that's bonkers you're getting a CHP with chilled water and you're suggesting we put in a few hundred grand worth of boreholes, why am I employing you?'.
8496	Which are still long but are acceptable to a public body but maybe not acceptable to a private body.
8933	The client wanted a report to be carried out.

G	Depends on planning / policies
6108	Once the council had made the decision that this was something they wanted to go ahead with they found the money and it happened.
8869	the primary factor it was felt was there was a driver between what the GLA requirements were in housing and what the GLA requirements were in energy.

H	**Depends on the project**
6108	It was felt generally around the Table that if you've got a swimming pool then you've got a fair chance to make a CHP stack up
7502	One of the problems we have with these schools is that they are given a fixed sum of capital funding and they don't have extra money to spend up front to actually give them payback.
7609	there are certain things are decided that cannot be changed such as the planning permission, you cannot change that. We said its an environmental school and we want to put this and we want to put that and actually this is the first environmental science specialism type of city academy built in the UK so that's a very convincing statement for the DFES.
8496	We also get penalised because the council has very low energy tariff agreements with its suppliers, it being a bulk user.
8869	Positively there is actually very little that can be said for it, CHP cannot be proven to be financially viable because nobody knows what the spark-gap is going to be in 5 years time. And also the requirements on bio energy the physical size required is a big influence that is not practical and the fuel's not available.

I	**Depends on the technology**
7609	Solar thermal and PV are items you can easily stick onto the roof which can be a more viable option. GSHP are not possible because of either technical aspects and also space and coordination with other stuff in the ground.
8869	Positively there is actually very little that can be said for it, CHP cannot be proven to be financially viable because nobody knows what the spark-gap is going to be in 5 years time. And also the requirements on bio energy the physical size required is a big influence that is not practical and the fuel's not available. Certain technologies, fuel cells for example, which aren't proven, are too expensive at the moment.

J	**Others**
2762	We did focus very quickly on this optimum solution, it hit all the right boxes, it was a demonstrateable project.
5671	We the design team had an awful lot of responsibility to ensure that the client and contractor understood what we were doing and why we were doing it.
6108	The decision to go down the CHP route was made fairly early on. and really from that it was a question of how big a CHP do you need.

6915	Anything negative would have more weight and the contractor, we were working for the contractor, really did not want these solar panels in at all, in fact at one point he told us to write a report to say that they would not be viable. There was no consideration of carbon savings or anything like that, which would have helped out. Perhaps in future we could do it that way. That will be the first solar panel that we have designed.
7238	the time we spent on it made it keep in the scheme. A structural engineer had to present something to people who were listening in a second language. It's only an iterative process in the workshops when you've got to keep it in the top of your head, which is quite hard sometimes, that's really hard because you're concentrating on your plant room size so you can't remember.
7272	Well it's a bit difficult because we didn't get to speak to the client until way too late in the project, so that was a negative aspect and that was partly us not planning ahead enough. And then the architects that we were dealing with weren't interested so that was negative.
7427	If you can actually inspire people to change the way they think you'll have a greater impact than running the building along low energy, if you can inspire people to turn their lights off once or twice the overall impact of that completely swamps, that's the value of the non-engineering side. Though in order to have a good story you've got to get the engineering right, there's always someone ready to snipe it down. I think that the project managers and cost consultants, Davis Langdon, would have been giving it all a little bit in the ear of the client to hurry things along because they probably take a view that they've looked at this on countless number of projects and it never stacks up. So there's one aspect that if you are to get your scheme then you need to get those kind of people on board as quick as you can. It's always very subjective but I believe we tried a simple scoring a weighting matrix. It's the kind of thing that if its done right it can be presented and it can be modified during a presentation, it doesn't take time, it doesn't always give the right end result but it's a method that can sometimes be of use.
7502	We tried to raise them as discussion points with the various bodies involved in the design, with variable success and they weren't seen as being core parts of the building in scheme design. We actually found things that were more important to the project as a whole to discuss most of the time. They weren't high enough up on anyone's agenda. but there was a lot of apathy floating around so we didn't really push it through, everyone had other fish to fry.
7609	A lot of this is just human understanding. There was no interaction with the client at all. We just put forward what we thought was sensible.

7617	We weren't really called upon, he made his own decisions and we told him how to build it, or how to install the technology, how to design the technology.

8. What changes would have helped to improve the effective implementation of AET's? Specifically how could the approach of the building consultant help this?

8A	Education
2762	Fundamentally what stopped this was having the appropriate contractor with the experience of drilling these type of boreholes. Anything that does have an impact on the main contractor that needs to be built in and he needs to programme for it.
5426	Generally there's a lack of awareness out there We're not 100% reliant on markets. Promoting awareness of these kind of systems, energy technologies.
5864	We could and should be more active in the research of these things, and with specialist manufacturers or companies to see if there are ways in which this technology can be incorporated into more buildings on some sort of rental.
5947	The experience isn't there in Ireland yet; it is all strange for lots of consultants they'd crank up their prices because of that, because they've never installed a GSHP before.
6108	having more knowledge about the financial assistance available to the client would always be useful, so that we could actually make the case more strongly for the who's a little unsure. And any kind of general advice to give us a little more confidence that we could ascertain the summer heating load, the minimum heating requirements that the CHP would have to cope with. As far as the other technologies are concerned it's just gaining experience of which are most appropriate in each instance.
6915	knowledge of the systems could help
7408	A better understanding from BH of how the contractual process worked between the architect and engineers.
7427	Most clients don't understand what sustainable means and they will automatically look to the engineer to provide a solution to the sustainability issue. Even architects will do that, they ignore the fact that the proposition of sustainability includes a number of other aspects apart from purely running costs and CO_2 emissions.
7502	more enthusiasm, that includes us to some extent, also keeping up to date with how these

	technologies evolve, particularly PV.
7609	I think the real barrier now is that the industry is still quite conservative.
8134	there needs to be information and education From our own point of view just to make sure we understand how to integrate them in with the rest of the building services to get the maximum benefit from them.
8209	There was maybe a certain lack of understanding and enthusiasm to actually get involved.
8285	If you're putting anything in that they didn't do on their last job it's going to cost money and you're only an engineer, unless you can demonstrate a thorough, professional, full holistic approach to it you'll never get anywhere.
8869	We need a better understanding of the costs involved, possibly also of the build ability issues, how easy to install, what's the ratio of floor area to roof area to make a solar thermal work, and the smaller scale wind technologies viable in acoustic considerations?

8B	**Information / Case studies**
2762	For us to learn and move forward we need to be able to benchmark it, compare against best practice; you need to demonstrate to the client that there is benefit in it, without proof they will still remain sceptical.
5671	What we do need is more feedback from actual installations rather than the theoretical feelings of the design team. So the more and more projects that get built and we can get positive feedback, finished installations, then I think that will help us make design decisions, it will help the client make design decisions. The building consultants have got the responsibility of collating this type of built information, I think it's the nature of a consultancy to do that and to find out what's happened in their precedent studies and having got their precedent projects then they should visit them and get feedback on costs and energy usage and maintenance etc.
6108	Any advice which would give us a bit more confidence might well encourage people to put this in. and more accurately sized CHP units in rather than erring on the safe side and putting a smaller one in. I think that hopefully that should come from feedback it will be interesting to find out what happens on Carterton. I think you just need to be armed with as much information on the subject as you can
6915	we could have done with some more costs from manufacturers. More knowledge at your finger tips and familiarity with design and installation issues.
7427	There is also trying to get the client to understand what they're buying in a sense, actually taking them to see buildings that have these technologies. Lots of clients simply will have heard about these things in the paper and not actually seen them in practice.
7502	Information about the cost of these technologies and what you get back, at a certain wind speed or certain orientation, or something like that. There's a lot of stuff out there, if you

	got to speak to Solar Century or whoever it might be and get information from them, but actually having that to hand, to be honest I don't know how much of it is to hand already in the practice, would be a real improvement.
8134	Availability of information in the market. Choice, certainly of wood-chip boilers there's very little available in the market in Ireland and fuel suppliers in Ireland. So people again need to be very interested to decide they want to do it and then to go and source their fuel supplies and all those kind of things, so that the industry needs encouragement.
8209	One thing that would have helped us, in terms of the boreholes, was we found it very difficult to get technical help from people because not many people actually put them underneath buildings before.
8285	It's the actual practical side of things that we need to be able to look beyond just the concept to advise the clients of what actually does happen with these things and how people do manage to make them profitable or viable. Once we've got that level of experience we are then able to cut off any issues that may be thrown at us by doubting Thomas's, people just do test you, you will be tested.
8496	I think better information to remove some of the assumptions on energy tariffs and capital cost of equipment. To a certain extent we're limited by what the industries can provide us in that respect.
8869	The other issue is that the electricity regulations are such a mess. It's very difficult to determine what you can and can't do and to be able to run your own private wire scheme and private generation scheme so it can actually afford to pay for itself and possibly make some money. The other thing that would have helped is a more definite view on gas and electricity prices. We should have to hand some really good rules of thumb

8C	**Communication**
5426	Slowly being driven down from the higher level down to people who are installing them, it's a very slow process.
5671	I think that we as designers probably know quite a lot of stuff; it's often left to us to convince the client of the effectiveness of what we are doing.
7238	It was given that we could do it. I think we really need to have a dedicated day just with the client, because it would be awful to be doing the wrong thing wouldn't it. And also with Copenhagen we have to hand it over to local engineers it would be good to do us presenting to the client and local engineers and a bit of a cross-over, that would help.
7272	And we should be a bit slicker, but that wouldn't work with everyone to be honest.
7408	I suspect that the language barrier was as much of a disincentive of the client interacting with us.

7427	rather than just have a whole list of nice-to-have's and vague comments as to have much more specific detail
8285	Carlyon there was more collaboration across the company with people who've been through this. This allowed our report to be more thorough
8933	maybe it's us advising on cost plan advice that can also help

8D	**New techniques / approaches**
2762	You need to have something to measure your effectiveness against if you try to sell too many options all on one scheme it's difficult to prove the benefit of one against the other.
5947	We want a less time-consuming way to assess payback and likely energy consumption and likely cost of energy to the client. I've never been able to master it in any quick and efficient fashion before, so we tend to squirm out of doing it. If we had some structured way of assessing them it would be brilliant
6915	Standard costs and like a flowchart, where would it be appropriate to use alternative technologies.
7427	focus as to what the options would be, what would be viable for the site, try to keep things at a very simplistic level and this should all be done at concept stage really. Then out of that hopefully would come some specific technologies which would then perhaps still be explored within a consultant's fee agreement at schematic stage But on recent jobs I've tried to raise the sustainability issue quite early on and to try to point out that there are other members of the team that have to contribute and really to try to get a feel for how, or the client understands by sustainability and alternative technologies and for really what they're prepared to do.
7502	It would be handy to have a more structured approach to reporting these things and comparing them. Useful internal models that we can use would be good so that we can very rapidly put together project specific information on different types of buildings
7609	Usually the early design process is limited to one or two individuals from the consultant. So if the senior people involved during the early design stage do not want to put forwards these then it's hard to have them in the plans further down the design process. you just need to forget about payback just see it as an investment in new technology. Just see the image or educational value.
8209	If we're going to propose something I think we are going to have to hit the design team with specifics rather than talking about renewable energy, because renewable energy is nothing tangible it doesn't go ahead. I think we need to say straight away 'Wind turbines, in a city centre are not practical'
8285	I think as we develop our approach, get a few more of these in place, we'll have a much more robust information to hang in our reports, I think it will be easier then. It's a virtuous

	cycle.
8869	The approach to push technologies is conversely one that's fairly pragmatic and practical it's not one that is we should do it because it's green it's clean and it's good, but is one that's this is affordable and this is how we can do it. It's also got to be looked at in a holistic approach, renewables are not the first things you look at, they're actually one of the last once you've got a nice secure building fabric. But because that isn't sexy in terms of what we try to sell people don't actually want to hear it.

8E	**Political**
5426	Government support not feeding through. Unless there's an incentive from planning purposes or in this instance running costs and savings in capital cost of a standby generator then the awareness not going to get better. On the advent of new part L regulations this might make systems that much easier to sell.
5864	funding or grants, government grants or private grants
5947	there isn't enough grant funding, the political will is not there.
6915	The thing that's changed at the moment is this new part L, we are able to do a lot more on the back of the new Part L.
7272	On the academy more backing from the department, actual real backing rather than just saying 'wouldn't it be nice'. The trouble is we have to go to the clear sky grant, why are we going to another department, it's just a government pot, why isn't the money transferred immediately. It drives me mad, it's all the same source and that puts people like me off and everyone else, because you have to do all those forms and all they're doing is using the same pool of money for the same thing. It's crazy; they should just have money available and decide to allocate it accordingly.
7427	Well one of the things that's definitely going to help is the new part L obligation to have up to 10% of the energy provided by renewable sources. I think it makes people think. It's always going to be on the agenda now, I think that even commercial developers are going now look at the baseline now as 'what's the best thing for this building, is it having a connection to a wind turbine or an array of PV's or is it having better thermal insulation, smaller windows, etc. So there's going to be an interesting development there, that's going to help.
7502	More funding
8134	I think that grant funding certainly helps Government sponsorship helps. More legislation would certainly help
8209	We could have shot the planners as well, that would have made it easier.
8869	The biggest change is probably having a coherent grant funding by the government, from a local, national and European level. because there's no coherent and consistent approach to

	funding then these won't be pushed forward. The other thing that may have improved it if it was a planning restriction, even the GLA energy policy says an aim of 10% and for large developments from renewables on-site, but that's if feasible. Maybe better master planning because I think it is valid. We've got to understand that people like the GLA, Merton, etc. are really pushing the green ticket because it means political points.

8F	Cost
5426	The economics of CHP are obviously tied in with the unit price of gas and electric and the change in the cost of electricity would make this a far more viable project.
5864	We should be and we do try at very early stages of projects, to get the client to agree a sum of money for sustainability or renewables in a project cost, whether that's a percentage of the project cost or whether that is an allocated sum of money.
5947	The cost of fuel is too low
7502	More expensive energy would help.
7609	Again the payback capital cost for some of the renewables such as PV just doesn't make any sense to do, you just need to forget about payback just see it as an investment in new technology.
8134	the costs of things like photovoltaics the output we get compared with the cost is a large factor in terms of people not taking them on-board. The only places where we have PV in Ireland are very much demonstration buildings where they have been grant funded. So until the costs per panel comes down the chances of wide scale usage are pretty thin. Higher fuel costs will definitely help people to look more towards renewables; I'm sure fuel costs will rise pretty soon.
8496	If the economics of PV improves then they'll get more widespread application.
8869	Many of the technologies aren't viable at the moment, because they're just too expensive

8G	Client
5426	At the end of the day if they don't want to take the option there is nothing we can do.
5671	it will help the client make design decisions. So that he's not feeling that he's taking risks out on his own, feeling vulnerable.
5864	We should be and we do try at very early stages of projects, to get the client to agree a sum of money for sustainability or renewables in a project cost
7272	On the academy more backing from the department, actual real backing rather than just saying 'wouldn't it be nice'. We should get to the client much faster, straight in to the client
7408	We would need more exposure to the client, which we spectacularly failed to get

7427	in Eden there was a keener client. I think most client say now that they would like to have a sustainable building and they just say it as a matter of fact. Most clients don't understand what sustainable means
8134	At the moment, especially in the domestic market solar thermal panels are really being installed by interested people who want to do something, your average person is not saying "I'll put a few solar panels up on my roof". People are nervous, I guess they think they are taking a risk with these things

8H	**No way**
7427	I think we are doing, as part of, in the process of Eden and Carlyon Bay

8I	**Other**
2762	any slippages in something that may be unproven does leave your client exposed to delays and the main contractor could claim quite large prohibitance costs associated with it.
5864	We've got to get these technologies into more buildings to make them more commercially economical so that more clients use them, buy them and install them. That's the catch 22 at the moment. The more people buy them the technology becomes better and cheaper and more people use it and it becomes automatically goes in a lot of projects.
5947	One good thing about public private partnerships is that the emphasis is on low energy and low maintenance so it's easier to get people to spend the capital cost on things when they're thinking about the whole life cost.
7238	It's that usual grind of the construction industry, it isn't really the individual engineers at BH it's more like you go to a meeting and you're so low down that you think 'do they not watch the news'. It's really frustrating because everybody talks about it but they don't actually do anything about it. The whole industry is the main contractor going first and the M&E going second, and M&E's not clearly understood and therefore left to the end of each meeting,
7408	Shooting the engineering team in the back of the head twice. We got away with some of the low energy rather renewable energy was to integrate them into the design at an early stage. By the time that they realised what we had done it was too late to go in and scrub it out.
7609	I think the UK government is doing not too bad in putting forward these technologies with the clear skies and help from BRE for establishing funding.
8209	I don't think we could have asked for a client who would have been more receptive.
8496	In a way when you've got a CHP scheme if you're putting solar thermal you're eating into a base load and potentially eating into the CHP viability because you've got to get the right

	balance of technology.
8869	Also worth understanding that jobs are phased, they're very rarely built as one big project, and the technologies and the systems that are installed to adapt to them need to understand that so be modular.
8933	What did help in making us get CHP in is the fact that the cost plan has been there from day 1.

8J	**Consultants role important**
2762	you need to demonstrate to the client that there is benefit in it, without proof they will still remain sceptical.
5671	it's often left to us to convince the client of the effectiveness of what we are doing. I think that a lot of it falls back onto consultants and designers to do this.
5947	I've never been able to master it in any quick and efficient fashion before, so we tend to squirm out of doing it
6108	I think you just need to be armed with as much information on the subject as you can, and more knowledge of tax breaks and everything else which enable a client to make up his mind.
7427	Actually getting the right consultant in the first place, either the right practice or the right people, if the right people are not on the team then it's simply not going to happen in the first place.
7502	more enthusiasm, that includes us to some extent
7609	I think that the building consultant could help implementing an energy efficient system; that would help a lot.
8134	I think we can help with the knowledge of the technologies to say to a particular client "This would make sense for your building" and show them the benefits of it and the costs in relation to that.

Appendix EPaper presented at the 2003 Conference for the Engineering Doctorate in Environmental Technology

The design of an anaerobic digester for reducing the environmental impact of a zoo building

R. Cooke[1,2], A. Cripps[1], and M. Kolokotroni[2]

1. **Buro Happold Consulting Engineers**
2. **Mechanical Engineering Department, Brunel University**

Abstract

The use of energy in buildings has major environmental impacts, as most of this energy originates from fossil fuels. The use of renewable energy in buildings can reduce these impacts. Anaerobic digestion of biomass material generated within the built environment provides a source of renewable energy, reduces wastes and produces a useful natural fertiliser. Biomass material is usually in plentiful supply in the built environment, typically in the form of organic wastes, and this is certainly the case in a zoo; where these wastes commonly provide a disposal problem.

Anaerobic digestion was considered as a possible technology option for a new pachyderm house being designed for a prominent zoo in Northern Europe. This building is to house 9 Asian elephants and aims to provide an educational resource for visitors whilst being environmentally sustainable in operation. There are a number of complex design factors associated with anaerobic digestion, that add to project time and financial costs, not least understanding the nature of the organic waste being input.

Approximately 350kg of elephant residue will be produced each day, with a moisture content of 80 % and a volatile solids (VS) content of 15%. From mixing with water and heating at mesophilic temperatures (36°C) in the digester for a period of 20 days each 350kg of virgin dung would provide about 6.8m^3 of methane capable of providing 2.05kW of net useful energy. This energy output is quite small, due to the fibrous nature of the input material. However, there are other benefits to this technology, such as converting a waste material into a useful liquid fertiliser. The costs and revenues from anaerobic digestion are difficult to predict without further analysis, though other studies have shown financial paybacks as low as four years.

Keywords: Buildings; Building design; Environmental impact, Renewable energy; Anaerobic digestion; Biomass.

1.0 Introduction

In the UK buildings are responsible for around 45% of primary energy use, which is primarily from environmentally damaging fossil and nuclear fuels. There is increasing pressure to reduce the environmental impact of buildings and one of the main solutions is to harness renewable forms of energy, such as solar, wind and biomass. This may lead to buildings generating a proportion of their own energy in the form of power and/or heat from local natural means (renewable embedded generation).

A major disadvantage for integrating renewable forms of energy into buildings is the lack of sufficient knowledge of these systems amongst building designers, in particular to inform early stage decisions. There may also be real barriers in terms of size, cost and maintenance. However, renewable energy technologies can offer long term cost savings and overall improvements in terms of sustainability. Through practical assessments it is the aim of this research to develop core design information along with a rationalized design methodology to help break down the barriers of design presently facing building consultants. This will help them to provide fast, accurate and reliable advice to clients whose buildings may be suitable for harnessing renewable energy.

Copenhagen zoo was founded in 1859 and in 1914 the existing elephant house was built, reflecting the concept in pachyderm houses of the time. By 2002 the number of elephants had increased to 9 and it was felt that a new elephant house was required to meet the needs of the animals and the operational staff. Over 1 million people visit the zoo each year and it serves as an important cultural and educational centre in the city. The aims of the new development are to respect the landscape and cultural history of the zoo, consider the social cohesion, management and welfare of the elephants and meet operational and environmental requirements of the future. Teamed with this the zoo issued an environmental programme; this one-page document highlighted the desire to be environmentally sustainable in the operation and construction of the new enclosure and to be of educational benefit to its visitors. This emphasis on minimising operational environmental impacts and increasing awareness gave a clear impetus for assessing the potential for using embedded renewable energy technologies.

2.0 Renewable energy design process

This paper describes the design process that was followed for selecting an appropriate renewable energy technology for the Copenhagen elephant house project, leading to a concept scheme design report. With reference to the Royal Institute of British Architects plan of work, figure 1., the objective was to complete a design report that would carry the project from stage C through to the completion of stage D. Another design team local to Copenhagen would then develop the early concepts through to detail design, tender, construction and operation.

a Project awareness	b Client development	A Inception	B Feasibility	C Outline proposals	D Scheme design	E Detail design	F Production information	G Bills of quantities	H Tender action
Pre-brief		**Briefing**		**Concept design**		**Detail design**			

Fig. 1. The Royal Institute of British Architects plan of work, showing the different design stages in a construction project through to tender, adapted from Standing [1].

Upon selecting the appropriate technology/ies worthy of analysis the following information is formulated for inclusion in the concept scheme design report:

- Basic technology description
- Technology characteristics
- System schematics
- General parameters of use
- Rule of thumb cost and size data
- Barriers to implementation
- Advantages of use
- Reference to case studies and previous examples

Ideally a number of different options would be considered at this design stage but due to time constraints and a lack of previous experience only one option could be selected for analysis. This selection depended on site characteristics, such as readily available heat and power through a district energy network and the clients' desire for environmental sustainability and education. The available embedded renewable energy options were wind power, solar power, solar hot water and biomass fuels. From this list biomass was chosen as the most appropriate option, due to the significant amount of wet and dry organic wastes generated at the zoo, client enthusiasm and the clear potential for environmental, educational and operational benefits.

3.0 Biomass

Biomass can be defined as recent organic matter originally derived from plants or animals, which can be used as a store of chemical energy to provide heat, electricity or transport fuel. Biomass fuels occur in many forms and variations. They can be separated into grown crops and waste products, and between dry solid and liquid (wet) consistency. Due to the different forms and sources of bio fuels the most suitable technologies for utilising them varies significantly between each project; with some of the process options relevant to this project shown in Fig. 2. Due to its adaptability and availability biomass is seen as holding massive potential for the replacement of fossil fuels but there is a requirement throughout Europe for the generation of a positive demand to force forward increased development [2], which this EngD project intends to assist.

