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BARRIERS TO ENERGY EFFICIENCY: EVIDENCE FROM SELECTED SECTORS

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CONTENTS

EXECUTIVE SUMMARY

As concern mounts about the hazards of global warming, it is becoming increasingly important to restrain the use of energy so as to limit greenhouse gas emissions. Consequently, as a contribution towards that objective, it is important that energy should be used efficiently. It is striking, therefore, that many analysts claim that there are numerous unexploited opportunities for companies and other organisations to invest in measures that would improve their energy efficiency. Furthermore, it is claimed that investment in many of these measures would be cost-effective, meaning that there would be a good financial return from such investment. This raises the question why do organisations not take up these cost-effective opportunities to improve their energy efficiency. What are the *barriers* that impede them from doing so?

The claim that there are many cost-effective energy efficiency opportunities that are not being exploited arises particularly from technologically-oriented analysts who use engineering-economic models. Some of these analysts have suggested that the common neglect of such energy efficiency opportunities is caused by barriers such as a shortage of capital or a lack of information, which prevent markets for energy and energy-using technologies from operating efficiently.

On the other hand, many economists claim that the markets for energy and energy-using technologies are broadly efficient. They suggest that if energy consumers do not invest in measures that are claimed to be cost-effective, then perhaps the real barriers lie in the fact that there are risks attached to these investments. Or perhaps there are "hidden costs" associated with the measures concerned, meaning costs that are not captured by the engineering-economic models. Thus, in this view it is more questionable whether there really are many unexploited energy efficiency opportunities that are genuinely cost-effective, when all the costs and risks are fully taken into account.

This study examines these issues in the context of the Irish economy. We consider whether it is true that there are many opportunities for cost-effective energy efficiency investment that are being neglected. We assess the importance of a range of possible barriers to energy efficiency that have been suggested to explain why this happens. We also aim to consider what would be the appropriate role for public policy in this situation.

To examine these issues, we use case studies from a variety of sectors. These case studies are drawn from the mechanical engineering, brewing and higher education sectors in Ireland. The mechanical engineering industry is selected as an example of light industry that has only low to average energy-intensity. The brewing industry is selected as an example of an industry with above-average energy-intensity, since it has a considerable requirement for energy in its production processes. The higher education sector is selected as an example from the public sector; in this case energy-intensity is low to average but distinctive decision-making frameworks are in place and the availability of capital is constrained by public policy.

Existence of Energy Efficiency Opportunities

In considering the question whether many cost-effective opportunities to improve energy efficiency are being neglected, it is important to note the meaning of the term "cost-effective" in this context. Cost-effective here means that an investment in energy efficiency would have a significantly better rate of return than the cost of capital to the organisation, when one takes account of the readily quantifiable costs such as capital costs and energy costs (and therefore, ignores any risks or "hidden costs" that could be difficult to measure).

The findings from the organisations in the three sectors studied indicate that there are many such cost-effective opportunities, in this sense, still available in most of the organisations concerned. A majority of interviewees in each of the three sectors agreed that there were many energy efficiency opportunities available in their organisations that would have quite short payback periods (namely three years, or five years in the case of brewing). Investments with such short payback periods would have a significantly better rate of return than the cost of capital. Comparable research that was carried out on the same three sectors in the UK and Germany also concluded that there were many such opportunities to improve energy efficiency that were not being taken up.

Companies in the brewing sector generally considered that there were fewer energy efficiency opportunities still available compared to those in the other two sectors. Since brewing is a more energy-intensive sector, which should cause it to pay more attention to energy efficiency, it is not surprising that the brewing industry would already have taken up more of the available energy-efficiency opportunities.

The Relative Importance of Different Barriers

From a review of existing literature, we identified a total of fifteen different barriers to energy efficiency that were previously suggested elsewhere as being potentially important. For each of our three sectors, we attempted as far as possible to rate the importance of each of these fifteen potential barriers. Table 1 shows that eight of these fifteen barriers were found to be of high importance in at least one of the three sectors.

Within this group of eight barriers that appear at least once in Table 1, two stand out as being particularly important, namely access to capital and hidden costs. These two are very important in all three of the sectors studied. Imperfect information is very important in two of the sectors, while the other five barriers are of high importance in only one sector each. It is also worth noting that seven other potential barriers were identified and considered, and although these are not included in Table 1, they are all of at least some importance in some sectors.

These findings from Ireland are similar in significant respects to the results from comparable studies of the same three sectors in the UK and Germany. In particular, access to capital and hidden costs were found to be the most important barriers in all three countries. In addition, imperfect information was found to be commonly of high importance in the three countries.

Table 1: Barriers Considered to be of High Importance in the Different Sectors

Barrier	Mechanical Engineering	Brewing	Higher Education	Total
Access to capital	*	*	*	3
Hidden costs	*	*(1)	*	3(1)
Imperfect information	*		*	2
Split incentives			*	1
Principal-agent			*	1
Form of information, credibility and trust			*	1
Values and organisational culture	*			1
Power or status			*	1

Notes: *The asterisk means that the barrier is identified as being of high importance.
(1) Hidden costs can be of high importance for smaller brewing firms, but not for large firms.

It is noticeable in Table 1 that the number and range of barriers of high importance varies between sectors, with the widest range occurring in higher education and the narrowest occurring in brewing. It is perhaps not surprising that interviewees in the brewing industry perceived only one or two really important barriers to energy efficiency while those in the other sectors identified more, since this is probably a reflection of the fact that brewing is more energy-intensive. Since energy accounts for a larger part of total costs in brewing, the benefits that it can gain by investing in energy efficiency would amount to savings of a greater proportion of total costs than in the case of less energy-intensive sectors. Compared to these relatively large benefits, most potential barriers to energy efficiency would appear to be quite small and it would be considered worthwhile to undertake the effort and expense required to overcome such barriers. In less energy-intensive sectors, however, the benefits that can be gained by investing in energy efficiency would amount to savings of a less significant proportion of total costs. Consequently, a range of barriers that would be overcome in a more energy-intensive sector may appear sufficiently great to actually prevent investments in energy efficiency in less energy-intensive sectors, and hence such barriers would be rated as very important.

CAPITAL CONSTRAINTS

A strong general message from the research is the importance of *limited access to capital* as a barrier to energy efficiency. This can apply at two levels: (1) an overall limitation on access to capital for the organisation as a whole; and (2) restricted access to capital for energy efficiency within internal capital budgeting procedures. The result of either or both of these factors, from the perspective of those responsible for energy management, is that they lack sufficient capital to invest in energy efficiency improvements.

The limitation on access to capital tends to take different forms in the different sectors. In the higher education sector, there were constraints associated with public sector funding, especially in the institutes of technology, as well as internal budgeting constraints. But in mechanical engineering and brewing, the firms in principle have access to commercial capital markets. There was practically no evidence that the case study firms had difficulties in borrowing capital at reasonable rates – as would be the case if there were capital market failures. Instead, the restrictions on access to capital were largely self-imposed internally through a reluctance to take on additional borrowing. These self-imposed restrictions mainly took the form of applying tight payback criteria (typically paybacks of just a few years) when assessing proposed investment projects, including investments in energy efficiency as well as other investments.

There are a number of possible explanations for companies' use of such stringent investment criteria. For example, this can be a method of allowing for business, financial or technical risks. It can be an attempt to deal with "principal-agent" control problems by ensuring that only very clearly cost-effective projects are undertaken. Or it can be a method of recovering some of the "hidden costs" such as the salary and other costs associated with energy management. Thus, firms' use of very stringent investment criteria can be quite a rational reaction to factors such as risks, concerns about financial gearing, or hidden costs, although it may not always be entirely rational.

TIME CONSTRAINTS

A second strong general message from the research is the importance of management time constraints as a barrier to energy efficiency. The general importance of "hidden costs" as a barrier that is seen in Table 1 is primarily a reflection of the aspects of hidden costs that involve putting demands on management time. When it is claimed that certain energy efficiency investments would be cost-effective, such claims may not take full account of the cost of management time that would be required to put such investments into effect. But it can take significant amounts of time for managers to keep up to date with technical information, to identify energy efficiency opportunities and to implement energy efficiency projects. Many interviewees across the different sectors emphasised that there were many competing demands on their time. Thus, their time is valuable and it cannot be regarded as costless.

The Role of Public Policy

The most important barriers to energy efficiency were identified as being: access to capital (in the private sector, specifically a reluctance to borrow as manifested in the use of stringent payback criteria); and hidden costs (especially demands on management time). A feature of both of these barriers is that they may imply that organisations are behaving rationally in their own interest, to a considerable extent, in allowing such barriers to deter them from investing in energy efficiency.

However, governments need to have a different perspective. The basic reason why governments should aim to improve energy efficiency is because of the need to reduce greenhouse gas emissions so as to combat undesirable climate change. If energy users cause environmental damage through greenhouse gas emissions, thereby imposing costs on society at large that are not reflected in a commensurate cost or penalty attached to the use of energy, this is a form of market failure. In this situation, there is a good case for policy intervention to improve energy efficiency and reduce energy consumption.

Although two particular types of barriers to energy efficiency were identified as being most generally important, there are considerable variations in the nature and range of the barriers to energy efficiency that apply to different sectors or organisations. The importance of some types of barriers varies considerably across sectors or companies. Therefore, effective policy solutions need to address the differing circumstances of energy using sectors and organisations. It is unlikely that there will be a single best policy solution for all. For each of the individual sectors studied, we have indicated possible policy recommendations. This gives a range of suggestions, based on the circumstances in each sector, which illustrate the diversity of approaches required.

However, there are certain broad-based national-level policy approaches that influence many or all sectors. For example, the introduction of a carbon tax and emissions trading has been announced and this should tend to raise energy prices generally. In addition, the Integrated Pollution Prevention and Control (IPPC) licensing system will require a range of important industries to use energy efficiently, as well as controlling their emissions of pollutants in general. These broad national measures should have the potential to achieve significant improvements in energy efficiency.

These types of policy measures are suited to addressing the two most pervasive barriers to energy efficiency, namely the access to capital barrier resulting from tight payback criteria, and the hidden costs barrier associated with management time. These measures would have the effect of increasing the incentive to invest in energy efficiency, while at the same time giving organisations cause to allocate more management time to energy efficiency matters. Companies can be compensated for higher energy costs by reducing taxes such as taxes on labour or profits, if it is desired to enhance their incentive to invest in energy efficiency without increasing their total tax burden.

While carbon taxes, emissions trading and IPPC licensing can address the access to capital and hidden costs barriers, these measures would also help to overcome some of the other barriers at the same time. For example, these measures should increase the importance of the energy management function within organisations, thereby helping to overcome the barriers associated with values and organisational culture and the power or status of energy managers.

In addition to these broad national-level measures, however, we have also indicated in the individual sector studies how other more specific measures at sector or firm level can address other barriers to energy efficiency that arise. Sectors with low energy intensity can ill-afford management time to be experts on energy matters. Informative energy labelling, meters and bills as well as demonstration case studies and encouragement to undertake audits could be targeted at these enterprises. Their industry associations may be the best conduit for this task and these associations may need help to focus their organisations. More intensive energy using enterprises could be encouraged to avail of energy service companies (ESCOs), provided that the latter can gain trust and expand their activities into genuine energy efficiency, with appropriate contracts. This aspect requires research and encouragement.

More widespread application of energy audits and of industry-specific or technology-specific guidelines and calculation of benchmarks of energy use could be promoted by Sustainable Energy Ireland (the expanded energy agency, previously the Irish Energy Centre). Use of proper investment appraisal methods should also be facilitated. This applies in particular to state-aided institutions, with incorporation of societal costs of externalities and of resources that are subsidised. Finally, in this list of measures to remove barriers to energy efficiency at the sector level, help should be forthcoming for recording prior and follow-up performance of investments, in order to provide future demonstration studies.

1. INTRODUCTION

As concern mounts about the hazards of global warming and climate change, it is becoming increasingly important to restrain the use of energy so as to limit greenhouse gas emissions. Consequently, as a contribution towards that objective, energy should be used efficiently. It is striking, therefore, that many analysts claim that there are numerous unexploited opportunities for companies and other organisations to invest in measures that would improve their energy efficiency. Furthermore, it is claimed that investment in many of these measures would be cost-effective, meaning that there would be a good financial return from such investment.[1] This raises the question why do organisations not take up these cost-effective opportunities to improve their energy efficiency. What are the *barriers* that impede them from doing so?

The claim that there are many cost-effective energy efficiency opportunities that are not being exploited arises particularly from technologically-oriented analysts who use engineering-economic models. These models incorporate detailed information on energy-using equipment and processes, and they indicate that there are profitable energy efficiency investment opportunities that are frequently overlooked. However, there is no firm consensus on the reasons why such opportunities are neglected. For example, some have suggested that this problem is caused by various barriers, such as lack of capital or lack of information, which prevent markets for energy and energy-using technologies from operating efficiently.

On the other hand, many economists claim that the markets for energy and energy-using technologies are broadly efficient. They would suggest that if energy consumers do not invest in measures that are claimed to be cost-effective, then perhaps the real barriers lie in the fact that there are risks attached to these investments. Or perhaps there is a range of "hidden costs" associated with the measures concerned that are not captured by the engineering-economic models. Thus, in this view it is more questionable whether there really are many unexploited energy efficiency opportunities that are genuinely cost-effective, when all the costs and risks are fully taken into account.

These issues have been quite widely debated; for example they were among the central themes of a special edition of *Energy Policy* on "Markets for Energy Efficiency" (see Huntington *et al.* (eds)., 1994). They have also been examined in a range of other literature referenced in Chapter 2

[1] See, for example, Krause (1996), Lovins and Lovins (1997), Interlaboratory Working Group (1997) and Fisher *et al.* (1998).

below. However, it has been recognised that more detailed empirical work is required to help to resolve the issues (Jacaard and Montgomery, 1996).

This study examines these issues in the context of the Irish economy. We consider whether it is true that there are many opportunities for cost-effective energy efficiency investment that are being neglected. And we assess the importance of a range of possible barriers to energy efficiency that might explain why this happens. In this context, a "barrier" is a postulated mechanism the outcome of which is an organisation's neglect of (apparently) cost-effective energy efficiency opportunities.

A wide range of possible barriers have been suggested in a number of different theoretical traditions. In this study, we outline many different suggested "barriers", drawing from ideas in several traditions including neo-classical economics, organisational economics, behavioural theory and organisational theory. We then test the validity of these ideas using case studies from a variety of sectors. These case studies are drawn from the mechanical engineering, brewing and higher education sectors in Ireland. Each case study involves an examination of the context and process of energy decision-making within the organisation, together with an examination of the significance of various potential barriers to energy efficiency.

Our objectives include the following. We aim to assess the validity of the claim that there are many cost-effective opportunities to improve energy efficiency that are not being exploited. We aim to assess to what extent is investment in cost-effective energy efficient technologies inhibited by various types of barrier to energy efficiency – what is the relative importance of each type of barrier and how does this vary between different sectors and different types of organisation? We also aim to consider whether there is a legitimate role for public policy intervention, and to consider the likely effectiveness of different policy measures for delivering energy efficiency improvements. It is assumed that the effectiveness of different measures will depend upon the nature of the barriers that need to be addressed.

We focus on organisations in three sectors:

- *The mechanical engineering* industry is selected as an example of light industry that has only low to average energy-intensity. It largely makes use of generic energy-using technologies, such as mechanical drives, space heating and lighting, and it does not have a particularly high demand for energy for production processes.
- *The brewing industry* is selected as an example of an industry with above-average (although not exceptionally high) energy-intensity. In addition to generic energy use such as space heating and lighting, it also has a considerable requirement for energy in its production processes.
- *The higher education* sector is selected as an example of a largely publicly funded sector. Here, energy-intensity is low to average and energy use is largely generic, but distinctive decision-making frameworks are in place and the availability of capital is constrained by public policy.

We do not include any example of the most highly energy-intensive sectors, such as production of steel, cement or certain chemicals. Such industries are not a particularly large proportion of the Irish economy. Furthermore, energy decisions in such industries are often site-specific and strategic, and energy accounts for such a large proportion of total costs that it can be assumed that it attracts serious management attention.

In the cases that we have selected, energy forms a smaller proportion of the organisation's total costs. In this context, energy may be neglected by management since managers have other priorities. However, a range of studies in the UK and elsewhere have suggested that many cost-effective opportunities to improve energy efficiency are available in these sectors. Furthermore, these types of sectors account for a large proportion of total final energy demand. If climate change targets are to be met, significant improvements must be achieved in the energy efficiency of sectors such as these.

It should also be mentioned that the research reported here was conducted as part of an international project that was carried out simultaneously in the United Kingdom and Germany as well as in Ireland. Highly summarised results from all three countries are reported in Sorrell *et al.* (2000), although that report has not actually been published. We concentrate here on presenting the full findings from Ireland, but we also refer at times to comparisons from the UK and Germany, particularly in our conclusions in Chapter 6.

The contents of the remainder of this report are as follows:

- *Chapter 2* sets out the theoretical framework for the research in some detail. It draws from a variety of theoretical traditions in order to identify and describe a range of possible barriers to energy efficiency. This leads to the development of a systematic classification of fifteen possible barriers, which is then used to guide the subsequent empirical research.
- *Chapters 3, 4 and 5* present the results of the empirical research in the mechanical engineering, brewing and higher education sectors respectively. The layout of each of these chapters is quite similar. It includes a description of key features of the sector, a structured description of the case study organisations, and an analysis of the evidence for each of the fifteen barriers to energy efficiency that are identified in the theoretical framework in Chapter 2. Within this, an attempt is made to identify which of these barriers are most important in each sector. Finally, there is some discussion of policy responses, although this topic is also addressed in Chapter 6.
- *Chapter 6* presents the overall conclusions and recommendations.

2. UNDERSTANDING BARRIERS TO ENERGY EFFICIENCY

A barrier to energy efficiency is a mechanism that inhibits investment in technologies that are both energy efficient and apparently cost-effective for the potential investor in such technologies.[2] The energy efficiency gap is the gap between what appears to be an attainable cost-effective level of energy efficiency and the level of energy efficiency actually observed in practice. This chapter develops a systematic classification of barriers to energy efficiency, based on a comprehensive review of the literature.[3] The aim is to define each barrier and to describe its mode of operation. Our classification of barriers synthesises ideas from three broad areas of literature: economics; behavioural/ psychological theories; and organisational theories. Within this, the economics literature is given the greatest emphasis as the concept of a barrier originates from within it. We refer to mainstream neo-classical economics as well as ideas from organisational economics and transaction cost economics.

Our review of the literature leads to an initial broad classification of barriers into the three groups: (i) economic; (ii) behavioural; and (iii) organisational. Table 2.1 introduces these three perspectives. In practice this typology is not exclusive since individual barriers can simultaneously have economic, behavioural and organisational aspects (Weber, 1997, p.834). The three groups form *perspectives* that highlight particular aspects of a complex situation. But it should be noted that these perspectives can overlap.

Table 2.1: Perspectives on Barriers

Perspective	Examples	Actors	Theory
Economic	Imperfect information, asymmetric information, hidden costs, risk	Individuals and organisations conceived of as rational and utility maximising	Neo-classical economics

[2] "Apparently cost-effective" in this context means that, considering the measurable costs such as capital costs and energy costs (i.e. ignoring any hidden costs or risks), the investment concerned would be cost-effective.

[3] More detail is provided in Chapter 3 in Sorrell *et al.* (2000), which contains a comprehensive literature review and a more detailed examination of concepts.

Behavioural	Inability to process information, form of information, trust, inertia	Individuals conceived of as boundedly rational with non-financial motives and a variety of social influences	Transaction cost economics, Psychology, decision theory
Organisational	Energy manager lacks power and influence; organisational culture leads to neglect of energy/environmental issues	Organisations conceived of as social systems influenced by goals, routines, culture, power structures etc.	Organisational theory

Historically, the theory of market barriers has been developed from within an economic perspective, and the contribution of alternative perspectives to the understanding of barriers is less well defined. However, we cannot assume from the outset that standard economic theories are sufficient on their own to provide an adequate explanation for the energy efficiency gap. Therefore, other perspectives also need to be explored. In the following sections we discuss in turn (1) economic barriers that arise from market failures, (2) economic barriers that arise from organisational failures, (3) economic barriers arising from neither market nor organisational failures, (4) behavioural barriers, and (5) organisational barriers. We conclude this chapter with a summary of all the potential barriers.

2.1 Economic Barriers 1: Market Failures

A potential source of barriers to energy efficiency is market failures. Market failures occur if the basic requirements for efficient allocation of resources through well functioning markets are violated. It is recognised in neo-classical economics that violations of the necessary requirements can lead to four broad types of market failure:

- incomplete markets;
- imperfect competition;
- imperfect information; and
- asymmetric information.

Most of the discussion of market failures in energy service markets centres on the last two – imperfect information and asymmetric information.

Market failures in the first two categories can be important, but they are less relevant to explaining the energy efficiency gap. For example, if an energy user causes environmental damage, thereby imposing costs on many others with no commensurate cost or penalty for the energy user, this is called an environmental externality and it represents a form of incomplete markets. But this would not explain why energy users do not adopt available energy efficient technologies that should be to *their own* financial advantage at current prices. The discussion below will concentrate on issues of imperfect and asymmetric information, since these are the types of market failures that are most relevant to explaining the energy efficiency gap.

2.1.1 IMPERFECT INFORMATION IN ENERGY SERVICES MARKETS

The importance and policy implications of imperfect information is one of the central issues in the energy policy debate. The primary claim is that the energy service market produces and transmits insufficient information about the energy performance of different technologies. This leads energy consumers to make sub-optimal decisions based on provisional and uncertain information, and consequently to under-invest in energy efficiency. Since imperfect information is one of the basic market failures recognised by economists, this is claimed to provide a rationale for policy intervention. The editors of a special edition of *Energy Policy* on energy efficiency note that: “Information problems taking different forms are the principal source of market failures that account for the ‘gap’ in energy efficiency investments” (Huntington *et al.*, 1994).

The information we are interested in falls into three broad categories:

- information on current energy consumption;
- information on energy-specific investment opportunities; and
- information on energy consumption of new buildings and purchased equipment.

There are several dimensions to imperfect information. Following Golove and Eto (1996, p.20) we can distinguish:

- *Lack of information*: Energy consumers may lack information on the energy performance of different technologies. As Eyre (1997, p.31) notes: “Faced with good information on capital costs and poor information on operating costs, consumers may rationally and systematically choose the low capital option”.
- *Cost of information*: There are costs associated with searching for and acquiring information on the energy performance of technologies. Because of these costs, energy consumers may act without full information.
- *Accuracy of information*: Accurate information may be difficult to obtain, since sellers of technologies may have incentives to exaggerate or manipulate performance data. Unbiased information may be available from other sources but this may be more costly.

As Hewett (1998, p.2.11) notes, the problem of imperfect information is likely to be most serious when:

1. the product or service is purchased infrequently;
2. performance characteristics are difficult to evaluate either before or soon after purchase; and
3. the rate of technology change is rapid relative to the interval between purchases.

All these apply in the case of energy service markets (Hewett, 1998, p.2.11). Energy efficiency consists of a wide range of complex products and services, purchased from an equally wide range of firms. Most products (boilers, lighting equipment, insulation etc.) are purchased infrequently and the technology will have changed substantially since the previous purchase. Also, customers may have great difficulty in evaluating performance claims. It is very difficult to evaluate the energy performance of technologies such as control systems, motors and variable speed drives, even after purchase. This is partly a consequence of the lack of information on energy consumption patterns and hence the lack of detailed feedback on inefficient purchases and behaviours (Hewett, 1998, p.2.13). Without low level sub-metering, all that is available is a monthly energy bill, which makes the operating costs of individual technologies fairly invisible. Kempton and Montgomery (1982) have compared the information value of the average energy bill to that of receiving a single monthly bill from the grocery store for "food"!

These features are important when we compare the purchase of energy efficiency to that of energy supply (e.g. electricity or gas). Here we have a simple, uniform and easy to understand product that is purchased from a small number of large, well established and trusted firms. Purchases are made regularly, market information is widely available and "performance" is judged largely on price. In short, the costs of acquiring information on energy efficiency greatly exceed those for energy supply. Now energy supply and energy efficiency may be understood as different means of delivering energy services (heat, light etc.). Viewed in this way, the latter is disadvantaged relative to the former. The result is likely to be over-consumption of energy and under-consumption of energy efficiency. Problems of imperfect information provide a rationale for policy intervention, such as government information schemes.

2.1.2 ASYMMETRIC INFORMATION IN ENERGY SERVICES MARKETS

Asymmetric information is a special form of imperfect information where parties to a transaction have access to different levels of information. For example, a seller may know more about the quality of a good than the buyer. Similarly, an insuree may know more about her level of precautionary behaviour than the insurer. Two important consequences of asymmetric information are *adverse selection* and *moral hazard*. In addition, the more familiar barrier of *split incentives* may also be interpreted as a consequence of asymmetric information.

These ideas are discussed in turn below.

Adverse Selection in Energy Services Markets

Adverse selection exists when one party in a transaction has private information that is not easily available to the other party before entering into a contract to sell or buy, and this may adversely affect the decisions of buyers or sellers, or both. For example, sellers who have superior products to sell may have difficulty in communicating that information effectively to potential buyers, because buyers may be unable to observe the superior quality of the products. If so, buyers will tend to select goods on the basis of visible aspects such as price, and they will be reluctant to pay the price premium for high quality products. As a result, too little of the high quality products may be sold. And hence, too few of such products may be offered for sale.

Problems of adverse selection may pervade the energy services market. Take housing as an example. In a perfect market, the resale value of an energy-efficient house would reflect the discounted value of energy efficiency investments. But asymmetric information at the point of sale prevents this. Buyers are unable to recognise the potential energy savings and to account for them when making a price offer. Estate agents have greater resources than buyers, but they similarly neglect energy efficiency when valuing a house. In such cases, one party (e.g. the builder) may have the relevant information, but transaction costs impede the transfer of that information to the potential purchaser. The result may be to discourage house builders from constructing energy efficient houses as they will not be able to capture the additional costs in selling prices.

The same processes are at work in a range of energy services markets. In many cases, producers may be unable to market desirable technologies since consumers are unable to observe their characteristics prior to sale (Howarth and Sanstad, 1995, p.106). For example, the energy efficiency of commercial buildings depends heavily on the detailed features of heating, ventilation and controls such as Building Energy Management Systems (BEMS). But in comparison to highly visible features such as outward form and aesthetics, the performance of building services equipment is extremely difficult for the customer to observe. Substitution of an inefficient or oversized piece of equipment in place of efficient equipment could be relatively easy. Thus, we may have bad (inefficient equipment/buildings) driving out good (efficient equipment/buildings), in a manner analogous to Akerlof's (1970) analysis of the second-hand car market.

The likelihood of adverse selection will depend on the nature of the good or service. Here, it is important to recognise that the energy services market is highly differentiated (Golove and Eto, 1996, p.28). At one end we have energy supply (kWh) and at the other we have energy efficiency investments, such as insulation. But in between, there are products that use energy (e.g. appliances) and products that affect the use of energy (e.g. building materials). These may be purchased directly, or via intermediaries such as construction firms or maintenance firms. In these intermediate cases, energy efficiency is a secondary feature of the product or service and often relatively invisible.

As Hewett (1998, p.2.14) points out, most energy efficiency products and services have the characteristic that consumers cannot readily ascertain their true quality even when they have had experience with their purchase. Inadequate sub-metering together with complicating factors such as changes in weather or production output will mean that the energy performance of newly purchased equipment cannot be observed, even after purchase. In this context, the purchasing decision is heavily influenced by the perceived trustworthiness of the seller.

Moral Hazard and Principal-Agent Relationships in Energy Services Markets

The term moral hazard originated in the insurance industry (Pindyk and Rubenfeld, 1998, Chapter 17). Insurance companies lack the ability to monitor the actions of policyholders after they have issued a policy. But the holder may act in a way that makes the insured loss more likely to occur. The term is now used more widely to describe any behaviour under a contract that is inefficient (Milgrom and Roberts, 1992, p.195). It refers to situations where the actions of one party are unobservable to a second party. Since the interests of the two parties may differ, this creates an incentive for the first party to act in an opportunistic manner to the detriment of the other.

An important example of moral hazard occurs within firms in the context of *principal-agent* relationships. Here, the "agent" is the party who acts (e.g. an employee) and the "principal" is the party whom the action affects (e.g. an employer). The principal's problem is to ensure that the agent acts to her benefit, but she lacks complete information – i.e. she cannot fully monitor and evaluate how hard the agent is working or whether she is being honest. There is an extensive literature on moral hazard and principal-agent relationships (Mohlo, 1998; Milgrom and Roberts, 1992; Prendergast, 2002).

Principal agent relationships are more relevant to barriers to energy efficiency *within* organisations than to the wider energy services market, and such barriers within organisations are discussed below in Section 2.2. But some features of the wider energy services market may be interpreted in these terms. For example, construction companies may be interpreted as acting as agents for the client. The latter may either be the ultimate occupier of the building or a speculative developer. The construction company may have incentives to take actions which are different from what the principal would prefer – notably to cut corners on energy efficiency to maximise profits. This is possible because the agent's actions are largely unobservable by the principal. In a similar manner, subcontractors to the main construction company may also face incentives to maximise profits by, for example, putting in cheaper and less efficient components.

Split Incentives (Appropriability) in Energy Services Markets

One of the most familiar barriers to energy efficiency is split incentives. The most commonly cited example is landlords and tenants in the housing market (Scott, 1997). The landlord of a building may be unwilling to retrofit an apartment to reduce energy use since the resulting savings would be realised by the tenant. But at the same time tenants will be unwilling to retrofit since they may move out before benefiting fully from the cost savings.

This type of problem may also be interpreted as a form of market failure resulting from asymmetric information (Jaffe & Stavins, 1994b, p. 805). One party may have the relevant information on the costs and benefits of an energy efficiency investment, but it may be difficult to convey this to the other party. If there were no information problems, landlords and tenants would be able to enter into contracts to share the costs and benefits of the investment. In practice, however, the gains that would be achievable through such arrangements are swamped by the information problems and transaction costs involved. The arrangements that would be needed to make rents reflect the capitalised value of energy savings could be highly complex.

Split incentives may, therefore, be understood in the more familiar terms of inability to *appropriate* the benefits of an investment, or alternatively as a manifestation of asymmetric information and transaction costs. In either case, the situation can be understood as a true market failure in the neo-classical sense.

Most literature on split incentives has focused on the household sector. But similar problems also arise in the public, commercial and industrial sectors through the *leasing* of buildings or equipment. This barrier is particularly important in commercial buildings as the leasing of office space is very common. In many leases, tenants simply pay a fixed pro rata share of the building's energy bill. This means the savings generated by one tenant's investment would accrue to all other tenants as well, diluting the investment incentive. The problem could be overcome through sub-metering, but this appears to be relatively rare.

2.2 Economic Barriers 2: Organisational Failures

Organisational failures fall into two broad categories:

- Principal-agent relationships within organisations
- Split incentives and appropriability within organisations

These are discussed below.

2.2.1 MORAL HAZARD AND PRINCIPAL-AGENT RELATIONSHIPS WITHIN ORGANISATIONS

Barriers within organisations are exemplified by the use of stringent payback criteria for energy efficiency investments. It is common to observe both: (a) the use of payback criteria in preference to discounted cash flow analysis; and (b) the use of very stringent payback criteria (2 or 3 years or even less) which implies a rate of return that is significantly greater than the firm's cost of capital (DeCanio, 1994). These observations run counter to the recommendations of neo-classical economics which are that firms should proceed with all investments where risk-adjusted rates of return exceed the firm's cost of capital. The fact that departures from this recommendation appear to be the norm demands explanation. Principal-agent relationships within the organisation may provide one possible explanation for this.

As indicated in Section 2.1.2, principal-agent relationships exist where the interests of one actor, the principal, depend on the action of another actor, the agent. The agency problem arises when the principal tries to ensure that the agent behaves in ways that are consistent with the principal's interests. Such principal-agent relationships are pervasive within hierarchical firms. Since the objectives of the principal and agent can diverge, the principal commonly aims to protect her interests by strictly *monitoring* the agent, and/or by creating an appropriate *incentive* structure (Rowlinson, 1997, p.31).

Principals (e.g. the company owner) cannot fully observe either the true quality of decision making or the true profitability of proposed investment projects. This creates the risk that profits are dissipated into "managerial slack" – defined as the excess use of resources over the minimum required for the task (DeCanio, 1993, p.909). One method of reducing this slack is to set the hurdle rate for investment projects to be substantially above the cost of capital to ensure that only genuinely profitable investments are undertaken (Antle and Eppen, 1985; Statman, 1982). Furthermore, we would expect the hurdle rate to be higher for small investments, since the transaction costs of determining the profitability of the investment represent a greater portion of the expected savings. Energy efficiency investments typically fall into this category of small, cost saving investments.

Several formal models have been developed to demonstrate this outcome (Narayanan, 1985; Chaney, 1989), which leads to second-best expedients. The principal second-best expedient is the use of high hurdle rates (short payback criteria) for energy efficiency investments. But the widely observed practice of capital rationing (Ross, 1986) may also be explained in these terms. Here, top-level managers reduce the funds available for small, cost saving projects to reduce the risk that, in the absence of effective monitoring, resources will be misallocated.

2.2.2 SPLIT INCENTIVES AND APPROPRIABILITY WITHIN ORGANISATIONS

It is often the case that managers remain in their posts for relatively short periods of time (DeCanio, 1993, p.908). In large companies, there may even be a policy of job rotation. But a manager who is in a post for only 2-3 years may have no incentive to initiate investments that have a longer payback period. The incentive structure is, therefore, skewed towards projects with rapid returns – although these may prove inferior to others if a full discounted cash flow analysis were performed. As with landlords and tenants, problems of information and communication prevent the incentive structure from being modified. Statman & Sepe (1984) point to a related issue in that, even without job rotation, management incentive structures are typically biased towards short-term performance.

The use of sub-metering and cost centres is another issue. It is necessary to ask, *what are the personal incentives for investing in energy saving*? The greatest incentive would be if the divisional managers were responsible for their own energy costs and could directly benefit from any savings. If the benefits of cost savings accrue elsewhere, then this incentive is diluted. To introduce such accountability, it may be necessary to sub-meter energy use by individual cost centres. Alternatively, accountability could be centralised, with individual posts of energy management staff made self-funding from the savings from efficiency improvements.

Very similar issues arise in equipment purchasing. The purchaser may have a strong incentive to minimise the capital costs of the purchase, but may not be accountable for running costs. Alternatively, maintenance staff may have strong incentives to minimise capital costs and/or to get failed equipment working again quickly, but may have no incentive to minimise running costs.

2.3 Economic Barriers 3: Rational Behaviour

The third category of economic barriers refers to factors that cannot be classified as either market failures or organisational failures. Here, the barriers are real features of the decision-making environment of firms, although the features concerned have proved difficult to incorporate in engineering-economic models. Thus, when engineering-economic models indicate that a particular investment in an energy-saving measure would be both energy-efficient and cost-effective for the investor, they may actually be overlooking some real cost or obstacle that would confront some or all potential investors. By not making such an "energy efficiency" investment, therefore, an organisation may be acting quite rationally when one takes full account of all its circumstances.

The three main barriers in this group are *heterogeneity*, *hidden costs* and *risk*. Problems with *access to capital* may also be included here, although this category is more contentious and it is sometimes less clear whether it really belongs in this group. These barriers are discussed in turn below.

2.3.1 HETEROGENEITY

The heterogeneity (or diversity) argument is straightforward (Jaffe and Stavins, 1994b, p.805; Golove and Eto, 1996, pp.13-14). The estimates of cost effectiveness for a particular technology are based on the characteristics of an *average* user within a particular class. For example, small scale CHP may be demonstrated to be cost effective for medium sized sites in the brewing industry. But within this definition of a class of users, there may be wide variation in actual characteristics. In the case of CHP, profitability depends on high annual utilisation and typically requires at least two-shift, 6 days/week working patterns. While this may be the norm in a particular sector, it may not apply in all cases. Hence, for a subset of the population with low annual operating hours, CHP will not be profitable.

The size of this subset will depend on the distribution of characteristics within a population. In some cases it could be large. If engineering-economic models do not reflect this variation, they will overstate the opportunities for a particular technology in a particular sector. Whether heterogeneity can provide an explanation for the apparent efficiency gap is an empirical question. It cannot be settled in the abstract.

2.3.2 HIDDEN COSTS

Hidden costs represent one of the most important arguments against the "efficiency gap" hypothesis. The claim is that engineering-economic studies fail to take account of the reduction in benefits associated with energy efficient technologies or the additional costs associated with them (Nichols, 1994). As a consequence, the studies overestimate efficiency potential.

Three broad categories of hidden costs can be identified:

- general *overhead* costs of energy management;
- costs *specific* to a technology investment; and
- loss of *benefits* associated with an efficient technology.

Possible elements of each type of cost are indicated in the following table.

Table 2.2: Possible Components of Hidden Costs

Category	Example
General overhead costs of energy management	• costs of employing specialist people (e.g. energy manager) • costs of energy information systems (including: gathering of energy consumption data; maintaining sub-metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); • cost of energy auditing;
Costs involved in individual technology decisions	• cost of (i) identifying opportunities; (ii) detailed investigation and design; (iii) formal investment appraisal; • cost of formal procedures for seeking approval of capital expenditures; • cost of specification and tendering for capital works to manufacturers and contractors • cost of disruptions and inconvenience; • additional staff costs for maintenance; • costs for replacement, early retirement, or retraining of staff;
Loss of benefits in individual technology decisions	• problems with safety, noise, working conditions, extra maintenance, reliability, service quality etc. (e.g. lighting levels).

An empirical example is provided by Hein and Blok (1994). They found that the search and information costs of a range of energy efficiency investments formed between 3 per cent and 8 per cent of the total investment cost.

The salary part of overhead costs of energy management may be of particular importance. For example, the UK EEBPP (the Energy Efficiency Best Practice Programme) recommends that a sum equivalent to 5 per cent of an organisation's annual energy expenditure should be reserved for energy efficiency investment. For a site with a £1million bill, this would equal £50,000. But the salary costs for a full-time energy manager may be £30,000, or 60 per cent of the annual investment budget. In this context, stringent payback criteria for investment projects may be justified as a means to recover the salary overhead costs. But is it reasonable to load *all* of the salary overheads onto investment projects? Much of energy management may be seen as an essential overhead, including tasks such as negotiating with energy suppliers and overseeing maintenance. The question of *what proportion* of overheads should be recovered through investment projects is difficult to answer and may vary between different organisations.

The inclusion of information costs as a hidden cost leads to an overlap with the true market failures discussed in Section 2.1. The argument is that there are costs entailed in, for example: identifying the investment opportunity; identifying the options available; identifying the energy performance of different technologies; verifying the quality of information; assessing the reliability of equipment suppliers, and so on. These costs may easily be neglected in standard engineering-economic models. But is the difficulty and cost of obtaining information a consequence of a failure in the market for information, or is the market working efficiently? The empirical starting point is the same – identifying whether information costs exist – but interpretation of the results is contentious.

2.3.3 RISK

Both the use of high discount rates for energy efficiency investments and the rejection of particular energy efficient technologies may represent a rational response to risk. For example, if there is some doubt that a business will survive over the next three years, stringent investment criteria may be entirely appropriate.

We may distinguish three broad categories of risk:

- *External risk*: e.g.
    - overall economic trends (e.g. recession);
    - expected reductions in fuel and electricity prices;[4]
    - political changes and government policy;
- *Business risk*: e.g.
    - sectoral economic trends;
    - individual business economic trends;
    - financing risk (reaction of capital markets to increases in borrowing);
- *Technical risk*: e.g.
    - technical performance of individual technologies
    - unreliability.

Risk, therefore, has many dimensions. Risk may be difficult to evaluate objectively and while *perceptions* of risk may inhibit investment, this does not necessarily mean that those perceptions are rational. These factors make risk particularly difficult to incorporate within engineering-economic models.

Technical risk will be specific to particular technologies. Many of the technologies recommended in energy efficiency literature are well proven and apparently low risk. This makes it unlikely that technical risk will often provide a rational reason for rejection, but there may be site-specific reasons.

Some economists argue that discounted cash-flow models are theoretically inadequate for studying energy efficiency investments and must be supplanted by more sophisticated techniques that take account of risk and uncertainty (Hassett and Metcalf, 1993; Metcalf, 1994; Sutherland, 1991). These models tend to predict use of higher discount rates and suggest that this represents a rational response to risk. As with other neo-classical approaches, the argument assumes that economic agents make optimising decisions. Furthermore, the suggested models imply highly sophisticated decision-making techniques which generally seem implausible to non-economists (Howarth and Sanstad, 1995, p.105).

[4] This could justify stringent investment criteria for energy efficiency projects if the direction of energy price changes was expected to be downwards.

Sutherland (1991) applies the Capital Asset Pricing Model to efficiency investments and concludes that investors will require higher returns from assets where yields are uncertain and where it is not possible to diversify risks. But Sanstad, Blumstein and Stoft (1995) have shown that Sutherland's model explains only a small risk premium. Also, Howarth and Sanstad (1995) have argued that uncertainty over the benefits of energy efficiency does not imply that such investments increase overall risk.

Hasset and Metcalf (1993) and Johnson (1994) present a similar argument to that of Sutherland. They develop a model which suggests that, given (a) fuel and capital price uncertainty and (b) the irreversibility of efficiency investments, the required rates of return for efficiency investments should be higher than conventional investment models predict. One reason for this is that there is an opportunity cost in acting today, rather than delaying the decision and resolving some uncertainties. The full cost of investment should, therefore, include the cost of foreclosing such options (Pindyck, 1991).

Again, Howarth and Sanstad (1995) have strongly criticised this model. They note that the model:

- fails to account (by some distance) for the observed high discount rates;
- ignores the costs involved in delaying decisions (e.g. the loss of services if an appliance is not replaced); and
- assumes that consumers are fully informed about the characteristics of technologies.

Hence, the argument that high discount rates can be considered a rational response to risk for *all* types of efficiency investment does not seem plausible. The quantitative predictions of the models fail on their own terms, quite apart from the implausibility of the behavioural assumptions. However, external, business or technical risk may be a relevant and important factor in individual circumstances.

2.3.4 ACCESS TO CAPITAL

Many energy consumers (particularly low-income households but also some SMEs) have access to capital only at costs that are well above the average rate of return on capital in the economy. Access to capital is, therefore, a commonly cited barrier to energy efficiency investments (Hirst and Brown, 1990; Eyre, 1997).

A neo-classical response to this point is that while inability to access capital may constitute a barrier, it need not imply a market failure in capital markets. In a perfect market, capital is allocated to projects with the highest *risk adjusted* rate of return. Sutherland (1996) and others argue that groups such as low-income households are high-risk borrowers. Hence the market is working efficiently in restricting capital to such groups.

This observation is important but it runs the risk of becoming a tautology. Are all low income consumers high risk? Some evidence suggests not. For example, the Gramreen bank in Bangladesh has lent micro-credit to very poor people for many years and has never had a default (Righter, 1998). If this is the case, then imperfections in capital markets may impede economic efficiency and thereby justify intervention.

Golove and Eto (1996, p.22) argue that this barrier can be better understood as an information problem. There is a cost entailed in investigating the creditworthiness of small firms and individuals. This cost may be sufficiently high to diminish the economic viability of such loans. Historical evidence may suggest that the probability of a default increases for smaller firms. While the risk could be investigated in a particular instance, the cost of acquiring information will be large because of the large number of potential clients.

Another aspect of the capital availability problem relates specifically to the public sector (and hence to the higher education sector in our study). In the public sector, access to capital is frequently directly rationed by government with the aim of controlling public borrowing. The assumption is that private sector investment is more productive and that excessive public expenditure will damage economic objectives (Eyre, 1997, p. 33). But such a ruling can pre-empt assessment of the cost effectiveness of individual projects and hence can inhibit economic investment.

Within private sector firms, restrictions on capital are often self imposed. Here firms seem to be reluctant to borrow money to finance low risk energy efficiency projects with rates of return that significantly exceed their weighted average cost of capital. There are two dimensions to this problem. First, there is a restriction on overall borrowing. Second, available finance is allocated to projects according to a priority list and energy efficiency typically comes low on the list. But are such restrictions rational?

Capital constraints may be self-imposed through concerns about the risk of increased *gearing*. Gearing refers to the ratio of loan finance to equity and there is a voluminous theoretical and empirical literature on the effect of gearing on a firm's cost of capital (Mclaney, 1994, Ch. 11).[5] The key observation here is that loan finance carries *risk* in that it imposes obligations both to meet annual interest charges and to repay the principal. In contrast to share dividends, these are fixed obligations and are not at the firm's discretion. High levels of gearing or loan finance expose the firm to the risk that it will not be able to meet its payment obligations should it experience a downturn in business.

The lenders have the legal right to enforce loan repayments, whereas ordinary shareholders do not have rights to enforce the payment of a dividend. This situation means that high levels of gearing expose the shareholders to greater risk as all the firm's profits could be eaten up in the repayment of loans. As a result, shareholders will demand higher returns as compensation. Furthermore, high levels of gearing also expose the *lenders* to greater risk as, should the firm go out of business, the asset value may be insufficient to pay off the outstanding loans. Hence, lenders too will demand higher interest payments on loans.

The net result of this is that high levels of gearing increase risk and raise a firm's cost of capital. That is, the cost of obtaining additional capital (the effective interest rate) may exceed the average cost under the existing debt/equity mix (Ross, 1986). Management will, therefore, restrict the level

[5] The key article in this field is Modigliani and Miller (1958), which challenged the traditional view of the effect of gearing. This was the starting point for much of the subsequent debate.

of gearing to a level they feel comfortable with. Whether this is rational in any one case depends upon the current level of gearing, judgements about how the financial market will respond to any increase in gearing, and judgements about the future business situation – including movements in exchange and interest rates. Since most energy efficiency investments involve relatively small sums of money, these should have little impact on the level of gearing for the firm as a whole. But borrowing requirements and "financing risk" are likely to be assessed for the firm as a whole, and not for individual investments. The effect would be to restrict the overall capital budget for investment, including that for energy efficiency.

These considerations suggest that it is particularly difficult to assess whether self-imposed restrictions on borrowing represent a rational response to financing risk. The answer will vary with the circumstances. If it is a rational response, then access to capital becomes a *risk* issue rather than a problem with capital markets. If it is not a rational response, then restrictions on borrowing can be considered as an organisational failure, rather than rational behaviour.

2.4 Behavioural Approaches to Barriers

Many of the economic barriers outlined in the previous three sections would impede economic efficiency even with fully rational agents – that is, with utility maximising consumers and profit maximising firms. But despite its dominance in economic models, the rationality hypothesis is widely criticised as a poor representation of actual behaviour (Hodgson, 1988). In the energy literature, a wide range of empirical research has demonstrated that assumptions of economic rationality on the part of energy users are fundamentally flawed (Katzev and Johnson, 1987). For example, Kempton and Montgomery (1982) demonstrate that energy consumers systematically deviate from cost minimising behaviour even when motivated to make careful decisions. As Sanstad and Howarth note, "...while consumers often lack complete information about the energy decisions they must make, they more importantly lack *expertise* in processing and applying the information that is available to them" (Sanstad and Howarth, 1994, p. 816).

The implication of this is that neo-classical economic analyses of barriers would be insufficient to explain the efficiency gap. Concepts from behavioural perspectives should also be employed. The following sections discuss two such approaches. Section 2.4.1 introduces an alternative conception of rational behaviour, known as *bounded rationality*, which emphasises constraints on agents' time, attention and the ability to process information. Section 2.4.2 summarises some additional insights on "the human dimension" that have emerged from psychological studies of energy decision making, focusing on the form of information, credibility and trust, inertia and values. A difference between the two approaches is that bounded rationality is considered by some economists to be amenable to modelling using modifications to the standard tools of optimisation theory (Howarth and Andersson, 1993). Bounded rationality has also been incorporated into several alternatives to mainstream economics, including evolutionary economics and transaction cost economics. In contrast, researchers in the "human dimension" tradition consider economic concepts to be insufficient for analysing and understanding energy related behaviour (Stern, 1986; Shove, 1995).

2.4.1 BOUNDED RATIONALITY

The concept of bounded rationality was first introduced by Herbert Simon in the 1950s and it has been highly influential (Simon, 1957; Simon, 1959). Simon draws a distinction between substantive and procedural rationality where:

- *Substantive* rationality implies that agents make decisions in the manner prescribed by formal optimisation models – or at least that their choices are consistent with the predictions of such models.
- *Procedural* rationality implies that people make decisions subject to constraints on their attention, resources and ability to process information – and hence that their choices are likely to differ significantly from the predictions of optimisation models.

Procedural rationality has two important implications. First, individuals and companies will aim to make satisfactory decisions rather than expend time and effort searching for the very best or optimum decision. This process is termed *satisficing* rather than optimising. As March and Simon note:

> Most human decision making, whether individual or organisational, is concerned with the discovery and selection of satisfactory alternatives; only in exceptional cases is it concerned with the discovery and selection of optimal alternatives. To optimise requires processes several orders of magnitude more complex than those required to satisfice. (March and Simon, 1958, p.171).

Second, individuals and organisations are rational in the sense that decisions are goal directed. But constraints on time, attention, resources and the ability to process information lead to optimising analyses being replaced by imprecise *routines* and *rules of thumb*. Means are found to economise on scarce cognitive resources. In organisations, this could mean focusing on core activities, such as the primary production process, rather than peripheral issues such as energy use. Decisionmaking is also divided up between specialists, with abstract global objectives being replaced with tangible sub-goals the achievement of which can be measured.

These basic ideas have been extensively developed. For example, they provide a central theme of *evolutionary economics* (Dosi and Nelson, 1994; Nelson and Winter, 1982). Evolutionary economics emphasises the:

> ...general occurrence of various rule-guided behaviours, often taking the form of relatively invariant *routines* whose origin is shaped by the learning history of the agent, their pre-existing knowledge and, most likely, their value system and prejudices...the behavioural foundations of evolutionary theories rest on learning processes involving imperfect adaptation and mistake ridden discoveries. (Dosi and Nelson, 1994, p.159).

Empirical studies of energy decisions overwhelmingly support the hypothesis of bounded rationality. For example, the provision of accurate information on costs and benefits does not necessarily improve the quality of decision making. In a survey of energy information programmes, Robinson (1991) concludes that "... it is clear that, with the exception of some labelling programmes, energy information programmes on their own have not to date resulted in significant energy savings".

An example of the importance of routines is given by de Almeida's study of the French market for energy efficient motors (de Almeida, 1998). In the general absence of neo-classical market failures, energy consumers consistently chose inefficient motors. De Almeida argues that this results from the use of cognitively efficient rules of thumb. For example, when small end-users had to buy motors in an emergency, the only parameters they considered were delivery time and price. The rule of thumb was to buy the same type and brand as the failed motor from the nearest retailer. Similarly, maintenance departments in large firms evaluated motors only in terms of maintenance costs and reliability. De Almeida's work demonstrates the importance of analysing specific technology decisions. The extent and importance of bounded rationality will vary with the decision – for example between emergency replacement, routine replacement and new requirement.

Three important conclusions follow from this. First, bounded rationality may be considered as an additional barrier that does not fit into conventional economic models (Sanstad and Howarth, 1994). Some commentators term this barrier a market failure. For example, Eyre notes that: "...There is a market failure to the extent that consumers do not attempt to maximise their utility or producers their profits." (Eyre, 1997, p.36). The benchmark for this judgement is substantive rationality. As Sanstad & Howarth note: "...individuals and firms do not always behave according to the logic of economic rationality *but they should*." (Sanstad and Howarth, 1994, p.179).

Second, real world departures from the substantive rationality assumed in most engineering-economic models can account for a proportion of the efficiency gap. How large a proportion is a (difficult) empirical question. It is not possible to determine, a priori, the relative importance of neo-classical barriers and bounded rationality.