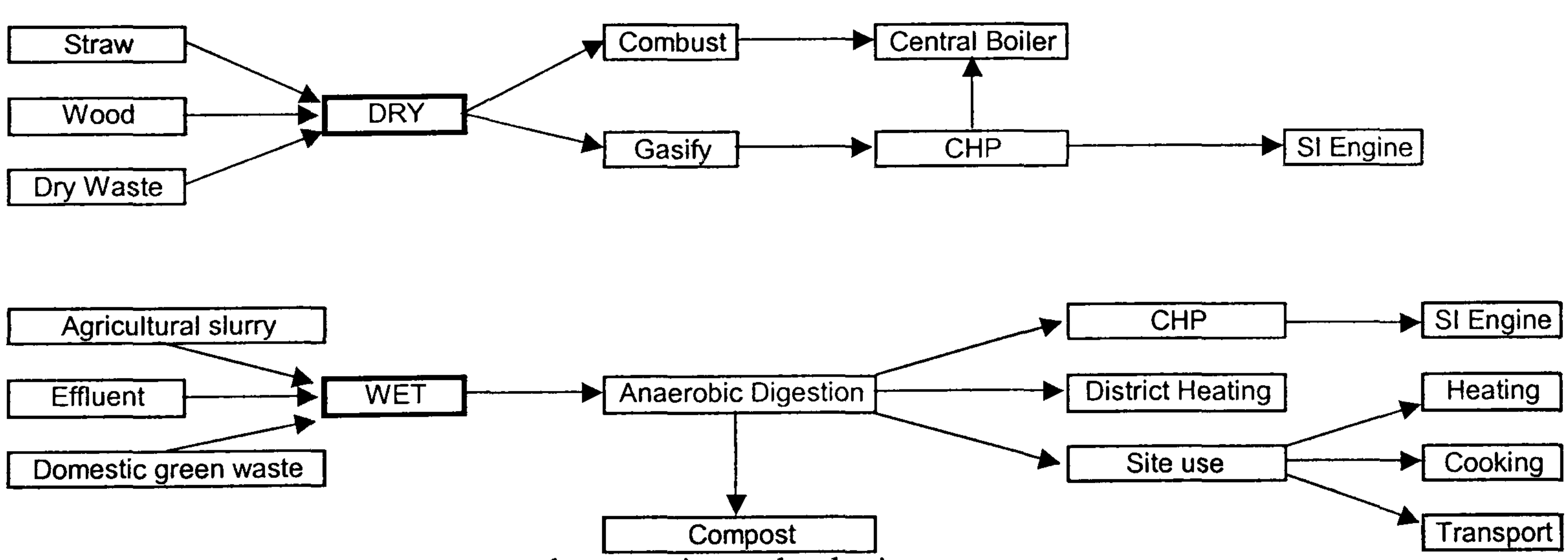

Fig. 2. Various biomass sources and conversion technologies.

For Copenhagen zoo the choice of biomass technology would depend on the moisture content of the fuel; for dry fuel direct combustion or gasification may be appropriate, whereas an input of wet biomass would require an anaerobic digestion process. Dry biomass could be in the form of waste wood and paper or from local wood crops, and wet biomass could be the diluted organic wastes from animals and visitors. In this case the use of anaerobic digestion is considered to be more suitable for the following reasons:

- Use of waste animal dung, which is readily available and would normally have to be transported away for disposal.

- The ability to sell liquid outputs to local farmers and recycle plant nutrients around the food chain, rather than burning them and using artificial fertilisers.
- It provides a renewable source of energy in the form of biogas.
- Helps to educate visitors by replicating a technique commonly used in rural Asia that maximises the practical and environmental benefits of a potential hazard.

4.0 Anaerobic digestion

Anaerobic digestion (AD) is 'the use of microbial organisms, in the absence of oxygen, for the stabilisation of organic materials by conversion to methane and inorganic products including carbon dioxide" [3]. This process occurs naturally within the stomachs of animals, particularly ruminants, though in this case on a much larger scale in heated, sealed vessels. The most common form of anaerobic digester is the continuous flow stirred tank reactor, which provides a continuous flow of gas and digestate whilst being fed with raw slurry from a holding tank. There are also batch systems and more complex continuous systems available but due to a lack of consistent information and a need for simplicity at this stage these are not considered in analysis.

However, there are a number of potential problems associated with the use of AD such as:

- The time and resources required for design
- High capital costs compared with traditional alternatives
- The need for process and storage space
- The need for a regular supply and demand
- Maintaining a consistent and controlled slurry input.

Due to the presence of animal waste handling and disposal at the zoo, a regular supply of material and an enthusiastic client the problems listed above are not as significant as with many commercial developments. However, they must be acknowledged within the design wherever relevant so that potential pitfalls in design and operation can be avoided.

The proposed anaerobic digestion plant should be integrated into the new enclosure and the zoo as a whole, the potential for this in operational terms is shown below in Fig. 3. It is clear from this schematic how the biogas plant fits both with the zoo environment and on the larger environmental scale, with natural resources and nutrients being harnessed and recycled wherever possible. This block diagram simply shows the anaerobic digester as a single unit, and on a small-scale this may well be the case but the material inputs will pass through a number of process stages. Firstly the mixed wastes are macerated and then pumped to a holding tank before being pasteurised to remove harmful pathogens. The liquid slurry then enters large digestion tanks regulated at 36°C where bacteria break down the volatile solids fraction to form biogas and leave a nutrient-rich digestate that can be used to replace fertilisers. The biogas is then cleaned before being stored alongside the digestate, where they await use.

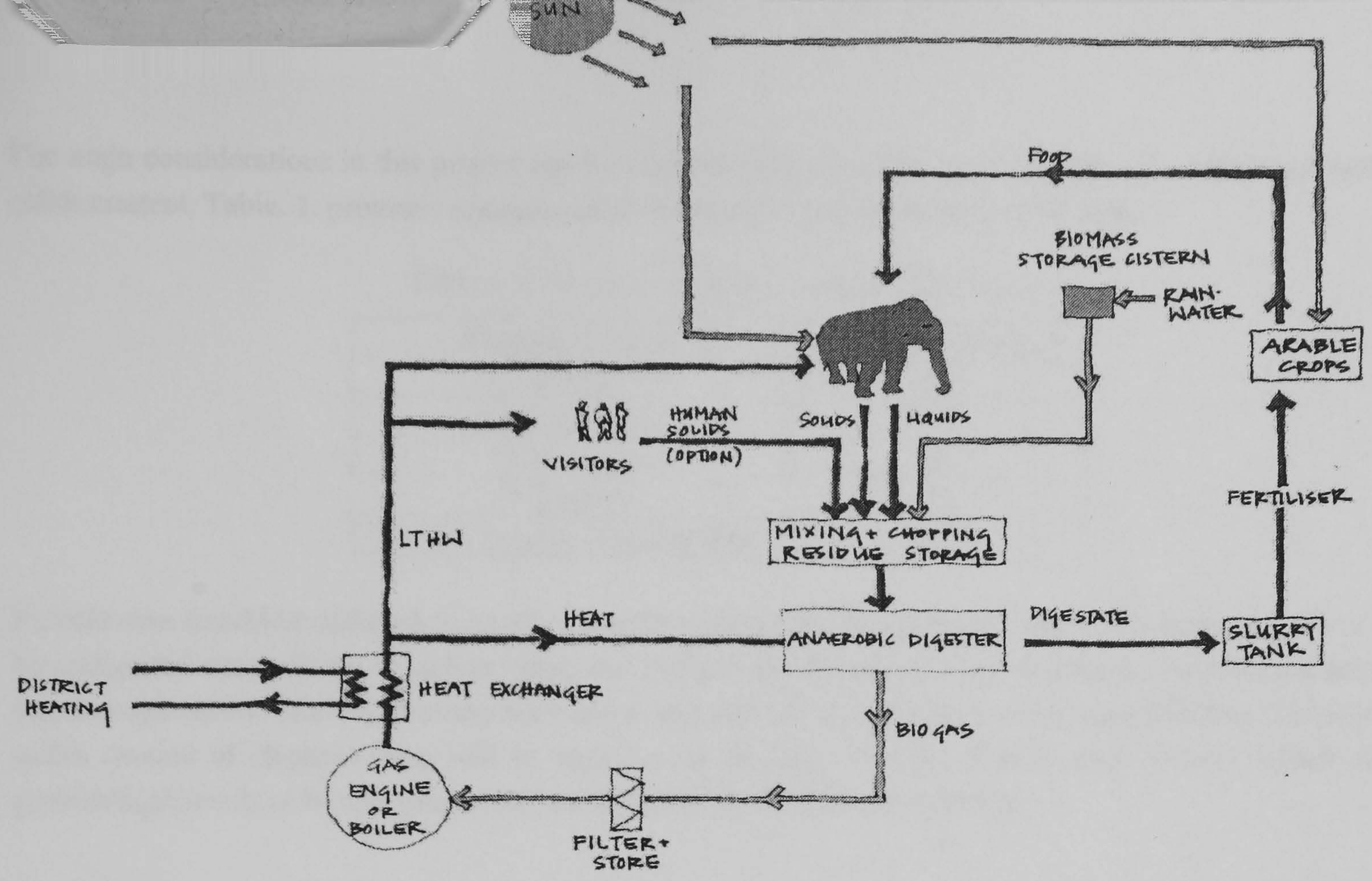

Fig. 3. Copenhagen elephant house, biogas plant schematic

With an AD operating under the correct conditions it will generate around 0.2-0.4m^3 of biogas per kg of total solids, with a calorific value of 20-25MJ/m^3, consisting of approximately 65% methane, 30% Carbon dioxide and some nitrogen (N_2), hydrogen sulphide (H_2S) and other products of digestion such as ammonia [4].

These optimum conditions are not always possible or simple to maintain and operation of an AD plant is affected by many different factors, including:

- Feedstock volumes and characteristics,
- Biogas production rates,
- Seasonal variations,
- Demand for fertiliser (digestate),
- Gas quality,
- Material handling, and
- Digester design.

In this case the regulating factor is the feedstock availability and digestion characteristics. Based on these elements the digester should be designed to be simple and reliable in operation, of sound financial value and generating as much gas and digestate as practically viable within a compact design. The most critical aspect of the system is the welfare of the digestion bacteria. Typically these operate at mesophilic temperatures around 35°C and are able to digest a high proportion of the volatile solids within a period of 20 days, generating biogas and a homogenous, inert fertiliser. Some of the major influences on bacteria performance apart from temperature are listed as follows, with ideal conditions given in parenthesis:

- Carbon/Nitrogen ratio (20-30),
- Acidity (pH 6.8 – 7.2),
- Particle size (minimum)
- Moisture content (4-10%)
- Lignin content (minimum)
- Volatile solids content (maximum)
- Loading rates (consistent).

It is also advisable to minimise the input of any foreign matter, such as sand, earth, oils, detergents and other chemicals to avoid harming the digestion process.

The main considerations in this project are the Carbon/Nitrogen (C/N) ratio, particle size, lignin and volatile solids content. Table. 1. provides examples of C/N ratios for various sources of biomass.

Table 1. C/N ratios of typical sources of biomass

Biomass Source	Carbon / Nitrogen
Wood	200+
Elephant dung	40
Food Scraps	30
Pig slurry	20
Human excreta / Poultry litter	10

Particle size should be reduced as much as possible when handling elephant waste, as a high proportion will be undigested straw. Straw is high in lignin and difficult for the bacteria to break down, but reducing particle size through maceration will increase the surface area and allow the bacteria to be more effective. The volatile solids content of elephant dung will be high due to the large amount of raw matter present, which could provide high levels of biogas generation if in a digestible form for the bacteria.

5.0 Results of analysis

The anaerobic digester was sized using an adapted model formulated by Harris [5]. This model estimates digester size and output for a small-scale continuous flow stirred tank reactor (CFSTR), based on a number of operating parameters. The parameters required are input rate, total solids (TS), proportion of volatile solids (VS), maximum methane yield (B_0), operating temperature, ambient temperature and retention time.

Four adult Asian elephants and five calves are estimated to generate around 50kg and 30kg a day/elephant respectively, hence 350kg per day in total. The carbon/nitrogen ratio of elephant dung is typically around 43, as elephants have a very inefficient digestion system so excrete a large proportion of the carbonaceous vegetation that they consume. The moisture content of elephant dung will depend on health, diet and climate but is usually around 28-25% dry matter when fresh [6]. In laboratory trials Klasson [7] obtained detailed properties for Asian elephant dung within a zoo environment, which were then used in this analysis, as follows:

B_0 = 0.2 litres CH_4/kg_{VS}; Total solids (TS) = 0.2 kg/kg_{slurry}; VS = 0.15 kg/kg_{slurry}.

To provide the optimum moisture content the elephant dung would be mixed with water, to give a TS content of around 10% and a VS content of 7.5%, this would approximately double the slurry input hence the daily throughput would be around 700kg. Assuming a dung density of 900kg/m^3 and a typical water density the volume of slurry would be around 0.74m^3/day; hence the proportion of VS is 71kg/m^3. Using these figures performance estimates were made and can be seen below under the title 'Mixture A' in Table. 2. Here it is calculated that from a daily input of 350kg of fresh elephant dung there is an average continuous net energy gain of around 2kW, hence 17.5MWh per year. This is not a substantial amount of energy and may restrict the economics of useful energy recovery. In such a case the main economic benefits must then surely come through reducing waste transport and disposal and the sale of digestate as fertiliser.

A significant reason for the low level of energy generation is the sub-optimum C/N ratio, which will restrict the methane generating bacteria, and hence gives a low B_0 value. To balance the C/N ratio the elephant dung could be mixed with an organic waste source rich in nitrogen, such as that from humans or birds. Such wastes should be easily available within the zoo and would significantly improve the output from a digester. Along with improving the C/N ratio the use of these wastes would also reduce the proportion of raw vegetation within the mixture. The original model was adapted to analyse an input of elephant dung mixed with human effluent, as opposed to rain water, to provide an appropriate C/N ratio and moisture content, assuming human effluent has a moisture content of around 5% [8]. The model outputs then depend on the value given for infinite methane yield, B_0, for which the actual values are unknown without the completion of physical trials, however they should be much improved due to better digestion characteristics. Based on figures from Harris [5], for various sources of biomass, approximate values were assumed generating results for 'Mixture B' and 'Mixture C' in Table 2., above. These calculations show that a small increase in throughput and by mixing wastes appropriately the net average energy output could be increased from 2kW to over 8kW, a significant improvement gained by potentially simple operational changes.

Table 2. Potential outputs from a CFSTR anaerobic digester fed with various slurry mixtures.

Daily waste input	Elephant kg	Human kg	Water kg	Total kg	Solids kg	TS %	VS %	Methane yield l/g VS
Mixture A	350	0	350	700	70	10%	7.5%	0.2
Mixture B	350	700	0	1050	105	10%	7.5%	0.303
Mixture C	350	700	0	1050	105	10%	7.5%	0.406

Process variables	Daily Effluent m3	Residence time days	Digester volume m3	Methane generation m3/day	Gross energy MJ/day	Gross energy kW	Net energy kW	Electrical energy kWe
Mixture A	0.74	20	14.78	6.8	265.2	3.07	2.05	0.51
Mixture B	1.17	20	23.33	16.2	631.8	7.31	5.85	1.46
Mixture C	1.17	20	23.33	21.7	846.3	9.80	8.34	2.08

The viability of anaerobic digestion will depend on the practicalities of operation as discussed above and also financial costs and benefits. Research throughout Europe has shown that construction costs of small-scale AD plant are inconsistent, ranging from 6,000 to 20,000 Euros per rated kW of electrical output. Along with these capital cost variations the potential operating costs and revenues can also differ greatly, hence having a significant effect on potential paybacks [9]. Capital cost variations are due to the use of different waste inputs, varying build standards, government intervention, levels of design complexities and factors such as construction labour rates and economies of scale affecting relative costs. Running costs meanwhile are affected by operation labour rates, the value of energy in different regions, waste disposal costs and the value of the organic fertilisers. For these reasons it is difficult and expensive at concept design to offer judgements stage on actual costs, revenues and financial paybacks. However, in consideration of the proposed outputs given in Table. 2., above, it is clear that financial viability cannot be assured based on the value of energy generated. To be financially viable there must be a significant advantage gained from reducing waste disposal costs and selling the digestate to local landowners. However Higham [9] considers that with the right local supply and demand infrastructure paybacks could be as low as four years.

6.0 Performance considerations

Some important considerations for the performance of an AD plant are particle size, quality and content of slurry input, operating temperature, the relationship between supply and demand and the value of the liquid digestate. This study has shown that the anaerobic digestion of elephant dung alone produces low levels of biogas, hence very little useful renewable energy. These estimates are highly dependant on results from laboratory tests on a small scale using elephant dung alone. Elephants have very inefficient digestion systems so their slurry is difficult for the bacteria to break down due to a high cellulose content restricting biogas production. The bacteria within the digestion tank rely on the organic solids for their food and will generate biogas and reproduce continually given the right conditions. So if this material can be macerated into smaller pieces and mixed with other, more suitable, organic wastes then the process will yield much higher rates of biogas, improving both the economics and practicalities of use.

The anaerobic digester model assumed a digestion temperature or 36°C (mesophilic), if this temperature were raised to 47°C (thermophilic) the digestion would occur at a faster rate, this would increase the daily biogas output and reduce digester size because of the shorter residence time required. However, operation at thermophilic temperatures is not so common because operating at higher temperatures increases the parasitic energy demand, removing the benefit of producing more biogas, and can also make the process unstable.

For practical application of an AD plant it is essential that there is a close relationship between the supply of slurry input and the demand for the digestion by-products, biogas and liquid fertiliser. At Copenhagen supply rates should be relatively consistent, therefore to avoid a build-up of raw wastes and unnecessary storage volumes it is essential to maintain a regular collection of liquid digestate and a practical use for the biogas. This would then reduce capital costs and plant space requirements by reducing the need for large storage vessels. The regular collection of digestate may involve the sale of products to visitors or through contractual obligations agreed with local land users or garden centres. However, the potential for such contracts requires consultation with local stakeholders and possible customers. Meanwhile the practical use of the biogas will require the design of dedicated biogas fuelled systems, or biogas cleaning systems that can provide pure methane for traditional catering, heating or transport use, to provide a consistent supply and demand relationship.

7.0 Conclusion

A major barrier to the consideration of renewable energy technologies in construction projects is the time and financial costs associated with overcoming the many uncertainties of design and operation. This paper has tried to break down and overcome some of these uncertainties to allow anaerobic digestion to be considered into the detailed design process. With this there are still many practical and financial uncertainties to be faced but a lot more is now known about the design of these systems, potential bonuses and pitfalls in design and the complexities associated with proposing an integrated waste and energy system. The aims of this paper were to examine the process required for designing an anaerobic digester, discuss the results of the system designed for Copenhagen elephant house, increase understanding of the design process and this innovative waste processing technology and to reduce the barriers to completing future designs.

There are clearly a number of operational benefits to be gained from the anaerobic digestion of elephant dung, including:

- The generation of biogas,
- reducing the transport and disposal of organic wastes,
- providing a continuous revenue stream from the sale of process products, and
- reducing the environmental impacts of the zoo in an educational manner, in line with design objectives.

When fed with around 350kg of elephant dung diluted with water into a slurry an AD plant operating under mesophilic temperatures would produce 6.8m^3 of methane each day in the form of biogas, providing a continuous net energy benefit of 2.05kW. There would also be a reduction in the waste exported and the generation of around 0.7m^3 of liquid fertiliser each day. To improve anaerobic digester performance it is recommended that the elephant dung be mixed with other organic wastes to improve the digestion characteristics. When combined with human effluent in theory the methane output could more than double and the average net energy output increase to between 5.8 and 8.4kW, depending on the exact mixture. Again there would be a reduction in waste and the production of up to 1.1m^3 of useful liquid fertiliser each day, which could be sold locally to replace the use of artificial fertilisers. However, to prove viable more detailed analysis is required of these different options, involving local stakeholders such as zookeepers, AD system suppliers, consultants and potential local consumers of the digestion products.

8.0 Future work

Further technical analysis of the AD process using various organic wastes is required for more reliable size and performance estimations. This may include scientific testing of the different waste streams and further research into practical trials completed elsewhere. Along with technical considerations social and financial analysis are also required to progress toward a detailed design specification, this may include social research involving various stakeholders, the assessment of available grant funding, environmental impact assessments and more detailed financial modelling.

In general it is necessary to follow-up the progress of this project and understand the reasons for success or failure, including understanding stakeholder perceptions. There must also be a continuation of the knowledge gained through this project in future projects. With this knowledge the early stages of design can be completed faster and more accurately allowing more time to focus on obtaining accurate financial, practical and environmental information.

Acknowledgement

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Appendix F Paper presented at the 2005 Conference for the Engineering Doctorate in Environmental Technology

An investigation of barriers to the integration of alternative energy technologies into building design

R.S. Cooke[1,2], A.J Cripps[1] and M. Kolokotroni[2]

1. **Buro Happold Consulting Engineers**, 17 Newman Street, London, W1T 1PD

2. **Brunel University, Department of Mechanical Engineering**, Uxbridge, Middlesex, UB8 3PH

Abstract

The use of energy in buildings has major environmental impacts, as most of this energy originates from fossil or nuclear fuels. Integration of alternative energy technologies in buildings can reduce these impacts, though there are a number of barriers to doing so.

In the selection of energy technologies in building projects, it is widely assumed that financial and engineering aspects are the most important factors. This paper presents the results of in-depth discussions with building stakeholders that highlight the importance of various drivers and barriers to the integration of alternative energy technologies in building projects. It was found that non-monetary and non-technical factors such as lack of experience, information and structured approaches are also important barriers. The building industry, and in particular building consultants have a key role to play in reducing these barriers through informing colleagues and clients in a more open and specific manner.

Keywords: Buildings; Building design; Renewable energy; Interviews; Decision making.

1.0 Introduction

Buildings have a large impact on the global environment and building designers and owners play a significant role in shaping present and future environmental impacts [1]. It has been estimated that 45.2% of the total UK energy consumption is from use within buildings [2] generating around 46% of the UK's CO_2 emissions [3]. In 2000 98.7% of the energy supplied in the UK was from fossil fuel or nuclear sources [4]. To meet the UK governments' aspiration for a 60% reduction in CO2 emissions by 2050 [5] buildings need to reduce their reliance on non-renewable energy. One possible method for doing this is to integrate alternative energy technologies into building designs.

The definition of alternative energy technologies used here is the provision of energy within the built environment through non-traditional, but technically proven means. It refers to local 'embedded generation' technologies which are either based on 'new' (i.e. not commonplace) more efficient methods or from a renewable resource. This excludes passive design techniques that seek to reduce demand rather than provide energy, large-scale offshore technologies such as wave power, established technologies such as nuclear power and blue-sky technologies. However, it does include the use of Combined Heat and Power (CHP) systems because they improve the efficiency of electricity generation through utilising the heat produced as a by-product. Whilst CHP is not a new concept it is still not commonplace in the UK, with only 1136 units operational in commercial, public sector and residential buildings in the year 2000 [4].

Therefore alternative energy technologies are in this research considered synonymous to 'new and renewable' energy technologies and defined as: solar photovoltaic, solar thermal collector, wind turbine, micro-hydro, ground source heat pump, biomass energy and combined heat and power (CHP) systems.

Though there are clearly drivers for the consideration of these technologies in building projects there are also a number of barriers. These aspects need to be defined and further understood to allow the building industry to shift the emphasis from the barriers to the drivers, and improve the level of implementation.

2.0 Methodology

A study into industry opinions and experiences has been conducted to investigate the drivers and barriers to using alternative energy technologies in building projects and understand how the non-technical constraints could be reduced. There is an increasing interest in such studies because they facilitate market penetration. For example, another study focussing on the use of energy-efficiency measures in UK universities has been conducted [6].

The research process was designed with reference to Oppenheim [7], Bouma and Atkinson [8] and to a previous study within the construction industry by Poole [9]. Focus groups were used initially to help develop a set of interview questions that could then be used in a succession of personal interviews. The advantage of using focus groups is that they encourage interaction among the respondents and allow people to change their opinions after discussion with others [10]. However, the use of interviews provides advantages in the detailed stage of the study in terms of organisation, cost and data analysis while maintaining human interaction.

2.1 Preliminary work

From the initial focus group, held with 6 senior building industry professionals with experience of these technologies, a list of key drivers and barriers was produced, as detailed in Table 1.