Third, the existence of bounded rationality may also undermine some intervention programmes designed to improve energy efficiency. If agents lack the ability to use information, there may be little point in providing more information. Instead, it may be necessary to employ a different type of intervention such as imposition of performance standards.

Rules and Routines as Solutions to Bounded Rationality

Simon's original work was focused on organisations and he saw the division of labour within organisations as a means of economising on bounded rationality (Simon, 1957). Regular and predictable patterns of behaviour in organisations may be understood as the result of *routines* rather than rational choice (Dosi and Nelson, 1994; Nelson and Winter, 1982). The importance of rules and routines depends upon the organisational structure, but rule following is pervasive. Most decisions are the consequence of applying a set of rules to a situation, rather than a systematic analysis of alternatives. As Stern notes: "Organisations generally solve problems and respond to environmental demands by applying existing routines rather than developing new ones" (Stern, 1984, p.109).

Payback rules represent one type of routine (Stern, 1984, p.109). Their attraction, from a bounded rationality perspective, is that they are simple, easy to communicate and intuitive. They economise on managerial effort in examining investment proposals across widely different operations.

Capital budgeting procedures represent a second type of rule, used in delegating the authority to spend money. Typically, the primary concern when evaluating an investment opportunity is whether there is money in the budget, rather than what is the rate of return (Stern, 1984, p.110). Expenditure that exceeds the budget (breaks the rule) requires administrative approval, a potentially complex and lengthy process that discourages attempts to do so. Routines, therefore, facilitate information handling, but can be inflexible.

Other types of rule include operation, safety and maintenance procedures, relationships with particular suppliers, design criteria, equipment replacement routines and so on. They may either be formally specified in written procedures or embedded in social practices. Routines are a means of allocating attention. Energy efficiency opportunities may receive little attention if they do not form part of standard routines and operating procedures.

2.4.2 THE HUMAN DIMENSION

The second approach in the behavioural literature derives from social psychology rather than economics and it has paid particular attention to improving the effectiveness of energy efficiency programmes (Stern, 1986; Katzev and Johnson, 1987). Many of these programmes date from the 1973 oil crisis, and the range of psychological literature seems to have declined in the 1980s as these programmes declined (Lutzenhiser, 1993, p.253). This literature is overwhelmingly dominated by studies of household energy consumption, with very few studies of organisations. Nevertheless, some useful insights can be drawn for our purposes.

The primary aim of this literature is to derive *realistic* descriptions of how individuals and organisations make decisions about energy use. It is argued that people do not respond to price signals in the way assumed in energy models. The following observations are typical (Stern, 1986):

- Economists assume people respond to marginal prices, but in practice they are more likely to respond to average prices or total costs.
- Demand is not a smooth function of price. People respond more to rapid change since the stimulus is more noticeable.
- People generally require a higher rate of return for smaller investments.

Similar points are made by Hewett (1998, p.2.16) who notes that the mental shortcuts used to economise on bounded rationality lead not simply to "limitedly rational" decisions but to systematically biased or erroneous decisions. Quoting Piattelli-Palmarini (1994), she terms these *cognitive illusions*.

A systematic alternative to economic theories of rationality has been developed by Kahneman and Tversky (1979). Termed "prospect theory", this notes that:

- people treat gains differently from losses and hence they undervalue opportunity costs;
- outcomes received with certainty are weighted more than those with uncertain outcomes;
- choices depend strongly on how a decision is framed, that is, on the reference point.

These and similar observations lead to three concepts from the psychological literature that may be framed as barriers:

- form of information;
- credibility and trust;
- inertia.

A further concept, *values*, is also discussed below. This does not strictly represent a barrier, but it may be an important variable in explaining energy decision making.

Form of Information

The costs of acquiring and verifying information have already been discussed. But the behavioural literature emphasises that there is more to information than cost. This is demonstrated by US evaluations of energy efficiency programmes which demonstrate that people ignore useful information even when it is costless (Kempton, *et al.*, 1984, p. 19). As Stern notes: '... the cost of searching does not seem to be the main reason people are ill informed. The effectiveness of information depends on more than its availability and content.' (Stern, 1984). In other words, the *form* of information is crucial.

Such a point is obvious to social psychologists and marketing departments, but it also has implications for energy efficiency policy. Five elements of information in particular are important:

- Information should be *specific and personalised*, e.g. individual energy audits will be more effective than general information on cost saving opportunities.
- Information should be *vivid*. For example, a US study showed that people who viewed a video about implementing domestic energy saving measures were significantly more likely to cut energy use than those who received the information in writing (Winett *et al.*, 1984, n24). Similarly, demonstration of tangible success with a technology is likely to have far more persuasive power than a sales pitch – hence the emphasis in government information programmes on technology demonstration schemes.
- Information should be *clear and simple*.
- Information should be available *close in time* to the relevant decision.
- *Feedback* should be given on the beneficial consequences of previous energy decisions if subsequent efficiency measures are to be encouraged (Seligman *et al.*, 1981).

Absence of information in a suitable form that is easy to assimilate could be considered a barrier to energy efficiency.

Credibility and Trust

A further dimension of information is the *credibility* of the source (Stern, 1984, p.43). Credibility involves a combination of expertise and trustworthiness. One possible explanation for why people ignore information that is both useful and free is that they do not trust the source.

A classic study by Craig and McCann (1978) illustrates this point. One thousand New York households were sent a pamphlet describing how to save energy. Half the households received the mailing from the local electric utility, and the other half from the state regulatory agency. The following month, households that had received pamphlets from the agency used about 8 per cent less electricity than those that had received the identical pamphlets from the utility.

Perceptions of credibility will depend on a variety of factors including: the nature of the source (e.g. private, governmental, charity or pressure group); past experience with the source; the nature of interactions with the source; recommendations from colleagues; and recommendations/impressions from a wide range of contacts within professional and social networks. Of these, it is clear that *interpersonal* contacts and recommendations count for significantly more than labels, pamphlets and paper qualifications (Stern, 1984, p.67). Most of these effective contacts are made through existing professional and social *networks* which, therefore, play a fundamental role in transmitting information and establishing trust.

Inertia

Some of the behavioural literature suggests that inertia may be an explanatory variable for the non-adoption of energy-efficient technologies. The findings of "prospect theory" are relevant here. First, we have the observation that gains are treated differently from losses. This means that opportunity costs, the gains foregone, are undervalued (Hewett, 1998, p.2.17). Organisations will consider themselves "endowed" with their existing buildings, equipment and energy bill. Foregone energy savings are considered an opportunity cost, while the investment costs of energy efficient equipment will be an out-of-pocket cost:

> [A] certain degree of inertia is introduced into the consumer choice process since goods that are included in the individual's endowment will be more highly valued than those not held in the endowment ... This follows because removing a good from the endowment creates a loss while adding the same good (to an endowment without it) generates a gain.[6]

Second, potential energy savings are uncertain, while continuing with the existing "endowment" will give predictable outcomes. Since outcomes that are known with certainty will be given greater weighting than those that are uncertain, this will reinforce the tendency to inertia.

A third factor is the desire to minimise regret:

[6] Thaler (1991, p 8), quoted in Hewett (1998, p 2.17)

> Action and decisions require a greater justification than inaction, than failing to decide ... Our mental economy has a built in economy for action. If our actions do not pan out, or cause a loss, we regret having acted. If, instead, we do not act, if we leave things as they are, and our investment does not pan out, or we lose, we still suffer regret but the regret is *lesser*.[7]

All three factors may cause individuals and organisations to favour the status quo, contrary to the predictions of neo-classical economics. Rather similar conclusions follow from a separate behavioural theory known as *cognitive dissonance* (Stern, 1984, p.69). This makes the following observations:

- people tend to rationalise previous decisions, emphasising the positive aspects of the decision and the negative aspects of the unchosen alternative;
- this tendency is greater for difficult, costly or irreversible decisions;
- people remember the plausible arguments for their own position and forget the plausible arguments opposing their position;
- once someone makes a small commitment in a given direction, that person is more likely to make a subsequent larger commitment.

Hence people resist change because they are committed to what they are doing, and they justify that inertia by the downgrading of contrary information. Thus, inertia may help explain the neglect of cost-effective energy efficiency opportunities. However, any positive results from efficiency investments that are undertaken can create a momentum leading to further savings in the future.

Values

In one sense, personal values and norms concerning the environment should not be relevant to explaining the "energy efficiency gap" in the sense in which we use that term. In specifying the existence of such a gap, potential energy efficiency investments are defined as being cost-effective under normal commercial criteria, and the basic motivation for investment is assumed to be the economic motivation. "Barrier" hypotheses purport to explain why an apparently cost-effective investment does not go ahead.

But in reality, economic considerations may provide only one element of a decision. The environmental impact of energy use has motivated energy efficiency for many years, and the recognition of global climate change has made it more relevant than ever. Values can, therefore, be explanatory variables in explaining the take-up of energy efficient technologies.

We can distinguish between personal values and corporate values, where the latter are embedded in the wider organisational culture. Issues of organisational culture are discussed below in Section 2.5. The personal values of influential individuals such as top management can be relevant, since it is often such a *product champion* who initiates action on energy efficiency. Values may play a role in sensitising an individual or

[7] Piatelli-Palmarini, 1994, p 27-28, quoted in Hewett (1998, p 2.17)

organisation to cost effective opportunities to save energy that may otherwise go unnoticed. A related dimension to this is the *visibility* of energy efficiency performance, and the impact of this on the public profile (image) of the organisation.

Household studies demonstrate that the relative importance of values in energy-related decisions depends on the cost and difficulty of the efficiency measure. For example, Stern *et al.* (1987) found that personal norms were a reliable predictor of low cost domestic energy conservation measures, but showed a weak relationship to major household investments.

While the absence of relevant environmental values does not strictly constitute a "barrier" in the classic sense, the importance of values should nevertheless be explored. If this were not done, we would miss a potentially important element of energy decision making.

2.5 Organisational Theory Approaches to Barriers

Organisational theory approaches to barriers are the least well developed of the three perspectives and what follows is necessarily tentative.

A broad distinction can be made between *organisational theory* and *organisational economics* (Rowlinson, 1997). The latter was described in previous sections and represents an application of a small number of relatively precise economic ideas to explain the structure and operation of organisations. In contrast, the discipline of organisational theory is notoriously diverse and eclectic. Ideas are borrowed from a wide range of disciplines and are employed as *metaphors* to explain different facets of organisational behaviour, e.g., organisations viewed as machines, as cultures, as political systems, etc.

While there is a wealth of literature on the behaviour of organisations,[8] there are very few studies dealing explicitly with energy efficiency. A notable exception is Cebon's (1992) study of US universities. Research in environmental management has borrowed extensively from the organisational literature (Welford, 1997), but energy policy research has largely neglected it. This is unfortunate, as it may have a lot to offer. An illustration of this is that ideas from organisational theory have been taken up in promotional *best practice* literature published by government agencies (EEO, 1995).

For our purposes, we select three concepts from the organisational theory literature that seem particularly relevant to energy efficiency. These are:

- organisational structure;
- power; and
- organisational culture.

2.5.1 ORGANISATIONAL STRUCTURE

Organisational structure is a primary focus of organisational theory. While we cannot formulate structure as a barrier to energy efficiency, it is clear

[8] For good overviews see Hatch (1997) and Morgan (1986).

that *organisational structure will constrain the range of viable opportunities for improved energy efficiency* (Cebon, 1992). The reasons for this can be related both to bounded rationality and power relations (discussed below). Hence, while structure is not a causal mechanism, it provides an important *framework* for understanding the operation of barrier mechanisms.

A tradition in organisational theory known as *contingency theory* emphasises that there is no one best way of organising (Burrell and Morgan, 1979). The appropriate structure will depend upon both the nature of the task and the demands of the environment. Management must be concerned with achieving a good fit between organisation, task and environment. Different approaches to management may be necessary to perform different tasks within the same organisation and different types of organisation may be appropriate in different environments.

An early study by Burns and Stalker (1961) established the distinction between *mechanistic* and *organic* approaches to organisation. Burns and Stalker argue that there is a continuum of organisational forms ranging from mechanistic forms, that are formal, hierarchical and stable, to organic forms, that are more informal, flexible and constantly evolving. They emphasise how the nature of different tasks and different environments lead to corresponding differences in the organisation of work, the nature of authority, the form of communications system and the nature of employee commitment. The more organic and flexible forms of organisation are required to deal with the more rapidly changing environments and technologies.

Subsequent work by Lawrence and Lorsch (1967) refined this approach by showing that organisation styles may differ *within* organisations, as sub-units perform different tasks and face different environments. For example, the organisational structure appropriate for a production task may be entirely inappropriate for an R&D laboratory. In relatively stable environments, conventional bureaucratic modes of organisation such as hierarchy, rules and so on may work quite well. In more turbulent environments, they need to be replaced by other modes, such as the use of multidisciplinary project teams. Matrix forms of organisation, midway between the hierarchical form and the multidisciplinary teams, represent a compromise between the two – combining a functional, departmental structure with a project-team structure (Galbraith, 1971).

Cebons's (1992) paper represents a valuable case study on how organisational structure at two universities influenced the type of energy efficiency technologies that were adopted. One university was administratively uniform with its different parties sharing centralised resources. The second was much more decentralised, with faculties managing their own budgets. Cebon examined the implementation of two very different technologies – compact fluorescent lighting and building energy management systems (BEMS).

The centralised university successfully implemented BEMS and similar technologies that were complex, expensive, technical and did not require significant interactions with users. The decentralised university, in contrast, was very late in implementing BEMS but was much more successful with compact fluorescent lighting and comparable technologies which were cheap, simple and involved the active participation of users.

Cebon emphasises that organisational structure acts as a filter on technology choices. The proposed causes for this are: (i) information limitations; and (ii) power and resources. In the case of information, the estates department in the centralised university could assess *technical* information and implement technical solutions, but lacked important *contextual* information such as the needs of users. The reverse was true for the decentralised university. This restricted the options available to each. More generally we can note that structure will influence:

- flows of information within and outside organisations;
- asymmetries of information, including principal-agent relationships and the scope for moral hazard; and
- the capacity to acquire and analyse information within individual departments.

The organisational structure in Cebon's universities corresponded to the mechanistic structure in Burns and Stalker's typology, and we may expect this type of structure to be more prone to such informational problems. The organic structures characteristic of new high technology industries tend to have highly skilled workers, lower status hierarchies, better communications and a more problem solving focus. This may act to reduce some of the informational barriers to energy efficiency. But equally, we must remember Lawrence and Lorsch's point about internal differentiation. If energy responsibilities are located in maintenance or estates departments with limited communication with other groups, some barriers are likely to remain.

Cebon's general point is that an actor will only be able to implement the subset of energy conservation technologies that are compatible with their access to information, and their extent of access will depend on the organisational structure (Cebon, 1992, p.808). Similarly, they will only be able to implement the subset of technologies that are compatible with their level of power or status within the organisation, since they need the co-operation and support of other groups.

2.5.2 POWER OR STATUS

Viewing the organisation as a political system focuses attention on the power relationships inherent in organisational structures and on the ability of individuals or departments to influence decisions. The relationship of this to the barriers debate hinges on the power available to those actors responsible for energy efficiency.

This perspective on organisations borrows ideas from political science. Organisations are viewed as: "...networks of people with divergent interests who gather together for the sake of expediency" (Morgan, 1986, p.154). Divergent interests lead to multiple goals, and structural divisions foster conflict. Hierarchical structures in particular lead to competition for limited resources. Power is the medium through which conflicts of interests get resolved. Power influences who gets what, when and how. It can take a variety of forms, including (Morgan, 1986, p.158):

- *Formal authority*: Typically associated with an agent's position in the organisational structure.
- *Control of scarce resources*: Such as skills, raw materials, particular technologies and, most importantly, money. Most organisational politics surrounds the process of budgeting and allocation of finance. Power rests in controlling resources on which an organisation is dependent.
- *Structure*: The size and status of a group or department within an organisation provides an indication of its power. Of particular importance is the degree of centralisation or decentralisation.
- *Information and knowledge*: Information is a key resource, which can influence the definition of organisational situations and create patterns of dependency.

The important question from the barriers perspective is: *How much power is available to the actors responsible for implementing energy efficiency?* In particular, what is their status within the hierarchy? How much control do they have over key resources? Do they have the required information?

Responsibility for energy matters is often assigned to engineering or maintenance departments that have a relatively low status within an organisation. Top management often views energy as a peripheral issue, of limited importance to the strategic direction of the organisation. Energy is often one of several responsibilities assigned to a single, low status individual. Lacking power, funds and management support, the scope for effective action is circumscribed. In addition, the best people will not be attracted to energy management if the compensation and prestige are less than the rewards of other positions.

The role of a *product champion* is also relevant to the power dimension. Product champions acquire a degree of power through their charisma and drive and win top management support through demonstrable success. But, product champions may have an uphill task in overcoming barriers created by divisional structures. DeCanio (1994) reports the blockage of promising energy efficiency retrofits because of "turf battles" between different divisions.

2.5.3 CULTURE

The concept of organisational culture is analogous to the personal values discussed in Section 2.4.2. Thus, while culture cannot be framed as a barrier, it may nevertheless be a relevant variable in explaining the adoption of energy efficient technologies. Culture is broadly defined as the mix of knowledge, ideology, values, norms, laws and day-to-day rituals that characterise a social group (Hatch, 1997, Chapter 6). Values are the principles and standards held to have worth, while norms are unwritten rules of behaviour. As Hatch (1997, p.135) notes:

> The essence of a culture is its core of basic assumptions and established beliefs. This core reaches outward through the values and behavioural norms that are recognised, responded to and maintained by members of the culture. The values and norms, in turn, influence the choices and other actions taken by cultural members.

Organisations may be viewed as mini-societies that have their own distinctive patterns of culture and sub-culture (Morgan, 1986, p.121). Organisations may be composed of many and different value systems that create a range of competing sub-cultures. Despite this, management theorists look to a uniform corporate culture as the "normative glue" that holds an organisation together (Morgan, 1986, p.135).

A consistent feature of the literature on organisational culture is the crucial role played by top management in shaping the values that guide an organisation (Morgan, 1986, p.126; Gladwin, 1992). Morgan argues that: "the attitudes and visions of top corporate staff tend to have a significant impact on the ethos and meaning system that pervades the whole organisation" (Morgan, 1986, p.126). Similarly, Schein argues that: "...the unique and essential function of leadership is the manipulation of culture." (Schein, 1985).

The relevance of this to the barriers debate is that the place of energy efficiency and environmental values within an organisation's culture may have a significant impact on the adoption of energy efficient technologies. Recognition of this is implicit in the strategy of agencies responsible for promoting energy efficiency, which place much emphasis on manipulating "soft" cultural factors – for example, encouraging the adoption of a corporate energy policy and marketing the benefits of energy management throughout an organisation (EEO, 1995; Higher Education Funding Council for England, 1996). If aspects of organisational culture can be levers for encouraging energy efficiency and improved environmental performance, then they should also be relevant in explaining differences in technology adoption between organisations.

2.6 Summary of Potential Barriers

Table 2.3 brings the discussion of the previous sections together. It sets out the taxonomy of fifteen potential barriers to energy efficiency developed for this study, and it summarises the claim that is being made in each case. This framework provides the basis for the empirical research that is reported in Chapters 3, 4 and 5. The empirical research aims to assess the relevance and importance of each claim through case studies of organisations in three different sectors.

In conducting the empirical research it was found that the distinctions between some of the barriers could not always be sustained in practice. In particular, in reporting some of the case study results, it was found to be necessary to combine *values* with *organisational culture* because of the difficulty of distinguishing between these two in practice.

It is also worth noting that, even at the conceptual level, the fifteen potential barriers to energy efficiency listed in Table 2.3 are not all entirely separate and independent from each other, since there are certain overlaps between them. For example, "access to capital" is listed as one potential barrier. It may be that the constraint on access to capital for investment in energy efficiency occurs in the form of the use of stringent payback criteria or tight capital budgeting. At the same time, the potential barriers called "risk" and "principal-agent relationships" would commonly have their effects by causing payback criteria or capital budgets to be tightened, so that these barriers could be at least part of the reason for the "access to capital" barrier. Another example of interdependence between the potential barriers is the fact that "imperfect information" is listed as one potential barrier, while at the same time various types of imperfect information could be at least part of the cause of other potential barriers such as "adverse selection". A third example is the fact that demands on management time can be seen as part of the "hidden costs" barrier, while demands on management time would also be part of the cause of the "bounded rationality" barrier.

Such overlaps or interdependencies between some of the potential barriers arise partly because these concepts are drawn from different types of literature, which have their own particular perspectives but are at least partly addressing the same or similar phenomena. However, despite the overlaps between some of the barriers, there are elements in each of them that are distinctive.

A final issue worth mentioning in relation to the taxonomy in Table 2.3 concerns the use of the term "market failure", and its implications for policy intervention. Market failures occur when the requirements for efficient allocation of resources through well functioning markets are violated. Some of the barriers listed in Table 2.3 are identified as arising from market failures while others are not, although it must be acknowledged that the classification of barriers as market failures or otherwise can be somewhat blurred and contentious. Neo-classical economists would say that public policy intervention to encourage economic efficiency is usually only justified when there exists some form of market failure. Furthermore, even in cases of market failure, they would say that this may not be sufficient to justify intervention; it is also necessary that the benefits arising from an intervention exceed the costs associated with the intervention (Jaffe and Stavins, 1994b, p.808). From this perspective, therefore, the occurrence of the "market failure" barriers may present grounds for policy intervention, whereas the other types of barriers would not *in themselves* justify intervention.

However, it is very important to note that there may also be *other* market failures related to energy use, i.e., market failures that do not give rise to "barriers" that would help to explain the energy efficiency gap. Such market failures are naturally not reflected in our taxonomy of barriers to energy efficiency in Table 2.3. These other market failures may justify public policy intervention to overcome barriers that are not in themselves market failures. The obvious example of such a market failure is "environmental externalities". If energy users cause environmental damage, thereby imposing costs on society at large that are not reflected in a commensurate cost or penalty attached to the use of energy, this is called an environmental externality and it is a form of market failure. In this situation, there may well be a case for policy intervention to improve energy efficiency and reduce energy consumption, even if the most important "barriers" to energy efficiency are not in themselves market failures.

Table 2.3: A Taxonomy of Barriers to Energy Efficiency

Perspective	Sub-division	Barrier	Claim
Economic	Non market failure	Heterogeneity	While a particular technology or measure may be cost effective on average, it may not be so in all cases. This may explain the non-adoption of some technologies at some of the organisations studied.
		Hidden Costs	Engineering-economic analyses fail to account for either the reduction in benefits associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies tend to overestimate efficiency potential. Examples of hidden costs include overhead costs for management, disruption, inconvenience, staff replacement and training, and the costs associated with gathering, analysing and applying information.
		Access to Capital	If an organisation has insufficient capital through either internal funds or borrowing, energy efficient investments may be prevented from going ahead. In the public sector, additional borrowing may be inhibited by public sector rules. In the private sector, companies may be reluctant to borrow due to concerns about the risk of increased gearing. Where internal funds are available, other priorities may take precedence, thereby also preventing the energy efficient investment.
		Risk	The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages adoption of short time horizons.
Economic	Market failure	Imperfect Information	Lack of information may lead to cost-effective energy efficiency opportunities being missed. This may be considered a market failure in that information has public good aspects, which make it likely that it will be under-supplied by markets. Furthermore, unlike energy supply, energy efficiency consists of a wide range of complex technologies and services, which are purchased infrequently and for which it is difficult to determine their quality either before or after purchase. As a consequence, the transaction costs for obtaining and processing information on energy efficiency are higher than for energy supply. Over-consumption of energy may be the result.
		Split Incentives	Energy efficiency opportunities are likely to be foregone if the party cannot appropriate the benefits of that investment. For example, individual departments in an organisation may not be accountable for their energy use and, therefore, have no incentive to improve efficiency.
		Adverse Selection	Suppliers know more about the energy performance of a good than purchasers. The latter face difficulties in both obtaining information prior to purchase and verifying performance subsequent to purchase. As a result, purchasers will tend to select goods on the basis of visible aspects such as price, and be reluctant to pay the price premium for high-efficiency products. In some cases, inefficient products will drive efficient products out of the market.
		Principal-agent Relationships	Principal-agent relationships occur when the interests of one party (the principal) depend on the actions of another (the agent). This type of relationship is pervasive in hierarchical firms. It is characterised by information asymmetry, since the principal lacks detailed information about the activities and performance of the agent – and in particular about the merits of individual investment projects proposed by the agent. Such monitoring and control problems can lead principals to impose stringent investment criteria to ensure that only unambiguously high value projects are undertaken.

Table 2.3: (cont'd)

Perspective	Sub-division	Barrier	Claim
Behavioural	Bounded Rationality	Bounded Rationality	Actors do not make optimising decisions in the manner assumed in standard economic models. Instead, constraints on time, attention, and the ability to process information lead to reliance on imprecise routines and rules of thumb. These economise on scarce cognitive resources. A consequence of this type of decision-making is that actors may not maximise utility, even when given good information and appropriate incentives. Hence, bounded rationality may be considered as an additional barrier that does not fit into conventional economic models.
	The Human Dimension	Form of information	The cost of acquiring information is only one aspect of decision-making. Research demonstrates that the *form* of information is critical. To be effective, information must be specific, personalised, vivid, simple and available close in time to the relevant decision.
		Credibility and Trust	Also critical is the *credibility* of the source and the *trust* placed in the source. Trust is particularly encouraged through interpersonal contacts. If these factors are absent from information on energy efficiency, inefficient choices will be made.
		Inertia	Agents resist change because they are committed to what they are doing and justify inertia by downgrading contrary information. Individuals also treat gains differently from losses, thereby undervaluing opportunity costs; give greater weighting to certain outcomes than uncertain outcomes; and have a strong desire to minimise regret. All these factors cause individuals to favour the status quo. Inertia creates a bias against energy efficiency since (unlike energy purchasing) this involves investing in hardware with uncertain outcomes and represents a departure from the status quo.
		Values	*Energy efficiency has clear environmental benefits. Individuals motivated by environmental values may, therefore, give a higher priority to efficiency improvements than those that are not. Efficiency improvements are most likely to be successful if "championed" by a key individual within top management. Hence, the environmental values of key individuals is a relevant variable in explaining organisational performance on energy efficiency.*
Organisation Theory		Power or Status	Organisations can be viewed as political systems, characterised by conflicts between groups with divergent interests. The influence of a particular group depends upon its formal authority, the control it has of scarce resources (particularly finance) and its access to information. It is commonly the case that energy management has a relatively low status and is viewed as a peripheral issue by top management. Lacking power, funds and top management support, the scope for effective action by energy management may be circumscribed. This may constitute an organisational barrier to efficiency improvement.
		Culture	*Organisations may encourage efficiency investment by developing a culture (values, norms and routines) that emphasises environmental improvement. This is more likely to be successful if "championed" by a key individual within top management. Hence, organisational culture is a relevant variable in explaining*

organisational performance on energy efficiency.