DRIVERS	BARRIERS
Subsidies	Design fee
Image	Proximity to resource
Planning	Cost (High capital and slow payback)
Environment, e.g. Climate change	Climate (variable)
Long-term economics	Ignorance and lack of understanding
Lack of infrastructure	Perceived risk
Politics	Stubbornness of energy industry
Corporate social responsibility	Incoherent policy and planning constraints
Need to save plant space	Unsuitable site
	Maintenance
	Complexity
	Unproven
	Lead time in construction
	Environmental and ecological impacts
	Lack of communication and common language

Table 1 Drivers and Barriers to integrating new and renewable energy technologies into building projects.

It can be seen (from Table 1) that some of the drivers and barriers are financial, (i.e. subsidies, cost, etc.) and others are technical, (i.e. plant space, maintenance, etc). Beyond these there are also human considerations and aspects related to the design process. These other aspects are influenced by the project team members, and thus are affected by the involvement and approach of the building consultant.

It is noticeable that more barriers (15) were listed than drivers (9). This may indicate that there is an imbalance between drivers and barriers, in favour of the latter. If this were so then it would seem to fit with present practice in light of the low proportion of buildings constructed that embrace alternative energy technologies.

2.2 Interviews

Interviews were held with 41 building project stakeholders, representing 8 stakeholder groups (Architects, Building Services Engineers, Clients, Consultants, Planners, Quantity Surveyors, Suppliers & Contractors), between October 2003 and May 2004. The interviewees had varying levels of experience of considering alternative energy technologies and hailed from a variety of backgrounds. However it is not possible to assume this is a cross-section of the industry. Therefore it is not the aim of this research to make general assumptions that the views expressed are representative of the whole industry, but only to make distinctions within the sample used.

The basis of the questions used are as follows:

1. What technologies do you consider are covered by the heading 'new and renewable energy technologies'?

2. From the definition used for the purposes of this research please indicate at which stage you have considered these technologies in building projects.

3. How much of a part does the consideration of these technologies have to play in building projects? How does this compare with other aspects of the design?

4. Based on your experience, what have been the drivers for using these technologies?

5. Based on your experience, what are the main barriers for using these technologies?

6. In the building design process how are the negative and positive aspects of these technologies considered and compared?

7. In the selection of energy technologies how are quantifiable factors compared against some of the less tangible factors?

8. How can the building industry help to improve the effective implementation of these technologies?

The interview questions were designed to:

- Understand their perspective of what constitutes new and renewable energy technologies.

- Assess their experience of projects where they have been considered.

- Challenge whether the consideration of alternative energy technologies is an important part of building projects and affirm whether there is any justification for assessing these technologies in detail.

- Understand the major drivers and barriers to using alternative energy technologies in building projects. This judgement is used to justify whether existing methods or other decision making approaches would reflect these drivers and barriers more adequately.

- Allow reflection of which areas can be influenced by the work of the building consultant, and so help to focus future study.

- Investigate the methods used in for addressing drivers and barriers and making system selections in practice. This should reflect on the limitations of existing analysis methods/decision approaches and indicate the extent to which various techniques are being used.

- Ask: 'how can the building consultant best influence the drivers and barriers to using alternative energy technologies, if at all'. This allows earlier points to be revisited and expanded upon and should help summarise whether or not it is worth the building consultant trying to influence the decision making approaches being used, or if another route is more worthwhile.

The results from these questions were analysed in detail, where "Data analysis is the process of bringing order, structure, and meaning to the mass of collected data. Qualitative data analysis is a search for general statements about relationships among categories of data; it builds grounded theory." [11].

2.3 Questions 4 and 5

In this paper, there is not sufficient space to present all of the study findings in detail. Therefore only the results of analysis of questions 4 and 5 have been selected to be presented and discussed. These two questions address the importance of drivers and barriers to the integration of alternative energy technologies in building projects and present a coherent set of findings. These results are key because the results will influence the conclusions drawn from the other questions asked.

Questions 4 and 5 are both closed and quantitative questions. For these questions the participants were given a list of the drivers and barriers, as in Table 1, and asked to provide a score out of 10 for each. The use of a 10 point scale has been used to try to allow for some of the variation in experiences between participants where a 10 could represent a mark of always very important and 1 never important at all. Medium scores may be used to represent very important infrequently, or always of some importance.

Not all of the participants provided scores for all of the categories. The first 3 participants did not offer scores due to the initial question being in an open, qualitative format. One other participant refused to give answers in number format and three did not provide answers for every one of the headings.

3.0 Results

This paper constitutes the first stage of analysis of these interviews. From the analysis of each of the questions a number of broad findings were observed. These findings are as follows:

- There is a lack of consistent understanding of alternative energy technologies in the building industry.
- There is little use of structured methodologies for assessing these technologies and for openly communicating each stakeholder's perceptions of pro's and con's.
- The level of experience of considering alternative energy technologies is variable.
- The consideration of these technologies is not a key aspect within the design of most standard buildings, though is becoming increasingly important.
- The main drivers and barriers to considering these technologies vary depending on a number of project-related factors.
- In addition to government intervention, changes in client demands and technical innovation building consultants are a vital component for improving the level of implementation of these technologies.

This section focuses on a detailed presentation of results focussed on Questions 4 and 5, covering the various drivers and barriers to building integration. The mean scores for the drivers and barriers are represented in Figures 1 and 2.

3.1 Drivers

Figure 1 shows that there is no single outstanding driver for the use of these technologies, but that there are 5 headings that stand out as consistently more important. These are: Long-term economics, Subsidies, Image, Environment and Corporate Social Responsibility (CSR). The first two of these are financial aspects, whereas the other three leading drivers are largely qualitative, personal factors dependent on the 'values' of the client.

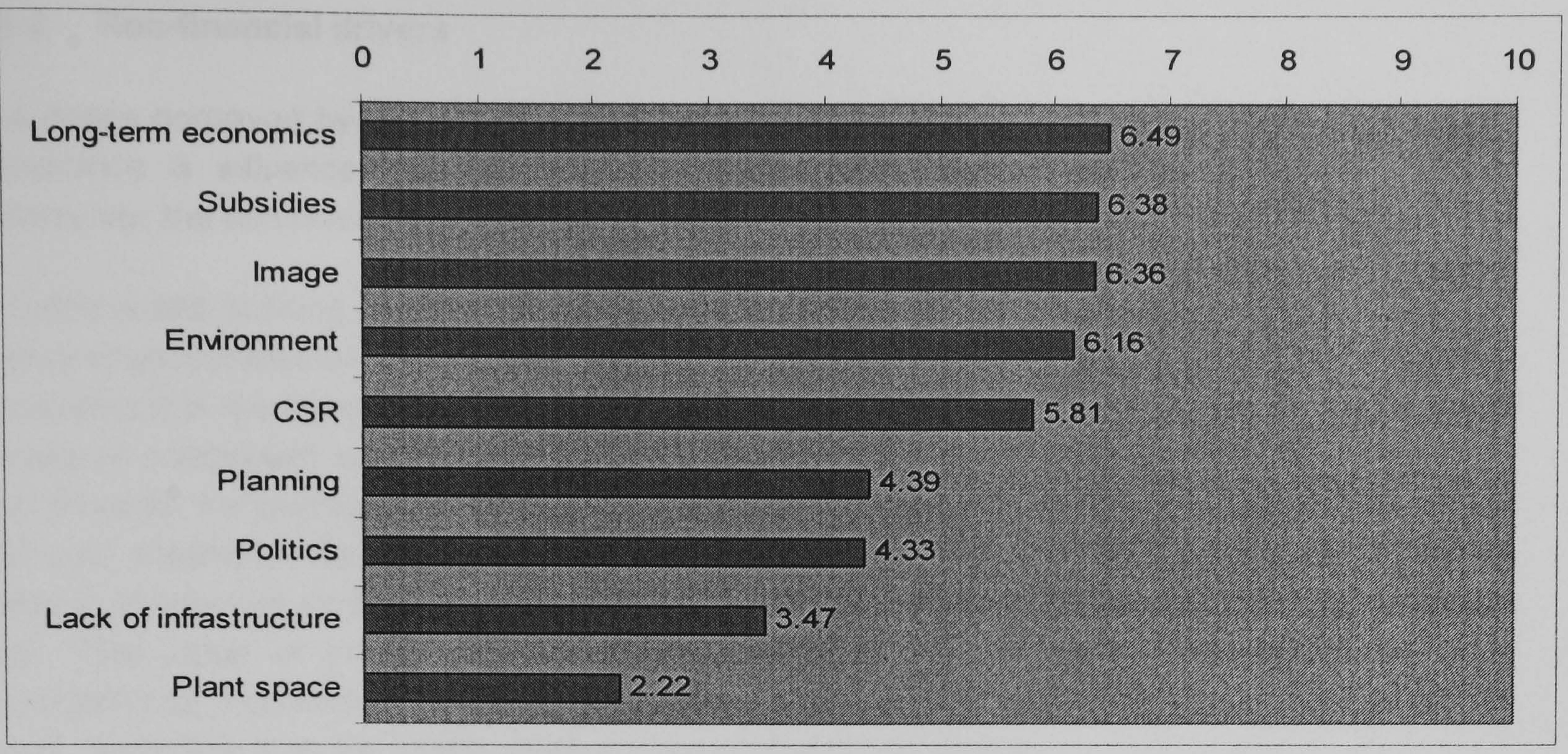

Figure 1 Mean score attributed to drivers for alternative energy technologies

3.1.1 Financial drivers

The importance of subsidies is heavily dependent on the nature of the client and the technologies being considered. For instance a large proportion of the government funding in the UK is applicable only to public sector or not-for-profit organisations. Awareness of the subsidies and being able to obtain them within the time constraints of a building project may also prove to be a restriction to the assistance they provide. It seems that if subsidies were equally available to all building projects and provided in a simple and timely manner then they would score more highly as a driver for these technologies. There are many quirks, inconsistencies and variables in the design and construction of a building; that the pursuit of subsidies adds to this reduces their appeal.

Long term economics are seen as a significant driver as these technologies tend to incur higher capital cost and lower operational costs than traditional systems. The reasoning behind it not being rated higher may be that the long-term savings are not sufficient, they are not considered important and they are difficult to predict due to uncertainties over future markets and performance.

Each of the alternative energy technologies offer different levels of economic viability, which varies between projects, for instance in some cases ground source heat pump systems are no more expensive than traditional systems whereas it is not uncommon for a solar photovoltaic system to have a financial payback in excess of 50 years.

Long-term savings are not seen as a benefit to many building developers, especially speculative commercial developers; who do not always pay the operational costs:

Architect 4 – *"These drivers are more important to owner-occupiers, in London most are speculative developers not occupying the buildings."*

Financial costs and returns are generally seen to be tangible numbers; however with these technologies there is not a lot of case experience in the industry to be able to closely predict capital costs or future performance. There are also a large number of variables that can affect future performance, such as changes in building use, and also future financial returns, such as oil, gas and electricity prices.

3.1.2 Non-financial drivers

The image portrayed by using these technologies is an important driver for their use. The level of importance is influenced by the type of building project, role of the client/developer in the community, the perceived value, trends in the industry and future changes in public awareness.

A highly public building, such as a school, or an organisation that may have a high profile and a history of environmental performance, such as an oil company, may see greater benefit in showing commitment in the form of the visible use of alternative forms of energy. In comparison a small service or component supplier may see less benefit unless there was direct customer pressure to act. However the perceived value that this improved image might bring is very difficult to quantify, and may depend on the personal perspective of the client. It is very difficult to provide a tangible value to image and so it is hard to compare it against a more quantifiable aspect such as capital cost. This value of image may also change in time. For instance if other schools, office developments, industrial competitors, etc. begin to implement these technologies due to changes in public perception then the image value may become a primary factor.

Image has strong parallels with two other drivers that are also score in the top 5 of the results, Environmental benefits and Corporate Social Responsibility. Both of these aspects could be the determining reason behind an image improvement. A key factor that limits the importance of these as a driver is the difficulty in measuring tangible benefit. Social and environmental benefits are difficult to bound and measure, though there are some scoring methodologies that can allow for comparison, such as BREEAM [12] and ExternE [13]. The value attributed to these factors is dependent on the level of accurate information and expertise available and on the needs and desires of the client.

3.2 Barriers

The results from Figure 2 show that the importance of barriers varies depending on a number of factors which include: client values, project location and the technology being considered.

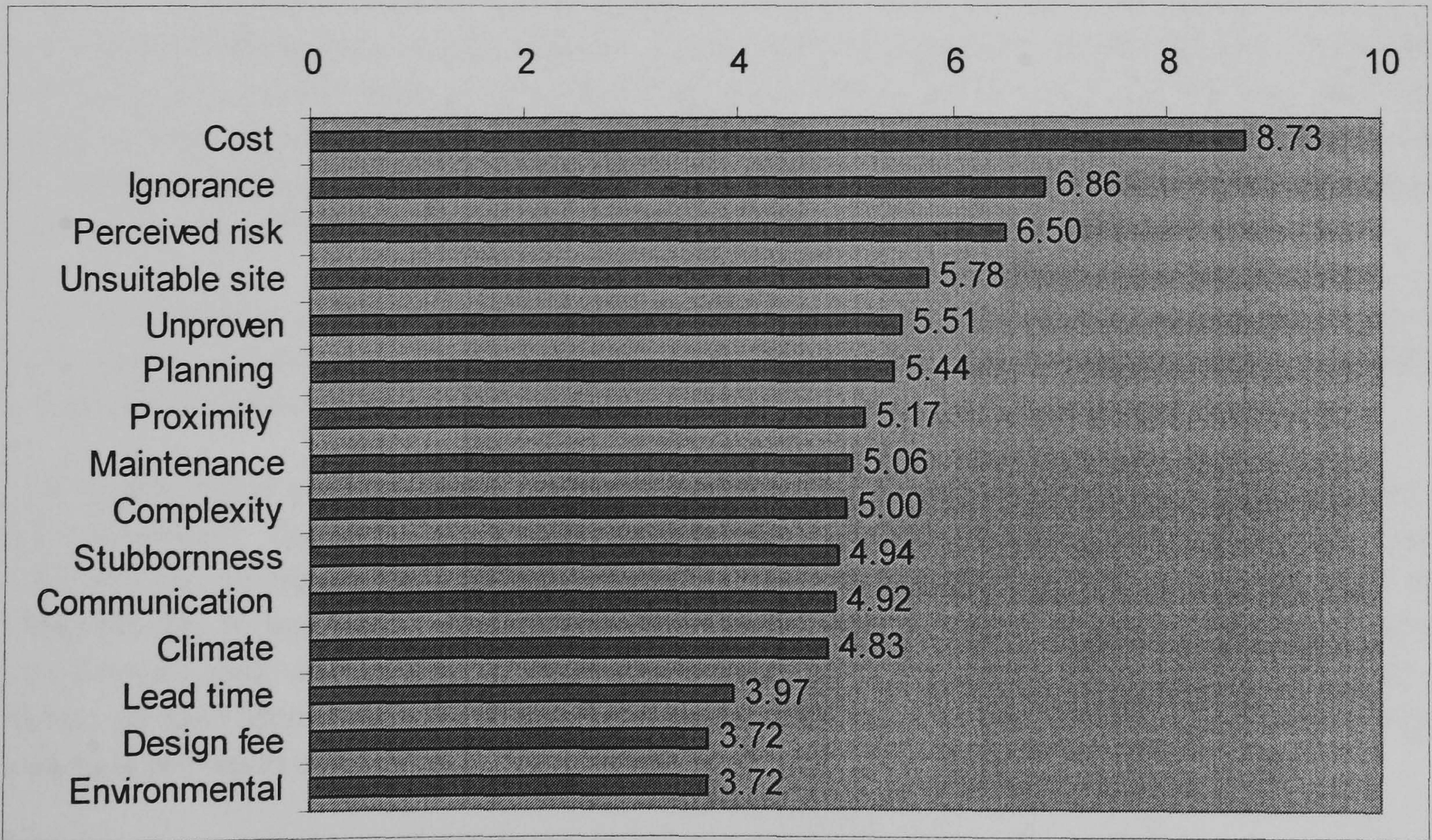

Figure 2 Mean score attributed to barriers for alternative energy technologies

3.2.1 Financial barriers

These results suggest that there is one single outstanding barrier for the use of these technologies, the additional capital cost compared with traditional technologies. That this is seen as the main barrier is of no surprise, it is also the most common form of judgement used for assessing these technologies.

In commercial developments the required payback times can be very short, and often only minimum capital cost is seen as reasonable. Public sector projects are also very limited by capital cost, though they may have desires and policies for the consideration of long-term economics. This is because all projects are subject to limited budgets and there are always pressures to keep costs to a minimum. Even outstanding environmentally-conscious projects such as 'The Eden Project' in the UK did not include alternative forms of energy in the initial construction, though some have been added in later phases.

3.2.2 Non-financial barriers

In the present economic status the alternative energy technologies will not be available at a lower capital cost than traditional options, other than in special cases. To have a chance of being used, the many benefits brought by these technologies need to be considered as opposed to just short-term, direct financial returns. However, the measurement and communication of these benefits is not as easy, reliable or well known as the measurement of simple payback. This is reflected in some of the other barriers that scored highly in the interviews, in particular: 'Ignorance and lack of understanding', 'Perceived risk' and 'Unproven'. These are social factors and highly dependent on the project team, their knowledge and experiences.

The social factors are variable between projects, dependent on the project team members. They are also very difficult to measure and compare between projects. When trying to understand the main barriers to using a technology it is easier to relate to cost figures but very difficult to show, for instance, that the client perceived the risk too great, the consultant felt uncertain about their use due to a lack of experience or the architect was unaware of relevant case studies. It is only possible to compare project personnel to spot a cautious client, an inexperienced consultant or a naïve architect through having experienced a large number of projects. Another problem is that the personnel in a project team, their understanding and the approach they use will vary between projects, and even during a project. If there was a reliable and consistent source of information and an accepted approach that allowed the team to voice and break down concerns then these social barriers may not be as influential.

Two other barriers that received high average scores are 'Unsuitable site' and 'Incoherent policy and planning constraints'. These are site-specific technical and political factors that are normally outside of the control of the project team.

The technical and political issues are site specific, so variable in terms of their importance as a potential barrier. They are two aspects that are very difficult to influence from within the project team, but can be crucial to the potential for using alternative energy technologies. It is important for these barriers to be recognised at a very early stage, this then prevents the team from spending unnecessary time considering technologies that will not prove viable. For instance if there is a history of opposition to wind turbines or if the wind regime is not suitable then the option of wind energy is not worth considering.

Compared with the drivers listed these points are much less about client 'values' and more about perception and the availability of reliable information. Some quotations articulate this further:

Client 5 – *"I do think people have always done it one way and don't want to change."*

Planner 4 – *"The clients don't know in the long term if the government will put the necessary fiscal policies in place. One of the real problems in planning terms is there's no one coherent strategy for renewable energy."*

It is clear that not all projects have the same drivers and barriers associated with them, indeed it was suggested that each technology will be affected differently by the various factors, for instance:

Client 1 – *"Proximity depends on the project."*

Consultant 2 – *"Planning most appropriate for wind."*

Supplier 2 – *"Building suitability, lack of summer load in schools,"*

4.0 Discussion

The results from questions 4 and 5 are very important. They demonstrate that the factors affecting the viability of the integration of these technologies into buildings are diverse and large in number. The opinions and experiences of the application of these technologies are varied. There is a hierarchy of importance, in which cost is at the top of but that other non-monetary and non-technical factors are also important to recognise and address.

It is essential for further development that the barriers are minimised and drivers are exploited as far as possible. The exploitation of drivers is reliant on a better understanding and effective modes of communication of the potential benefits. These drivers are based on estimations of future markets and performance, and on human values. Reducing the impact of barriers is reliant on technical developments, political decisions and influencing human perception within the project team.

The use of alternative energy technologies is not solely in the hands of the technology developers or the governments who are supporting their use. Buildings are responsible for a large proportion of energy use in the UK, they play a fundamental part in our lives and can indirectly influence the way we live outside of buildings. The building consultant has significant influence over understanding, communication and human perception of these technologies; so for a technology to be integrated into a building it needs to be supported and understood by the building consultant, and this support reiterated to the client.

5.0 Conclusions

There are clear drivers for increasing the use of alternative energy technologies in buildings within the UK, not least the environmental benefits they offer. However, to date there has been a very low level of deployment except for within demonstration or exemplar projects.

The initial rationale for completing this investigation was the hypothesis that: The use of a multiple criteria decision making approach (by the building consultant) would improve the likelihood of integrating alternative energy technologies in building projects.

From the analysis of the interviews to-date a number of insights can be made:

- The potential for using alternative energy technologies is heavily influenced by the client, project constraints/drivers and the design team used. The knowledge and understanding of alternative energy technologies is not a consistent one. There is limited experience of applying these technologies through to construction.

- Initial assessments are primarily made based on capital cost. Cost is the most significant barrier to the use of these technologies, whilst long-term economics are a significant driver for alternative energy technologies.

- Beyond the capital cost and technical constraints that cannot be influenced through the role of the consulting engineer there are other significant barriers such as ignorance, a perceived risk and a perception that these technologies are unproven.

- Building professionals need to be more educated and enthusiastic, to use detailed case study information and use more informed 'life cycle' approaches to decision making.

In general it is clear that there are a large number of barriers to using alternative energy technologies. Of these the non-technical and non-monetary barriers play a large part. This suggests that an informed multiple-criteria decision making approach, taking into account qualitative and quantitative factors, may improve the chances of alternative energy technologies being used in building projects.

The next stage of the research project is to present the findings from the other questions asked in this study, develop these findings into a final report and expand on these findings through further research. This will investigate the different approaches used in practice for a number of selected building projects and evaluate whether there's a link between specific project influences and the stage of design to which alternative energy technologies are considered (i.e. a measure of their success).

Acknowledgement

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Eden Project Biomass Energy Crop Feasibility Study

R. Cooke[1,2], A. Cripps[1], and M. Kolokotroni[2]

[1] Buro Happold Consulting Engineers, London, UK
[2] Mechanical Engineering Department, Brunel University, Uxbridge, UK

A biomass feasibility study has been completed for The Eden Project in Cornwall, England. The aims of this study are to investigate the feasibility of using energy crops as an alternative energy source, replacing the need for fossil-fuelled energy systems whilst providing assistance to the local agricultural economy.
The supply of Short Rotation Coppice, miscanthus and local forestry wastes are shown to be viable for the scheme. Each of these sources could be grown or sourced locally, providing economic, practical and environmental benefits to Eden and the local community over the long term. The most appropriate energy system is a 300kW wood-chip boiler providing the base load site hot water requirement all year round. The development of a mixed biomass fuel supply, based at first on local forestry wastes, with energy crops input over time once they have been established, is recommended. This provides support for, the development of a quality wood fuel supply infrastructure and a secure supply route for locally grown energy crops. However, there are a number of issues with integrating the biomass boiler within the existing site that still need to be overcome.

Keywords: Buildings; Building design; Environmental impact, Renewable energy; Biomass.

1. INTRODUCTION

1.1 Biomass

Biomass can be defined as recent organic matter originally derived from plants or animals, which can be used as a store of chemical energy to provide heat, electricity or transport fuels [1]. The sources of biomass considered in this study encompass cultivated energy crops and woodfuel from forestry cuttings and wood processing. With energy crops limited to willow and poplar short rotation coppice (SRC) and miscanthus (elephant grass). Such crops can be seen to provide the following benefits [2, 3]:

- Use of agricultural land set aside;
- Improvement to the use of agricultural land;
- Help to the rural economy;
- Provide local environmental benefits and local amenity;
- Provide landscape variety and a habitat for many species of plants, birds and wildlife.

Biomass is a renewable fuel and a valuable method of supporting a local rural economy. Because of these benefits the UK government has committed support to using biomass in many ways including the schemes listed in figure 1.

- The Energy Crops Scheme (ECS)
- CAP reform
- Woodland Grant Scheme
- Clear skies
- Community Energy Programme
- Bio-Energy Capital Grants Scheme
- Bio-Energy Infrastructure Scheme
- Renewables Obligation Order

Figure 1: Government support for biomass fuels [4]

1.2 The Eden Project

The Eden Project is a highly successful and educational visitor attraction within the South West of England designed to promote the understanding and responsible management of the vital relationship between plants, people and resources leading to a sustainable future for all.

Due to the position of Eden there is an opportunity for presenting biomass as a viable, local and environmentally friendly source of energy that helps support local economies and improve agricultural biodiversity.

Presently, the energy needs of The Eden Project are met by centralised natural gas-fired boiler plant and power purchased from a 'green' electricity supplier. The Eden project is being developed to include a new education and resource centre. Under the role of building services consultant Buro Happold were asked to advise on the potential for generating renewable energy on-site as part of on-going development work.

An initial renewable energy analysis including consideration of solar photovoltaics, solar thermal collectors, wind power, geothermal energy and biomass sources was completed. On the basis of this a more detailed feasibility study into the potential use of local biomass fuels was carried out.

This study covered the feasibility of delivering biomass energy to provide an important part of the energy needs of the Eden Project. It considered the infrastructure and equipment needed to grow, harvest and burn biomass, and the nature of interactions with suppliers, the community and the environment that a biomass system would require.

This paper reports, briefly, the key findings of the study.

2. OBJECTIVES

The primary objective of this feasibility study was to compare the various biomass fuel options with other modes of energy production. These options included variations in source type, harvesting, storage, supply, procurement and combustion. Through considering these variations the most appropriate options were selected and then evaluated in terms of practical viability, environmental impacts and life-cycle financial issues.

The aims of the study included the

- Identification of potential energy demands
- Estimation of the supply of biomass required to meet these loads
- Estimation of the cost, size and location of plant and storage facilities
- Consideration of production and delivery aspects
- Investigation into the potential for growing biomass energy crops in the local vicinity
- Consideration of supply security and operational costs
- Production of a written report recommending the solutions to meet the client need.

3. STUDY PROGRESS

The approach to the feasibility study included the following areas of focus:

- Background Information
- Energy demand assessment
- Biomass and system options
- Skills and Training
- Environmental assessment
- Financial assessment
- Procurement and Risk
- Recommendations

Each of these topics are addressed briefly below and then key points expanded upon in section 4.

3.1 Background Information

Along with a consideration of key literature this part of the study also encompassed a review of UK case studies, relevant legislation and meetings with relevant local organisations.

The case studies reviewed included the ARBRE scheme and the biomass heating system at Worcestershire County Hall.

The most relevant legislation to the project is The Clean Air Act (1993), regulated by the local authority. The Act stipulates that a detailed submission be made to the local authority on the anticipated performance of the plant and its operation and maintenance procedures. The local authority, on application, will advise the emissions limits for grit and dust under the Act.

The industrial contacts made included groups such as the Cornwall Sustainable Energy Partnership, English Nature and the Forestry Commission. Contact was also made with research bodies and biomass practitioners. These contacts provided useful leads, information and advice that helped to shape and direct the feasibility study.

3.2 Energy demand assessment

The energy demand study was concerned mostly with the heat energy and the daily profile of the magnitude, frequency and duration of the demand. In order to obtain reliable results a detailed analysis was undertaken including the review of installed plant commissioning figures and energy bills. This was compared with the computer modelling of existing and future buildings and an air leakage test of the biomes completed by colleagues in Buro Happold.

3.3 Biomass and system options

This included a review of the potential sources of biomass, a land assessment, and a review of the different harvesting, chipping, storage, transport and combustion technologies/combinations available. This study was informed by the background information generated and through the work of A Russell [5].

Some details of the sources and land assessment are given in the assessment section of this paper. The more descriptive notes on harvesting, chipping, storage transport and combustion are not included apart from where they have informed the environmental or financial analysis.

3.4 Skills and Training

The training requirements for each stage of the energy delivery process were considered along with the availability of these skills in a region such as Cornwall; compiled with assistance from A Russell [5]. This section is not detailed further in this paper.

3.5 Environmental assessment

A diagrammatical breakdown of each of the stages of a biomass system, from preparation of soil through to combustion, was produced. Estimates for environmental impacts were then generated based on the background information generated. These environmental considerations included:

- Energy use
- Wildlife impact
- Fertiliser and pesticide usage
- Water resources
- Carbon capture
- Soil erosion
- Bioremediation
- Noise
- Air emissions
- Transport

This paper does not cover all of these considerations further but outlines the main conclusions that can be drawn from considering the ratio between energy inputs and outputs.

3.6 Financial assessment

The approach used for the financial assessment was based on the biomass system breakdown used for the environmental assessment. It follows a life-cycle approach to economic analysis starting with establishment costs and considering the costs of harvest and maintenance for a 15 year period. These are broken into two parts here, firstly establishment costs and secondly annual operating costs.

In general, studies focussed on the agricultural sector primarily consider the financial aspects of farming energy crops alone. Meanwhile biomass energy studies commonly assume a fuel value and perform a cost analysis of the supply of heat/power.

This study attempts to follow through the complete process and recognise the sensitive aspects of the analysis that will affect the financial viability of the supply of heat to Eden. It is important to do this in the recognition that for the project to be successful it must be viable for all parties throughout its life. The client wishes to see the fuel supplier achieving a viable business, whilst they receive an appropriately priced fuel.

3.7 Procurement and Risk

Building upon the financial model the study of procurement looked at the different management approaches common in the operation of biomass schemes. This was followed by a description of the different establishment and operational risks that could impact on the viability of a biomass energy system at Eden.

3.8 Recommendations

The final section of the feasibility study provided a series of recommendations based on the research completed and details of possible next steps.

4. ASSESSMENT OF RESULTS

4.1 Energy demand assessment

The results of detailed analysis demonstrated that there is good reason to recommend a 300kW boiler.

Heat is presently provided by three 3MW rated natural gas-fired boilers. Analysis has shown that the present peak site demand, combined with estimates for the new developments, is in the region of 2.3MW. The base load, domestic hot water, is around 2MWh per day, which, based on a 8 hour day, equates to around 250kW. Thermal simulation showed that for around 5500 hours per year the site heat demand was less than 300kW.

The heating loads at Eden are dependent on two factors, the number of visitors and the external environment. The main exhibition buildings need to be maintained at constant temperature and so demand heat over night and throughout the winter. They demand very little heat between April and October. The other buildings, including the new education centre require heat in the daytime, for winter heating and for domestic hot water (proportional to visitor numbers). The peak in visitor numbers from April to October provides a daily base load all year round. Effectively then a 300kW boiler would operate on average at full load for 10 hours of every day, delivering around 1100MWh of heat.

The efficiency of a 3MW boiler operating at a load factor of less than 10% load is very poor. The installation of a small, 300kW lead boiler would allow the 3MW boilers to be shut down for around 5500 hours per year, and so would greatly increase the system efficiency by reducing standing losses.

4.2 Biomass and system options

A 300 kW biomass boiler operating at full load for 10 hours per day would generate around 1100 MWh a year. Assuming a combustion efficiency of 80% this equates to a fuel energy input of approximately 1370 MWh. Using net calorific values of 18.326 MJ/kg for SRC and woodfuel, and 17.68 MJ/kg for miscanthus [6], a supply of 270 and 280 oven dry tonnes (odt), respectively, of fuel per year would be required.

Assuming a conservative yield of 10 odt/ha/year for SRC and 14 odt/ha/year for miscanthus, and a processing loss factor of 1.1 it is possible to estimate the amount of land required for using energy crops. This equates to around 30 hectares for SRC and 22 hectares for Miscanthus.

Assuming a delivered bulk density of woodfuel, with a moisture content (m.c.) of 30%, of around 200 kg/m3 it has been estimated that around 2000 m^3 of delivered woodchip would be required. The Forestry Commission have indicated that around $7m^3$ of woodfuel at 30% m.c. is available per hectare of sustainably managed forestry. Hence around 320 hectares of managed forestry would be required.

Cornwall covers approximately 355,000 ha, within this approximately 76% of the land is agricultural and 8% woodland [7]. A desk top resource assessment was carried out for the area within a 20 km radius of The Eden Project [8]. This study, using GIS data, showed that more than sufficient annual yields from energy crops were possible from a 5km radius, and from existing forestry within a 10 km radius (assuming a resource of 2 odt/ha). In total a potential yield of 55,000 odt/year is achievable within 20km of The Eden Project based on only 5% of the available land being utilised for energy crops. This local availability minimises the need for transport and may remove the need for a central woodchip store.

4.3 Environmental assessment

One of the main environmental considerations for growing energy crops is the energy ratio of useful energy out to energy input in growing and processing the fuel. An example of energy ratios for different crops is given in Table I.

Table I: Energy ratios for a range of UK crops [9]

Crop	*Energy in (MJ/ha)*	*Energy out (MJ/ha)*	*Ratio*
Miscanthus	9,223	300,000	32.53
Willow	6,003	180,000	29.99
Hemp	13,298	112,500	8.46
Wheat	21,465	189,338	8.82
HEA Rape	19,390	72,000	3.76

In comparison with these estimates Bullard and Metcalfe [10] have carried out a detailed energy analysis for the phases of growing and processing of Miscanthus. In this they estimate the energy ratio to be approximately 36 units of output to every unit of energy input. They also show a breakdown of their figures, indicating that the application of pesticides and the harvesting of the crop represent the most important factors in terms of energy.

Other representative figures need to be sought for the other crops if possible, though obviously the best results would come from a site-specific analysis.

4.4 Financial assessment

In the review of potential costs and revenues throughout the life of a biomass project there are a number of variables that will influence the overall balance sheet. It is critically important to recognise these variables, to understand their significance and to understand their limitations.

The variables noted in this study include:

- biomass yield,
- availability of existing machinery/infrastructure,
- transport distance,
- moisture content of delivered biomass,
- The chopping method used,
- fertiliser use,
- storage and delivery methods.

Of the cost estimates available in the literature it is not always clear what assumptions have been made and how they can be affected by market or system variations. In particular there needs to be clarity in costing as to:

- In what form the fuel is delivered (in the round or chipped)?
- How dry the fuel is when delivered?
- Where and by whom the fuel is to be stored?
- Who is transporting the fuel to the combustion plant, and how far?

The 15-year cost assessment conducted is considered here in two parts, starting with establishment costs.

Establishment costs

The establishment costs are made up of ground preparation, planting, fencing and the purchase of biomass conditioning and combustion systems.

Preparing the ground for planting is described as being similar to that for any arable crop. The requirements for nutrients are limited, but will clearly depend on the condition of the particular land. Here there is an allowance for additional fertiliser of £50/ha. Standard practice seems to presume that herbicide will be applied to suppress weeds. The alternative will be to weed mechanically, and this is likely to be more expensive, but in keeping with the desire for low-impact-farming has been included with an estimated cost of £100/ha.

Other costs per hectare for SRC establishment were estimated based on figures given by Nix [11] and by Walsh & Brown [12], as follows:

Cultivations (ploughing)	£70
Planting	£200
Plants	£800
Cut back after year 1	£35
Fencing	£170

These combine to give a total establishment cost of SRC of £1425 per Ha. With the £1000/ha ECS establishment grant from DEFRA [4] this then equates to £425/ha.

Other costs per hectare for miscanthus establishment were estimated based on figures from Nix [11] and by MAFF [13], as follows:

Miscanthus rhizomes are slightly more expensive than willow saplings, but there is not the same need for fencing, which results in a similar establishment cost of around £1500. Estimates from other sources vary from £1300 to £1750 per Ha, with the price of planting material the main variable. With the £920/ha ECS establishment grant from DEFRA [4] this then equates to £580/ha.

It is assumed that the use of woodfuel from managed forestry would incur no such establishment costs.

The construction costs for the boiler plant, handling equipment and necessary local storage facility have been estimated at £65,000. These costs do not account for the construction of an annual drying store because of the assumption that such storage facilities are available to existing local wood supply contractors. They are also only a broad estimate and could vary considerably depending on factors such as system selection, final site location, and logistics.

Recurring costs

The second part of the assessment considers the recurring costs, over the life of the project. These are the most important costs to be considered as a crop may last for over 15 years. They are also subject to the most variation due to natural changes over time and to differences in approach/scope between researchers.

Recurring costs are made up of harvesting, storage, transport, and land maintenance and ownership costs. The costs of these vary greatly, one example being those for SRC harvesting costs, with quotes from £180 [12] to £350 [11]. In this case it is unlikely they are comparing like with like, and this is common within the literature.

Based on the literature [11, 12, 13] and the case study material our estimates of the main costs per hectare are:

Item	SRC	Miscanthus
Harvesting	£250	£150
Storing	£150	£50
Transport	£200	£70
Weed control	£70	£70
Top up fertiliser	£50	£0
Total	£720	£330

It should be noted in these that the costs for SRC are higher, but this reflects the larger quantities of material cut each harvest, and they are only incurred every third year.

Costs for storage and transport are linked to the options taken for how the fuel is dried, and what form it is delivered in. These will vary between schemes, as will the costs for weed control and fertiliser, which will be affected by soil quality. Other land costs will be incurred in terms of land rental and management, assumed to be around £150/ha/yr, of which £31/ha can be offset by the annual set-aside payment for energy crops [11], equalling an additional cost of £119/ha/year.

Other recurring costs are the general operation, maintenance and servicing of conditioning, storage and combustion plant. The servicing costs are assumed to be £250 per service, with a quarterly service required for biomass boilers compared with the bi-annual service for natural gas boiler plant. There is also an assumed £250 annual cost for spares compared with £150 for the natural gas system [5].

Table II below summarises the establishment costs, recurring annual 'fuel supply' costs and boiler operation costs. It also provides a comparison with the cost of using the present 3 MW rated gas boilers for meeting the annual base heat load over a 15-year period.

Table II: A comparison of 15-year costs for the existing Natural Gas system, and a 300 kW biomass boiler fed with 30% m.c. woodchip either from locally grown SRC supplied at cost or woodfuel supplied at £30/tonne.

	Gas	*SRC*	*Woodfuel*
Capital			
Establish	£0	£12,572	£0
Boiler	£0	£65,000	£65,000
Total	£0	£77,572	£65,000
Annual			
Harvest		£7,099	£8,874
Land use		£3,520	
Transport		£2,958	£2,958
Fuel	£27,375	£13,577	£11,832
Operation	£650	£1,250	£1,250
15 yr cost	£420,375	£299,980	£261,230
£/MWh	£25.59	£18.26	£15.90
Savings	£0	£120,395	£159,145
NPV		£58,301	£88,838

The fuel costs for the existing 3 x 3 MW boiler plant are based on the assumption that when supplying heat at a rate less than 300kW the thermal efficiency is much reduced. In this case the assumption is that efficiency could be as low as 50% (based on standing losses of 4% of maximum rating), a very low value. The price for natural gas is assumed constant at 1.25p/kWh, inclusive of the 0.15p/kWh Climate Change Levy.

It should be clear that in short term economic terms, the cheapest option will be to continue to use the existing gas boilers. This table does not take into account any changes in fuel price, price of labour, transport, storage or any other factor involved. The results do show that woodfuel sold in the rounds for £30/tonne could provide cost savings in the long term, whilst the energy crops also provide a life cost saving through annual savings of over £10,000 per year. In operational terms a biomass system can be cheaper to run, as long as the price of the biomass does not exceed a key value – currently around £45 per tonne based on the assumptions used here. Though the Net Present Value (NPV) calculation, assuming a discount factor of 6%, shows a smaller benefit for the biomass options in real cost terms. This is due to the initial capital costs.

From the calculations made the difference in efficiencies between the existing and new proposed system seems to be the most crucial factor of all the costs. From altering the efficiencies within a spreadsheet the paybacks change greatly. The same effect is felt if the load factor is altered, and so these figures need to be considered further.

Table III compares the cost of the proposed biomass energy system with other forms of alternative technology. From this chart is clear that the 15 year life costs of running a biomass system is cheaper than the other options. The estimates for the solar thermal collector are based on an installed cost of £500/m^2, minimal running costs and a useful output of 500kWh/m^2/year. The estimates for the Ground Source Heat Pump (GSHP) system are based on an installed cost of £1000/kW rated output, an electricity price of 3.5p/kWh and a Coefficient of Performance of 3.5. The costs quoted for the biomass system are inclusive of financial support for energy crops (apart from where forestry is considered). There may also be capital funding support available from DEFRA [4] for the biomass system up to 50% of installed cost.

Table III: A comparison of 15-year costs for providing 1100MWh of heat/year by solar thermal collectors, a Ground Source Heat Pump and a 300kW biomass boiler.

Technology	Capital	Annual	15year
Solar thermal	£1,100	£1	£1,115
GSHP	£300	£11	£465
SRC	£78	£15	£300
Woodfuel	£65	£13	£261

In the long term it is likely that the unit costs and overall cost effectiveness of biomass will improve. At present the handling systems and process for biomass are new and the efficiency and productively will undoubtedly improve as further experiences are gained. There may also be the possibility that natural gas prices and taxation levels on fossil fuels will increase within the near future, improving the viability of renewable fuels such as biomass further.

5. KEY FINDINGS

In principle biomass can be considered to be financially viable for the Eden Project. However there are particular circumstances of the site and other developments that have restricted implementation to-date.

The capital costs and space requirements are the most significant barriers to implementation. This is primarily due to additional costs and difficulties incurred through trying to retrofit the system into the existing infrastructure.

This study suggests that there is little net financial difference between the three forms of Energy crop, willow and poplar SRC or miscanthus. However the costs and yields used are dependent on a large number of assumptions, so there may be another outcome under different circumstances.

It is important to have a detailed understanding of energy loads; this reduces uncertainty and allows unique opportunities to be investigated.

6. CONCLUSIONS

The recommendation was for a 300 kW biomass boiler to be installed as the lead boiler in conjunction with the existing site heating system, to meet the year round base load. This would provide a useful source of renewable energy, improve site operational efficiency, provide educational benefits and help to establish the first stages of a biomass supply infrastructure.

Any of three options for Biomass fuel considered here are viable, namely:

- Short Rotation Coppice (SRC)
- Miscanthus
- Woodfuel

It is likely that woodfuel would be the cheapest option, but using this alone would miss the opportunity to demonstrate the possibilities for agriculture of the other options. From this it was recommended that Eden take forward a plan to develop a mixed fuel supply covering all three fuels.

A crucial factor of this system proving economic is the load factor of the 300kW wood boiler when compared to the load factor of the existing three 3MW boilers in place. The Eden site load is below 300kW for over 60% of the year and from this it has been assumed that the gas boiler efficiency is very poor, allowing a small biomass-fired boiler to benefit from the advantage of higher efficiencies.

In the short-term, it is hard to justify a switch to a biomass system on economic grounds. The capital outlay on a biomass system will take a long time to repay through the savings on fuel costs, particularly given that Eden have an established gas heating system.

However there are significant environmental benefits from using biomass, which are of particular relevance to The Eden Project. Thus the final report recommended that a biomass boiler be integrated into the present scheme to further demonstrate their environmental commitment and the viability of using biomass fuels in Cornwall.

On an economic level, the use of biomass will replace the cost of natural gas with a locally produced fuel, keeping resources within the local community. Further to this biomass requires maximum work outside of the normal peak farming seasons, helping to balance farm workloads.

Finally, there are a number of supply routes for biomass, in terms of biomass source, storage, drying, transport and procurement options. Development of a supply network at Eden would help provide a secure system that could be the basis for further local use. However, firstly there are barriers caused by the existing infrastructure that need be overcome. Prompting that further heating system designs need to be made flexible to the use of biomass for it to be a viable fuel source in the future.

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Appendix H Paper submitted to Building Research and Information 5th October 2005

Alternative energy technologies in buildings: stakeholder perceptions

Robert Cooke (Corresponding author),

Buro Happold Consulting Engineers, 17 Newman Street, London, W1T 1PD.

Brunel University, Uxbridge, Middlesex.

rob.cooke@burohappold.com

Dr Andrew Cripps,

Buro Happold Consulting Engineers, 17 Newman Street, London, W1T 1PD

andrew.cripps@burohappold.com

Prof Alan Irwin,

The University of Liverpool, Abercrombie Square, Liverpool, L69 7ZG

alan.irwin@liverpool.ac.uk

Dr Maria Kolokotroni,

Brunel University, Uxbridge, Middlesex, UB8 3PH

maria.kolokotroni@brunel.ac.uk

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Alternative energy technologies in buildings: stakeholder perceptions

Abstract

This paper explores the factors affecting the use of Alternative Energy Technologies (AET's) in buildings through the eyes of building project stakeholders. While there are many published lists of incentives and restrictions to using these technologies there are few reports of their impact in practical contexts. The paper reports on the results of a qualitative study of building project stakeholders in the UK – their experience of AET's, the factors that influence assessments and their views on how to improve the chances of using AET's in future projects. The large amount of variation in the importance of drivers and barriers to using AET's between projects is revealed. Despite this variation the emphasis for assessment methods is on financial concerns, largely ignoring more qualitative concerns. This lack of suitable assessment methodologies along with a lack of education, motivation and case-study information in the building industry are restricting the use of AET's in UK building projects.

Keywords: Building design; Renewable energy; Interviews; Decision making.

Glossary

AET's Alternative Energy Technologies

CHP Combined Heat and Power Systems

GSHP Ground Source Heat Pumps

PV Solar Photovoltaics

Introduction

Buildings have a large impact on the global environment and building designers and owners play a significant role in shaping present and future environmental impacts

(Bordass, 2001). The UK government has targets for reducing environmental impacts, including carbon emissions from the generation and use of energy, through the Energy White Paper (DTI, 2003). They have also applied a climate-change levy on carbon-emitting fuels and support the use of renewable energy through the Renewables Obligation. However despite this and other schemes carbon emissions in the UK rose by 1.5% in 2004, with energy consumption rising by 1% (DTI, 2005).

It has been estimated that 45.2% of the total UK energy consumption is from use within buildings (CIBSE, 1998) generating around 46% of the UK's CO2 emissions (ECD, 2001). At present renewable sources only provide around 1.7% of the UK's total primary energy requirements, with the remainder from fossil fuel or nuclear sources (DTI, 2005). To meet the UK government's aspiration for a 60% reduction in CO2 emissions by 2050 (DTI, 2003) buildings need to reduce their reliance on non-renewable energy. One possible method for doing this is to integrate alternative energy technologies (AET's), defined as renewable energy and CHP technologies, into building designs.

There are a number of significant actors in the building process, and each has a role that can influence the chances of using AET's. The present paper investigates the experiences of a range of stakeholders and their perceptions of what factors influence the chances of using AET's most often, what methods are used for assessment and what the building industry can do to help AET's become more commonplace.

Defining the problem

The increased use of embedded AET's is important because, amongst other drivers (REPP, 2001), they meet UK policies (DTI, 2003), and provide societal, economic, engineering and environmental benefits (Lovins et al., 2002; Elliott, 2003). However, in the UK this need is not being met and this paper looks at why AET's are not being used in building projects and how the building industry can help to rectify this.

The subject of installing AET's in buildings crosses a number of topic boundaries. These technologies and their application are discussed in publications covering the subjects of: green buildings, sustainable communities, sustainable construction, sustainable energy, renewable energy, energy efficiency, eco-design, local embedded generation, planning policy and energy policy. Hence there is a broad range of literature covering the subject of AET's and their role in providing more environmentally friendly buildings.

International research reflects the large and diverse number of barriers to AET's in different contexts:

- Lovins et al, (2002) discuss 207 barriers to distributed energy generation.
- In his framework for identifying and addressing barriers to using renewables in developing countries Painuly (2001) suggests 40 barrier elements within 7 categories.
- Maldonado and Marquez (1996) offer 4 main barrier categories related to use of renewables in Latin America: Market, Technological or R&D, Institutional and Socio-economic.
- Using their framework for analysing innovation, Foxon et al. (2005) consider the factors affecting renewable energy in the UK from the evidence of gaps in the innovation chain, listing 4 risk factors and 6 other barriers.

These barriers vary throughout the world, are site and situation specific (Shove, 1998). They also vary with each technology, and studies have been performed for bioenergy (Roos et al., 1999), CHP (Bourgeois et al., 2003) and Solar Photovoltaics (Oliver and Jackson, 1999). Political barriers and support approaches are covered in many cases (Charters, 2001), including the UK (Elliott, 2003).

Sustainable construction and the deployment of energy efficiency measures are covered in a number of cases (Lovins, 1996; Sorrell, 2003; Roos et al., 1999; Hawken et al., 1999), with important sustainable construction barriers including:

- The balance of incentives for designers favours inefficient buildings (Lovins, 1992).