3. The Mechanical Engineering Industry

3.1 Characterising the Sector

The mechanical engineering industry is the branch of manufacturing that makes productive machinery and equipment for use in most sectors of industry, as well as in agriculture and many types of services. Mechanical engineering in Ireland employed 11,810 people and had gross output valued at £1,044 million in 1999. The sector accounted for 4.7 per cent of total Irish manufacturing employment and 1.8 per cent of total manufacturing gross output.[9] This means that mechanical engineering makes up a smaller share of total manufacturing in Ireland than in the EU as a whole.

Foreign-owned firms accounted for 15 per cent of the industry's "local units" or factories, 46 per cent of its employment and 55 per cent of its gross output in 1999.[10] This degree of foreign ownership is not unusual in manufacturing in Ireland, since foreign firms account for a similar proportion of total manufacturing (Barry, Bradley and O'Malley, 1999).

The output of the mechanical engineering industry in Ireland is spread across quite a wide range of categories of product, with no major specialisation in any particular large product category. However, compared with much larger economies such as Germany or the UK, there are some substantial gaps in the product range in Ireland. For example, there are no large firms in Ireland producing tractors, combine harvesters or bulldozers. Among the more important components of the industry in Ireland are tool-making, pumps and compressors, lifting and handling equipment, non-domestic cooling and ventilation equipment, and agricultural machinery. A further point worth noting is that manufacture of parts of machines (as opposed to complete pieces of machinery), together with activities such as installation, repair and maintenance, constitute a significant minority of the value of the industry's sales.

The mechanical engineering industry is highly export-oriented. As much as 72 per cent of its production was exported in 1999.[11] The fact

[9] *Census of Industrial Production* (1999). These figures refer to NACE Rev 1 sector 29, "manufacture of machinery and equipment not elsewhere classified (n.e.c.)", excluding category 297, "manufacture of domestic appliances". Some of the other statistics quoted here will refer to the whole of sector 29, without excluding 297, because of data constraints.

[10] These data refer to the whole of sector 29.

[11] The figure quoted refers to all of sector 29.

that the industry exports such a high proportion of its output suggests that many of its firms must be internationally competitive.

3.1.1 ENVIRONMENTAL POLICY INTERVENTIONS

Government support for energy efficiency declined in the 1980s reflecting the softening of oil prices from the mid-eighties and onwards. In the 1990s, however, the *Operational Programme for Economic Infrastructure 1994-1999* included a Sub-Programme on Energy Efficiency. This sub-programme represented the principal national programme for energy efficiency during that time and it had funding of £34 million over the programme period. Co-ordination and implementation of the energy efficiency programme were the responsibility of the then Irish Energy Centre (now Sustainable Energy Ireland). The principal elements of the programme that applied to manufacturing industries were as follows:

– The Energy Audit Grant Scheme (EAGS)
– The Energy Efficiency Investment Support Scheme (EEISS)
– Energy Self-Audit and Statement of Energy Accounts Scheme
– Best Practice Programme
– Steam System Boiler Evaluation Scheme.[12]

The EAGS provided grants to organisations that engaged consultants to carry out energy audits and surveys. A grant of 40 per cent, subject to a maximum of £5,000, was available towards the cost of conducting an audit.

The EEISS provided grants to organisations that invested in energy saving technologies or measures. A grant of up to 40 per cent of the cost could be awarded (limited in general to £100,000 per site).

The Energy Self-Audit and Statement of Energy Accounts scheme provided a formal framework within which an organisation could make energy a strategic component of corporate policy. Companies in the scheme made a public commitment to assess energy consumption, define targets and strategies for reduction, and provide an annual statement on energy performance. The scheme was directed primarily at companies that were substantial users of energy by Irish standards, and there was a relatively small number of participants but they accounted for over 25 per cent of the industrial sector's spending on energy.

The Best Practice Programme aimed to promote energy efficient technologies and practices. Information on best practice technologies was transmitted through seminars, workshops, site visits and publication of best practice guides and case histories.

The Steam System Boiler Evaluation Scheme aimed to encourage fuel savings in the use of boilers, through grant aid, training and awareness programmes, and a boiler awards scheme that publicly acknowledged good practice.

The above-mentioned schemes were applicable to the mechanical engineering industry, as well as to many other industries, for a number of

[12]The following brief account of these schemes draws from H. Greer of Network Resources Limited (NRL), "Energy Efficiency Policy and Programmes in Ireland: A Review", 1997, personal communication.

years up to the time when our study was carried out. Since mechanical engineering was not a particularly energy-intensive industry, it was not a high priority sector for policy attention, but this did not prevent companies in the sector from applying to participate in the various schemes.

3.1.2 ENERGY USE

In 1999, the mechanical engineering industry spent £11.1 million on fuel and power, which amounted to 1.1 per cent of the value of its gross output. Expenditure on fuel and power can also be expressed as a percentage of expenditure on industrial inputs, where "industrial inputs" means purchases of materials for processing and industrial services as well as fuel and power. Spending on fuel and power in 1999 amounted to 2.1 per cent of purchases of industrial inputs in mechanical engineering.[13] For comparison, expenditure on fuel and power amounted to 2.0 per cent of purchases of industrial inputs in all Irish manufacturing, indicating that mechanical engineering has about the same level of energy-intensity as the average industry. Energy use in the sector tends to be quite largely for generic purposes such as space heating and lighting, while most of its production processes are not particularly energy-intensive.

Spending on electricity is the largest component of the industry's expenditure on energy, accounting for 56 per cent of total energy expenditure in the mid-1990s, followed by petroleum oils (30 per cent) and piped gas (5 per cent). The share of piped gas has been increasing.

Since the mid-1980s, the value of energy purchases by the mechanical engineering industry has increased more slowly than the value of the industry's production. Thus the industry's expenditure on fuel and power declined as a percentage of the value of its gross output between the mid-1980s and the end of the 1990s. Its expenditure on fuel and power expressed as a percentage of purchases of "industrial inputs" also declined during that period. However, much of this decline occurred in the second half of the 1980s, and sharply declining fuel prices in 1985-87 were largely responsible for that trend, rather than a real decline in the energy-intensity of the industry. We estimate that there was actually some real increase in the industry's energy-intensity in the late 1980s and that there was little or no real decline in the industry's energy-intensity at least up to the mid-1990s.[14]

As regards opportunities to improve energy efficiency, there is little formal documentation available from Irish sources on energy efficiency opportunities which are specific to mechanical engineering. However, based largely on UK sources, we identified a list of 23 conventionally recommended measures for improving energy efficiency that would commonly be appropriate for mechanical engineering firms. This list of 23 measures was given in Question 9 of the "pre-interview" questionnaire sent to participating firms, which is reproduced as Appendix 1. The purpose of this question was to try to identify the extent to which

[13] These figures refer to sector 29 excluding 297.

[14] Some of the data used to make such estimates are not available for more recent years.

companies had availed of opportunities to improve their energy efficiency. Following further consultation with the then Irish Energy Centre, we also identified a shorter list of the seven most important energy efficiency measures that would be suitable for Irish mechanical engineering companies. This shortlist is as follows:

1. A detailed energy audit has been conducted;
2. A Building Energy Management System (BEMS) has been installed;
3. Energy efficient equipment has been purchased;
4. Programming of heating and ventilation controls to match occupancy patterns and outside temperature;
5. Replacement of tungsten filament lamps with slim or compact fluorescence or high pressure sodium lighting;
6. Specification of high standards of energy efficiency in new buildings;
7. Use of variable speed drives in pumps, fans and other applications.

This shortlist was taken into consideration in our study, as a further yardstick when assessing the extent to which firms had adopted energy efficiency opportunities, as discussed below.

3.2 Case Studies

In this section we now proceed to describe the selection of the case studies.

3.2.1 SELECTION

Firms employing over 50 people were to be selected to participate in the project. A total of eleven companies in mechanical engineering were identified from the list of the top 1,000 companies, published by the business magazine *Business and Finance*. The eleven were contacted, and seven of these agreed to participate as case studies. These seven companies, being among the larger firms in the industry in Ireland, were all branches of multinational companies. They make products that include dies, tools, pumps, fasteners, lifting and handling equipment, engine components and machinery for agriculture and specific manufacturing industries.

The initial approach to companies was made by phone to identify the person having most responsibility for energy matters and to ask if the company would participate. There was usually no one person with the job title of "energy manager" in firms in this sector. Persons spoken to at the initial stage included the technical manager, maintenance manager, safety and environment manager, production manager and chief executive. If they agreed to participate they were sent a "pre-interview" questionnaire (or PIQ). The return of the PIQ was followed up with detailed follow-up interviews of key individuals in the establishments, focusing most closely on any aspects having a bearing on barriers to energy efficiency that had been suggested by replies to the pre-interview questionnaire.

The detailed follow-up interviews were semi-structured, using a more lengthy questionnaire based on the theoretical framework developed in Chapter 2, and they were administered by telephone. For an example of the interview protocol, readers are referred to Appendix 2. Between one and three people were interviewed in each enterprise, the average number being two persons, as Table 3.1 shows. There being no energy manager as such in these enterprises, the persons having most dealings with energy went under a variety of titles and it appeared that division of responsibility was not always clearcut.

Table 3.1: Number of Persons Interviewed in Each Case Study, their Job Titles and Background

Case Study Code Number	Number of Interviewees	Job Titles (and background, in brackets)
1	2	Maintenance Manager (electrical engineer), Managing Director
2	2	Maintenance Supervisor (engineer), Accounts Manager
3	3	Health Safety and Environment Manager (engineer, plus safety and environmental management qualification), Technical Manager, Operations Manager
4	1	Electrical Maintenance Manager (electrician)
5	1	Engineering Manager (engineer),
6	2	Works Manager, Manufacturing Engineer (engineer)
7	3	Quality Manager (engineer), Purchasing Officer, Operations Manager
	14	Total number interviewed
	2	Average number of persons interviewed per case study

3.2.2 DESCRIPTION OF CASE STUDY COMPANIES

Before describing the seven case studies, it is interesting to note that there was a quite consistent pattern in the companies' responses relating to implementation of energy efficiency measures and their perceptions of barriers to energy efficiency. Firms were ranked according to the number of energy efficiency measures that they had implemented, recorded in the PIQ (pre-interview questionnaire), and also according to the number from the shortlist of seven really important measures. The numbers of measures implemented are shown in the first two columns. Of course, this is a little arbitrary since certain measures might not be applicable to all the firms. The firm that implemented most measures was ranked firm 1, the firm implementing the second most was ranked firm 2, with the firm implementing least measures ranked firm 7, as shown on the left-hand side of Table 3.2. These rank numbers are used as the codes for the case studies from here on.

The ranking can be compared with firms' self-assessment of their management of energy in the third column, and with the number of barriers to energy efficiency that they perceived as "often important", in the fourth column. The ranking can be further compared with their perception of whether or not there were energy efficiency opportunities still available with paybacks of less than three years, in the final column.

Table 3.2: Ranking of Firms by Number of Measures Implemented, and Firms' Perceptions of their Energy Management, Barriers to Energy Efficiency and Opportunities

	Number of Measures Implemented		Self- Assessed Profiles	Number of Barriers "Often Important"	Opportunities Exist with Payback <3yrs?
	From Shortlist	From PIQ List			

Firm 1	6.5	10	2+	2	Disagree
Firm 2	5	12.5	2	5	Disagree
Firm 3	4.5	12	1+	3	Agree
Firm 4	4	7	1-	12	Neutral
Firm 5	2	4	0+	5	Agree
Firm 6	2	1.5	0+	12	Agree
Firm 7	0(1)	0(2)	1	12(8)	Agree

Notes: In the columns showing number of measures implemented, a measure would be considered to be half adopted if it was revealed in subsequent conversation that it had been partially implemented only. Two different replies might be given if the pre-interview questionnaire (PIQ) was filled in by two different people, and this accounts for there being two entries in some cells.

A few interesting points emerge from the table. Twenty-three possible barriers to energy efficiency were listed in the PIQ and respondents could tick the barriers that they considered were often important. It is seen in the fourth column that in general more barriers are perceived to be important by firms that had implemented the least number of energy efficiency measures. In addition, the last column shows whether or not firms agree that they are missing potential opportunities for energy efficiency that would yield a payback in less than three years. The adopters of most energy efficiency measures (ranked at the top) indicate that there are no remaining opportunities, while the non-adopters say that there are untapped opportunities. This pattern of responses is reasonable and consistent.

In the third column a score is given that represents each firm's self-assessment of its energy management practices, recorded in the PIQ; the higher the score, the more developed the energy management practices. Here again a consistent pattern can be discerned, with the firms that adopt most energy efficiency measures also having the highest score on energy management practices, self-assessed. This analysis is of course not exact. But the general pattern of responses does at least show an encouraging degree of rationality and consistency on the part of the respondents.

Next, we should ask how representative of the sector are these seven case studies? Being relatively large firms they were not typical, but they were reasonably representative of the sector in some significant respects. As Table 3.3 shows, the number of employees accounted for by the case studies is 1,431, which amounts to 13 per cent of the total number employed in mechanical engineering in 1998. Sales by the case study firms, amounting to about £142 million, represent 14 per cent of the sector's gross output. Total expenditure on energy by the firms, at £1.5 million, amounts to 1.07 per cent of their own value of sales, and this compares with the figure of 1.1 per cent of gross output for the sector as a whole.

Table 3.3: Firms' Employment, Sales and Energy Expenditure

	Number of Employees	Sales £m	Total Energy Expenditure £000
Firm 1	285	20	190
Firm 2	326	21	297
Firm 3	180	20	500
Firm 4	125	25	73
Firm 5	138	19	96
Firm 6	165	6	81

Firm 7	212	31	280
Total	1,431	142	1,516
Average	204	20	217

It is worth mentioning some characteristics of the individual firms. First, it can be seen from Table 3.3 that the first five firms have similar levels of sales, in the range £19 million to £25 million, and that Firms 4, 5 and 6 have the lowest energy bills. In terms of employment the largest firms are the first two, and their sales are similar. Firm 1, however, uses considerably less energy, partly due to the fact that it contracts out its heat treatment. This fact in itself could be an efficiency measure, if the outside contractor is specialised and efficient. Firm 2, though having the second highest energy bill, had the highest number of employees and said that it considered that "energy is not an issue, wages are what matters", adding that the overriding consideration was that "production must go on". However, its record on adoption of energy efficiency measures put it high in the ranking.

Firm 3 had within the last year taken on a safety and environment manager, which is not surprising since it has the highest energy bill. The high bill had stimulated the firm to lobby for cheaper fuel but also to undertake conservation measures. Firm 4 had the lowest number of employees and the lowest energy expenditure. Accordingly, only low cost energy efficiency measures were taken and the three year payback criterion was applied, the rationalisation being that if it were longer the "machines could be out of date". In firm 5 the driving need for production to go on was underlined by the award of bonuses related to production and machine uptime, but not to energy efficiency. Firm 6 was subject to foreign customer pressure to ensure that its processes were safe healthwise, for example, but the only internal pressure to improve energy or environmental performance came from the staff to supply more heat to the premises.

Finally, firm 7 was an outlier. It had the highest level of sales with possibly the lowest adoption of energy efficiency measures. However, it was in the initial phase of ISO 14001 certification, on the instruction of its head office which is situated abroad. Its line of work is not renowned for being environmentally friendly and head office had become conscious of their public image. The consequence of a poor image is that the share price can deteriorate. Firm 7 was in a good position to explain its perceptions of the barriers at this initial stage of a major reform, which entailed establishing an entirely new structure of energy management.

In trying to apply benchmarks such as energy intensity, one is hampered by the fact that the industry is very heterogeneous. This makes it difficult to devise meaningful measures of energy intensity, apart from the broad measure of expenditure on energy as a share of sales or turnover. The Energy Efficiency Office in the UK has calculated benchmarks based on floor area, as shown in the first two rows of Table 3.4. However, the figure of 85 kWh in the third column in the table clearly relates mainly to light manufacturing. The level of detail available from our own case studies is insufficient to enable real comparisons to be made except at the aggregate level, that is, for buildings and process energy, in the final column.

Table 3.4: Benchmarks for the Engineering Sector, General Manufacturing and for the Combined Seven Irish Case Studies, $kWh/m^2/year$

	Average Number of Shifts	Buildings Energy	Process Energy	Buildings and Process Energy
Engineering	1.7	302	85	387
General Manufacturing	3.0	409	495	904
Seven Irish case studies	2.9	(Fuel 390)	(Electricity 332)	(Total 722)

Source: Energy Efficiency Office in the UK (1993).

The average annual amount of total energy used by our case studies is 722 kWh per metre squared, which is within the UK range, at any rate. The average for fuel use, that is non-electric energy, in our case studies is 390 kWh and for electricity it is 332 kWh per square metre, again roughly within the UK range. However, the figures for fuel consumption in our case studies are only approximate. Only one firm actually answered the question on quantities of energy used. For the other firms, only replies on energy expenditure were given and these had to be converted to quantities using assumed prices. Therefore, the resulting figures on quantities are only estimates.

Table 3.5: Energy Intensity: Energy Use Per Employee and in Relation to the Value of Sales

	Total Energy per Employee		Total Energy/Sales	
Firm	£/Employee	kWh/Employee	Thousand kWh/£m Sales	Expenditure as % of Sales
1	667	16,880	241	0.95
2	911	24,369	378	1.41
3	2,778	123,789	1,114	2.50
4	581	12,216	61	0.29
5	694	15,033	111	0.51
6	490	10,224	281	1.35
7	1,321	33,858	232	0.90

Table 3.5 shows the estimated energy intensity of the case study firms, in terms of energy per employee and per unit of sales, and there are remarkable differences in the figures between firms. If any pattern is discernible it is that the first three firms, the ones that have implemented most energy efficiency measures, tend to have higher energy use per employee, shown in the first two columns. Firm 7, a high user, is an exception as mentioned and was just embarking on a programme of energy

efficiency within the ISO 14001 framework. But overall the sector seems to be very heterogeneous.

It follows therefore that the benchmark measure expressed in terms of kWh per square metre discussed above is unlikely to be very informative unless it is applied to products that are more narrowly defined. Table 3.6 shows this benchmark measure, such as it is, in the first column and the variation in it is notable. Shown in the last three columns are the respondents' expenditure on energy and the percentage breakdown between electricity and other fuels.

Table 3.6: Benchmark Measure of Energy Use and Percentage Breakdown of Energy Expenditure

	Total Energy Benchmark kWh/m^2/Year	Total Energy Expenditure £000	Breakdown of Expenditure Electricity %	Fuel %
Firm 1	481	190	79	21
Firm 2	475	297	66	34
Firm 3	1,599	500	50	50
Firm 4	314	73	86	14
Firm 5	519	96	89	11
Firm 6	241	81	86	14
Firm 7	773	280	89	11

The breakdown of expenditure shown in the last two columns suggests that firms at the top of the table that have adopted most energy efficiency measures also have a higher share of fuel as opposed to electricity. This pattern could be the result of chance or of the nature of the outputs produced. Alternatively, it is possible that these firms have deliberately tried to reduce electricity use and to switch to other fuels, because of the cost of electricity relative to that of other forms of energy. It is reasonable to suggest that firms at the top end of the energy efficiency league are the ones that are most likely to have attempted to switch to alternatives to electricity.

We already saw in Table 3.2 that a clear pattern emerges in the extent of implementation of energy efficiency measures and in behaviour and perceptions. Table 3.7 adds further information about energy management behaviour. The pattern here is faint but is again suggestive of consistent behaviour, particularly in relation to monitoring energy use. Those firms that have implemented most energy efficiency measures tend to be those that monitor trends in energy use.

Table 3.7: Energy Management Behaviour

	Monitor Trends?	Electricity Metered at	Use Monitoring and Targeting?	Use Benchmarks?
Firm 1	Yes	Site	No	No
Firm 2	Yes	Bldg+equip	Yes	No
Firm 3	Yes/no	Bldg	No	Yes
Firm 4	Yes	Site	No ans	No
Firm 5	No	Bldg	No	No
Firm 6	No	Site	No	No
Firm 7	Yes	Site	No	No

Metering at building level, monitoring and targeting and use of benchmarks are not prevalent practices, evidently. However, those firms in which these tasks are undertaken tend to be closer to the top of the table.

3.2.3 SUMMARY OF CASE STUDIES

The firms selected and agreeing to participate show a good degree of consistency in their responses on the pre-interview questionnaire. However, one should have some reservations about the extent to which replies truly reflect reality within the firm, since different interviewees sometimes gave different answers, an interesting finding in itself.

Firms revealed a wide range of performance on energy efficiency. Some had installed most of the potential measures on the shortlist of really important actions and others had barely implemented any. Similarly, their perceptions of the number of barriers that were important ranged from very few to about a dozen. Importantly, over half of the firms felt that there were energy efficiency opportunities available with paybacks of less than three years, which could be implemented in their company. The others, firms ranked at the top of the list, said that there were few remaining untapped possibilities.

A fairly coherent picture has emerged of implementation of energy efficiency measures, of perceptions and of behaviour. The next task is to see what this tells us about each of the hypothesised barriers to investment in energy efficiency, which are the subject of the next section.

3.3 Evidence of Barriers in the Mechanical Engineering Industry

We have seen that most firms felt that there were untapped opportunities for improving energy efficiency. In this section evidence from the case studies is used to investigate the barriers that might explain the various levels of adoption of energy efficiency measures. The firms that had implemented many measures, ranked at the top of our list of firms, evidently did not face barriers or else had succeeded in overcoming them. The firms at the bottom of the list who are foregoing energy efficiency opportunities are assumed to be impeded by barriers. The question is: which are the important barriers to energy efficiency? The major barriers proposed as candidates in Chapter 2 will now be investigated in turn starting with heterogeneity.

3.3.1 HETEROGENEITY

Heterogeneity operates as a barrier if energy efficiency measures that are generally suitable in most firms in a sector are not suitable in certain specific firms. In the mechanical engineering sector, it appears that this could be a possibility because the sector is rather heterogeneous. On the other hand, many of the energy uses are generic in type, such as compressed air, heat treatment, space heating and so on, such that many straightforward energy saving measures might be applicable to all firms. So what was the evidence?

Two of the firms did say that certain energy efficiency technologies would be inappropriate at their site. Firm 1 for example contracted out the heat treatment of its product and so the option of furnace heat recovery, insulation and controls does not apply. Firm 4 manufactured a specialised product and consequently off-the-peg technology might not always be suitable. They find that when they "look into it in detail, it is not quite the relevant machine" for their purposes and they build a lot of machinery in house.

While this evidence is not very strong, variations of process and product within the sector combined with the statements from the two firms above suggest that heterogeneity is a factor in some cases. That said, mechanical engineering is not an energy intensive sector and a lot of its energy use is indeed for generic uses rather than specialised applications. The environmental manager in firm 3 endorsed this by saying that their energy use does not entail "rocket science – it is compressed air and gas usage".

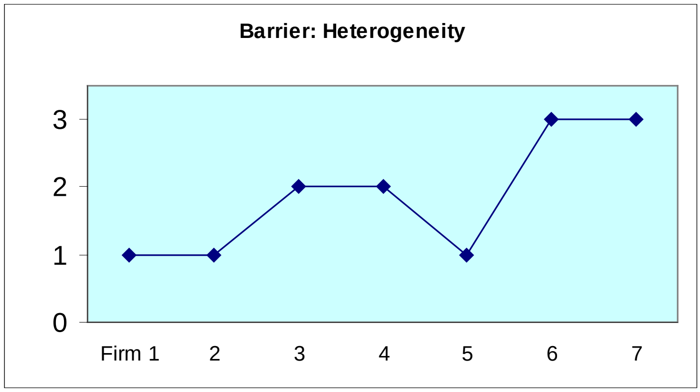
Firms were specifically asked how important they thought that energy efficiency technology being "inappropriate at this site" would be as a reason for not undertaking energy efficiency opportunities. Figure 3.1 shows firms on the horizontal axis, ranked in the same order of adoption of energy efficiency measures as before. Firms could rate this heterogeneity barrier as "rarely important", "sometimes important" or "often important", and these ratings were allotted scores of 1, 2 and 3 respectively, on the vertical axis. The illustrated pattern of replies suggests that this barrier is perceived to be more important by those firms that have adopted less measures, that is, by those on the right hand side of the chart.

The pattern in the chart is only broken by firm 5 but, as this firm states that it only invests in low cost measures in any case, this reply is reasonable. This points to a verdict that heterogeneity is not often a barrier, but it is a factor in some cases.

3.3.2 HIDDEN COSTS

Hidden costs are real and they comprise all costs other than known costs of purchasing and installing energy efficiency equipment. Hidden costs include, for example, the cost of identifying and assessing the investment, the cost of retraining staff to use new equipment, potential disruption and loss of product quality and so on. Such costs, if perceived by the firm to be substantial, could lead it to forego implementing a measure, although the measure is deemed financially worthwhile based on its known costs alone.

Figure 3.1: Importance of Heterogeneity as a Barrier as Perceived by Firms



Note: On the vertical axis, the reason "technology inappropriate at this site" is considered to be:
1 = rarely important, 2 = sometimes important, 3 = often important, for not making energy efficiency investments.