- Dissemination of new knowledge, and adaptation of new approaches in UK construction is poor (Gann, 2003).
- More awareness of environmental impacts in building design is required (Bartlett and Howard, 2000).

Research into barriers to energy efficiency were reviewed by Weber (1997) and summarised as: market, institutional, organisational and behavioural barriers (including professional conservatism, uncertainty and risk).

Beyond defining barriers to using AET's in practice there are many approaches for overcoming them. Policy measures for reducing barriers are offered in a number of studies including Elliott (2003) and Lovins et al. (2002), however institutional support alone will not solve all the problems faced. Making technology choices for a building development is a social and highly contextual process (Shove, 1998), hence very much affected by the perceptions of project stakeholders and unique project characteristics. There is a need to be able to account for external (environmental, social and financial) costs and for improving the level of knowledge of technologies and their associated impacts/benefits (Roos, 1999; Charters, 2001; Elliott, 2003). Some of this research has shown that the design team, and a less fragmented, more integrated and informed design approach are crucial to success (Hawken et al., 1999; Cole, 2000) as design decisions strongly influence building in-use energy and environmental impacts (Andreu and Oreszczyn, 2004).

In the literature an array of technical, political and financial barriers to distributed generation and use of renewables are revealed. However, there has been no attempt to generate a perceived hierarchy of importance of drivers and barriers to using AET's in UK building projects. Also the significance of the role of the UK building industry in influencing the rate of implementation of AET's has yet to be fully explored.

Following the recommendation of Painuly (2001) that locally specific studies need to be conducted for informing the best approach to combating the barriers to renewables, this paper gives a stakeholder eye-view of values and conduct within the building industry. The descriptive findings highlight the large number of factors that affect the chances of AET's being deployed, the lack of experience and a lack of detailed approaches to options assessment. The paper concludes with a discussion of the implications for the building industry and particularly the role of the building consultant and their energy technology assessment strategy.

The research setting and sample

The study is a qualitative and partly quantitative investigation of building project stakeholders in the UK. It was conducted between October 2003 and May 2004 to explore the approaches used in assessing AET's and how actions and perceptions vary in the industry. 41 personal interviews were conducted in all with participants chosen because of previous experience of considering AET's in building projects.

The building design and construction process is very fragmented and there are a number of stakeholders influencing the process from a diverse range of backgrounds. 8 different stakeholder groups (as shown in table 1) were defined for this study and representatives from each group were contacted within the UK to help with investigating their experiences of considering AET's. In this paper each participant is represented by an alphanumeric to allow identification of quotes, for instance the term A3 represents the third architect. This range of participants was chosen to give a broad perspective of the issues from across the industry. Due to the small sample of each group it is not possible to show the differences in perspective between the disciplines.

Findings

The findings are clustered under six major themes:

1. The lack of education and experience of installing AET's in buildings within design teams;
2. How a variety of key factors affect their viability on each project;
3. The role of specific drivers and barriers;
4. The importance of capital cost as a major barrier and the principle factor in decision-making;
5. The low use of other assessment methods; and
6. The important role that building consultants can play.

The following sections develop these in turn.

1. Experience and education

Participants were chosen because of their previous experience of considering AET's in building projects. The process of finding people from each of the stakeholder groups with the relevant experience was very difficult and time-consuming. Even still, of the respondents interviewed, 14 had not been involved in a project where these technologies had been included at the construction stage. The participants have far more experience of considering technologies at concept stage than at construction, with a ratio of around 3 to 1. The consultants and planners interviewed had very low experience of AET's being constructed, whilst contractors had a very high level of experience and a high percentage of systems constructed of those considered at concept (this reflects on the project stage that these stakeholders are involved). There is also variation in experience between each of the technologies, with some respondents only experiencing one or two of the technologies in detail. The most common of the technologies to be included through to construction was CHP, with 14 respondents having experienced this technology in their projects.

Across the participants there was strong support for the case that ignorance in the construction industry is a problem and that further education and presentation of experiences are required. Of the 41 interviews only 9 of them didn't mention the lack of knowledge and information within the industry. Also in terms of the importance of barriers to using AET's in buildings 'Ignorance and lack of understanding' was rated highly, with a median score of 7 out of 10. Participants C2, C5 and T4 were the only ones to give a score of lower than 4/10.

When asked how the building industry can help to improve the chances of using AET's in building projects three responses in particular highlighted the present level of ignorance:

> A3 – "Exterminate the whole industry and start again! Education and training is a starter, for all aspects of the construction industry. Increasing the number in the design industry holding to environmental ideals. Architects and services engineers need to be up to speed and understand the benefits of these things."

> C3 – "Education is the key, somebody has to educate architects and consultants that these technologies are well worth considering openly without bias. Have met so many M&E consultants that are blinkered. Many opinions [are] raised when all they've done is read one article, need people to really understand what can be done. I've found it very difficult."

> S3 – "Wake up! The industry needs to start learning. There's not enough knowledge within the building profession. The methods of consideration and comparison are not mature; each project is a fresh start."

There was little suggestion of where this education should come from, though a few comments were made about the role of Universities, CPD training and the need for apprenticeship schemes. There was variation on the opinion of information availability, some of the responses commented on the lack of good quality information whilst others suggested that the information was there but not being accessed.

2. Key factors

The results of these interviews show that the relevance of AET's and the significance of each driver and barrier vary a great deal between projects and different people. This variation is due to a number of key factors such as project location, contract type, building type, the client type, client motivations, planning requirements, and the technologies being considered. Each of these are mentioned throughout the interviews and stem from the experiences of each of the participants in trying to apply AET's or similar technologies.

On top of this complexity, the interview responses have shown that AET's are not consistently considered as important factors in the design of a building. This level of importance is thought to be increasing and is highly dependent on client motivations and the particular constraints of projects. Regular reference was made to the importance of the client and their background; this was highlighted by 35 out of the 41 respondents.

Some of the answers suggest that the client holds the cards and it's entirely up to them.

> B3 – "Depends on the client group, it varies a lot. If talking to developer then all interest is economics, much less interested in green issues and other good things. Government clients able to be more flexible, willing to listen to more drivers and arguments."
>
> O2 – "Depends on the client, only important if the client wants to show some commitment to sustainability."
>
> T1 – "Generally they are driven by what the client wants in their brief. Unless the client wants them there is nothing you can do."

Other responses show that clients are influenced by past experiences and the advice of members of the project team.

B6 – "Unless they are informed clients they need to be convinced that these systems will work and will not have to be replaced with expensive traditional replacements after occupancy."

C3 – "From the clients point of view we ask them to consider renewables in the long term to save money and save the planet. On the negative side the consultant, contractor and architect say no because it makes the projects longer and more difficult, that's how they see it. Though it doesn't always prove that way in the end."

This shows that the likelihood of using AET's in building projects is often dependent on the type of client and their perspective on the importance of reducing environmental impacts. However, other project team members also have an obligation / opportunity to inform the client of the potential role that AET's could play and also influence their perspective on the worth of the environment. This is reflected in the client responses, which showed that they were disappointed by the level of understanding and commitment shown by the project team and particularly that of the engineering consultants.

This research cannot help to define the ideal combination of project and client type and other factors that would lead to the successful deployment of AET's in buildings. What it does show is that each assessment is not straightforward, there are a number of factors that will influence the viability of each technology. How the client and project team perceive cost and value is highly important, while project specific factors will affect the actual costs and value returned by each technology.

We have already seen that there is a lack of experience of considering AET's within the building industry. The differences between projects accentuates the impact of this and also make it essential that any judgement is based on the specific characteristics of each project.

3. Drivers and barriers

Along with defining drivers and barriers to using AET's in building projects this research has sought to rank them in terms of how important they have been in practice, and to see how this ranking can vary. To do this each of the participants reflected on their own project experience and gave a score (between 1 and 10) for each of a list of common drivers and barriers. The results of these scores are summarised by Figures 1 and 2, showing the maximum, minimum, interquartile ranges and median scores for each heading.

Based on the median scores, Figure 1 shows that the main reasons for using AET's in building projects are perceived to be: (a) long-term economic benefits, (b) the availability of subsidies, (c) image benefits, (d) the desire to reduce environmental impacts and (e) Corporate Social Responsibility (CSR). The first two of these are financial aspects, whereas the other three leading drivers are largely qualitative, personal factors dependent on the perceived 'values' of the client.

In the same manner, Figure 2 shows that the most common barriers to using AET's are perceived to be: (a) high capital costs and long payback times, (b) ignorance and a lack of understanding, (c) a perception of risk, (d) an unsuitable site, (e) a perception that AET's are unproven and (f) incoherent policy and planning constraints. Of these six most prominent barriers, three are social factors, two are project specific issues and one is a financial aspect.

This ranking of the headings is very loosely defined due to the large variation in scores attributed by each participant. As previously noted, there are a number of factors that influence the viability of AET's for each project in many different ways, including political, personal and practical issues. The drivers and barriers that varied the most between the experiences of respondents in this study are:

Drivers

- Planning constraints,

- Political drivers,
- Corporate Social Responsibility.

Barriers

- Proximity to the resource,
- Variable output from technologies,
- Unsuitable site,
- Stubbornness of the energy industry,
- Complexity,
- Ignorance and lack of understanding.

The variation between projects has led to a moderate median score for each of these headings, though individual perceptions were often less than moderate, with many headings attributed scores throughout the full range of 1 to 10. This shows that many of the barriers and drivers listed can have a deciding influence on the use of AET's, depending on the project. This variation is illustrated by the two following views on the impact of planning:

> A5 – "I have never met a situation where planning is a driver for renewables."
>
> T3 – "For us it's simple, the issue is we consider them where there is a driver upon [The contractor], such as from the land seller or planning authority when they would like us to look at these issues."

One notable exception to this rule is 'ignorance and lack of understanding' which, despite having a large inter-quartile range in Figure 2, has a high median score; this is because it received very few low scores, with all but 3 answers between 4 and 10. This again highlights that a lack of experience in the industry is a consistent and influential restriction to the use of AET's in building projects in the UK.

Figure 2 also shows that there is a perception that AET's provide an additional risk to building projects and that this is consistently a major factor in restricting their use, achieving a median score of 7 and a very small inter-quartile range. This perception is illustrated further by the following quotations:

> S5 – "Contractual barriers and a lack of awareness by the professionals, fear factor; it's easier to duck out of dealing with it rather than finding out. Their professional indemnity means that if they take it seriously they must investigate it as an option. Barriers are created by the contractors; in design and build projects there will be contractual implications for them and so they will try a lot to stop it from happening.

> T5 – "I would imagine there's a great element of risk taking these technologies on for 30 years as there is no benchmark out there. I gather there are not that many companies developing these technologies."

From the results we see that each driver and barrier considered in this study may not be of paramount importance for every project, but nearly every respondent had experienced them being crucial in the consideration of AET's in building projects at some point. Therefore any assessment method devised or used should be adaptable to the variations between projects, and should not focus on the same driver or barrier for every case.

4. The importance of economics

From these interviews the majority of the responses suggest that financial viability is considered to be the most important deciding factor in the selection of AET's in building projects. 'High capital costs and slow payback' are consistently rated as a highly important barrier to using AET's, shown in Figure 2. 'Long term economics' and 'Subsidies' also rank highly in the list of drivers shown in Figure 1. These high ratings reflect many of the answers to other questions in the interview process.

When asked to consider the best way of helping to increase the use of AET's in buildings 15 respondents were resolute that unless the technologies become cheaper and traditional energy supplies more expensive that AET's will not be deployed more frequently. For instance:

> C1 – "I think that the first thing is government. Only way to get payback down is push cost energy up and hardware down. The main thing is get payback down. Once it becomes normal they get their own momentum. Make it so attractive that people want to do it."

> Q3 "Most clients want to know about lowest capital cost and operating cost. No client has ever been interested just in energy innovation, they are always keen to get long term costs down. The only way to change the behaviour of clients is to force them, this could be done by the government forcing things to change. There needs to be penalties on the use of fuel."

Together with these strong views on the importance of financial viability there is also an indication that this is the main factor being used for comparison of technologies. Most of the respondents cited that in projects simple financial payback is the most common assessment methodology, with few responses mentioning methods for comparison of less tangible factors.

> Q4 – "Cost takes precedence because it can be quantified easily, it's easily understandable. Money is a common language."

> T4 – "All they count is money. They far out weigh the less tangible."

In terms of more detailed assessment methods there was some mention of the way we look at costs, with calls for more consideration of life cycle costing. However fewer than a third of participants referred to using life cycle costing in practice when considering AET's.

A5 – "[They are] concerned with basic economic equations, payback is the most significant discussion you have, and then what's the Life Cycle Costs of the system."

B2 – "Capital cost comparisons, primary. On top of that is payback (2nd), more critical than life cycle costs (3rd)."

5. Other assessment methods

The dominance of simple payback as a comparison method reflects on the lack of detail applied to the assessment of AET's in building projects. This leads to the main emphasis of this research. If indeed decisions 'all come down to cost' and high capital cost is the biggest single barrier then there is little that the building industry can do, leaving the emphasis on suppliers to lower prices and Governments to provide financial incentives. However, the results from these interviews show this is a naive view and that there is a complex array of drivers and barriers that vary in importance between stakeholders, technologies and projects. Due to these variations it is clearly not possible to simply assume a hierarchy of technologies to fit every project. This means that any assessment approach ought to be adaptable and backed up with sufficient information to allow for these natural project variations and inform what is a complex decision to make. Very few of the interviewees could mention having experience of techniques being applied that accommodated for this complexity. A problem emphasised by the large number of answers calling for new techniques to be developed and applied.

C5 – "In many cases this is part of the great problem that architects and engineers don't tend to take sustainable development seriously; it's always a fragmented approach. No overall building infrastructure approach. Needs to be built in from the start of the process rather than just looking at a few green alternatives."

P1 – "Need for planning tools and guidance. Need for an overview guide of technologies available that links through to the individual players in the decision process and back to the flow chart of critical things and when."

Q4 – "The majority of designs are focussed on payback periods and savings in the long run, nobody focuses really on other parts of the building and the other benefits of doing away with traditional systems."

Financial payback is an important consideration and a common factor in most cases. Meanwhile there are well-established means of financial assessment. However, no consistent, structured approaches are used in the assessment of AET's that take account of all the other reasons for and against using these technologies. The main considerations for decision making mentioned in the interviews were financial viability, practical risk and calculating carbon savings. Some assessment methods such as BREEAM or Ecohomes were mentioned, but these are general approaches that inform the overall building design process rather than acting as a method of technology selection. To accommodate factors such as risk many project teams made intuitive assessments or compared pro's and con's in the form of a report and presented this to the client.

A4 – "No formal format was used, matrices were used to compare different technologies, decisions were mostly intuitive."

B5 – "One can flag to the client the pro's and con's but then you must compare solely on words. Depends on the decision process used, we often use a scoring system which in a way is pseudo-quantification."

O2 – "Produce a written report that explains quantifiable and less tangible aspects. State factors for each technology and draw conclusions. No proper procedure. Present it to the client and they usually have a preference toward one technology."

In unravelling the role of drivers and barriers to using AET's and the techniques being used to assess their viability it's clear that the existing approaches to decision-making are primitive and ignore much of the complexity of the problem. The assessment approaches used do little to enhance the impact of drivers for AET's and to reduce the impact of barriers. There is little experience of using approaches that compare qualitative and quantitative considerations in an organised manner. In terms of comparing quantitative factors such as financial cost with less tangible factors the most common answer was that such a comparison had not been made, as follows:

> B2 – "Very difficult to do. I don't think there is a method really. It needs a selection tool for use by the engineers. Engineers can quantify things but I don't know if there is any way of comparing the less tangible, the only way is to discuss and reflect on case studies."
>
> C4 – "If it's new then difficult to compare, so it can be all guess work. There's a lot of guess work and going into the unknown. It's the job of the team preparing the case to eliminate all the improbables and be fair and accurate."
>
> S3 – "There is no structured method of comparison."

6. Building services engineers

There are many factors that influence the viability of AET's in building projects, including financial, political, technical and non-technical factors. Building consultants are limited in the influence they can have over some of these factors. They cannot change the cost of technologies or purchasing energy, neither can they directly change government policy, the type of client or the building location. However, results from these interviews show that the building consultant still has a key role to play in advising clients and informing the decision making process. Some examples reflecting on the role of building consultants show this:

B3 – "Key, unless we propose it is unlikely to happen otherwise."

C1 – "Absolutely vital at the end of day, the contractor builds what he is told to build and the client is advised by the consultant."

Q2 – "They're key really, that's the expert you rely on to advise you on the systems, what they can do and their ramifications."

T2 – "They are the first point of contact for the client."

We have seen that the level of experience of AET's within the building industry is considered to be very poor, and engineers have a key role in the industry of understanding these technologies and advising the project team. Building services engineers need to be educated to give them a better understanding of AET's and appropriate assessment methods. With the aim of this education to allow them to bring clear and timely knowledge to inform decisions and to consider using assessment approaches that incorporate quantitative and qualitative considerations.

Conclusions

41 interviews with building project stakeholders have shown:

- There's a lack of experience of installing AET's in buildings in the UK, and the understanding of these technologies is variable.
- There are a number of key factors that affect the viability of implementing AET's in building projects.
- There are a number of drivers and barriers to the use of AET's in buildings, and the relevance of each of these varies between projects, with time and with the technology.
- The high capital cost and subsequently long payback period is seen as the most

significant barrier, and is the main focus of existing assessment approaches.

- No structured approaches to assessment that specifically address AET's and the drivers and barriers to implementation are being used in the industry. Further education and new approaches to assessment are required, to move the emphasis away from capital cost and toward the benefits provided by AET's.
- Building services engineers play a key role in the technology selection process and also in raising awareness of AET's in the industry.

Important factors

The specific factors affecting the viability of the integration of AET's into buildings in the UK are diverse and large in number: The opinions and experiences of applying these technologies are varied, and the potential for use of AET's is heavily influenced by the client, the project brief, specific project considerations and the motivations and approach of the design team used.

Drivers and barriers

Stakeholders have experienced that each project has its own hierarchy of drivers and barriers, of these financial cost is often a major barrier, though other factors can be equally significant. Beyond the capital cost and technical constraints that cannot be influenced through the role of the building services engineer there are other significant barriers, such as ignorance, perceived risks and the view that these technologies are unproven. This is supported by other research showing the large number of factors restricting distributed generation (Lovins et al., 2002), uptake of renewables in developing countries (Painuly, 2001) and more sustainable construction (Gann, 2003), the common emphasis on cost alone (Horsley, 2003) and the need to consider social and environmental factors (Bartlett and Howard, 2000; Elliott, 2003; Reddy and Painuly, 2004).

Overcoming barriers

It is essential for further development of AET's that drivers and barriers are recognised, barriers minimised and drivers exploited as far as possible. This progress is reliant on technical developments, political decisions and influencing human perception within the project team. The exploitation of drivers is reliant on a better understanding and effective modes of communication of the potential benefits (Charters, 2001). The building consultant has a key role in interacting with the client and other team members from an early stage of project conception (Bordass, 2001) and influencing their understanding, perceptions and eventual decision-making.

Recommendations for action

The perspectives of motivations, barriers and approaches for considering alternative energy technologies has been reviewed under the context of UK building projects. The recommendations for change are specific to this context but are generated from interviewing a broad perspective of building industry stakeholders.

Building professionals, and particularly building consultants have a key role to play in integrating AET's into building projects. To do so, they need to be more educated and enthusiastic, to use detailed case study information and use more informed 'holistic' approaches to decision making. These approaches must be based on a better understanding of qualitative and quantitative aspects such as whole life financial, environmental and social impacts and clearly defined client value criteria. This will help to improve the chances of integrating alternative energy technologies into building projects, beyond the use of subsidies and legislation to reduce the up-front financial burden of investment.

Acknowledgements

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Tables

Table 1 Interview sample

Code	**Stakeholder**	**Participants**
A	Architect	5
B	Building services engineer	6
C	Client	5
O	Specialist Consultant	5
P	Planner	5
Q	Project manager / Quantity surveyor	5
S	Technology supplier	5
T	Contractor	5

Figures

Figure 1 The perceived importance of drivers for the use of alternative energy technologies in buildings

Figure 2 The perceived importance of barriers to the use of alternative energy technologies in buildings

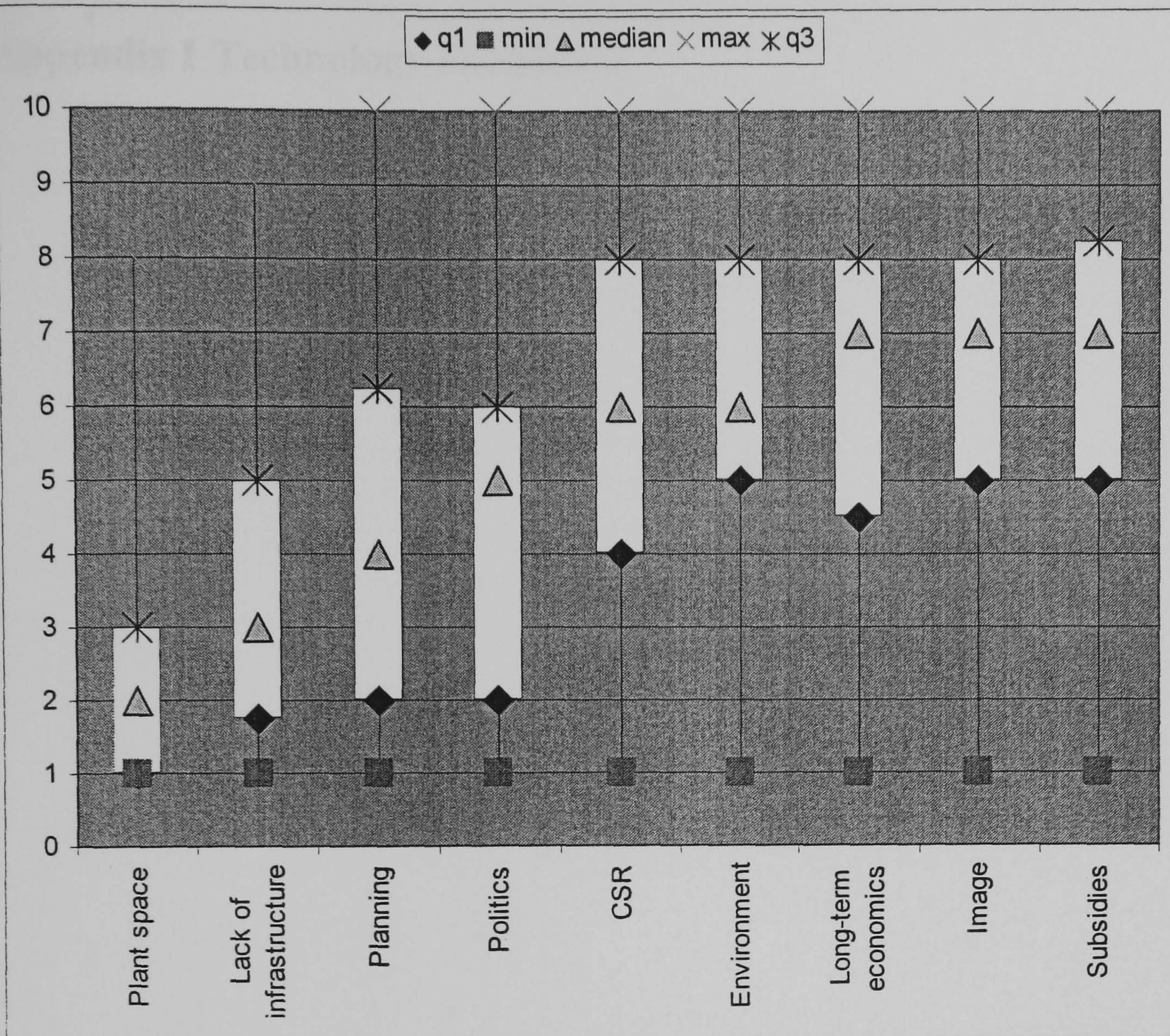


Figure 1

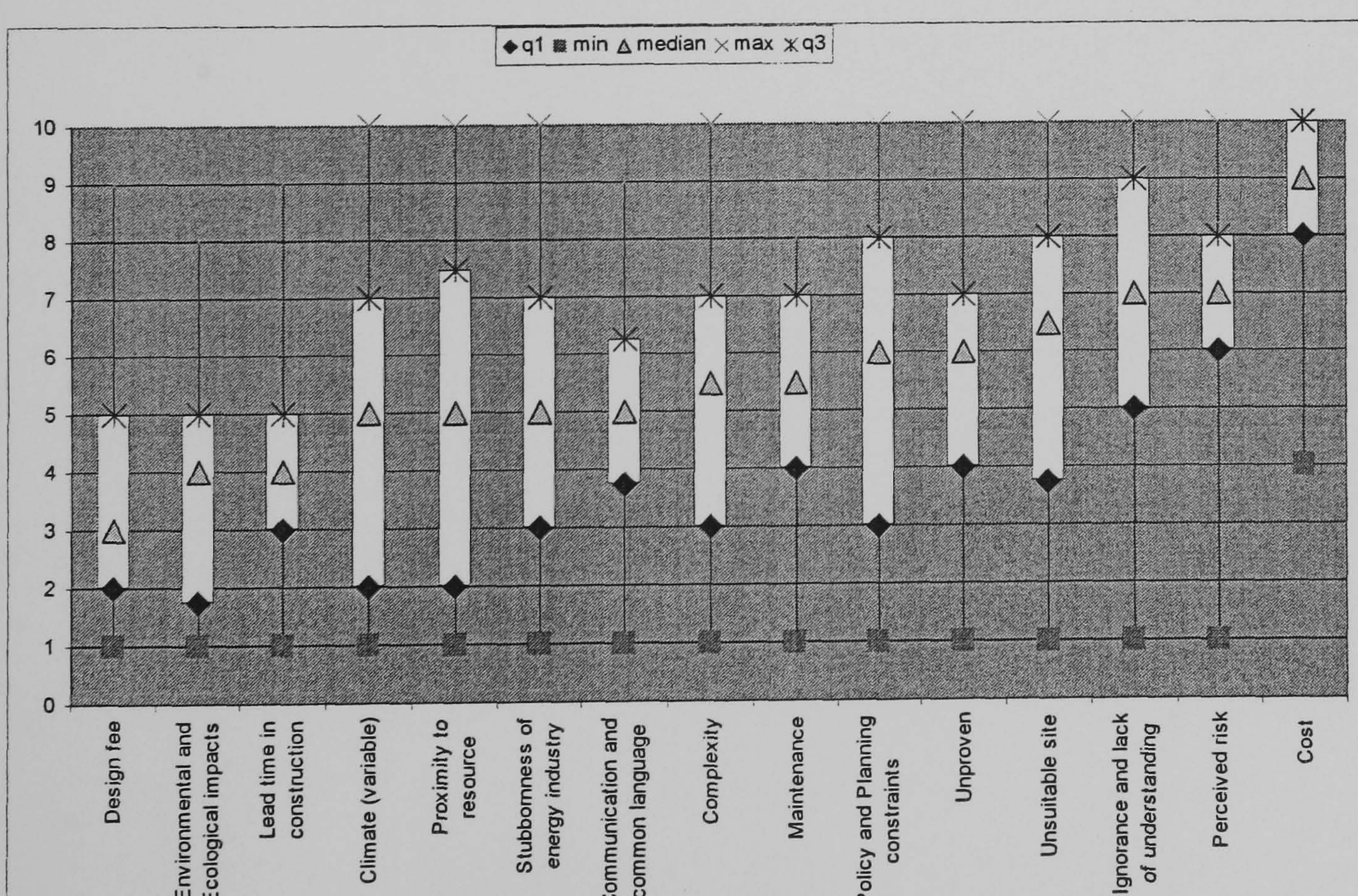


Figure 2

Appendix I Technology Factsheets

Alternative Energy Technologies Factsheets Introduction

Alternative energy technologies (AET's) use local generation techniques to reduce the energy consumed via the national grid and gas supply network. They include the following technology options:

Biomass - Direct combustion & Anaerobic Digestion
Combined Heat and Power (CHP)
Ground Source Heat Pumps (GSHP)
Micro-hydro power
Solar photovoltaics
Solar thermal collectors
Wind turbines

There are continual developments in the market for AET's, in terms of technology, economy, public perception and government policy. Some of the present day pro's and con's for these technologies are summarised as follows:

Drivers for using AET's	Barriers for using AET's
Fuel availability and risk reduction through diversification	Increased capital cost compared with traditional options.
Educational benefits for occupiers, visitors and the local community; improving awareness and feeling of identity.	Possibilities for additional space requirements.
Opportunities for the provision of local jobs (Specifically for biomass energy)	A lack of understanding of the technologies or the techniques used to assess their viability.
Less reliance on imported fossil fuel supplies.	A lack of skilled installers and maintenance
Ability to obtain funding and other financial benefits for installation and through the use of renewable energy.	Programme constraints, where there are inhibitive design and construction time restrictions.
Greater publicity.	
Reduce operational costs and so reduce the potential for fuel poverty.	
Minimise the adverse impact from future energy price rises.	
Environmental benefits through reducing the environmental impact of building operation.	

The viability of AET's is influenced by:

The site layout;
The site energy demands;
Availability of space;
Client objectives;
Local council waste and energy objectives;
Planning constraints;
The consideration of future energy prices, and whole life costing issues;
The availability of alternative fuels and energy technologies;
Project timescales and phasing.
Availability of funding for feasibility studies and for implementation;

Title **Biomass and waste fuels**

Introduction

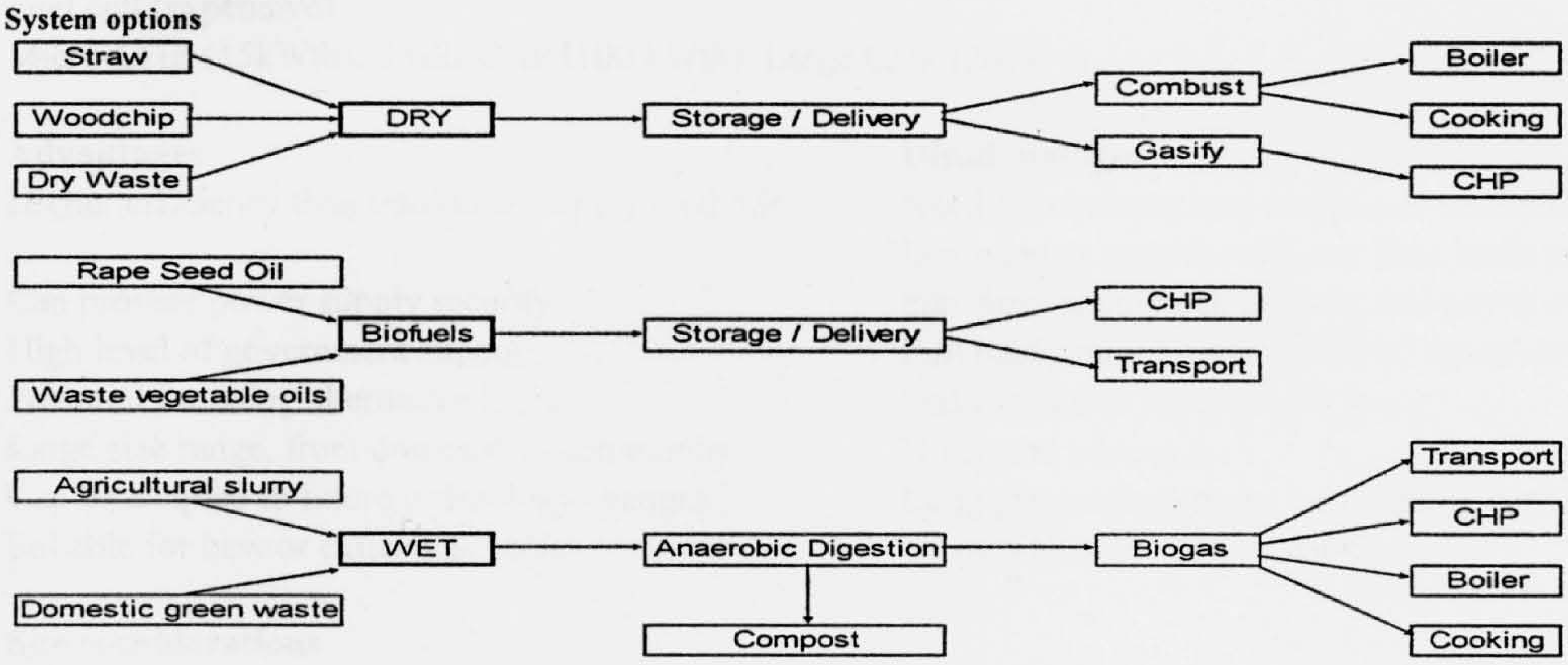
Biomass energy is the most commonly used form of renewable energy in the world. Biomass is a broad definition that encompasses many different products, all of which are readily available in various levels throughout the UK, in both urban and rural locations.

Dry biomass can be grown on a large scale in the form of energy crops or can be made up of dry domestic and woody garden wastes. The level of dry biomass available will be limited by the number of households in the local vicinity and the space available for woodland or energy crops. There is a large

Biofuels are grown as crops, rape seed oil being a typical example, or reprocessed from commercial sources such as waste vegetable oils from chip shops. There use is more suited to transport fuels than as a stationary fuel.

Anaerobic digestion is the process of turning wet organic waste into a useful supply of biogas and a stable soil conditioner, using active bacteria in a sealed, heated tank. Being an enclosed system the nature of anaerobic digestion is to ensure all nutrients and other useful properties of the feedstock are collected and not lost to atmosphere. Organic household waste would be delivered and stored before being digested, matured and used/sold as compost. The gas produced is a very useful fuel and could be used in the district heating or CHP system.

System options



Advantages
- Local source of renewable energy
- Biomass crops use set-aside
- Opportunities for establishment grants
- Agricultural support
- Reduction of waste to landfill
- Minimal cost of fuel
- Numerous sources of supply
- Carbon neutral
- Reliable systems based on traditional tech.
- Ability to adapt to demand
- No additional back-up required

Disadvantages
- High capital costs
- Long project lead-times
- Reliant on infrastructure and partnerships
- Operations and maintenance required
- Reliant on consistent fuel supply
- Crop yields are site specific
- Material handling and chopping required
- Low bulk density
- High transport costs and high fuel storage space requirements

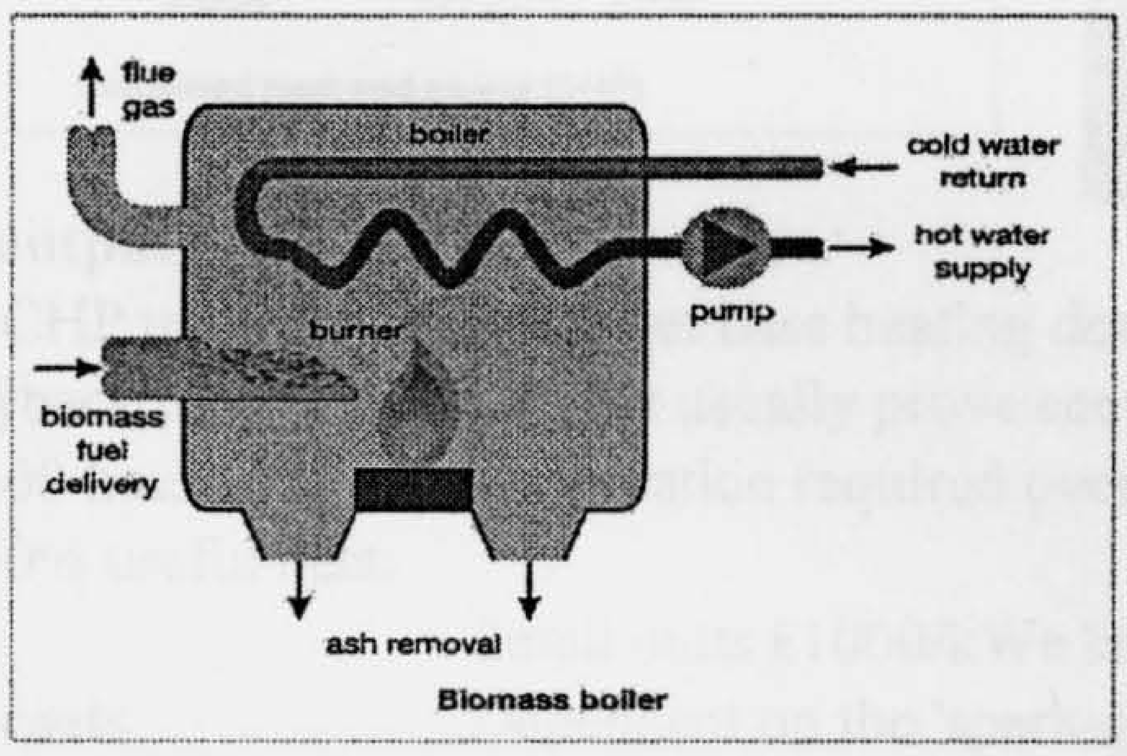
Site considerations

Biomass fuels are most appropriate in rural or semi-rural localities, but this is not essential. Waste fuels are appropriate in all locations, dependent on the availability of separated waste streams and suitable transport infrastructure. Waste and biomass fuels will require handling, treatment and combustion processes, so local social and environmental aspects must be considered.

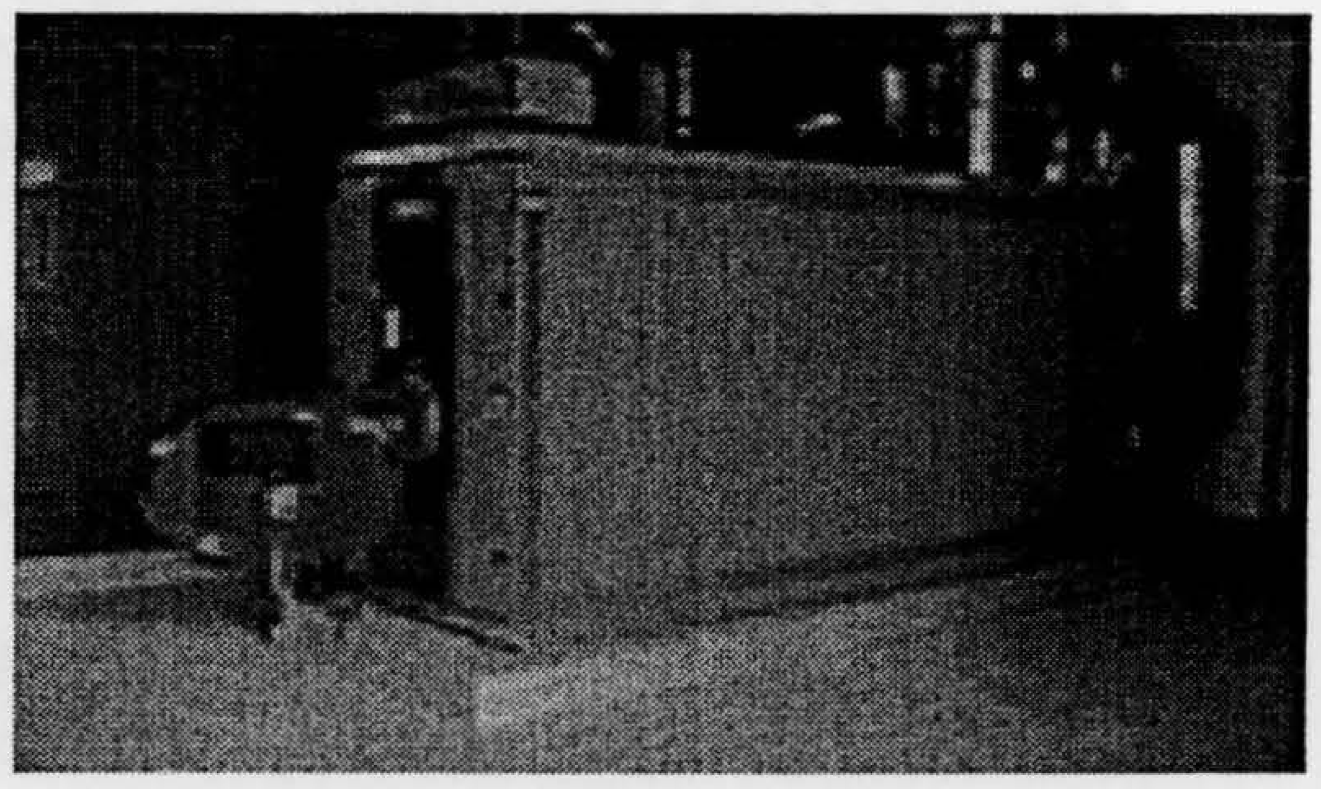
Biomass energy crops are most suitable where arable set-aside land is available and where there is an existing supply network.

For all biomass and waste fuels there must be space for storing and conditioning locally to the combustion plant.

Diagram



Biomass boiler



Size and cost 300 kW boiler needs around 4m x 4m x 3m space. System budget £50,000 + construction costs.

Running costs Equivalent to 1.5p/kWh at £45 per oven dry tonne of woodchip

Funding DTI Clear Skies. Bioenergy capital grants

Legislation Clean air act

UK Suppliers Econergy, Mercia Energy, Rural Energy

Books and documents Biomass system Procurement Guidleines (Buro Happold)

BH projects Eden Project. Coillte (EIRE)

Summary

In general biomass or waste fuels are the cheapest method, in terms of £/kWh delivered, of providing renewable energy to a development. Heating systems are easy to maintain and manage and are very much suited to combination with community heating systems. Over 16% of all dwellings in Austria are heated by biomass, along with a large number of developments in Scandinavia.

Title **Combined Heat and Power**

Introduction

CHP is the simultaneous generation of useful heat and power, providing efficiency benefits over traditional forms of power generation. For maximum efficiency CHP units generate to serve a steady load. Peaks and troughs in power demand are then met through imports or exports to the national grid; heat loads are matched through the use of additional boilers, and by using thermal storage or heat dumping.

System options

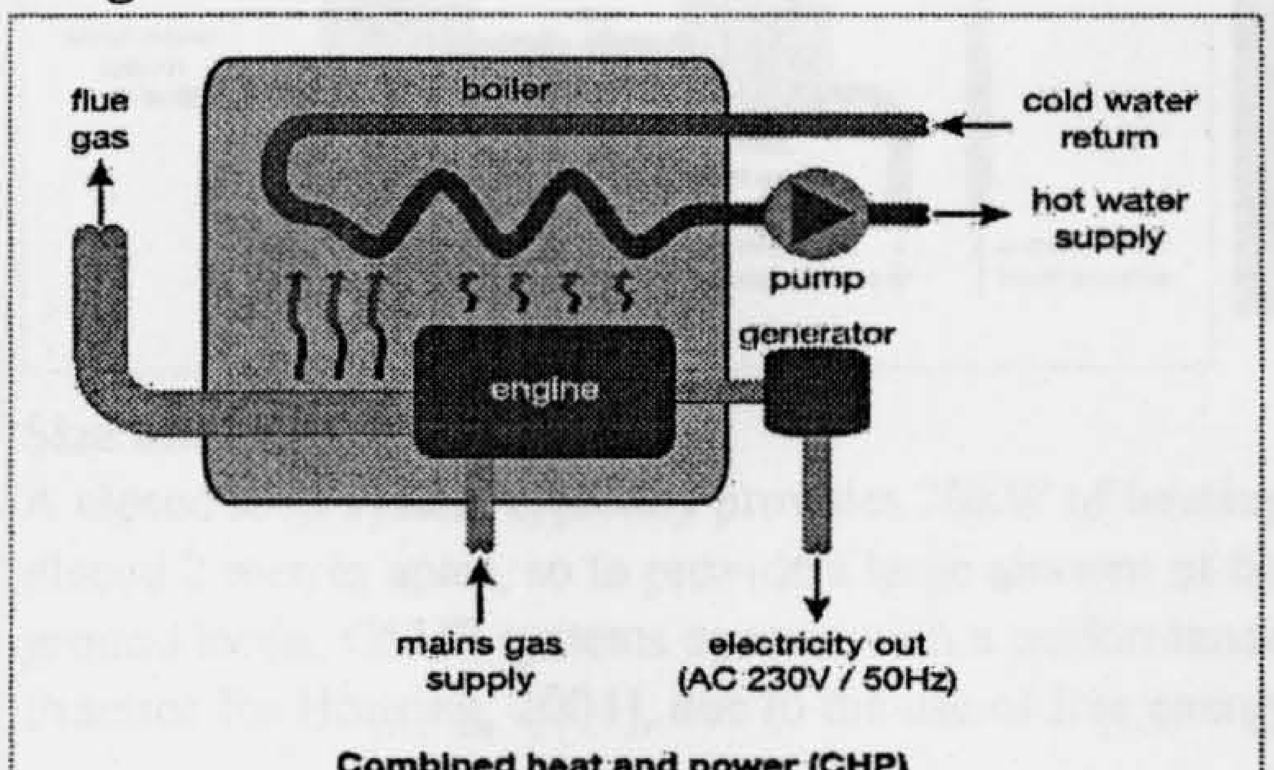
Gas engine (most common)
Gas turbine (mainly for industrial use)
Fuel cell (expensive)
Micro-CHP (15kWth), Small-CHP (100 kWth), Large CHP (2MW+).

Advantages	**Disadvantages**
Higher efficiency than traditional supply methods	Need for accurate heat and power load estimates
Can provide power supply security	Designed to meet the summer heat loads and so they may need supplementary heat and power supplies.
High level of government support	Full load running for 4500-6000 hours/annum min.
Potential for using alternative fuels	Load variation reduces efficiency
Large size range, from domestic to community	Noise and vibration.
Can be adapted to future technology changes.	Long project lead-times for planning consent, design, construction and commissioning.
Suitable for new or existing schemes	

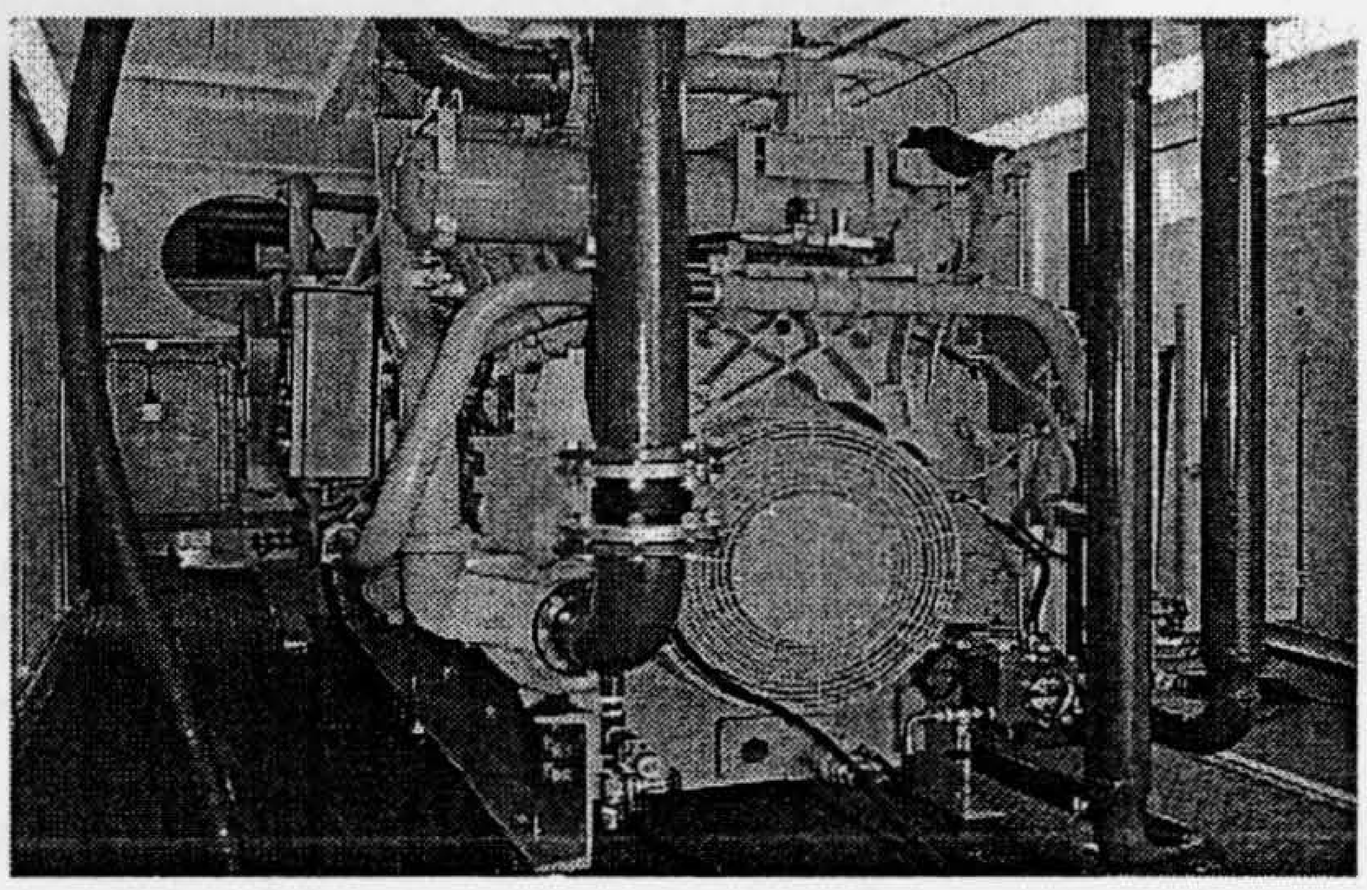
Site considerations

Combined Heat and Power systems rely on a high base load heat requirement, they are most appropriate where heat loads are consistent for most of the year. The use of low temperature systems, district heating or thermal storage improves the viability of CHP.
Mixed use developments and sites with high hot water loads, such as swimming pools, hotels and hospitals are generally most suitable.
Sites with long periods of low occupancy, i.e. schools, are generally not suitable.