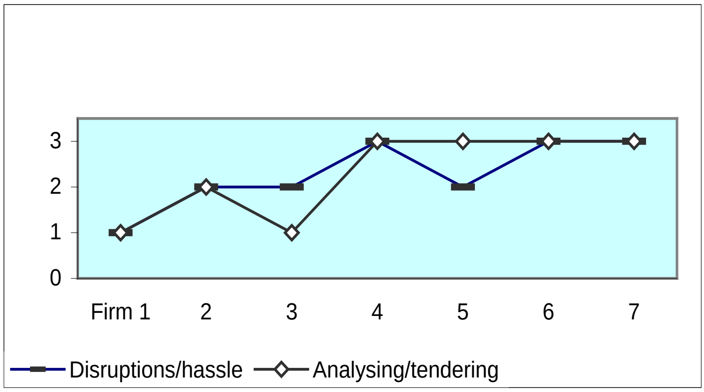
Firms were presented with a list of these hidden costs, which included six types. These were the cost of (1) production disruptions, hassle and inconvenience; (2) identifying opportunities, analysing cost effectiveness and tendering; (3) staff replacement, retirement and/or retraining; (4) possible poor performance of equipment; (5) difficulty and cost of obtaining information on the energy consumption of purchased equipment, and (6) lack of time and the existence of other priorities. Again, the rating system of allotting scores of 1, 2 and 3 according to increasing importance is applied.

Looking at two of the above hidden costs at a time, each of the following three graphs in turn shows all the firms' views about their importance. Starting in Figure 3.2 with the first two hidden costs, which are the problems of disruption/hassle and costs of analysing/tendering, over half of firms perceive the latter as often important. Disruptions rate hardly less strongly, being at least sometimes important to all but one firm. The indications from this group of firms are that these two barriers matter.

It is again worth noting the general pattern of responses. The firms that have adopted most energy efficiency measures attach less importance to these barriers. This could be an example of how the fulfilment of a task can leave one feeling that it was not so difficult and the barriers were unimportant. In addition, or alternatively, these firms may have good coping and analytical skills that enabled them to proceed with the adoption of technologies.

The next two hidden costs to be considered are the costs of staff replacement, retirement and retraining, and the possible poor performance of equipment. As Figure 3.3 shows, the latter is

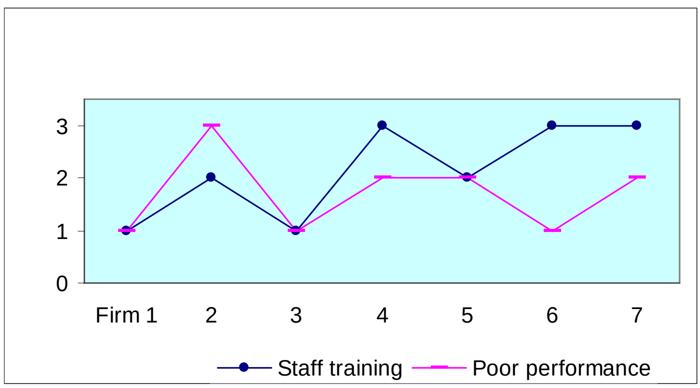
Figure 3.2: Hidden Costs: Importance of Disruptions/Hassle and Costs of Analysing and Tendering



Note: On the vertical axis, 1 = rarely important, 2 = sometimes important, 3 = often important.

considered to be no more than just "sometimes important", except by firm 2. The respondent for this firm was the maintenance supervisor who would be mindful of the need to guarantee continuing production, though adding that poor performance is unlikely because they are not risky machines in their case. Firm 4 cited an example of poor performance of variable speed drives that took too long to get to full speed, while firm 6 said that they experienced benefits, such as more silent compressors.

Figure 3.3: Hidden Costs: Importance of Staff Retraining and Possible Poor Performance of Equipment

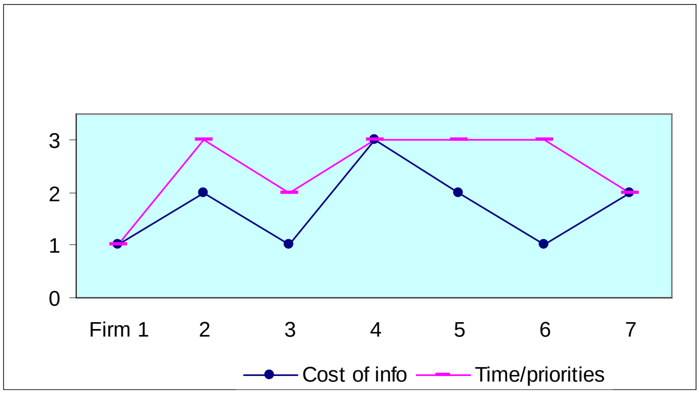


Note: On the vertical axis, 1 = rarely important, 2 = sometimes important, 3 = often important.

More serious is the hidden cost centring on staff retraining, which is often important in the view of three firms. The pattern is again seen that firms on the left, having adopted the most technologies, perceive training to be less important as a barrier. Again we are not sure about the direction of causation: do these firms think these barriers are unimportant because they have overcome them or were they minor issues to them in the first place?

The next two types of hidden costs are the difficulty/cost of obtaining information on the energy consumption of purchased equipment, and lack of time/other priorities, illustrated in Figure 3.4. Looking first at the difficulty and cost of obtaining information, our firms consider that this barrier is not prominent. The exception is firm 4, which is relatively specialised.

Figure 3.4: Hidden Costs: Difficulty/Cost of Obtaining Information on Equipment and Lack of Time/Priorities



Note: On the vertical axis, 1 = rarely important, 2 = sometimes important, 3 = often important.

The barrier of lack of time and the existence of other priorities, however, is a serious consideration. Most firms saw it as often important, and only firm 1 saw it as rarely important. The managing director in firm 1 strongly believed that energy efficiency saves money, so this initial belief would automatically make energy efficiency a priority for this firm. Among the "non-adopters", firm 7 admittedly is out of line but it had just recently allotted the time to designated people to implement efficiency measures that were now a priority for head office.

To sum up on the six types of hidden costs, the first two and the last hidden costs are serious considerations. It is useful to grade the four serious hidden costs according to their perceived importance, albeit crudely. Using the same weights for levels of importance, the ranking in Table 3.8 is obtained.

Table 3.8: Ranking of Hidden Costs by Importance

Rank	Hidden Cost
First	Lack of time/other priorities (6)
Equal second	Identifying opportunities, analysing cost effectiveness and tendering (2)
	Production disruptions/hassle/inconvenience (1)
Fourth	Staff replacement, retirement, retraining (3)

Source: Pre-interview questionnaire.

Finally, a factor that possibly increases hidden costs is small size of firm in terms of numbers employed. The more people that are employed, the more feasible it is for staff to have specialised functions. It may be no coincidence that the first two firms are the largest employers. Though the seventh firm had not implemented much in the line of energy efficiency measures and is also large, it had taken the decision to undertake a serious programme of environmental/energy reforms. Size is described as an important factor by other studies, such as Gruber and Brand (1991), who show that SMEs are at a disadvantage for reasons such as lack of a person who can be "afforded" time to develop specialised knowledge of energy consumption. Our findings are consistent with this.

Having identified the significant hidden costs, it would be helpful to estimate their magnitude. How much actual time is put into "identifying, analysing, tendering" and the like? Unfortunately, most firms could only estimate the hours spent on day-to-day energy management, and were not able to distinguish time spent on investments in energy efficiency. This difficulty may stem from the fact that the energy saving part of an investment can be impossible to isolate from other benefits such as saving money generally and improving production. Person-hours spent on day-to-day energy management amounted to between about one hour and seventeen hours per month.

That said, firm 7 did give a helpful indication of the person-hours that would be spent over the next few years on appraising various investments and on establishing policies and routines within the firm. Unfortunately, this applies to environmental and energy matters jointly, being the resources that they will devote to gaining ISO 14001 certification. The operations manager charged with the implementation of the programme "for my sins" (vividly indicating a perception of hassle and inconvenience) said that they would now be spending fifty hours per week, involving 4 or 5 people. This could amount to an annual cost of between £40,000 and £50,000 for a year or two and would include the time devoted to environmental, health and safety issues as well as to energy efficiency measures.

It is not possible to say what proportion of this outlay would apply to energy efficiency alone. One might take a figure of £15,000, or £30,000 worth of personnel time spent over the two years, which needs to be seen in the context of an energy bill of some £0.28 million, annually. Working backwards by applying their 3-year payback rule and assuming for the sake of argument that a 10 per cent saving on their annual energy bills is offered by advanced technology, they could justify an investment of £84,000, ignoring discounting. If they intend *in any case* to invest in cleaner, safer technology and if there is a choice of machines that vary only by energy usage, this is the extra amount that they could spend on the energy efficiency component. The personnel costs of £30,000 would therefore represent a sizeable share or addition, though ISO certification would also have been achieved.

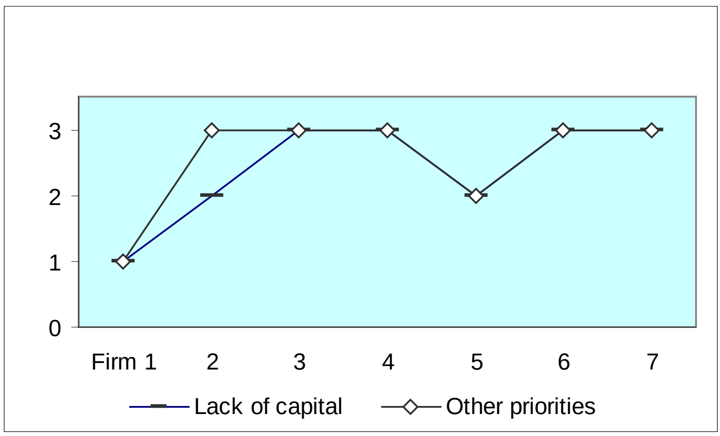
In practice, attributes of machinery are not usually separable in this way and it is not easy to isolate investment costs attributable to energy efficiency measures, let alone hidden costs. Therefore, even with a real example, it is difficult to calculate the hidden costs ratio.

3.3.3 ACCESS TO CAPITAL

It emerged from our case studies that access to capital for the purpose of investment in energy efficiency was the most important barrier to energy efficiency, and yet access to capital was generally not a problem at the level of the firm as a whole. Although firms generally had access to funds, whether internal or borrowed, an investment could still be barred due to other priorities taking precedence. In some cases, strict adherence to capital budgets could be the barrier especially in the presence of other priorities.

All of the firms bar firm 5 were able to borrow for capital investment in general although they tended to favour availing of internal funds. For large investments they might require approval from head office which, with some exceptions, seemed to exercise fairly relaxed control where decisions about energy efficiency were concerned. Despite this, lack of capital and other priorities for investment were still considered to be important as Figure 3.5 illustrates.

Figure 3.5: Importance of Lack of Capital and Other Priorities for Investment, as Barriers to Energy Efficiency Improvement



Note: On the vertical axis, 1 = rarely important, 2 = sometimes important, 3 = often important

As the graph shows, all but firm 1 thought that lack of capital or other priorities for capital investment were often or sometimes important as barriers. In order to explain how this could be true, given that most firms were able to borrow and energy efficiency technologies are cost effective, one has to consider the investment criteria used by firms.

The firms mostly use the payback period as a criterion and the length of period chosen was between two and five years. One firm uses 2.5 years but calculates the proper Net Present Value for big investments, and firm 1 simply stated that if the investment produces a good return it would be considered. In firm 3 some investments were required to show a 15 per cent return. At least two operated both a payback period and a fixed investment budget.

Application of such short payback criteria could rule out a number of projects with good Net Present Values. Furthermore, in cases where the investment budget is fixed, these projects might find themselves squeezed out by projects that were deemed "essential" or "an environmental imperative". The latter category, imposed by licence requirements or perhaps necessary to avoid a bad image, could also be termed "essential" for the continued operation or wellbeing of the firm.

The payback rule alone would not explain everything as four firms in our sample said that there were unexploited energy efficiency opportunities in their company that would yield paybacks of less than three years at current energy prices. There are likely to be other factors besides finance that are squeezing out potential schemes in such cases.

In theory, at least, third party finance could be used to overcome barriers arising from strict payback rules or relegation by other priorities vying for fixed capital budgets. Third party finance will be discussed later in the section on policy.

3.3.4 RISK

Risk usually makes for more cautious behaviour and could delay or reduce investment in non-essential measures. Two sorts of risk were mentioned. Technical risk is the risk that the technology would be found wanting or outdated. The second type of risk is business risk or market uncertainty. In the replies technical risk was considered no more than sometimes important and only firm 6 thought that market uncertainty could often be important (Figure 3.6).

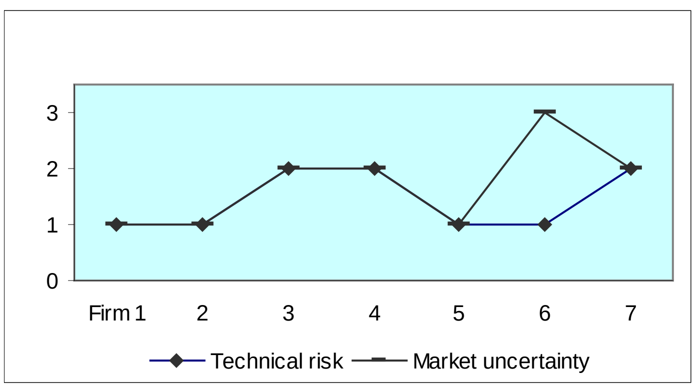
In subsequent elaboration of the kinds of risks facing them firms mentioned:

– Currency fluctuations;
– A big customer in financial difficulty;
– Reduction in customer use affecting their sales;
– Competitors in Europe, and in countries where labour is cheap.

Two instances of non-market risk were quoted:

– Stiff environmental legislation, and
– Machines not performing.

Figure 3.6: Importance of Risk as a Barrier to Energy Efficiency Investment



Note: On the vertical axis, 1 = rarely important, 2 = sometimes important, 3 = often important

Despite the fairly low importance attributed to risk as shown in the graph, the risks actually faced could justify the use of cautious investment criteria. A strict payback rule is likely to be a safeguard, adopted in order to screen out lengthy and therefore risky paybacks. As was seen, firm 4 thought the “machines could be out of date in a few years”, adding “there is a lot of technical change going on”. Risk may be part of the reason for cautious investment criteria, another being the need to have simple rules, an idea that will be developed below.

3.3.5 IMPERFECT INFORMATION

Firms may not be aware of energy efficiency opportunities or may not know how to get information. Their understanding of their current energy usage is the starting point and, as already described, their knowledge of current energy use is patchy.

An objective assessment of firms’ knowledge of opportunities was not attempted, but roughly a half of firms had undertaken an audit at some time. Experience varied considerably. Some had done full audits that pointed to good opportunities that were taken up, so they were very satisfied. One had an audit that told them a lot of what they already knew. Another only took part of the advice on board. The Irish Energy Centre (now Sustainable Energy Ireland) had supplied one firm with advice on consultants. The Electricity Supply Board had undertaken an audit of compressors in one firm and advised them on a supplier of equipment. In response the firm shifted its timing of electricity use to avail of better rates and consequently reduced its bills considerably, though not its energy consumption. In most cases, where a proper audit was undertaken it did help to overcome information barriers.

When asked about the adequacy of information on energy efficiency opportunities, two firms said that they had access to good information and would tend to contact the then Irish Energy Centre. Two others mentioned the Electricity Supply Board. Some firms reckoned that the problem was not the information but the time needed to use it, although most firms agreed that inadequate information is sometimes or often an important barrier. Figures on energy use of equipment were sometimes considered to be hard to get. The same applied to information on energy use of buildings and refurbishment.

Figure 3.7 shows in summary form how useful were the various sources of information to firms. The four potential sources represented by the four lines in the graph are:

– The Irish Energy Centre (denoted IEC),
– Professional associations, trade and technical journals (denoted Assoc./jls),
– Technical conferences and seminars,
– Energy suppliers.

Firms were able to answer that the information sources were:

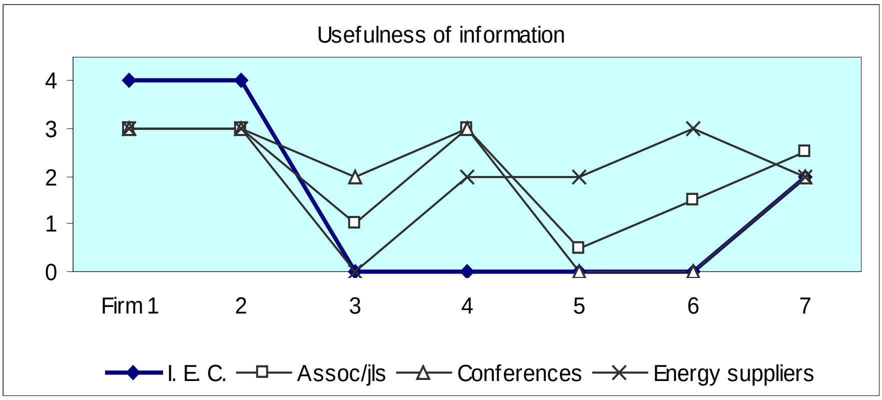
Excellent,	coded as 4 on the vertical axis
Good,	coded as 3
Average,	coded as 2
Poor,	coded as 1

Don't use, coded as 0

Where two respondents from the firm gave different answers, an average of the codes was used.

A clear message is that the then Irish Energy Centre was perceived by those who use it as supplying useful information, as represented by the bold line. The firms at the left hand side of the figure are those that have implemented most measures and they are the ones that declare the usefulness of information from the Irish Energy Centre to be excellent.

Figure 3.7: Firms' Ranking of the Usefulness of Information Sources



Note: On the vertical axis, 0 = don't use, 1 = poor, 2 = average, 3 = good, 4 = excellent

Firm 7, which was about to embark on an environmental programme, also found the Irish Energy Centre to be good but the others did not use it. Professional associations and trade and technical journals were considered to be good except, perhaps, by those implementing least energy efficiency measures, and the same applies to technical conferences and seminars. The journal called *The Plant Engineer,* published by the UK Institution of Plant Engineers (now the Society of Operations Engineers), was mentioned as providing worthwhile information on equipment and on what others were doing, as well as on maintenance of machines. Energy suppliers were considered to be good and seemingly replaced the other sources of information for those firms that had implemented least measures.

Firms also gave their opinions on other sources of information that were listed in the questionnaire. These sources include equipment suppliers, considered by firms to be rather middling. Views on consultants as a source of information were strikingly varied, ranging from "very good" to "don't use" and "poor". Networks of contacts within the sector and energy manager groups ranged from good to poor. The only "excellent" verdicts were awarded to the Irish Energy Centre by the two firms that had introduced most energy efficiency measures, and to "colleagues within the company" by two other firms.

Firms were also asked about their awareness of grant schemes and information sources. Several were not aware of any grant schemes. Another heard about a scheme too late, although the firm had availed of grants for low-energy lighting, which were useful. Another claimed that their firm was small and therefore not targeted. Meanwhile another firm believed that there was a government agency but was not familiar with it, and in any event received such a mountain of information that one "would go brain dead".

This leads to another important issue which is the form of information. Much information may be available, but the form in which it is presented may amount to a barrier. This can be significant given the stated scarcity of time available to management of firms in the mechanical engineering sector. Another consideration is the technical ability of management. Information needs to be well targeted, concise and relevant to the firm's specific circumstances. Firms made plentiful suggestions as to the sorts of information that they find most helpful.

Firms felt that information should not be theoretical or merely pilot studies, but should be targeted at their specific industry and should relate to similar technology. They wanted information that told them about equipment and on what others were doing. Case studies were considered to be worthwhile but only if they were in their field. "Before and after" figures on specific plant were thought to be very desirable, in fact the next best thing to seeing it for oneself. Those that used information from the Electricity Supply Board valued the way in which it analysed the bill and advised on it. The view was expressed that information needs "to make us start to measure and set targets".

The desired method of receiving information tended to be conferences or seminars, preferably half-day conferences that were relevant. Emphasis on the word "relevant" seemed to suggest a wide gap between available information and knowing what to do specifically, and that practical on-site solutions were what they would ideally like. However, it should be restated that most firms that had audits undertaken felt that they gained most or all the information that they needed.

In sum the form of information is probably a barrier to small firms if it is not geared quite closely to their specific requirements. Having an audit undertaken is possibly the most useful way to obtain information.

3.3.6 SPLIT INCENTIVES

Split incentives prevail when those implementing energy efficiency measures will not be major beneficiaries of their efforts. This can occur when buildings or machinery are *leased* rather than owned. This was rarely the case and it was therefore not applicable. Rapid *job rotation* would be another instance where split incentives could impede implementation because any incentive to save energy is diluted if the employee is not in place to see the programme through. This too did not seem important.

Accountability for energy costs on the part of departments within firms was an issue of some importance according to the respondents. Respondents mostly felt that departments would change their behaviour were they made accountable. However, they appeared not to think that huge savings would materialise and several foresaw problems in attributing energy use separately. In the short run, therefore, this barrier would not appear to hold much force, though it is interesting that respondents seemed to feel that in principle accountability was an important issue.

3.3.7 PRINCIPAL-AGENT

In hierarchical organisations, monitoring and control problems can lead the principal to specify strict investment criteria, such as a short payback rule, for the agent to follow. If use of over-simplified rules cannot be removed, it could be worth having additional simplified rules that incorporate energy considerations into standard operating procedures. Firms that indicated that such additional rules were incorporated into company practices were the two firms at the top of our list. While this could suggest that such rules are good for overcoming barriers, it is interesting to speculate whether the rules are indeed the cause, or whether they are actually the result of other factors.

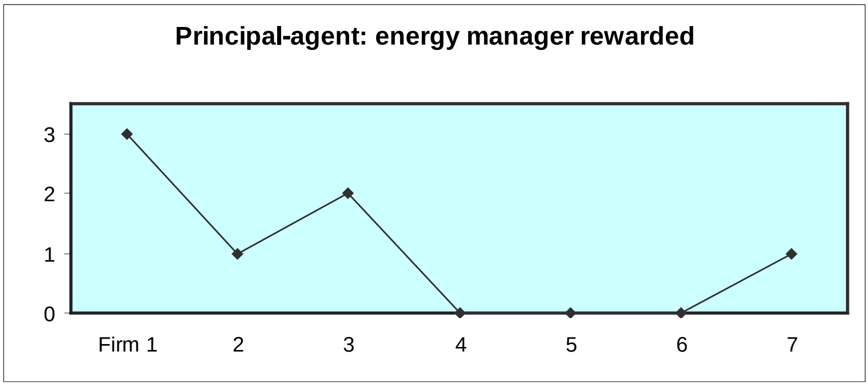
Rather than just impose rules, it is possible for a firm to implement a reward system, although monitoring and assessment can be a problem. The performance of investment by our firms would appear not to be assessed, at least not properly with "before and after" calculations. With an ever-changing business climate, knowledge of what would have happened in the absence of the investment would be imperfect in any case. In three firms nevertheless there must have been some evidence that the agent effected an improvement compared to the "before" case because, as Figure 3.8 shows, these firms rewarded energy efficiency improvements by their employees. In firm 1 the reward was quite substantial. In firm 2 the respondent received recognition and in firm 3 there are bonuses for environmental achievements. In firm 7 the branch would be rewarded with a bonus for making or saving the company money. The close relationship of the incentive with energy efficiency performance is remarkable.

3.3.8 CREDIBILITY AND TRUST

If firms are to devote funds to energy efficiency measures they need to feel confident that advice received is trustworthy and credible.

Firms were fairly evenly divided between those that used, and therefore presumably trusted, the Irish Energy Centre and the Electricity Supply Board. One firm felt that the only source was the Electricity Supply Board and where the Irish Energy Centre's advice was concerned they "wouldn't be looking for it". One had received "useful" grants from the Irish Energy Centre but seemed vague about its information value. The Clean Technology Unit in Cork was a source for one firm, as was the Environmental Protection Agency.

Figure 3.8: Is the "Energy Manager" Rewarded for Energy Efficiency?



Note: On the vertical axis, 3 = substantial reward, 2 = reward, 1 = recognition, 0 = no reward.

As mentioned, several said that they would like to see case studies, with before and after information. It appears that they were not aware of any.

3.3.9 VALUES AND ORGANISATIONAL CULTURE

The values held by key individuals in a company are likely to influence that company's performance. This in fact appears to be borne out in the case studies.

Firms 3, 4, 5 and 6 appeared not to have a culture strongly motivated by environmental values, either on the part of respondents or on the part of senior management. These respondents appeared not to belong to any environmental group, neither did they volunteer the information that they participated in an activity that would heighten their awareness of the environment. From the other three firms that had or were about to implement significant energy efficiency measures, respondents stated that they were a "fisherman", "belong to Birdwatch" or "I was born in the country and can see what's happened to the countryside", adding "you need commitment from the top".

From four firms (firms 1, 2, 3 and 7), statements about management reveal that direction had indeed come from the top. In firm 1 the managing director brought up the profile of energy in the organisation, though emphatically for cost-saving reasons. Firms 3 and 7 said it was head office that was pushing forward the environmental/energy efficiency programme. These four firms with impetus coming from the top are also big energy users, each spending about £0.2 million or more per year on energy.

In one firm in particular the new emphasis on the environment derived from the importance of image and its effect on share price. Share prices can now deteriorate if the company receives bad publicity, because the "public are buying shares directly", whereas financial institutions are less discerning on that score. There is a growing consciousness of share value within companies because "employees own shares in their company". However, apparently "energy is not seen to be as important as the environment", so that effort tends to be directed more towards environmental rather than just energy improvements.

3.3.10 POWER AND STATUS

The power and the status of energy management personnel determine their ability to get things done.

It was clear that firm 1's energy manager has the formal authority to influence energy related decisions, since he did not need to "fight his corner". The same would, or will, apply in four other firms but the respondents had insufficient time, or energy efficiency was low on their list of priorities. Another seemed not to have as much influence as he would like, and similarly with another energy manager who stated that the production manager "gets his way".