Diagram



Combined heat and power (CHP)



Size and output

Typically CHP units are sized to meet base heating demands to ensure that running time is sufficiently high. In simple payback terms CHP does not usually prove economic compared with traditional supplies unless there are at least 4500 hours of full load operation required over the course of a year. Gas engines 75% efficiency, 25% elec and 50% useful heat.

Costs Small units £1000/kWe large units £500 / kWe

Running costs Dependent on the 'spark-gap' price difference between gas and electricity

Funding Community Energy Programme Capital Grants

Legislation Grid connection, noise, NOx emissions

UK Suppliers Ener.G; Vital Energi; Ecocentragen

Books and documents CHPA; CHP Club Guides

BH projects Royal Mills, Carterton Leisure Centre

Summary CHP is a more efecient means of supplying energy than remote power generation. It relies on simple and well established technologies that prove economically viable if there are steady energy loads. They also have the capability of providing standby generation back-up in case of grid problems.

Title **Ground Source Heat Pumps**

Introduction

Heat pumps upgrade low value energy with the use of electrical power via the refrigeration cycle. In the case of a closed Ground Source Heat Pump (GSHP) system a water-based solution is pumped through pipes drilled 60 to 100 metres into the ground using the relative warm ground temperature in the winter to provide heating at 40°C to the property, and the relatively cool ground temp in the summer to provide cooling. To do this they will require sufficient free underground area. It is not advised to drill the ground loops underneath the building construction, and usually they are positioned within an adjacent car park.

System options

Closed loop and open-loop

Heating, cooling or reversible (heat and cool)

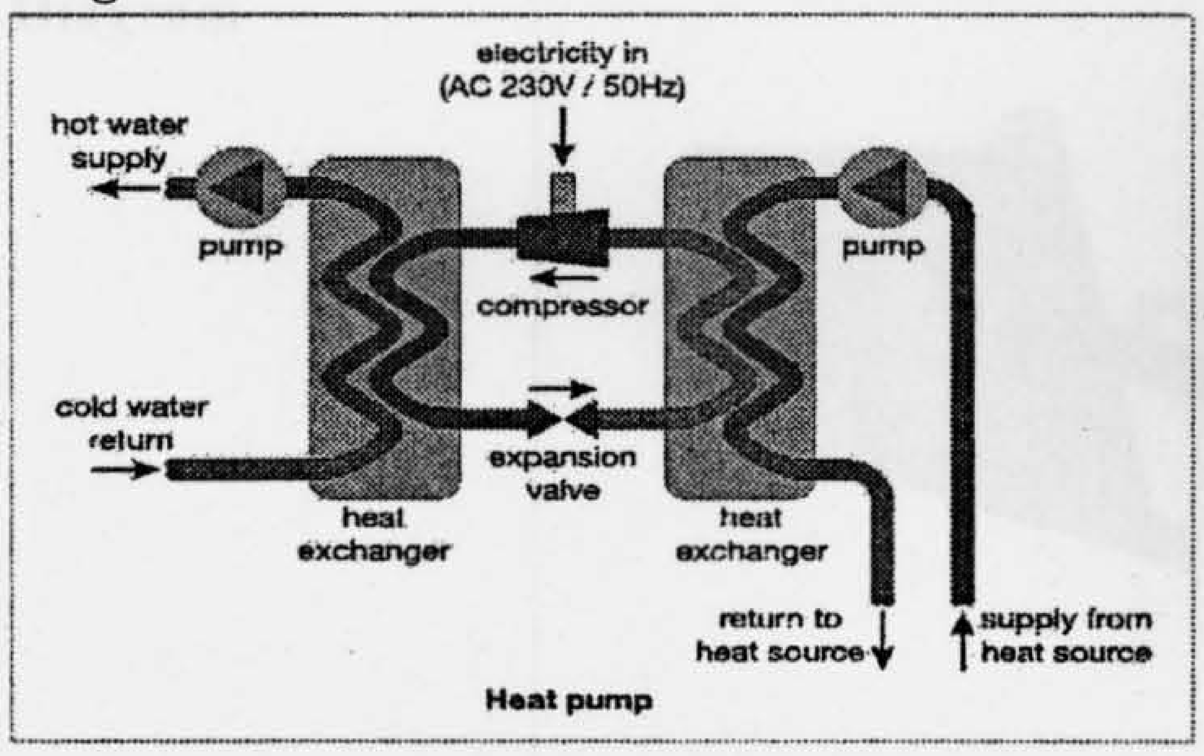
Advantages	Disadvantages
Provides heating and cooling at high efficiencies	Low temperature/high area systems only
Space saving	Uses electricity
Quiet	Dependent on electricity prices
Output can be varied to match demand	Performance dependent on ground conditions
Modularity	External area required for ground loop
Clear skies grants available	Seasonal performance variation
	May require additional peak supply system

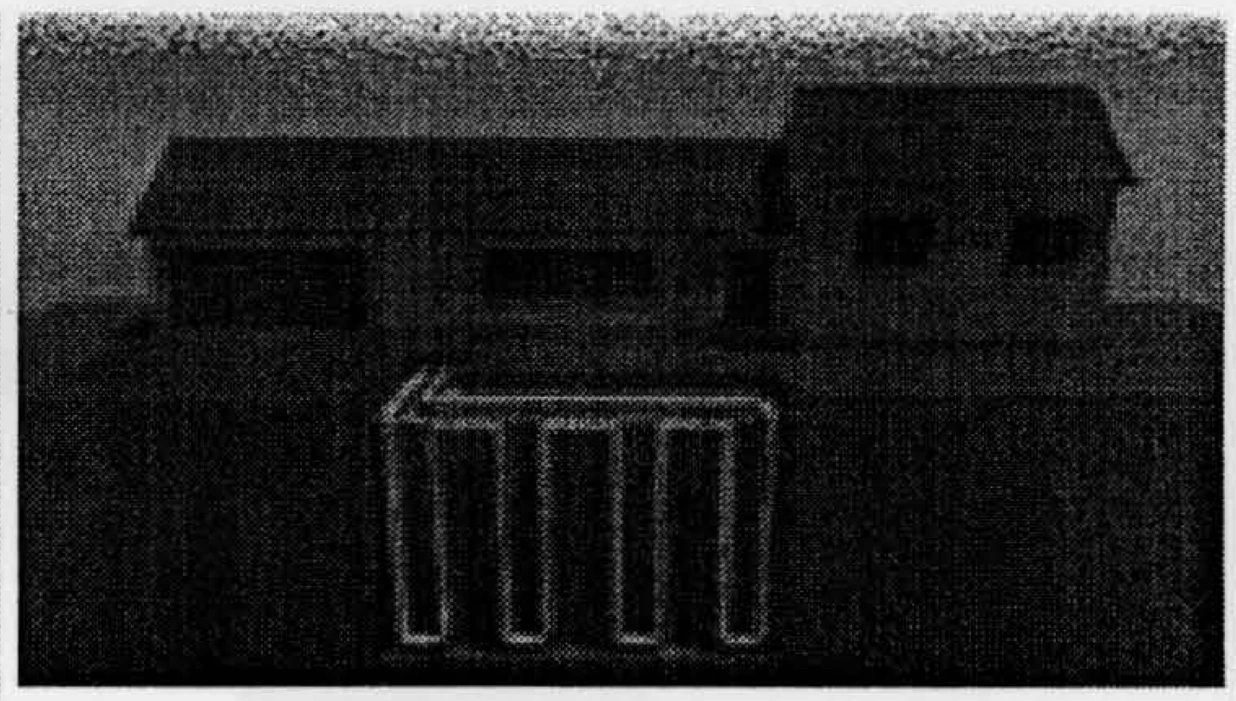
Site considerations

Ground Source Heat Pumps can be applied anywhere given that there is room for installing ground loops, often areas used for car parks or gardens can be used. The land is suitable for reuse after installation is complete. Hence it can prove more complicated for existing buildings. They are best used in schemes that have an equal requirement for heating and cooling over the course of the year, providing optimum efficiency and minimising capital costs. This technology is only applicable for providing low temperature heating, i.e. 40oC, so high area systems such as underfloor systems are required.

These systems are suitable for remote buildings without access to heating fuels or district heating, and for buildings with heating and cooling requirements such as museums or highly glazed offices.

Diagram





Size and output

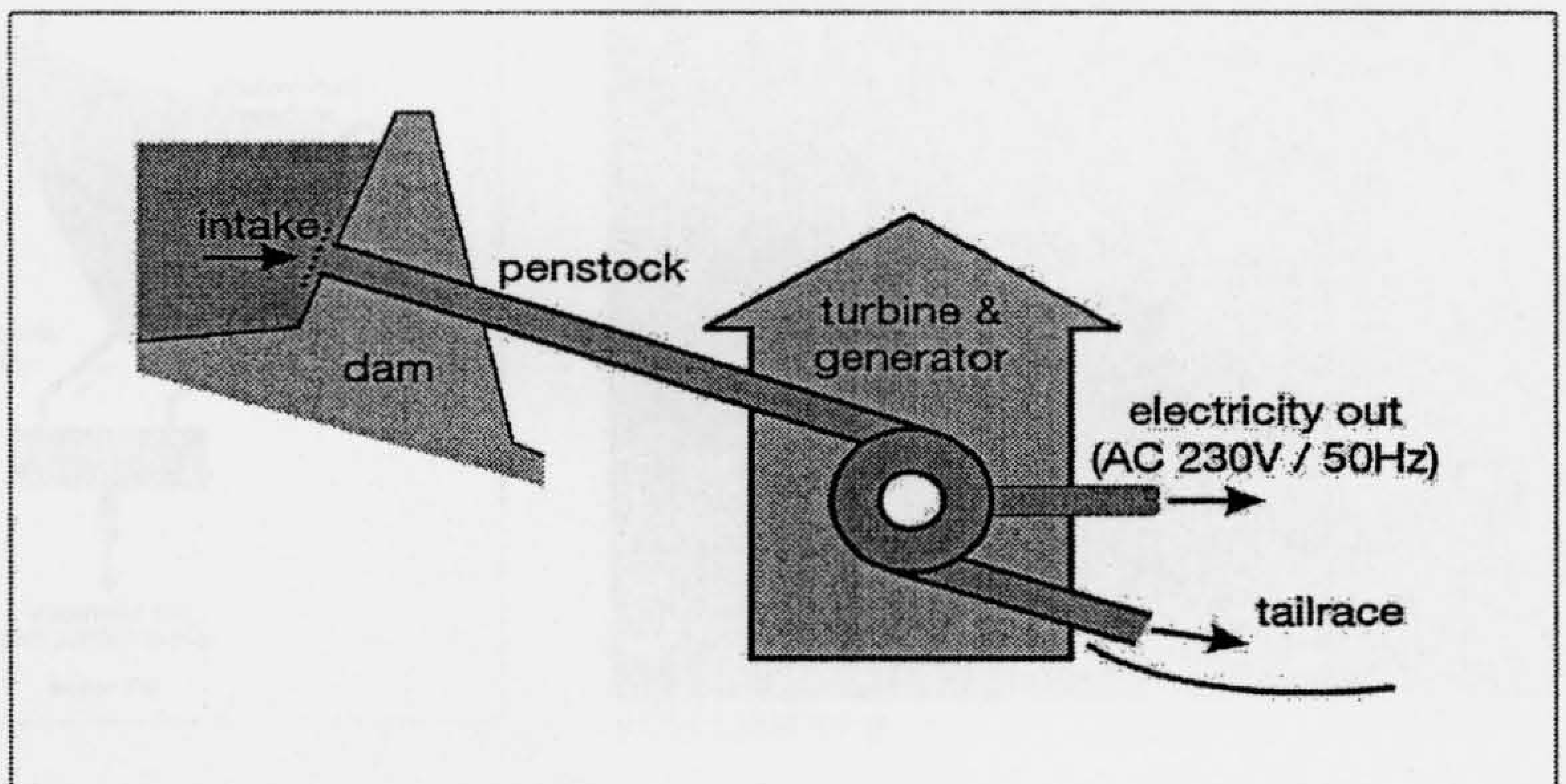
A closed loop system typically provides 20kW of heating for every 100 metre borehole; with each borehole placed 2 metres apart, so to provide a large amount of heating a substantial free area would be required for the ground loops. GSHP systems operate with a performance efficiency of around 300% [Energy Efficiency Best Practice for Housing, 2004], due to the use of free energy from the ground.

Costs	Installation cost approx £1000/kW output
Running costs	Every unit of heat requires 3 units of electricity, dependent on price of electricity
Funding	Clear Skies
Legislation	Water extraction licence for open systems
UK Suppliers	Geoscience, Groenholland
Books and documents	International Heat Pump Association
BH projects	Queens University Belafast Library

Other points

A heat pump system would be able to supply cooling at temperatures as low as 6degC and heating at temperatures up to 45degC. This would require the use of low-temperature/high-volume heating systems throughout the development, typically in the form of underfloor circuits. This places a restriction on the future design of heating and cooling systems. Another barrier is the reliance on electrical power to provide heating, this may be an issue in the long-term if electricity prices are predicted to rise.

Summary GSHP can provide a more efficient means of supplying heat and cooling if site conditions allow.

Title	**Microhydro**
Introduction	Micro-hydro power is a traditional means of providing useful energy, however it is very site-specific and is only viable where there is an existing stream or river with suitable head.
System options	Type of turbine used: Francis, Pelton, Kaplan, Propeller, Crossflow, etc.
Advantages	Renewable source of electrical power Reliable and consistent supply Long operational life Zero environmental impacts Low maintenance requirements Clear skies grants available
Disadvantages	Site specific High capital costs Lack of specialist designers and installers within the UK May suffer from seasonal variation Requires an additional back-up system
Site considerations	The use of hydropower is highly site specific. There must be sufficient flow head to prove economic. If there is a river situated locally to the site it is possible a micro-hydro device could be suitable and cost-effective. As with all local power generation options there are complexities and costs associated with connecting to the national grid. Traditionally suitable sites include historic water mills and hilly areas with spring-fed streams.
Diagram	

Hydro power

Size and output	Can range from a few kW up to MW scale. Depends on available head and flow. Hydro Power (kW) = Head (m) x Flow (m^3/s) x 9.81*
Costs	Construction costs will be site-specific, though if a suitable site it should be commercially viable. Lower cost turbine-generator units have now been developed for a wide range of heads and flows. These are manufactured in the UK and available at prices of less than £2000 per kW.
Running costs	Minimal
Funding	Clear Skies
Legislation	Environment Agency will need to be notified
UK Suppliers	www.hydrogeneration.co.uk
Other points	New turbine designs are cheaper, lighter and easier to install/maintain than traditional mill designs.
Summary	Microhydro is an excellent renewable energy option where a river or stream can is available nearby providing sufficient head and flow. Output may vary with the seasons depending on the resource.

Title Solar Photovoltaics

Introduction Solar photovoltaics convert incident solar irradiation into d.c. electricity. They can be used as elements of the building fabric for power generation along with providing weather protection, shading, etc.

System options
- Monocrystalline silicon (Most efficient)
- Polycrystalline silicon
- Amorphous silicon (Flexible and semi-transparent)
- Thin film technologies (Flexible and semi-transparent)

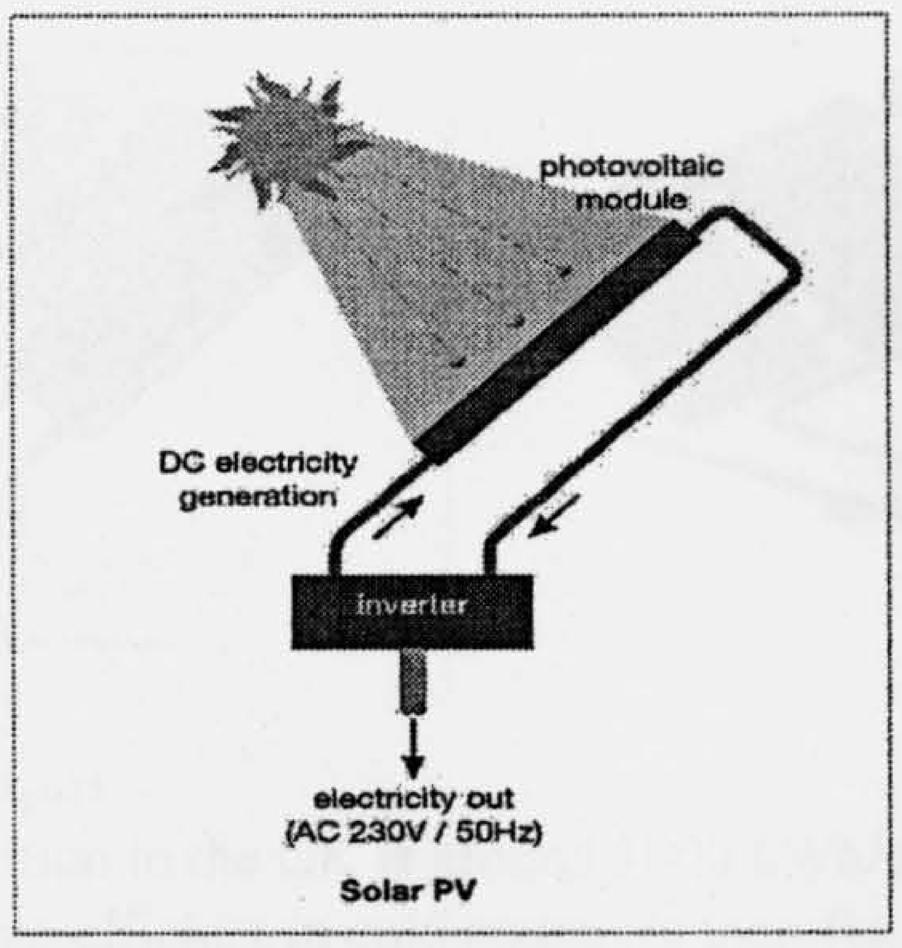
Advantages	**Disadvantages**
Renewable source of electrical power	Very high capital cost
High-tech reputation	Low energy density
High visibility	Slow adoption in the UK despite high backing
Long life	Lack of industry experience
Building integration	Intermittent output, heavily influenced by local shading and seasonal variation
Variety of technology options	Requires an additional back-up system
Output matches cooling loads	
Low maintenance	
Simple to design and install	
Photovoltaic demonstration grants available	

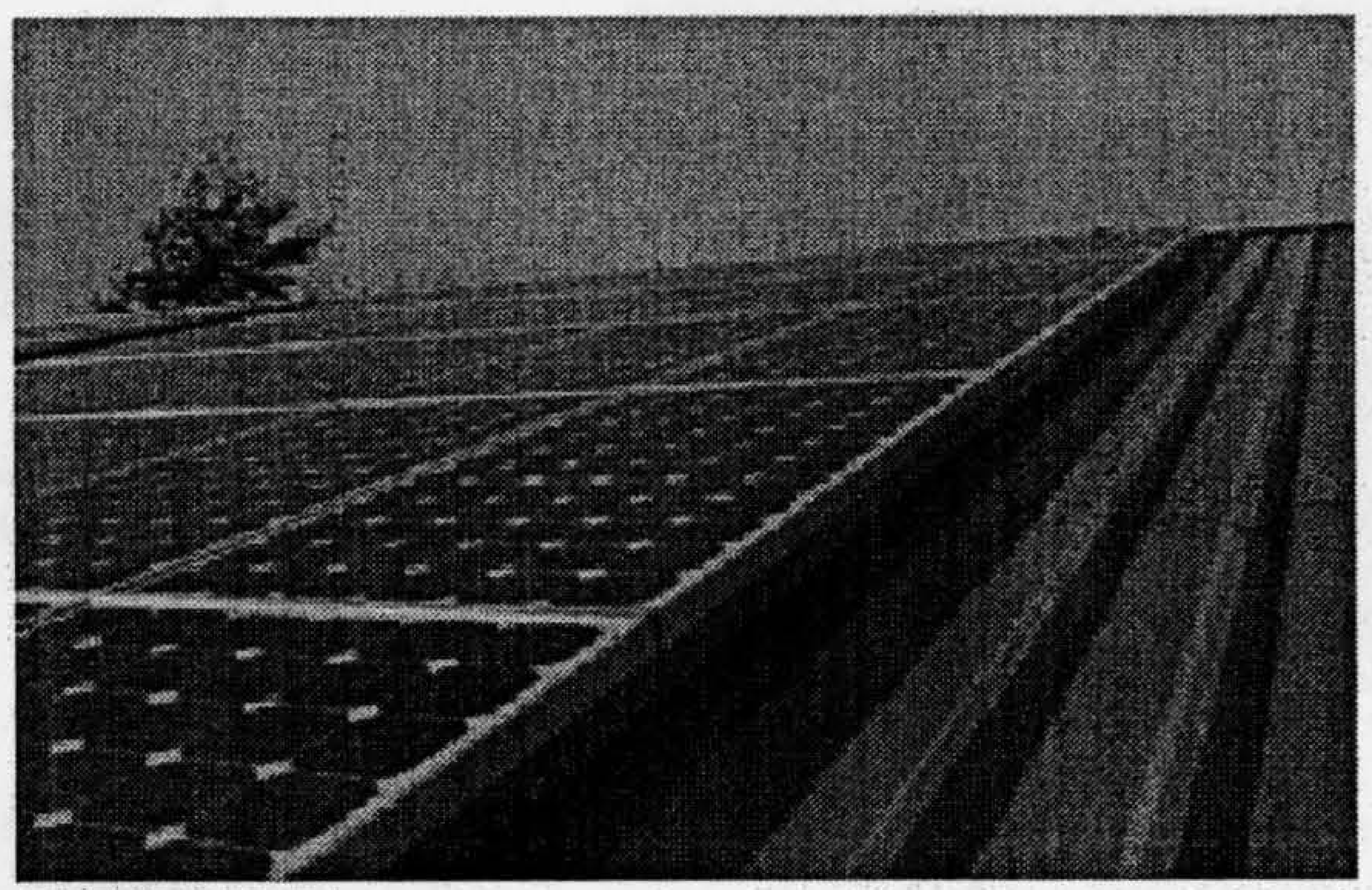
Site considerations

Solar PV panels are suitable for all types of building, they are available in many different forms from solid panels to semi-transparent flexible sheets to roof tiles. It is essential for optimum performance that they are south-facing at 30deg and away from any shading. Future developments and other local considerations (such as trees) may also be an issue if they cast shadows on the panels.