The pattern of formal authority and power fits closely with the culture and interest in energy efficiency of senior management. The status of energy management, however, also reflected to some extent the energy intensity of the firm. Accordingly, the status was quite low in the mechanical engineering sector in general. This was evident from the difficulty we sometimes encountered in identifying the relevant person, or persons, to approach about energy efficiency in the firm.

3.3.11 COMMENTS ON BARRIERS BY RESPONDENTS

Respondents themselves were asked to sum up by saying what they thought were the major barriers to energy efficiency. Most said it was shortage of time. An exception was the firm that said that they had exhausted all opportunities, even if a ten-year payback were to be applied, while another felt that the barrier was cost, probably implying that not enough money would be saved.

In the nature of case study analysis, the sample is rather small and therefore, not able to support strong generalisation about the population. However, the insights are useful and very coherent, which is encouraging. There is a good level of consistency within and between the replies. The pattern is also consistent with many previous writings on behaviour in relation to energy use and with a body of economic literature, which lends a ring of truth to the findings.

3.3.12 SUMMARY OF BARRIERS

We now attempt to distil the results of the investigation of barriers. Table 3.9 summarises what emerge as four prominent categories of barriers. A more detailed tabular presentation is given in Annex 3.1 at the end of this chapter. The four main categories are hidden costs, access to capital, imperfect information and values/ organisational culture.

Closer inspection of some of the barriers reveals that they are unavoidable, such as market risk for the firms' product. The hidden costs barrier might also be unavoidable, to some extent. Hidden costs include management time and inconvenience and hassle. However, many of the barriers can be reduced if they are understood and some effort to address them can be afforded. The next section, on policies, explores the possibilities.

Table 3.9: Barriers to Implementing Energy Efficiency Measures Found to be of High Importance in the Mechanical Engineering Sector

Barrier category	Specific instances	Comments
Hidden costs	Management time/other priorities. Identifying/analysing/ tendering. Production. disruptions/hassle. Staff replacement/retraining.	Among the hidden costs, lack of time and other priorities were the most quoted reasons for not implementing energy efficiency investments.
Access to capital (Related are: Risk, Principal-agent problems)	Other priorities for capital. Strict adherence to budgets and payback rules.	Access to borrowing is apparently not restricted, but tight payback rules or capital budgeting restrict some good investments. NPV, IRR or calculations based on "reasonable" length-of-life are rarely used. Strict payback rules may be applied to contain risk, stemming from market uncertainty, meaning that risk is indirectly significant. The rule may also be due to principal-agent problems stemming from concerns about control.
Imperfect information (Related are: Form of information, Credibility of information and trust)	On opportunities for energy saving. On opportunities in buildings. On energy use of equipment.	The form of information is important in order to avoid having to spend a lot of managerial time absorbing it. Unwise choices, delays or inaction result when agents are poorly informed. Low take-up of energy efficiency opportunities was associated with failure to undertake audits or consult with specialists such as the Irish Energy Centre. A desire for "relevant" case studies indicated a need for believable advice to counteract the related barrier of lack of credibility and trust.
Values/organisational culture (Related are: Power and status of the energy manager, Split incentives)	Attitude of top management. No identifiable person with responsibility for energy. Accountability.	Performance declines where top management is not concerned about energy and/or environmental matters. Absence of incentives or rewards is associated with low performance. Lack of accountability through separate metering is perceived as a barrier, though overcoming it could be impracticable except at construction/refurbishment stage.

3.4 Possible Policy Responses

3.4.1 INTRODUCTION

Barriers to energy efficiency measures in the mechanical engineering industry have been discussed and distilled into four main categories of high importance. These comprise hidden costs, access to capital, information and, fourthly, values/organisational culture. With a view to overcoming these barriers, directions for policy are now suggested. Possible policies will be discussed in broad terms only and they fall into three levels of policy decision, namely:

1. Policy at the level of the firm – the firm's organisational policy;
2. Sector specific policy, directed at and by the mechanical engineering sector;
3. Energy efficiency policy at national level.

These levels of policy response will now be looked at in turn.

3.4.2 POLICY AT THE LEVEL OF THE FIRM

The case studies suggest several things that firms can do to make their organisations more amenable to undertaking worthwhile energy efficiency measures. It is in firms' own interests to introduce efficiency measures if they will be profitable, taking hidden costs into account. They might also find it desirable to introduce such measures if they are subject to pressure of one form or another.

Pressure that simultaneously renders energy efficiency more profitable is likely to come from the introduction of emissions trading and a carbon tax, which are among the measures announced in the government's *National Climate Change Strategy* and the *Green Paper on Sustainable Energy* (DELG, 2000; DPE, 1999). Under emissions trading, the price paid by energy suppliers for emissions permits would naturally be passed on to energy consumers so that the result will be a price rise, as with a carbon tax, if less predictable.

Starting with the policy suggestions emanating from respondents themselves, those firms that had availed of advice and schemes of the then Irish Energy Centre found it very helpful. The view was also put that management needs to become more aware, because savings are indeed possible. Being in contact with the IEC was therefore a good move.

From their own experience, firms benefit from undertaking an audit and should be encouraged to do so. An audit gives good insights, and indicates what firms ought to know and the extent to which they are unable to account for their energy use. Firms would also find advice from elsewhere helpful, such as that from suppliers, though it is better if advice can be supplied by an impartial party. Journals from elsewhere provided what some respondents needed, that is, relevant case studies in like companies using similar technology.

The dictum "if we can't measure we can't manage" and the issue of accountability were dear to several respondents who would have liked the units within their organisations to be accountable for the energy they used. While this did not appear practicable or profitable in the short term, it may be practicable in the medium term. When investing in new or refurbished buildings firms might consider installing separate accounting at very little or no extra cost, in contrast with the cost of retro-fitting. Firms could also be more demanding of equipment sellers about information on the energy use of equipment.

In addition, firms could profitably review the investment criteria that they use. Worthwhile investments are better flagged by use of NPV or IRR criteria and these should be combined with a realistic assumption on length of use of the equipment. Risk needs to be taken into account but a less crude method than the three year payback is to look at outcomes for various pessimistic assumptions. Firms could also ask head office to look into producing benchmarks.

Firms would benefit by allocating responsibility for energy matters to a designated energy manager, with clear areas of control. A system of rewards or recognition is suggested by evidence from the study. The problem is that such measures need to be directed from the top, and both administrative resources and attitudes held at the top can be determining factors. It appears that head office or the MD needs to put energy efficiency "on the map".

3.4.3 SECTOR SPECIFIC POLICY

We saw that many firms in this sector are small, lacking expertise in energy matters and producing a specialised good. Sectors with these characteristics are quite difficult to encourage, especially when the general environment and low energy price have been unsupportive of energy efficiency.

Because of the varied nature of this sector, advice on energy efficiency should concentrate on such broad categories of energy use as space heating, compressed air, heat treatment and so on. This would be the approach that was employed by the Irish Energy Centre towards organisations of small or medium size and with low energy intensity.

Management time is one of the most serious hidden costs. Firms tended not to use benchmarks in terms of energy use per employee, per £1 million turnover, or whatever, and they could benefit from the Irish Energy Centre's successor or their trade organisations calculating such things for them to use. There may be modules of benchmarking that can be promoted for specific branches of mechanical engineering. Deciding on investments is difficult at the best of times. By contrast negotiating a lower gas price for example could be more clear-cut and financially rewarding, whereas energy efficiency could be viewed as an unknown journey. Benchmarks could act as signposts.

Information directed at this sector also needs to be in a form that firms can avail of easily, such as half-day seminars specific to the sector. Firms repeatedly said that they would find case studies particularly useful. They felt that they receive a lot of irrelevant and unfocused literature.

Efforts on the part of firms themselves is also likely to be beneficial. This underlies the thinking behind the existing self-audit schemes aimed at large energy users. Firms are likely to absorb more effectively things that they have learned themselves and in this way they can build up a knowledge base. There is a strong argument for reinforcing activities by the state body that assimilates and disseminates information, given the economies of scale and the external benefits.

The examples of case studies that respondents said that they would like could be drawn from the recent experience of programmes of audits and efficiency grants. The analysis would entail using figures of energy use before and after the investment, and would need to allow for "other things not being equal" such as output, weather and the like. Uncertainty in respect of actual achievable financial savings could be reduced with the help of evidence from the many actual investments that have taken place in programmes of the recent past. None of our case study firms had gone back to appraise the investments they had made, mostly with the help of grants. Evidence from analysing recent programmes should go a long way to dispel distrust. It may be found that savings are actually small owing to the decline in the real price of energy in recent years. This would lend weight to the need for refocusing national policy, to which we now turn.

3.4.4 ENERGY EFFICIENCY POLICY AT NATIONAL LEVEL

As mentioned above, the introduction of carbon taxes and emissions trading have been announced. Until now energy efficiency has been unsupported by policies, like carbon taxes, that would charge the polluter. Therefore, energy prices have been rather low, and consequently the barriers of management time, access to capital, imperfect information, values and low status have been perceived as substantial, relative to the potential gains from reducing energy consumption. With higher energy prices, such barriers become relatively less significant, although of course many would still be there.

Also countervailing the barriers to energy efficiency is the change in attitudes to the environment, though the link in the public mind between energy use and environmental damage is still weak. The shift in attitudes on the environment has been helped to some extent by NGOs in Ireland, whose work goes largely unsupported by public policy. NGO action and environmental image is apparently now taken seriously by some industrial head offices. This is the background that forms the context for general policy.

The barrier of management time can be reduced by provision of information in many forms, which should be possible with the energy agency's increased allocation of funds in the *National Development Plan 2000-2006* (Stationery Office, 1999). According to our case studies, implementation of monitoring and targeting and use of benchmarks and audits were patchy, and most firms had no idea what typical energy consumption in their industry would be, or could be. A central agency is well placed to undertake and disseminate the calculations. An example might be energy use per employee and per million pounds of turnover, at the most detailed level of industrial classification derived from the *Census of Industrial Production*. Ready reckoners and packs or software for calculating performance, combined perhaps with a support service, would help.

Past work on audits by the agency has stimulated the interest of availing respondents and evaluation of such schemes should be undertaken. Such follow up needs to be costed in the initiation of schemes and used as material in presentation of case studies, to overcome the barrier of credibility and trust. It could be a clearly specified condition of any future grants that "before and after" information be provided to the agency to enable it to do the analysis.

Improvements could be made in information on energy use of equipment. The same can be said of buildings. Certification of materials and designs and the specification of standards need to be improved. It would also be worth considering whether energy bills should be required to be more informative and readily understandable. They could give trends and graphs, of the past and previous years' consumption, say, as well as interpretations of metered breakdowns of energy use and proportions, presented in an understandable manner. Perhaps the Regulator could encourage such a measure. Furthermore, the readability of meters might be an area for improvement, over the long run at least. These are suggestions for investigation, to help reduce management time, to overcome the information barrier and to improve credibility and trust.

The barrier of access to capital can of course be typically addressed by subsidies but certain problems arise. Subsidies often entail paperwork and bureaucracy. As pointed out by Gruber and Brand (1991) firms, especially small firms, do not have time to read brochures or to fill in application forms. Subsidies need therefore to be very straightforward and this runs the risk of subsidies going to firms that do not need them. Another problem is that subsidies have to be successfully publicised. In the above-mentioned study, some 57 per cent of small and medium-sized firms in West Germany had not heard of a subsidy programme on energy conservation that had existed for ten years.

Another measure that facilitates investment is third party finance, which operates rather like a mortgage. More specialised agencies that can take over aspects of energy management, such as Energy Service Companies (ESCOs), including CHP companies, Contract Energy Management, and Facilities Management, additionally can share risk and overcome the barriers of information and expertise. The companies that were interviewed had generally not heard of ESCOs, and had not availed of their services except for audits and some investment advice. When the potential role of ESCOs was explained and companies were asked if they considered that contract energy management could be an attractive option, opinions varied. Replies ranged from "It would appeal to us – ESCOs have resources while we don't" to "We would consider it, but our processes aren't rocket science, we could do it ourselves" through to "We wouldn't trust them. It would reflect badly on us if they saved money".

Though a heterogeneous sector, mechanical engineering consists of many firms where energy use is not especially large and where management time is ill-afforded to acquire specialist knowledge about it. Financing energy efficiency investment might also be seen as a risky prospect. These factors all suggest that the sector could benefit from engaging ESCOs, Contract Energy Management or Third Party Finance and that there would be a latent demand for the role that these could play. Unfortunately, many firms in mechanical engineering would not have sufficiently high energy consumption, which would need to be above £100,000 per year, for ESCOs to consider it worthwhile becoming involved. With the exception of our large users of energy, despite the factors that favour the use of ESCOs, there is a notable mismatch between the companies that could benefit and the type of client that appeals to ESCOs. Another issue is the lack of trust, hinted at above, and this may point to the need for the sector association to arrange for third party finance and ESCO-type provision.

Turning to other national policies, it pays to do a regular check of the fiscal system and to review energy policies generally to see whether there are incentives or disincentives that operate perversely. These may operate directly or, equally important though less perceptible, they may operate indirectly or in relative terms. For example, energy efficiency investment enjoys the usual capital allowances for investment, with plant and machinery being written off over seven years. More favourable terms, however, are allowed for investment in new companies set up to invest in renewable energy generation. Companies supplying electricity under the Alternative Energy Requirement (AER) also have their sales prices guaranteed. These favourable treatments are applied to renewable energy but not to energy efficiency *per se,* which might find it easier to compete for funds if there were a more level playing field.

Understandably, special fiscal treatment for energy efficient investment is sometimes called for. However, one needs to bear in mind the aim to simplify the tax system overall and to have low rates of tax, which are made possible by having a streamlined system in which exemptions and special regimes are kept to a minimum. If special regimes are operated, they are better for being overt, as in subsidies, to enable easier tracking. Subsidies can also perform a useful service as the carrot in a carrot-and-stick approach, often considered to be a fruitful approach, especially when carbon taxes or tradable permits are introduced. Subsidies bring their own problems, of course, and gradual introduction of carbon taxes, optimal reduction of other taxes and due regard for implementation issues could be the best course (McCoy and Scott, 2002; Scott, 1999).

Fairly low energy prices have kept down the profitability of energy efficiency measures in recent years. Every firm in the sample made some comment relating to profitability of energy efficiency investment, from statements such as "the electricity bill concentrates the mind a bit more than government policy", "measures must save money", to "we'd look at the monitoring system if the bill became higher…the heating system could be looked at".

A switch in taxation away from labour taxes to a carbon tax could help these firms "to concentrate the mind" and, in the case of labour intensive firms, may improve the bottom line. This is because mechanical engineering as a whole is not energy intensive and some firms could be at an advantage if taxes were switched in this manner. Meanwhile, ongoing deregulation of the energy market is likely to reduce energy prices although the extent of price declines on foot of deregulation is uncertain. The carbon tax could be undermined somewhat thereby, although it is obviously still worth introducing.

If the announced introduction of emissions trading is limited to large energy importers/users, then mechanical engineering firms, being small, would not be directly involved. This would save them from having to devote further scarce management time to negotiating allocations of emissions permits and to trading. There has been a good deal of uncertainty surrounding aspects of current policy, contributing to the barrier of risk.

Ireland's national energy authority, Sustainable Energy Ireland (formerly the Irish Energy Centre), with twice the staff and five times the budget of the previous organisation is well-placed to help with some of the requirements emerging from this study. Its mission is to promote and assist the development of sustainable energy in Ireland, with programmes in the fields of renewable energy, energy efficiency in industry and built environment, research and development, and consumer information (Department of Public Enterprise, 1999). The research and development programme is designed to assist the development of a least-cost path to CO_2 reduction and will focus on increasing energy efficiency, on product and service innovation and international collaboration (Department of the Environment, 2000). These goals are in line with the areas found here to be in need of development, including the provision of sectoral benchmarks, the development of third-party finance and focused case studies and documentation of the performance of investments.

3.5 Summary

This chapter has described the investigations into barriers to energy efficiency in the Irish mechanical engineering sector, a sector that employs over 11,000 people and produces gross output valued at 1.3 billion euro.

Over half the output of the sector is accounted for by foreign-owned firms, which tend to be larger than Irish-owned ones. The sector produces a wide range of categories of output, the majority of which is exported. Energy would tend to be used mostly in generic applications, such as space heating, lighting and heat treatment, and most opportunities for efficiency lie in these areas.

Seven firms were selected and agreed to participate as case studies, representing 13 and 14 per cent respectively of the sector's employment and sales. The firms were engaged in the manufacture of dies, tools, pumps, fasteners, lifting and handling equipment, engine components and machinery for agriculture and specific industries. For ease of discussion, firms were ranked according to the number of energy efficiency measures that they had implemented. This ranking revealed that the firms that had adopted most energy efficiency measures tended to be the larger firms that spent most on energy. They had undertaken an energy audit, tended to undertake most energy reporting routines, and perceived there to be less unexploited opportunities and less barriers.

The firms' patterns of adoption of measures were investigated to see which of the dozen or so possible barriers suggested in Chapter 2 stood out. The barriers identified were distilled into four main categories. These include hidden costs and management time in particular. Time would be needed to identify the opportunities, analyse them and tender for new technology. It was felt that other priorities received precedence over energy efficiency. A second important barrier was access to capital for the purpose of investment in energy efficiency. Although companies did not experience a general difficulty in obtaining capital it was difficult for energy managers to access capital within their company. This problem of access to capital operated via the imposition of short payback rules or strict capital budgeting rather than through more sound criteria such as net present value or internal rate of return, possibly for reasons of risk avoidance and managerial control. It is worth adding that compared with the firms studied in the UK's mechanical engineering sector, Irish firms appeared to have more discretion over their investment and its funding.

Third, imperfect information on opportunities for energy saving in buildings and equipment use was an obvious impediment. Encouragement to firms to undertake well-executed audits is recommended and the studies of firms in the UK and in Germany also supported such encouragement. This applies to both SMEs and large companies. In some of the Irish cases it was more a question of the relevance of the information received. The final barrier centred round values and organisational culture. Again a consistent pattern was found, with performance declining where top management was not concerned about energy or environmental matters.

Evidently a range of policy measures is required to address these diverse barriers. A selection of possible measures is now discussed, starting at the level of the firm, proceeding to the level of the mechanical engineering sector, and then to national level. These suggestions are supported by those emanating from the studies of the sector in Germany and the UK. Some of the barriers, such as the existence of market risk, would be unavoidable. Others can be reduced.

At the level of the firm, a prerequisite would be to vest responsibility for energy matters in a person who would be charged with energy efficiency and monitoring. Another prerequisite would be to undertake a well-executed energy audit. Outsourcing utilities management could also be a worthwhile route.

Turning to the sectoral level, because many firms in the sector are small they cannot afford an energy manager. They would benefit from receiving centralised information of a generic nature, on such issues as heat treatment and compressed air. Sustainable Energy Ireland or the trade association could help with information, including sectoral benchmarks, and illustrations of relevant case studies, giving "before and after" analyses. Also, professional bodies, such as engineering and branch-specific working groups, and supplier and user associations, could become more involved in disseminating such information.

At national level, understanding of the link between energy and the environment could receive encouragement. In turn there could be encouragement to make the environment an issue among shareholders and in the boardroom, with the supply of public information on, and encouragement for, certification to environmental standards and "ethical" funds. The energy regulators could require energy suppliers to make meters and bills clear and informative, showing trends of the customer's energy use, so that purchasers can become more energy numerate. Energy labelling and efficiency standards would simplify decision-making and save time, and should be promoted. Sectoral associations to promote third party finance companies, contract energy management or ESCOs would be worth investigating. National fiscal policy needs gradual pre-announced correction to address the failure to charge for energy users' external costs. The carrot in such a policy might be financial help with undertaking audits.

The mechanical engineering sector could by and large stand to gain if carbon taxes are introduced at the same time as reductions in labour taxes.

In sum, the aim of policy should be to provide accessible, relevant and credible information on opportunities and encourage audits, energy monitoring and numeracy. This should occur in a supportive regulatory and pricing environment that is as risk-free as possible and that accounts for external damage costs. Given that one policy measure on its own cannot be the solution, action is required on many fronts.

Annex 3.1: Detailed Summary of the Importance of Barriers to Energy Efficiency in the Irish Mechanical Engineering Sector

Potential barrier	Assessed Importance (Respondents' average scores in brackets*)	Comments
1. Heterogeneity	Medium (1.9)	The sector is varied but generic energy use is similar.
2. Hidden costs	High (2)	Management time is the most serious hidden cost
of which:		
Analysing/tendering	(2.3)	
Disruptions/hassle	(2.3)	
Staff training	(2.1)	
Poor performance	(1.7)	
Information: equipment	(1.7)	
Time/other priorities	(2.4)	
3. Access to capital	High (2.4)	Access to borrowing is not a barrier, but tight payback rules or capital budgets restrict some good investments.
of which:		
Other priorities	(2.6)	
Lack of capital	(2.4)	Rarely use NPV or IRR with "realistic" lifespan.
Strict adherence: budgets	(2.3)	
4. Risk	Medium	Genuine risks exist, contributing to short payback rule, therefore, indirectly significant.
of which:		
Market uncertainty	(1.7)	
Technical risk	(1.4)	
5. Imperfect information	High (1.9)	Undertaking an audit and consulting the Irish Energy Centre helped overcome barrier.
of which:		
Opportunities for energy saving	(2)	
Energy use of equipment	(1.7)	Other sources also useful. Information on use of energy by equipment and buildings is poor.
Form of information	High	Important barrier if availing of information takes much time
6. Split incentives	Medium to low	
of which:		
Accountability of departments	(2.1)	Important although impractical in short run.
Leasing	Low	Not important (leasing).
Job rotation	Probably low	No evidence of job rotation.
7. Credibility of information and trust	High	Information must be relevant and convincing.
8. Values/organisational culture	High	Barrier reduced if head office or MD take the lead
of which:		
Staff awareness	(2.1)	

9. Power/status of energy manager	High	Especially important if much investment is underway

* *Note:* The scores in brackets are respondents' ratings, where 1 = rarely important, 2 = sometimes important, 3 = often important.
Assessed importance takes respondents' scores into account, but can differ from them slightly in some cases, owing to further information emerging from in-depth interviews.

4. THE BREWING INDUSTRY

4.1 Description of the Brewing Industry

4.1.1 SIZE, COMPOSITION AND ECONOMIC PERFORMANCE

The brewing industry sold 12.58 million hectolitres (or 1,258 million litres) of beer in 1998. Its sales were worth £960.4 million, up from £509.8 million in 1995.[15] According to the Census of Industrial Production, brewing accounted for 1.6 per cent of total Irish manufacturing production and 0.9 per cent of total manufacturing employment in the mid-1990s.

The brewing industry in Ireland is very highly concentrated in three principal companies that together produce over 99 per cent of the industry's output. Guinness Ireland is by far the largest of these three, and a large majority of the whole industry's production comes from this one company.

Guinness was originally established in Dublin in the eighteenth century but it eventually became a predominantly British-owned company mainly as a result of floating its shares on the London Stock Exchange. The company built a large new brewery in England in the 1930s, and it subsequently established breweries in many other countries and then moved its corporate headquarters from Ireland to England. Guinness Ireland today is one of the top twenty companies in Ireland (ranked by turnover), but it is now only a part of the multinational Guinness group. The whole Guinness group, in turn, is one part of Diageo, a major predominantly British-owned multinational company, with interests not only in brewing but also in other sectors such as distilling and fast food restaurants.

In Ireland, the principal Guinness brewery is in Dublin, and this is one of the largest breweries in the world producing millions of hectolitres of beer per year. (The industry uses hectolitres as the measure of output, where one hectolitre equals 100 litres). However, Guinness has a total of five breweries in Ireland, with two in Dundalk and one each in Kilkenny and Waterford in addition to the Dublin brewery.[16] Two of these other breweries, apart from the Dublin one, are large by most standards with production of over a million hectolitres per year, while production in the remaining two is in the range 0.2-0.5 million hectolitres per year. Guinness Ireland produces a range of different beers, including its own brands of

[15] Central Statistics Office, *PRODCOM – Product Sales*, 1998 and 1995. Later editions do not present data on brewing output.

[16] The information here was correct at the time when our research was undertaken. However, in July 2000 Guinness announced that it would be closing one of its breweries in Dundalk and would be cutting employment by 60 per cent in the other Dundalk brewery.

stout, ale and lager, as well as a variety of foreign brands under licence. The individual breweries tend to specialise in producing one or more particular beers. But there is also a degree of flexibility as regards which brands are produced where, depending on factors such as the strength in demand for different brands and the location of the availability of spare production capacity.

Murphy Brewery Ireland and Beamish & Crawford are the two other principal brewing companies. They are also long established, being more than 140 years old. These two companies have one brewery each, both of them located in Cork. Production in each of these two breweries is less than 1 million hectolitres per year, but more than 0.2 million hectolitres per year. Although these companies originated in Ireland, they are both now part of much larger foreign-owned companies. The Dutch multinational brewing firm, Heineken, is the parent of Murphy Brewery Ireland, while Beamish & Crawford's parent company is Scottish and Newcastle, one of the largest firms in the UK brewing industry. Both of the Cork breweries produce their own brands of stout and ale, while they also produce foreign brands of lager.

Since about the mid-1990s, a number of very small "microbreweries" have commenced operations in Ireland. There were about ten or more such microbreweries operating in Ireland by the late 1990s. However, the volume of output from these companies is insignificant in relation to the scale of the Irish brewing industry and some of the microbreweries sell to only one or two individual retail outlets.[17] Thus, to sum up on the structure of companies in the Irish brewing industry, there are three major companies, operating seven substantial breweries, which together account for over 99 per cent of the industry's production. In addition, there are a number of very much smaller microbreweries.

Most of the beer produced in Ireland is sold in the domestic market, but exports are quite substantial. Exports accounted for about 15 per cent of the value of sales and about 26 per cent of the volume of products sold in 1998. Ireland has a relatively strong competitive position in international trade in beer, since the value of exports exceeds the value of imports by a ratio of almost three to one while the volume of exports exceeds the volume of imports by a ratio of almost four to one.

The output of the brewing industry grew quite rapidly in the 1990s, with the value of output rising from IR£415.2 million in 1991 to IR£542.6 million in 1995, which was an increase of 6.9 per cent per year, in *current* values (*Census of Industrial Production)*. There is no official price index for brewing as such but, using the price index for the drinks industry as a whole, we estimate that the increase in the volume of production in the brewing industry amounted to over 6 per cent per year in 1991-95. More recently, in the period 1995-98, data on the volume of product sold by the brewing industry show an increase from 8.13 million hectolitres in 1995 to

[17]"New Taste for Old-Fashioned Drinks", *The Irish Times*, 17 April 1998. "Craft Brewers Want Excise Cut to Boost Industry", *Sunday Business Post*, 17 November 2002.

12.58 million hectolitres in 1998 (*PRODCOM – Product Sales*). This amounted to growth of over 15 per cent per year.[18]

4.1.2 ENERGY USE IN BREWING

The brewing process is basically quite similar in any brewery, with similar energy using technologies being employed. However, there can be variations in the amounts of energy required per unit of output because of factors such as differences between breweries in their scale of operations and differences in the mix of products and packaging. A notable characteristic of the Irish industry, compared to countries such as the UK or Germany, is that only a tiny fraction of Irish production comes from small breweries with output of less than 0.2 million hectolitres per year. UK data indicate that large breweries tend to use less energy per unit volume of beer than small ones (Harris, 1979).

The brewing industry is a relatively energy-intensive sector compared to most other industries in Ireland, and it is also regarded as being relatively conscious of energy efficiency issues. In 1995, the brewing industry spent IR£7.5 million on fuel and power, which amounted to 1.4 per cent of the value of its gross output. Expenditure on fuel and power can also be expressed as a percentage of purchases of "industrial inputs", meaning purchases of materials for processing, industrial services, and fuel and power combined. Spending on fuel and power in 1995 amounted to 6.6 per cent of purchases of industrial inputs in brewing. For comparison, expenditure on fuel and power amounted to just 2.4 per cent of purchases of industrial inputs in all Irish manufacturing.[19] The principal energy source used by the brewing industry is gas, followed by electricity.

Since the mid-1980s, the value of energy purchases by the brewing industry has declined considerably. As the value of the industry's production was increasing at the same time, its expenditure on fuel and power as a percentage of the value of its gross output fell very substantially from almost 6 per cent in 1985 to under 2 per cent by 1995. The expenditure on fuel and power expressed as a percentage of purchases of "industrial inputs" fell from over 15 per cent in 1985 to under 7 per cent in 1995. Much of this decline occurred in the second half of the 1980s, and sharply declining fuel prices between 1985 and 1987 were partly responsible for this trend. But even allowing for this, we estimate that there was a significant real decline in the energy-intensity of the brewing industry.

A number of government policy measures have aimed to improve energy efficiency in Irish industry, including the brewing industry. These include a grant scheme for energy audits, a scheme to support investment in energy efficiency, an energy self-audit and statement of energy accounts scheme, information programmes on best practice, and a scheme to promote

[18] More recent data on the value of brewing sales or the volume of output are not available from these sources.

[19] The data quoted come from the *Census of Industrial Production*, which does not distinguish brewing as an industry separate from distilling and malting in later years.

fuel savings in the use of boilers. The content of these schemes is outlined in more detail above in Section 3.1 in the chapter on the mechanical engineering industry.

4.2 Methodology

For the purpose of our research on the brewing industry we undertook a number of case studies of breweries. There was little scope to be selective in choosing these case studies, as there are only three principal companies with seven sizeable breweries in the Irish brewing industry. While there are also a number of very small microbreweries, it seemed clear that the scale and nature of their operation is so very different from the mainstream of the industry that they would not be appropriate as case studies. Consequently, we decided to approach all seven of the larger breweries, and the five of those that agreed to co-operate constituted our case studies. Given that the five participating breweries together account for a large majority of production in the industry, they provide a good representation of the industry. Each of the breweries concerned is part of a larger multi-plant enterprise but we were satisfied that, in matters relating to managing energy efficiency, the more appropriate unit to study was the individual brewery rather than the enterprise as a whole.

In carrying out the case studies, we used an initial "pre-interview" questionnaire, sent by post, to obtain certain types of basic but important information on energy use, energy management, energy efficiency measures employed and perceived barriers to energy efficiency.[20] Then we followed this up with more in-depth and qualitative face-to-face interviews. These interviews were semi-structured, using a detailed questionnaire to ensure that all potentially important issues would be covered, but allowing for variations in the amount of attention given to different issues depending on the circumstances of each case and the results from the "pre-interview" stage. (The questionnaire for these face-to-face interviews is shown in Appendix 2.)

The number of interviews carried out in each brewery ranged from one to three. The priority was to interview the energy manager (if such a position existed) or the person who had most responsibility for energy management. In practice, the people giving these priority interviews were generally described as the engineering manager or production services manager, or a variation on these titles. We also carried out additional interviews where possible with other relevant people, such as maintenance, production or environmental managers. The objective of the interviews was to obtain both factual information and perceptions and opinions relating to a variety of topics such as the conduct and status of energy policy and energy management, energy performance, energy information systems, information on energy efficiency opportunities, procedures

[20] The pre-interview questionnaire employed was similar to the one used for the mechanical engineering industry, as shown in Appendix 1, apart from some industry-specific details such as the question about implementation of specific energy efficiency measures. The brewing questionnaire is available from the authors.

governing budgeting and investment, and the importance of a range of potential barriers to greater energy efficiency.

4.3 Description of Case Study Companies

In this section we describe the five breweries that participated as case studies. In doing this, we are constrained by the need to preserve confidentiality as promised to all those who co-operated in the study. Therefore, we cannot present detailed descriptions of each of the case studies in turn, but instead we describe the five of them collectively as a group.

4.3.1 CONTEXT OF THE CASE STUDIES

The five breweries are quite diverse in size. In terms of the quantity of beer produced per year, the smallest is in the 0.2-0.5 million hectolitres category, with the largest being well inside the category of a million hectolitres plus. However, compared to the size distribution of breweries existing in the UK or Germany, these can all be regarded as either large or medium-size breweries. In the UK for instance, over 40 out of 87 breweries produce less than 0.2 million hectolitres per year, and none of the five Irish cases are as small as that. The numbers employed in the five Irish breweries range from less than 200 to about 400. All of them are long-established, for the most part originating in the eighteenth or nineteenth centuries, but of course investment and new developments over time have meant that many of their present buildings and facilities are much more modern; there is considerable variation in this regard between the five cases.

All of the five produce more than one brand of beer, and some of them produce two or three of the categories ale, stout or lager on the one site. While packaging (in kegs, cans or bottles) is performed on-site in some cases, this is not true for all of the output of all of the breweries. Some output leaves the breweries in larger bulk containers to be packaged elsewhere for the retail trade.

Most of the variations between the different breweries that are mentioned above would have some implications for energy requirements or energy intensity. Thus, other things being equal, energy requirements per litre of output could be expected to decline with scale, to rise with age of production facilities, to be higher for lager than for other beers, and to be higher where more packaging is carried out. In addition, some other variations between the breweries were encountered which would give rise to differing energy requirements per unit of output. Examples are the presence on-site of substantial research and development facilities, office-based service activities, tourism- or heritage-related facilities, or other energy-using production facilities not directly and solely related to the brewery's own production requirements. Where such activities are present, this would tend to raise energy usage per unit of output above what it would be otherwise.

In each of the five companies, expenditure on electricity accounts for more than half of total energy expenditure, but this mainly reflects the higher price of electricity than other energy sources. In fact, electricity accounts for a relatively small minority of total energy usage in all five cases, and they all rely mainly on gas as their principal energy source. In most cases, gas and electricity are supplied directly to the breweries by the relevant public utility companies, but in one case there is a CHP plant on-site that uses gas as an input and provides steam and electricity to the brewery.

A final point worth noting here is that breweries are substantial producers of CO_2, as a by-product of the fermentation process. Traditionally, this CO_2 was simply released into the atmosphere. However, breweries also use CO_2 as an input for carbonating the beer, and they used to have to purchase this from outside suppliers. In recent years, since about the mid-1990s, all five of our case study breweries have introduced systems to recover and use their own CO_2, and by now they are mostly either self-sufficient or largely self-sufficient in CO_2, while at least one of them has a surplus to sell outside the brewery. This required significant investment, but it has generally proved worthwhile financially because of the reduction in input costs. While this is not an energy efficiency measure as such, it has had similar effects both in cutting the breweries' costs and in reducing greenhouse gas emissions attributable to the brewing industry.

4.3.2 ENERGY POLICY

There is considerable variation in the degree to which formal and systematic energy policies are in place in the five different breweries. However, a significant point worth noting is that none of the five suggest that they have no explicit energy policy. Having said that, at one extreme one of the breweries indicated that it has just an "unwritten set of guidelines". At the other extreme, one of the breweries indicated that it has a fully developed "energy policy, action plan and regular review with commitment of top management". The other three place themselves somewhere between these situations, indicating that they have an energy policy set by a senior departmental manager, but perhaps not formally adopted and generally without very active commitment from top management to energy policy as such. In most of the companies, it seems that there is a real interest among top management in reducing costs in general, and energy policy or management is seen as essentially an aspect of that broader objective.

The companies are generally well aware of their performance on overall energy use and its relation to their output. They have targets for use of energy as well as water, and sometimes for recovery of CO_2.

In recent years, they have been required to obtain IPC (integrated pollution control) licenses from the Environmental Protection Agency. This licensing system involves the implementation within companies of environmental management programmes which aim to ensure that there is continuing improvement in their environmental performance.

4.3.3 ENERGY MANAGEMENT

There is some variation among the five breweries in the degree to which energy management is formally organised and integrated into the overall management structure. However, the first point to note here is that all of the five do have some type of formal energy management with some formal delegation of responsibility for energy consumption. In one case, the structure is highly developed and energy management is fully integrated into the management structure, with clear delegation of responsibility for energy consumption. The other four cases are fairly similar to each other, with energy management generally being the part-time responsibility of someone with limited authority. Typically, the persons concerned have broader responsibilities beyond energy management alone, such as plant maintenance, new investment projects and environmental management. Reflecting these responsibilities, they are not described as the "energy manager" but are usually called engineering managers or some variant of that title. The proportion of their time that is devoted to energy management as such varies from about 10 per cent to about 50 per cent or more, although there are usually also other staff, and occasionally outside consultants, available to work on improvements in energy efficiency. They generally report to a more senior manager within the brewery who would have to give clearance for significant expenditures on energy efficiency measures.

Since all of the five breweries are part of larger enterprises, they must also seek clearance from a higher level for substantial expenditures on energy efficiency measures or other investments. They are generally subject to specified payback criteria for investments and they must put forward a case justifying substantial expenditures. Also arising from their position as part of larger enterprises, they share ideas and experiences with their parent and sister companies, and can benefit appreciably from such exchanges of information and from co-operation on technical matters including energy efficiency. This process facilitates the diffusion of technical improvements to different breweries within larger enterprises.

In most of the breweries, energy management is essentially conducted in-house, without ongoing use of outside contract energy management or ESCOs (energy service companies). However, in some of these cases it is possible that there may be future changes in this regard. Up to the present, these breweries have made use of outside consultants, but only from time to time for specific purposes. In one of the five cases, there is a CHP plant on-site that is operated by an outside contractor, with the brewery paying them agreed prices for the electricity and steam supplied.

As regards the status of energy management, there is general agreement that it is taken quite seriously. There is real recognition in brewing companies that energy is an appreciable cost for them, and this fact alone would ensure that energy management is given significant attention. Some interviewees felt that the status of energy management is essentially proportionate to its role in the cost structure and that it has little further significance for top management; it receives no special attention when things are going well, but it does if performance goes off target. However, a few of the interviewees felt that energy management is accorded a somewhat higher status and importance in their companies. This is mainly because, as an aspect of environmental performance in general, it can have implications for the corporate image and public relations.

4.3.4 ENERGY INFORMATION SYSTEMS

All five of the breweries record their energy use regularly, although there are variations in the level of detail and frequency with which they do so. For example, electricity use is metered at the detailed level of individual processes in four out of five cases, and at the level of individual buildings in the fifth case. Use of steam/hot water is metered at the level of individual processes in two cases, at the level of individual buildings in one case, and only at the level of the site as a whole in two cases. As regards the frequency of recording energy use, this is done daily in one of the breweries and weekly in all of the others, although several of them have the capability to monitor energy use in detail much more closely if the need arises.

One of the five cases has a very comprehensive system for using information on energy consumption. It sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking. Three of the others also have quite elaborate systems, using their information to calculate energy consumption per unit of production, to compare this with sector benchmarks, and to apply monitoring and targeting schemes for energy use. The fifth one also records energy consumption per unit of output and compares this information with sector benchmarks, without employing a monitoring and targeting scheme. In general, if adverse trends occur in aspects of energy consumption, these are investigated as they arise.

In most cases, information and analysis on energy use, or at least energy expenditure, is passed on regularly to senior management. Most of the interviewees were broadly satisfied with the quality of their energy information systems, although they do see some room for improvements. Apart from their regular gathering and review of information on energy consumption, most of the breweries have also used more in-depth energy audits at times.

4.3.5 ACCOUNTABILITY FOR ENERGY USE

The five case study breweries have little or nothing in the way of arrangements for charging energy costs to individual subdivisions within the brewery. Nor do they use devolved energy budgets for individual subdivisions, or financial incentives for subdivisions or staff to use energy more efficiently.

Several of the breweries would be able, or almost able, to measure the energy consumption of individual subdivisions and to charge them for it, although they have acquired such capabilities only quite recently. But at least one of the breweries does not have the equipment to implement such a system and would have to make significant additional investments to do so. Most, but not all, of the interviewees felt that such a system of devolved accountability would result in improvements in energy efficiency, but perhaps not very large improvements. A few of them suggested that there might be savings of about 3 to 5 per cent. A few potential obstacles to implementing devolved accountability were mentioned, including the fact that steam meters are not very accurate and that there would be some need for vigilance to ensure that product quality would not suffer. In addition, as mentioned above, at least one of the breweries would need to undertake significant expenditure to measure energy consumption by individual subdivisions, and it is not clear that this would be financially worthwhile.

While there are generally no systems of financial incentives for individual subdivisions to minimise energy use, the senior managers with most responsibility for energy management in some of the breweries do have personal financial incentives related to performance, including energy performance. But such incentives related to energy performance are generally only a small part of their total remuneration. Some of the people concerned indicated that such incentives have rather little impact on their motivation to improve energy performance, because the incentives are relatively small and because they would be sufficiently motivated in any case.

4.3.6 ENERGY EFFICIENCY PERFORMANCE

The energy efficiency performance of the case study breweries looks relatively good by comparison with benchmarks available from the UK. Average energy consumption in UK breweries in 1996 was 178 MJ per hectolitre (or 1.78 MJ per litre). The figure tended to be higher for the smaller breweries, so that it was 251 MJ per hectolitre for those producing 0.2-0.5 million hectolitres per year, 167 MJ per hectolitre for those producing 0.5-1 million hectolitres, and 168 MJ per hectolitre for those producing over 1 million hectolitres per year.[21] Compared to these figures, four of the five Irish case study breweries had energy consumption rates in 1999 that were no more than 81 per cent of the overall UK average for 1996, and that ranged between 57 per cent and 76 per cent of the UK average for their own size class. The fifth Irish brewery had an energy consumption rate that was not better than the UK average and hence was out of line with the other Irish cases. However, there appeared to be good explanations for this on account of the mix of activities carried out at the site concerned, which would give rise to significant additional energy consumption. Given these explanations, together with other indications of exceptional attention being given to energy efficiency measures in the brewery concerned, it appears that that this case too can be regarded as a relatively good performer on energy consumption. As regards trends over time, the Irish breweries were able to show significant reductions in energy consumption per hectolitre in the 1990s.

Consistent with the impression given by the figures, the breweries generally regard themselves as having an above-average performance on energy efficiency (obviously they cannot all be above average for Ireland, but their frame of reference tends to be Ireland plus the UK). One of the breweries estimated that it is in the top 10 per cent on energy efficiency performance, another reckoned that it is in the top 30 per cent, and a third

[21] Brewers & Licensed Retailers Association Energy Survey 1996.

one was estimated to be "one of the best". The other two were less specific about this.

In our pre-interview questionnaire, the five case study breweries were presented with a list of 41 possible measures for reducing energy consumption and they were asked to indicate whether they had implemented or at least considered implementing each of the measures. Nearly all the breweries pointed out that some of the measures were not applicable to them for various reasons (although this applied to quite a small minority of the measures). Leaving aside the measures that were regarded as not applicable to each case, three of the five breweries have implemented half or more of the possible measures, and they have implemented or considered two-thirds or more of them. Thus, in these three cases, only one-third or less of the possible energy-saving measures have been neither implemented nor considered. In the remaining two breweries, less than half of the possible measures have been implemented, but they have considered many of the other measures. Consequently, in these cases too, only one-third or less of the possible energy-saving measures have been neither implemented nor considered.

It is perhaps of interest to note that there is no clear correspondence between the ranking of breweries in terms of energy consumption per hectolitre and their ranking in terms of the proportion of energy-saving measures implemented. No doubt this is partly (or largely) a reflection of diversity among the breweries in terms of size, age, mix of production, etc., which would mean that their energy requirements would differ even if they all gave the same attention to energy efficiency measures. Because of this situation, it is difficult to perceive a clear overall ranking on energy performance among these breweries. However, the relatively low proportion of possible energy-saving measures that have neither been implemented nor considered tends to confirm the impression that probably all of these breweries are relatively good performers on energy efficiency.

Nonetheless, most of the breweries believe that there are significant energy saving opportunities that they have not yet implemented. Three of them agreed with the proposition that there is a wide range of energy efficiency measures that could be implemented in their breweries that would yield paybacks of less than five years at current energy prices. One of the others was doubtful whether this proposition applied in their case, while the fifth one disagreed with this proposition. (The one case that disagreed with this proposition was also the one that had actually implemented the highest proportion of energy-saving measures.) The reason they gave most commonly for not implementing possible energy efficiency measures that would yield paybacks of less than five years was because the investments they make are subject to payback criteria which are more demanding than a five-year criterion (see Section 4.3.7 below). This is also a common reason for not even considering some possible measures, since it can be quite obvious that some measures would not get close to satisfying their payback criteria. However, the breweries also indicated that there is a range of other barriers or obstacles to implementing energy saving measures which can be significant at times, as will be discussed in Section 4.4 below.

4.3.7 CAPITAL AND INVESTMENT

None of the five breweries has a separate budget for investment in energy efficiency as such. Instead, investment in improving energy efficiency is usually treated as an aspect of investment in general. Apart from some rather exceptional circumstances, this means that investment in energy efficiency is generally subject to the same payback criteria as other investments, which are usually quite short-term payback criteria.

Since there is generally no separate budget for energy efficiency investment, and since the managers who are most responsible for energy management must also divide their time among other responsibilities, the breweries usually cannot put a precise figure on their overhead costs of energy management. The rough estimates that they provided for this indicate that the overhead costs of energy management range from the equivalent of less than one person-year up to perhaps three person-years.

In assessing investments in energy efficiency measures, the breweries usually apply payback criteria that are the same as for other investments, as mentioned above. The payback criteria are generally quite tight, typically about three years or so. Some of the interviewees said that the criterion applied to them has been tightening in recent times, for example from a four year payback a few years ago to three or even two years now. These tight payback criteria for investments would not usually apply to replacement of plant that is absolutely necessary for the core function of producing beer. Rather they apply to other desirable but not entirely essential investments, which would include many energy efficiency measures.

The payback criteria for investment are generally set at the top level of the company as a whole, above the level of the individual breweries. When seeking capital to make investments, usually above a specified amount (for example £50,000 or £100,000), the breweries generally have to make a formal case to parent companies justifying the investment in terms of the payback criteria.

Our interviewees put forward some reasons why the payback criteria are generally so tight. A key reason is that there is competition within the whole company for the available capital from all types of other projects, including investments in marketing which are important for brewing companies. The payback criterion is a method for making selections among diverse types of projects, given a limit on capital availability. The companies appear to be mostly unwilling to borrow significantly more capital to invest in additional projects, even though there may be some additional projects that could adequately repay the cost of borrowing over a longer period than the specified payback time. Another reason suggested for the tight payback criteria is because this is a means of allowing for some risk that projects will not be as successful as expected by those proposing the projects.

The payback criteria are not entirely rigid in all cases and there seems to be some flexibility depending on the circumstances. For example, if grants can be secured to help fund investments this can allow the payback criteria to be relaxed. Or an exception might be made if it is possible to argue a case that a highly visible investment in energy efficiency would have additional benefits for the company's public relations, or that an investment in energy efficiency would have additional benefits in improving safety or in reducing maintenance costs. However, most of the breweries were able to identify some realistic potential investments in improving energy efficiency that are effectively ruled out by the strictness of their company's payback criterion.

There are some risks or threats in the overall business environment that appear to have an influence on investment criteria for the breweries. For example, the breweries are very aware of the effects of competition and market trends (in the UK as well as Ireland) and this puts constant pressure on them to reduce costs and expenditure. Some interviewees felt that strict investment payback criteria are partly a reflection of competition and the resulting general pressure to minimise expenditure. In addition, there has been a considerable amount of recent speculation concerning possible mergers, acquisitions, sales or closures of breweries or brewing companies. It seems that such possibilities have led to a climate of some uncertainty about the future which has tended to put more emphasis on short-term rather than longer-term goals in relation to assessing investment expenditure. This would reinforce any preference for using short payback criteria and avoiding borrowing to fund investment.

4.3.8 NEW BUILDINGS AND REFURBISHMENT

The issue of incorporating energy efficiency considerations in the design of new or refurbished buildings has not been very significant in recent years for most of the breweries, as relatively little new building has occurred. In so far as it has occurred, energy efficiency has generally been taken into account at the design stage.

4.3.9 PURCHASING

The brewing companies generally do take account of energy efficiency considerations when purchasing equipment, although there may be no written rules or policy documents governing this to ensure that it is done systematically. Some of the interviewees indicated that energy efficiency is considered seriously when purchasing equipment that uses a good deal of energy, but that it may tend to be neglected to some extent in the case of purchasing other equipment that uses less energy. Several of them also said that there can be a difficulty sometimes in obtaining reliable information on the energy performance of equipment that they are thinking of purchasing, although this is not usually a problem.

4.3.10 AWARENESS AND CULTURE

Some of the breweries organise regular staff awareness programmes concerning energy efficiency, and the others at least carry out *ad hoc* staff awareness training and dissemination of information. These measures seem to be reasonably successful for the most part, since nearly all of the interviewees say that lack of staff awareness is rarely significant as a barrier to energy efficiency.

The breweries all experience some external pressures to improve their energy/environmental performance. In particular, in recent years they have been required to obtain IPC (integrated pollution control) licenses from the Environmental Protection Agency. These licenses involve the implementation within companies of environmental management programmes which aim to ensure that there is continuing improvement in their environmental performance. In addition, the breweries are conscious of a need for good public relations, with the local community and more widely, which means that they need to be concerned with their environmental performance.

As regards internal pressures to improve energy or environmental performance, most but not all of the interviewees said that there are some pressures of this type from employees, who are often local people sharing the same environment. There are also such pressures from top-level management. All the interviewees agreed that energy efficiency and energy management are taken quite seriously by their top management. At the least, there is real recognition by top management that energy is an appreciable cost for breweries, and this fact alone would ensure that energy management is given significant attention. Most of the interviewees felt that a concern for good public relations gives a further motivation for their senior management to be concerned with energy performance and environmental performance more generally. In addition, a couple of the interviewees said that there is also a somewhat deeper commitment to environmental values by their top management, going beyond the motivations mentioned above.

At the same time, most of the interviewees said that there is an ongoing need for individuals within the breweries to champion and push for particular energy saving or environmental projects. It is generally necessary for the managers with responsibility for these areas to put forward a case justifying expenditures on such projects. Most of these managers describe themselves as being motivated to some degree by environmental values.

4.3.11 ESCOs

Most of the breweries make no regular use of outside contract energy management or ESCOs (energy service companies), although in some cases it is possible that there may be future changes in this regard. Several of the breweries were having wide-ranging reviews of their operations undertaken at about the time we carried out our interviews, which could result in significant changes. In one large case study brewery, there is a CHP plant on-site that is operated by an outside contractor. There was a temporary situation during which time they would not gain from improving energy efficiency, so this constituted a barrier, but this no longer applies. It demonstrates the importance of contractual arrangements. The brewery now pays agreed prices for the electricity and steam supplied and there is a 15-year contract between the brewery and the contractor.

Breweries expressed some degree of openness to considering contract energy management as a possibility. In general they were keeping their options open.

4.3.12 VIEWS ON GOVERNMENT POLICY

Most of the case study breweries had fairly positive views about government policy measures to promote energy efficiency, although a minority had neutral or slightly negative views on this. Specifically, three out of five regarded the Irish Energy Centre (now Sustainable Energy Ireland) as a good or excellent source of information on energy efficiency opportunities, while the others described it as average. More generally, the view was expressed that the government has been quite progressive and effective to date, although it remains to be seen if it would have the resolve to impose radical measures. Several of the breweries said that they had found government-funded grants and subsidies to be useful.

As regards recommendations concerning what the government should do to improve energy efficiency, one suggestion was that companies could be taxed on above-average CO_2 emissions, while receiving tax credits for below-average emissions. This might be acceptable to many companies, more so than a straightforward tax alone. In addition, it was suggested that it is useful for government agencies to identify energy efficiency opportunities, to disseminate this information through demonstration projects or free (or grant-assisted) energy audits, and to provide grants to support implementation of such energy saving measures.

4.3.13 VIEWS ON BARRIERS TO ENERGY EFFICIENCY

As was noted in Section 4.3.6, most of the case study breweries agreed with the proposition that there is a wide range of energy efficiency measures that could be implemented that would yield paybacks of less than five years, although a couple of them felt that the remaining energy efficiency opportunities are rather limited. Most of them also said that they could readily identify a number of specific energy efficiency projects that could be implemented.