Typically PV will only be capable of providing a small proportion of the annual energy requirements, with much of the energy output being in the summer. PV is not economically viable unless replacing building elements (i.e roof tiles) or used for an application remote from the grid supply. Typical remote applications are summer evening display/show lighting and off-grid parking meters. Another use for PV is for it to be directly linked to a building cooling/ventilation system, reducing the need for control systems.

Diagram





Size and output

Annual radiation in the UK is around 1000 kWh/m^2. Crystalline silicon cells are around 18-20% efficient and amorphous cells are 9-10% efficient. Actual performance is reduced due to transformer losses, shading and overheating. A well designed 1m^2 crystalline silicon array will provide 0.15kW peak and around 100kWh/year.

Costs Installed costs are estimated to be £4-600 / m^2 for crystalline systems and £2-300 for amorphous/thin film systems. Installed costs equivalent to £743/m^2, 0.13Wp/m2 and 101.6 kWh/m2 have been experienced in BH.

Running costs Little maintenance. Replace inverter every 5 years, panel life minimum 25 years.

Funding DTI Major photovoltaic demonstration programme provides up to 60% of costs. Electricity company 'Green Energy' funding schemes. Income from sale of Renewables Obligation Certificates 4p/kWh.

Legislation Connection to grid - G59 connection. Inverters must comply with G83/1

UK Suppliers BP Solar, Solar Century, SolarGen

Websites www.pv-uk.org.uk, www.solarpvgrants.co.uk

Books and documents An introduction to Photovoltaic Power, Factsheet, CAT Publications. Photovoltaics in buildings, BP Solar. Photovoltaics in buildings: a review, Dr A Cripps. Digest 438, Photovoltaics: integration into buildings, BRE.

BH projects Kensington Academy (Solar Century), Eden Project (BP Solar). Reports: Syddansk, Yorkshire Artspace, Boston MFA , Nottingham City Academy.

Other points Embodied energy payback is in the region of 2-5 years, Economic payback is usually in excess of 25 years. Inverter selection and avoiding shading is important for good performance.

Summary Solar PV is not financially economic for energy generation to the grid. It is viable where remote power is needed, i.e. for street-lighting, or where there is an established educational or image benefit. The technology is highly visible, is easily building integrated, flexible, and can be useful for showing 'green' credentials.

Title **Solar Thermal Collectors**

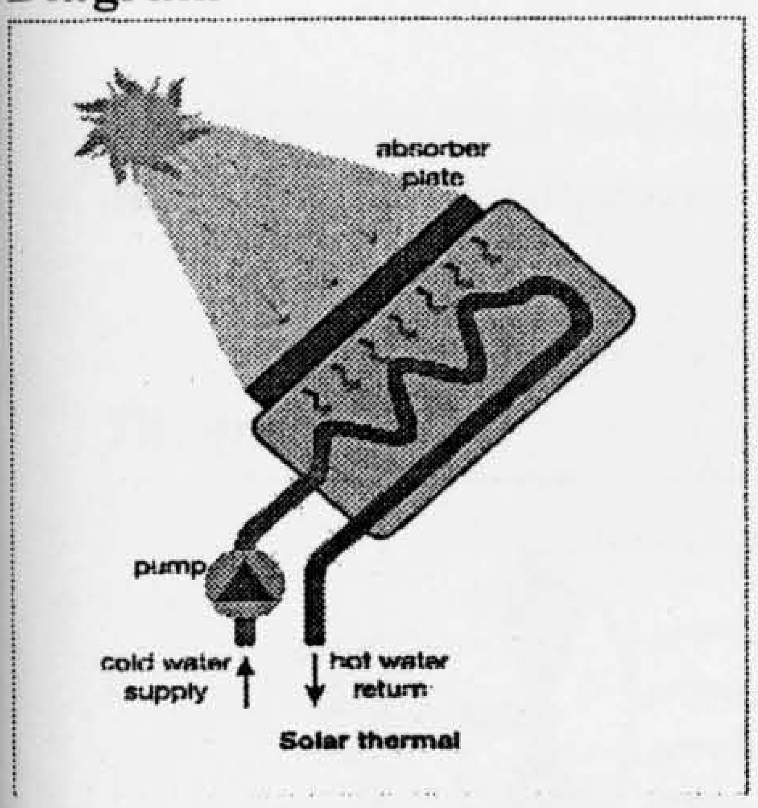
Introduction Solar thermal collectors absorb direct solar radiation and transfer it to circulating water, which exchanges the heat obtained with a hot water cylinder for pre-heating domestic hot water and heating systems. Maximum output is in the summer, though they still work in cloudy conditions. Collectors are usually sized based on daily summer hot water loads, which for a domestic property gives 50% of the energy required for hot water over the year.

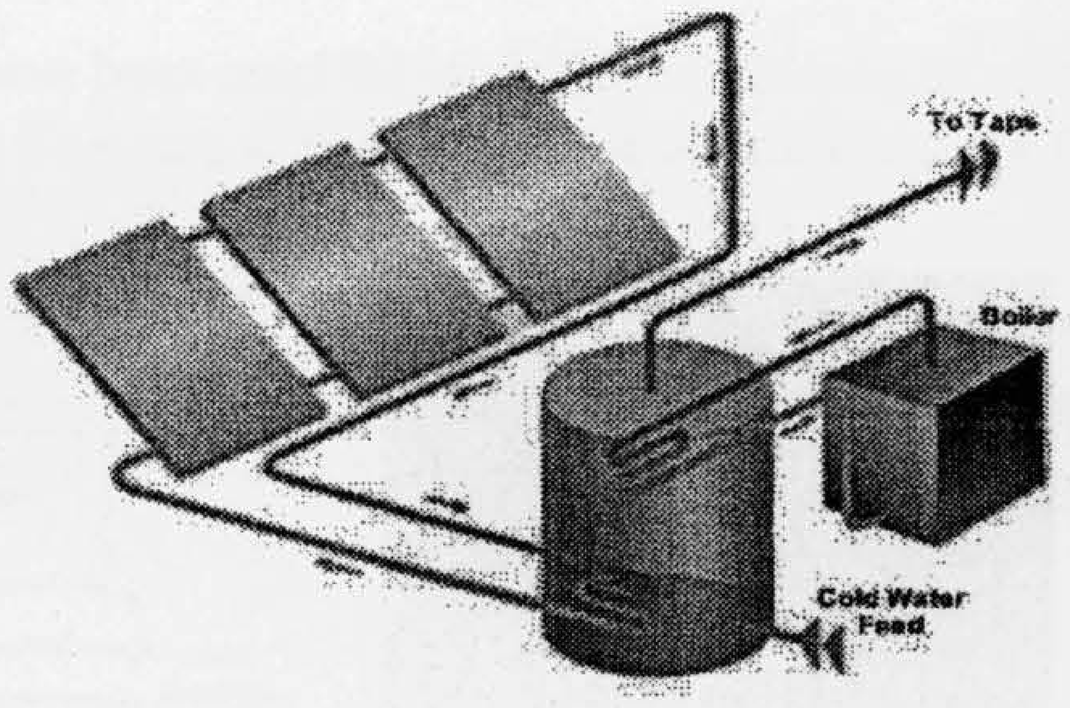
System options
Evacuated tube collectors (Most efficient)
Glazed flat plate collectors

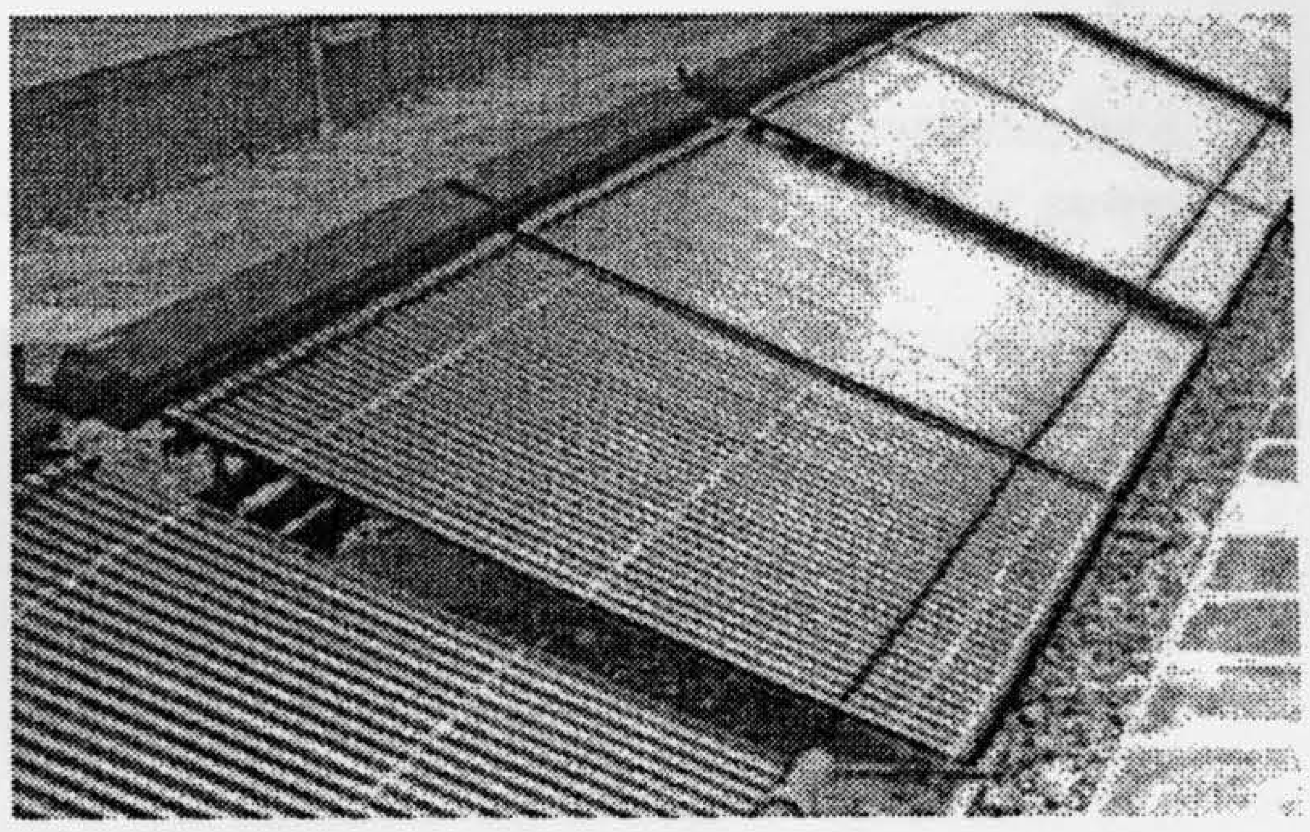
Advantages	**Disadvantages**
Natural source of heat	High capital cost
High visibility	Requires an additional back-up system
Long life	Output mainly in the summer
Building integration	Lack of industry experience
Variety of technology options	Storage tanks and collectors must be closely located
Low maintenance	Space requirements
Clear skies grants available	

Site considerations
Solar thermal collectors require south-facing roofs for optimum output, though are less sensitive to location or shading than solar photovoltaics. They only really provide useful heat in the summer months and are usually sized to meet summer hot water demands. Typical uses are remote summer buildings, swimming pool heating and hotel hot water supply. They have a good relationship with district heating, providing hot water needs in the summer and so allowing the central system to shut down when at its least efficient. However solar thermal does not have a good relationship with CHP as it removes part of the essential heating base load.
The hot water storage tanks require additional plant room space and must be located as near to the collectors as possible, consideration of hot water loads, system sizing and integration is crucial to performance.

Diagram







Size and output
Annual radiation in the UK is around 1000 kWh/m2. Annual efficiency is around 35% and peak efficiencies are up to 70%. Evacuated tubes are more efficient in cold countries than flat plate collectors, though are more expensive. Actual performance is optimised by orienting south at an angle of 30 o, using large storage tanks and low system temperatures. A well designed 4m2 evacuated tube collector (typical for a domestic property) will provide up to 3kW peak and around 1400kWh/year. Typically 1m3 of storage is required per 10m2 of panel.

Costs Installed costs are estimated to be £1000 to 1500/m2, including storage cylinders. Installed costs equivalent to £3,200/m2 and outputs of 0.6Wp/m2 and 358 kWh/m2 have been experienced in BH.

Running costs Little maintenance if well designed, paybacks are very slow so any maintenance seriously affects viability, design must accommodate for freezing and overheating to avoid unde maintenance. Panel life minimum 25 years.

Funding Clear Skies Programm provides up to 50% of costs, though this may not be available for long. Electricity company 'Green Energy' funding schemes. Possible Renewable Heat obligation in the future.

Legislation Nothing specific

UK Suppliers Viessmann, Filsol, The very efficient heating company (installers),

Websites www.greenenergy.org.uk/sta, www.clear-skies.org

Books and documents Tapping the Sun - A guide to solr water heating (CAT Publications); Solar Thermal Systems - Successful planning and construction (Viessmann)

BH projects Kensington Academy, Wessex Water, Coillte

Other points Collector and storage sizing and proximity is important for good performance. Minimise risk of overheating and freezing where possible to avoid unecessary maintenance. Cheap systems using plastic piping may not be as reliable as plumbed systems.

Summary Solar thermal systems are not financially economic for energy generation compared with gas condensing boilers, however can compete better against electric hot water heating. They are not standalone and require full back-up. If designed well they can supply a simple, reliable and visible form of renewable energy and can be fitted to most south-facing walls or flat roofs.

Title **Wind power**

Introduction Wind turbines use natural wind currents to generate electricity. They can be used in urban or rural environments, though the rate of output is dependent on the average wind flow rate, so high speed, undisturbed currents are the most ideal. At present large wind turbines are the most efficient and cost-effective method of generating renewable power within the UK.

System options
Horizontal-axis (fan-type)
Vertical-axis (whisk-type)
Building integrated small-scale

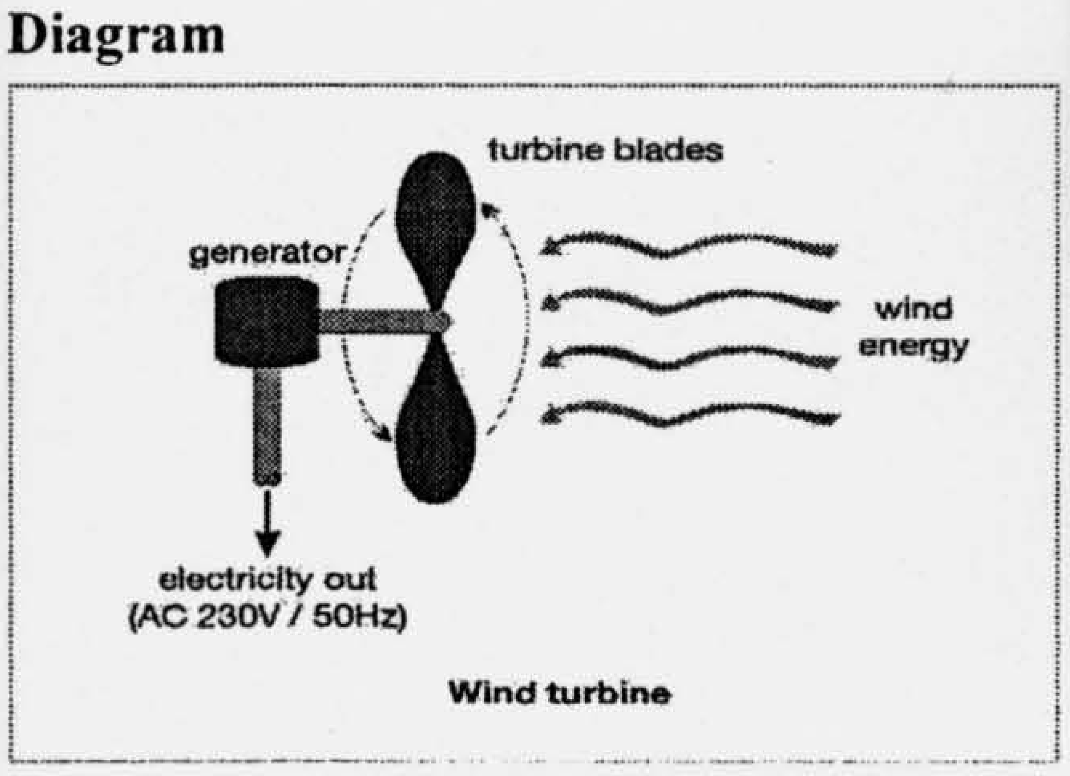
Advantages
Renewable source of electrical power
Life costs competitive with traditional energy supplies
Reliable and consistent supply
Long operational life
Minimal environmental impacts
Low maintenance requirements
Large size range, from 5kW to 3MW
High energy density.
Clear skies grants available

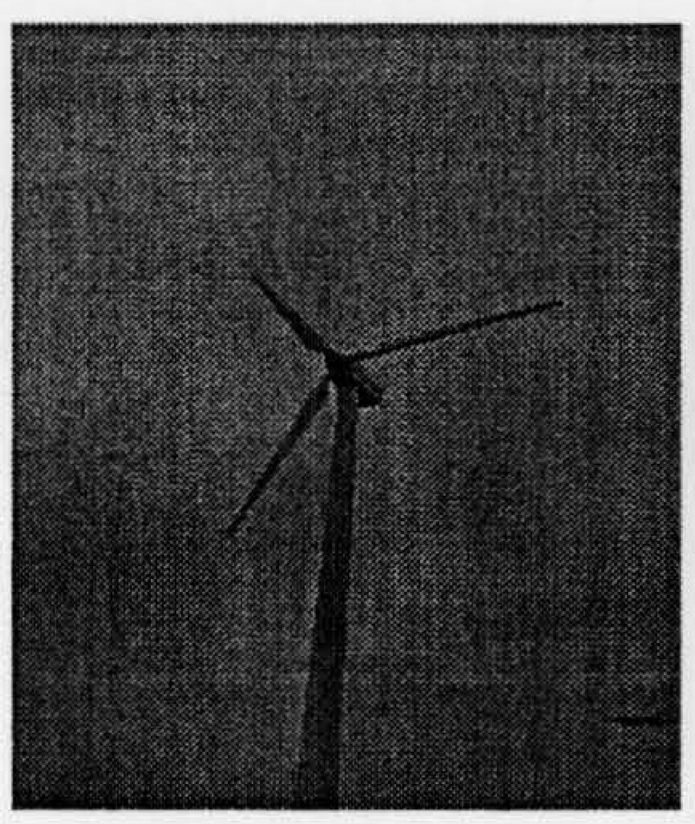
Disadvantages
Site specific
Planning permission required
Local social barriers
Long lead-time
High capital costs
Lack of specialist experience within the UK
Seasonal variation
Requires an additional back-up system

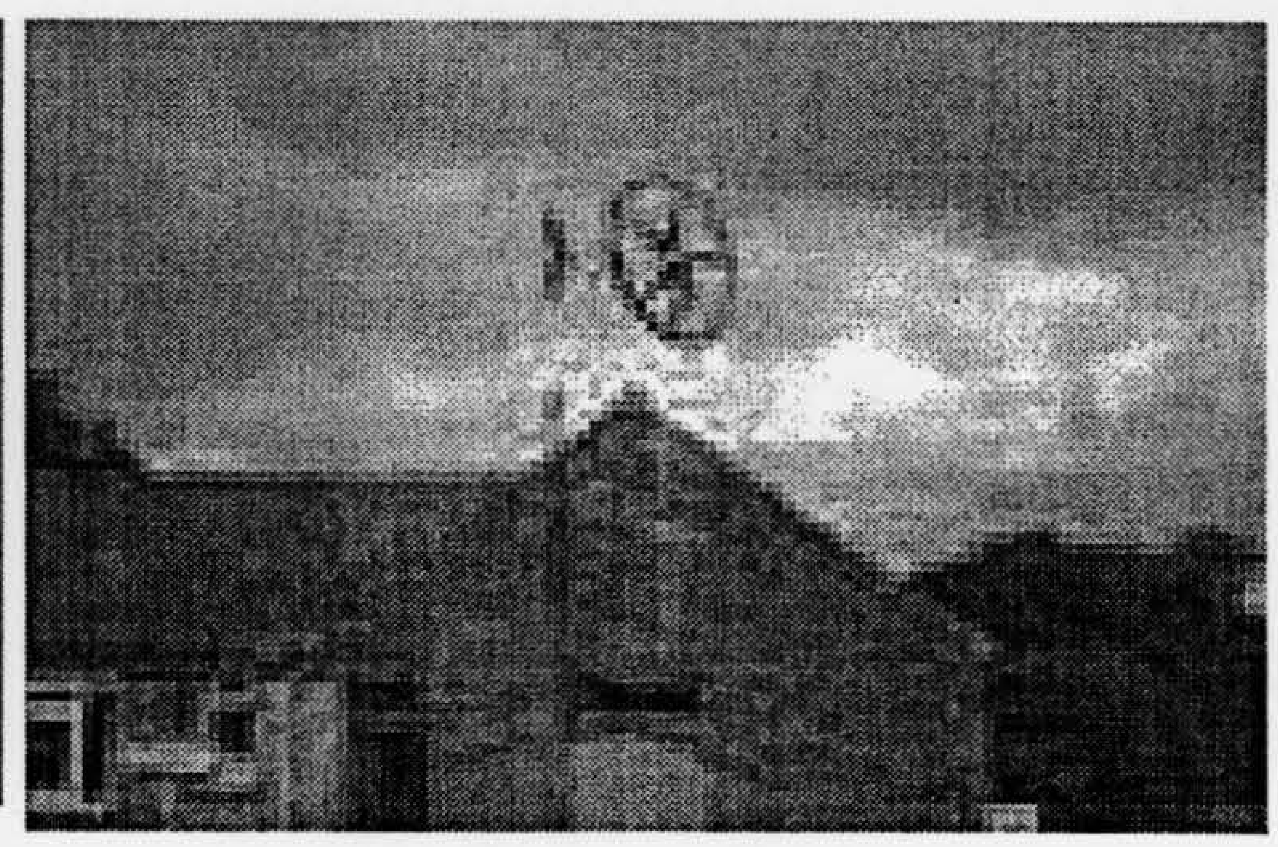
Site considerations
Wind power is most appropriate in an open and rural location or alongside sources of noise such as motorways. Small wind turbines can be suitable for schools and parks and as a rule of thumb should be at least 400 metres from the nearest residence. Little space is required for the turbine itself but there needs to be minimal obstruction of the wind for optimum performance. Large wind turbines are only really suited to remote locations and will be subject to an EIA as part of the planning application. Building integrated urban wind turbines are not common, but there are a number of new innovative developments forthcoming.

Traditionally wind turbines have been used for island developments providing most of a communities power, supplemented by a small engine-based generator. They are seen to provide a central focus for the community and a source of free and reliable power.

Diagram







Size and output 1.5 kW 4200 kWh/year (2.1 metre diameter); 6kW 12-15 MWh/year (5.5 metre dia); Output varies with wind speed and so figures should only be used as a guideline.

Costs Building integrated systems are retailing at £1500 (SWIFT 1.5kW), £18000 inst (Proven 6kW), £90000 (60kW)

Running costs Estimated 5% of capital costs per year

Funding Clear skies grants providing up to 50% of costs for small community schemes. Electricity company 'Green Energy' funding schemes. Income from sale of Renewables Obligation Certificates £4/kWh.

Legislation Local planning issues, especially regarding effect on radar, noise and visual impact.

UK Suppliers Small: Proven energy, Windsave. Large: Ecotricity, Renewable Energy Systems

Books and documents www.bwea.com

BH projects Lambay Island

Other points The potential for using wind turbines is an issue of scale, and deciding what is appropriate and cost-effective. The two extremes of scale are the use of a large, circa 250kW, wind turbine (sited on the Thames), to a series of small building-integrated, circa 15kW, turbines on the roof of high-rise properties. The cost-effectiveness and performance of the large turbine would exceed that of the smaller turbines, with a cost per kW of around £1000 as opposed to £2000 for smaller units.

Summary Wind turbines are available in a range of sizes, from 0.5kW to 5MW. They can provide a cheap and reliable form of renewable power in many locations. Consideration of visual and noise impacts has to be made.