When they were asked to identify the main barriers or obstacles to implementing more energy efficiency measures, they pointed to quite a wide range of barriers as being of some significance at times, and we discuss these barriers individually in Section 4.4 below. However, it is worth noting here that the reason they gave most commonly for not implementing possible energy efficiency measures is because the investments they make, including investments in energy efficiency, are subject to quite stringent payback criteria (as was outlined in Section 4.3.7). These payback criteria are a reflection of competition for capital within the companies, from a wide range of potential investment projects, and the payback criteria are a means of making selections among these projects. The tight payback criteria tend to rule out a significant number of possible investments in energy efficiency.

4.4 Evidence of Barriers to Energy Efficiency

As was noted above, it is mostly agreed that there are some measures that could be implemented in the Irish breweries to improve energy efficiency, which have not actually been implemented. In this section we consider the various barriers to energy efficiency which might explain why energy efficiency measures have not been implemented more widely.

4.4.1 HETEROGENEITY

An energy efficiency measure may be known to be financially attractive for a "typical" or "average" company, but it may not be attractive in fact for all individual companies because of diversity or *heterogeneity* among companies.

We found some examples of such situations among the case study breweries. Our pre-interview questionnaire presented the companies with a list of 41 conventionally recommended measures for reducing energy consumption in breweries and asked if they had implemented these measures. Four of the five breweries said that some of these recommended measures would not be appropriate in their particular circumstances, although this applied to only one measure in two of the breweries and to only six measures (out of 41) in the other two breweries. Commonly occurring examples were to be found among the measures intended to reduce energy consumption in packaging, since some of the breweries do not carry out certain types of packaging operations such as bottling or canning and hence they could gain little or no benefit from some of the recommended measures.

Overall, however, heterogeneity did not arise very frequently as an important explanation for non-implementation of energy efficiency measures.

4.4.2 HIDDEN COSTS

Hidden costs are costs that can arise indirectly or in association with energy efficiency measures, but are not usually counted explicitly as part of the cost of implementing the measures as such. Hidden costs might include, for example, the cost of identifying and assessing the measure, the cost of retraining staff to use new equipment, the cost of disruption to production and general inconvenience.

In our pre-interview questionnaire, the companies were presented with a list of different types of hidden costs and they were asked to indicate how often these arise as important barriers to improving energy efficiency. The ones that emerged as most often important were those relating to demands on management time – specifically "lack of time/other priorities" and the "cost of identifying opportunities, analysing cost effectiveness and tendering". All of the interviewees described the first of these as often important or sometimes important, while four out of five described the second one as often important or sometimes important. The less important types of hidden costs were "possible poor performance of equipment", "cost of production disruptions, hassle and inconvenience" and "cost of staff replacement, retirement and retraining". The interviewees were about evenly divided between describing each of these as sometimes important and rarely important.

When the issue of hidden costs was explored in more depth, all of the interviewees said that some hidden costs can be important, particularly those relating to demands on management time, and they can often have the effect of delaying the introduction of energy efficiency measures. At the same time, three of the five breweries also said that the hidden costs were seldom important enough to actually prevent the implementation of possible energy efficiency measures, except perhaps in the case of new and unfamiliar technologies that could be particularly costly and time-consuming to examine. However, one of the other two breweries suggested that hidden costs – specifically demands on management time – would actually represent one of the two biggest obstacles to energy efficiency, in their experience. The remaining one suggested that the "cost of identifying opportunities, analysing cost effectiveness and tendering" – again an aspect of demands on management time – is probably the single greatest barrier to improving energy efficiency in his experience.

Perhaps not surprisingly, there appears to be some relationship here between size of company and the perceived importance of the barriers presented by demands on management time. For the larger breweries with a larger and more specialised management structure, this is seen as less of a barrier than it is for the smaller breweries.

Overall, therefore, the aspects of hidden costs that relate to demands on management time are often important enough to delay significantly the introduction of energy efficiency measures. But they seldom result in ultimate non-implementation of such measures in larger breweries, although they can be more serious barriers in the smaller breweries.

4.4.3 ACCESS TO CAPITAL

The interviewees who are responsible for energy management in the breweries all agreed that lack of access to sufficient capital, for the purpose of investing in energy efficiency, is one of the major barriers to improving energy efficiency. Overall, this seems to be the single most important barrier.

The constraint on access to capital for investment in energy efficiency occurs in the form of quite stringent payback criteria which are imposed by the brewing companies on investment in general, including investments in energy efficiency measures. The payback criteria vary a little between different breweries but they are typically about three years or so, and in some cases they have been tightening in recent times. The process of applying the payback criteria does not usually discriminate in favour of energy efficiency investments, nor does it discriminate against them.

The payback criteria are used as a means of making selections among potential investment projects. The fact that the payback criteria are so tight is seen primarily as a reflection of the amount of competition for capital, within the company as a whole, from a wide range of potential investment projects. Thus, in the pre-interview questionnaire, four of the five breweries said that "other priorities for capital investment" is often important as a barrier, while the fifth one said that it is sometimes important.

For the most part, the parent companies of the breweries are not regarded as being especially constrained in terms of their access to capital, but it seems that they have an excess supply of potentially rewarding investment projects. In principle, the parent companies should be able to borrow more capital, but in practice they appear to be mostly unwilling to borrow significantly more to invest in additional projects even though some additional projects could adequately repay the cost of borrowing eventually. It seems that this partly reflects concerns about market trends and the existence of a degree of uncertainty about the future, arising from the possibility of mergers, acquisitions, disposals or closures of breweries.[22] This may tend to put more emphasis on short-term rather than longer-term goals in relation to assessing investment expenditure. This would reinforce any preference for using short payback criteria and avoiding borrowing to fund investment.

It is also worth noting that a couple of the breweries suggested that there is another reason for the tight payback criteria, apart from being a means of allocating capital between a relatively large number of competing investment projects. This is because this is a means of allowing for some risk that projects will not be as successful as expected.

To conclude on this, when the interviewees were asked what would they regard as the biggest obstacle to making further improvements in energy efficiency, two of them said that strict payback criteria and the associated constraint on access to capital was the greatest obstacle, while two others said that this is one of the two greatest obstacles. The fifth one identified it as one of the greatest barriers, but not the single most important one. Nearly all of the interviewees could identify a number of feasible energy saving projects that could not go ahead because of the strict payback criteria, and one of them said that all the substantial energy saving opportunities that have not yet been implemented are ruled out for this reason.

4.4.4 RISK

There are a number of types of risks that could generate barriers to investment in greater energy efficiency. These include, for example, risks perceived in the general economic environment or in the specific business sector, the possibility of changes in energy prices, or technical risks associated with specific energy-saving technologies.

The interviewees in the breweries indicated that there are two main types of risk that can create barriers to energy efficiency measures, namely, technical risk related to specific projects, and business/market uncertainty. In the pre-interview questionnaires, all of the respondents said that both these types of risk are often important or sometimes important as obstacles to implementing energy efficiency opportunities. In the more in-depth interviews it emerged that, for most of them, the area of risk related to

[22] Giving some substance to these suggestions, in July 2000 (after our field work was completed), Guinness announced that it would be closing one of its breweries in Dundalk and would be cutting employment by 60 per cent in its other Dundalk brewery, having apparently decided initially to close both of these breweries.

business/market uncertainty was perceived as the more significant of these two types of risk.

Most of the interviewees put rather little stress on problems of technical risk. It seems that for most of them this can be a cause of some delay in checking out the merits of the technologies involved before deciding to implement energy efficiency measures, but it is seldom experienced as a critical barrier that would actually prevent measures being undertaken. As an exception, one of the breweries was untypical in saying that technical risk is one of the two biggest barriers to implementing more energy efficiency measures. This was the same brewery that had already implemented the highest proportion of the 41 conventionally recommended energy saving measures listed in our pre-interview questionnaire. It seems that they have undertaken most of the well-tried measures and would now be close to the frontier of proven energy-saving technology. Thus, there would be greater technical risk associated with further, less well-tried technologies that they could consider now.

As regards risk related to business/market uncertainty, most of the interviewees maintained that this is generally a significant factor, more so than technical risk. The most common concern was that there seems to be a degree of uncertainty about the future, arising from adverse market trends and/or the possibility of mergers, acquisitions and disposals of breweries. As was noted above in Section 4.4.3, this is seen as a factor that would tend to lead to more short-term thinking and short payback criteria. Thus, it could help to explain why payback criteria have been tightening in some breweries in recent times, creating a significant barrier to implementing more energy efficiency measures. However, it is worth noting too that, to some extent, tight payback criteria could also be a means of simply allowing for some risk (for technical or other reasons) that projects will not be as successful as expected.

4.4.5 IMPERFECT INFORMATION

Barriers to improvements in energy efficiency could be created by imperfect information on three principal areas, namely, inadequate information on the company's own energy consumption patterns, poor information on the energy consumption of equipment being purchased, or imperfect information on available opportunities to improve energy efficiency.

The situation of the breweries regarding information on their own energy consumption was described above in Section 4.3.4, and the situation regarding information when purchasing equipment was described in Section 4.3.9. To recap, most of the interviewees were broadly satisfied with the quality of their energy information systems and they would not see this area as a particularly important source of barriers to energy efficiency. As regards information issues when purchasing equipment, the interviewees indicated that this area also is not a very important source of barriers to energy efficiency.

As regards information on available opportunities to improve energy efficiency, imperfect information in this respect emerged as only a relatively minor barrier to energy efficiency for nearly all of the breweries.

The pre-interview questionnaire asked how important is "lack of information/poor quality information on energy efficiency opportunities" as a barrier to energy efficiency improvement. Four of the five responses said that this is "rarely important" or only "sometimes important", although the fifth one said that this is "often important". In the more in-depth interviews, it was clear that nearly all of the respondents saw little or no real problem with information on energy efficiency opportunities. They did not regard lack of information on such opportunities as a barrier of primary importance, and they said that constraints on actually using existing information were much more of a problem. However, one of the respondents was noticeably less satisfied about the availability of information on energy efficiency opportunities.

The interviewees find a range of different sources useful for information on energy efficiency opportunities. Among the most useful sources that they cited (in approximately the following order) are: colleagues within the company, the Irish Energy Centre (now Sustainable Energy Ireland), contacts in other companies, technical conferences and seminars, trade/technical journals and energy manager groups. The least used sources of information are equipment suppliers and trade associations, while energy supply industries are found to be useful by some but are not used at all by others.

4.4.6 SPLIT INCENTIVES

The main examples of split incentive situations that might arise concerning energy efficiency in companies include: situations where buildings or equipment are leased rather than owned, excessively short-term incentives facing key individuals (e.g. because of frequent job rotation), or lack of appropriate accountability for energy consumption or waste of energy.

If buildings are leased, both the landlord and the tenant might face insufficient incentive to invest in making the buildings more energy efficient. Similarly, if equipment is leased, both parties might face insufficient incentive to retrofit energy saving measures. In the brewery case studies, however, situations of this type scarcely arose to any significant extent.

Another problem that might arise would occur if key individuals, such as the managers responsible for energy consumption, were effectively judged only on short-term performance, because of frequent job rotation. However, this type of situation was not an evident feature of the brewery case studies. The interviewees who had the main responsibility for energy management had generally been in their posts for ten years or more. Thus, the managers' own employment situation would not induce an excessively short-term perspective.

The other main example of inadequate incentives could arise if there is a lack of appropriate accountability for energy consumption, so that individual departments or sub-divisions in a company have little incentive to reduce energy consumption. The situation in this regard in the case study breweries was outlined in Section 4.3.5 above. To recap, the five case study breweries have little or nothing in the way of arrangements for charging energy costs to individual subdivisions within the brewery. Nor do they use devolved energy budgets for individual subdivisions, or financial incentives for subdivisions or staff to use energy more efficiently. It is worth noting, however, that this does not mean that they have simply no incentive to be careful in their use of energy. The breweries do monitor energy consumption regularly, they identify unusual trends occurring in aspects of energy consumption, and these are investigated as they arise.

Most, but not all, of the interviewees felt that a more formal system of devolved accountability would result in improvements in energy efficiency, but probably not very large improvements. Thus, while it seems that defects in the devolution of accountability and incentives do present something of a barrier to improving energy efficiency, this is probably not a very important barrier.

4.4.7 ADVERSE SELECTION

Adverse selection occurs when purchasers cannot readily obtain reliable information on some important aspects of a good. Consequently, they tend to select goods based on visible aspects such as the price, although in other respects this may be the wrong choice for them. For our purposes, the relevant questions under this heading are: do breweries commonly have difficulties in obtaining reliable information about the energy efficiency performance of equipment they wish to purchase? And do they consequently tend to purchase equipment that uses energy inefficiently and will therefore cost them more in the long run?

It was already noted above that the brewing companies generally are able to take reasonable account of energy efficiency considerations when purchasing equipment. Thus, adverse selection does not appear to be an important source of barriers to energy efficiency.

4.4.8 PRINCIPAL-AGENT

Principal-agent relationships occur when the interests of one party (the principal) depend on the actions of another (the agent). For example, top-level management depends on lower level management and staff to act in the interests of the goals of the firm. The principals (top level management) generally cannot be as well informed as their agents (in lower level management) about the merits of particular investment projects proposed by the agents. Since the principals may have some doubts about investment proposals put forward by their agents, they may tend to impose rather strict investment criteria in an effort to play it safe in ensuring that all investment projects that go ahead really will be profitable. This type of principal-agent relationship could present barriers to energy efficiency, since it may cause companies to effectively rule out some investments in energy efficiency that actually would be in their own interests.

In the brewing companies studied, the criteria imposed on investments in energy efficiency, as on investments in general, are indeed quite strict. But this in itself is not necessarily evidence of a principal-agent problem. Before one could conclude that there is a problem of this type, the question to be answered is precisely why are the investment criteria so tight. As was discussed above, the prevailing view among our interviewees was that the strict payback criteria are primarily a reflection of the amount of competition for capital, within the company as a whole, from a wide range of potential investment projects.

It was also commonly felt that the tight payback criteria and reluctance to borrow more to finance more investment at least partly reflect the existence of a degree of business/market uncertainty, arising from adverse market trends and/or the possibility of mergers, acquisitions and disposals of breweries.

In addition, a couple of the breweries suggested that another, apparently less important, reason for the tight payback criteria is because this is a means of allowing for some possibility that projects will not be as successful as expected, for reasons of technical risk or other reasons. It is here that there could be some influence of the principal-agent relationship in causing the tight payback criteria, although there is little hard evidence that this is an important aspect of the situation.

4.4.9 BOUNDED RATIONALITY

Bounded rationality occurs when people have to make decisions subject to significant constraints on their attention and time as well as their ability to use information. Rather than expending much time and effort in searching for the very best decision, they tend to aim for decisions that are reasonably satisfactory, given the limitations on their time and their ability to use information. The relevance of this for energy efficiency in companies is that managers may be highly constrained in terms of time or their technical ability to use information. They may habitually give relatively little attention to secondary matters, such as energy efficiency, when they are making decisions about matters such as production or purchasing that have some implications for energy consumption.

There is some evidence relating to this issue from our brewery case studies. As regards technical ability to use information relating to energy efficiency, this aspect does not appear to present much of a problem. Our pre-interview questionnaire asked how important is "lack of technical skills to analyse/operate" as a barrier to energy efficiency, and the responses were almost unanimous in saying that this is rarely important. In addition, as was outlined above in Section 4.4.5, nearly all of the interviewees felt that there is no very important barrier to energy efficiency arising from difficulties in accessing appropriate information, although this can occasionally be a problem.

All of the interviewees did indicate that constraints on management time can be important, and this can often have the effect of delaying improvements in energy efficiency, as was outlined in Section 4.4.2. At the same time, however, three of the five breweries also said that this was seldom important enough to actually prevent the implementation of possible energy efficiency measures. But two of the five suggested that constraints on management time would represent particularly important obstacles to energy efficiency, in their experience. This issue appears to be most important for the smallest breweries.

Finally, the pre-interview questionnaire asked whether important barriers to energy efficiency often arise as a result of energy objectives not being "integrated into operating, maintenance or purchasing procedures". The responses to this were about equally divided between saying that this is sometimes important or rarely important, which suggests that this can be something of a barrier but not a major one. If energy objectives are not always integrated into the procedures mentioned, this could create situations where energy efficiency is neglected in favour of more central concerns, because of constraints on management time.

4.4.10 THE FORM OF INFORMATION

Information may be available to companies on opportunities to improve their energy efficiency, but if the information is unclear, unduly complex or inaccessible to the target group, this will present a barrier to its use in improving energy efficiency.

As regards the brewery case studies, however, this type of problem does not appear to arise to any very significant extent. As was discussed in various places above but particularly in Section 4.4.5, deficiencies in the availability of information on opportunities to improve energy efficiency emerged as only a relatively minor barrier to energy efficiency for nearly all of the breweries. Furthermore, as was mentioned in Section 4.4.9 above, the interviewees generally have little or no problem in terms of their technical ability to use the available information relating to energy efficiency.

4.4.11 CREDIBILITY AND TRUST

Obstacles to improvements in energy efficiency could arise if the potential users of information on energy efficiency do not adequately trust the sources of such information.

Such a problem did not arise to any significant extent in our brewery case studies, and this does not seem to be a real barrier to energy efficiency. As was noted above in Section 4.4.5, the interviewees had reasonably favourable views on quite a wide range of different sources of information on energy efficiency opportunities. The most useful sources, in approximately the following order, were: colleagues within the company, the Irish Energy Centre, contacts in other companies, technical conferences and seminars, trade/technical journals and energy manager groups. With one exception, the breweries were making little or no use of contract energy management or ESCOs (energy service companies), but there was little suggestion that this was because of a lack of trust.

4.4.12 INERTIA

The idea of inertia as a possible barrier to energy efficiency is essentially that people may tend to resist making changes because they are committed to what they are already doing. Such tendencies can be reinforced by past experiences of failed or disappointing attempts to make positive changes. On the other hand, past experiences of successful changes can have the opposite effect of creating a continuing momentum leading towards further positive changes.

There is no evidence of inertia in this sense being a significant barrier to energy efficiency in the breweries. They have implemented a considerable number of energy efficiency measures, and they said that generally favourable experiences with measures previously undertaken tend to encourage consideration of further measures.

4.4.13 VALUES AND ORGANISATIONAL CULTURE

Environmental values or environmental concern, either at the level of the company as a whole or at the level of key individuals, could in principle have important influences in motivating improvements in energy efficiency.

In the case study breweries, the general situation is that there is an awareness and concern about energy efficiency issues, motivated most obviously because of their significance for costs. There is also a concern about environmental/energy performance that is motivated by a number of external and internal pressures, as was outlined in Section 4.3.10. For example, the breweries are conscious of a need for good public relations and a good corporate image, which means that they need to be concerned with their environmental performance. In addition, a couple of the interviewees felt that there is also a somewhat deeper commitment to environmental values by their top management, going beyond the motivations mentioned above.

At the same time, most of the interviewees said that there is an ongoing need for individuals within the breweries to champion and push for particular energy saving or environmental projects. It is generally necessary for the managers with responsibility for these areas to put forward a case justifying expenditures on such projects. Most of these managers described themselves as being personally motivated to some degree by environmental values.

Overall, values and organisational culture could hardly be seen as barriers to energy efficiency. They are more like favourable influences. This is true even if the predominant motivations for being concerned about energy efficiency or the environment are standard commercial motivations and concern for the corporate image, more than environmental concern *per se*.

4.4.14 STATUS OF ENERGY MANAGEMENT

If energy management has only a low status within a company, this could present a significant barrier to improving energy efficiency since the issue might not be taken sufficiently seriously.

In the case study breweries, there was general agreement that energy management is accorded a reasonable level of status, with some even saying that it is treated as "important" or "high status". There is real recognition in brewing companies that energy is an appreciable cost for them, and this fact alone would ensure that energy management is given significant attention. Some interviewees felt that the status of energy management is simply proportionate to its role in the cost structure and that it has little further significance in the eyes of top management. However, some of the interviewees felt that energy management is accorded a somewhat higher status and importance in their companies. This is mainly because, as an aspect of environmental performance in general, it can have implications for the corporate image and public relations.

To conclude, it could not be said that energy management is accorded such a low status that this amounts to a real barrier to energy efficiency.

4.5 Possible Policy Responses

Table 4.1 lists all of the possible barriers to energy efficiency that were considered in part 4.4, and it attempts to summarise very briefly their actual importance as barriers to improving energy efficiency in the Irish brewing industry. As far as possible, the importance of each potential barrier is rated in one of four categories, from "not a barrier" through "low" and "medium" to "high". Given that some of the potential barriers are rated as "not a barrier", the term "low" here means that something is a barrier, but that its importance is low compared to those described as being of medium or high importance.

To clarify matters, it may be worth pointing out that the potential barriers to energy efficiency listed in Table 4.1 are not all entirely separate and independent from each other, since there are certain overlaps between some of them. Specifically, "access to capital" is listed as one potential barrier. In practice, the constraint on access to capital for investment in energy efficiency in the brewing companies occurs in the form of quite stringent payback criteria. At the same time, the potential barriers called "risk" and "principal-agent" would typically have their effects by causing payback criteria to be tightened, so that these barriers would be part of the reason for the "access to capital" barrier. Another example of interdependence between the potential barriers is the fact that "imperfect information" is listed as one potential barrier, while at the same time various types of imperfect information could be at least part of the cause of other potential barriers such as "adverse selection" or "bounded rationality". A third example is the fact that demands on management time is listed as part of the "hidden costs" barrier. At the same time, demands on management time would be part of the cause of the "bounded rationality" barrier.

Table 4.1: The Importance in Practice of the Potential Barriers to Energy Efficiency

Potential Barrier to Energy Efficiency	Importance as a Barrier to Energy Efficiency
Heterogeneity	Low. Occurs infrequently
Hidden costs:-	
Demands on management time	Low to medium for larger firms; can cause delays. Possibly high for smaller firms
Other hidden costs	Low
Access to capital	High. The single most important barrier
Risk:-	
Business/market risk	Medium. Contributes to access to capital barrier
Technical risk	Low in most cases. Medium for new technologies. Contributes to access to capital barrier
Imperfect information	Low for nearly all firms

Split incentives	Low, for devolved accountability. Not a barrier in other respects.
Adverse selection	Low
Principal-agent	Probably low to medium. Contributes to access to capital barrier.
Bounded rationality	Probably low to medium
Form of information	Not a barrier
Credibility and trust	Not a barrier
Inertia	Not a barrier
Values and organisational culture	Not a barrier
Status of energy management	Not a barrier

As Table 4.1 indicates, five of the fourteen possible barriers, are rated as "not a barrier", meaning that they have virtually no importance in the Irish brewing industry. These five potential barriers are the ones at the end of the table.

At the other extreme, one of the potential barriers, namely access to capital, is rated as being of "high" importance in the Irish brewing industry. Related to this, the risk and principal-agent barriers, rated as low or medium, contribute to the access to capital barrier, as mentioned above.

Demands on management time and bounded rationality are related to each other, as mentioned above, and these are rated as being of low to medium importance, or possibly high for smaller firms.

The remaining potential barriers are all considered to be of generally low importance – namely imperfect information and adverse selection (which are related to each other), as well as heterogeneity, other hidden costs, and split incentives (specifically lack of devolved accountability).

We now need to consider possible policy responses that could aim to overcome the barriers to greater energy efficiency. In doing this, it is worth bearing in mind that the energy efficiency performance of the Irish brewing industry looks relatively good, at least by comparison with benchmarks from the UK, while its energy intensity in relation to output has also been declining for some time past. Given that brewing is a relatively energy-intensive industry, companies in the sector do tend to give quite serious attention to energy management, and they are not easily deterred by minor barriers from making improvements in energy efficiency. It should also be borne in mind that there are already in place a number of policy measures to promote energy conservation in Irish industry. Thus, in examining possible policy responses here, we focus particularly on measures that would aim to overcome those remaining barriers to energy efficiency that are found to be most important in our study.

We review the policy issues at three different levels, (i) internal company policies, for individual firms in the brewing industry, (ii) government policy relating specifically to the brewing sector, and (iii) government policy for energy efficiency in general, applicable to many sectors.

4.5.1 COMPANY POLICY

The findings of our study suggest that there are three main issues for brewing companies to consider with regard to overcoming barriers to improving energy efficiency in their own firms. These three issues relate to the payback criteria employed, demands on management time, and devolved accountability for energy consumption.

Companies need to consider whether the payback criteria that they apply to investments in energy efficiency are too tight. Would it not be in their interests to take a longer-term view or to be less averse to risk, and to apply somewhat less stringent criteria, even if this means borrowing more to finance more investment? The use of more relaxed criteria could still be consistent with positive financial returns for the company, so from the company's point of view the question is whether it may be forgoing possible significant benefits by applying criteria that are too strict.

Companies could also consider whether they are giving sufficient management time to energy efficiency issues. Would it be in their interests to allocate more management time to this area if that would result in worthwhile savings from greater energy efficiency? As part of this, they could consider whether adequate time and attention is consistently given to energy efficiency matters in the course of procedures such as operating, maintenance or purchasing procedures.

Finally, companies could review the situation relating to incentives and devolution of accountability for energy consumption within the firm. Would it be in their interests to have more formal systems of devolved accountability, so as to improve the incentive for subdivisions or staff to minimise energy use?

4.5.2 SECTOR-SPECIFIC GOVERNMENT POLICY

The issues that arise for government policy from our study of the Irish brewing industry are for the most part not unique or specific to that industry. The most important barriers to energy efficiency in the industry are barriers that could occur in many different sectors rather than being peculiar to the brewing sector. These most important barriers to energy efficiency in brewing are those related to access to capital and strict payback criteria, as well as limitations on management time. Other types of potential barriers that could be more sector-specific – such as those related to imperfect information, credibility and trust, or values and organisational culture – are generally of more limited or no importance in the brewing industry.

In principle, there are a number of different policy approaches that government could adopt to address the sort of barriers to energy efficiency that are found to be most important in the brewing industry. One such approach could involve regulation or licensing. That type of approach is being introduced in Ireland for certain industries including brewing, and it includes elements that are specific to individual industries. But it is worth bearing in mind that there are also other policy approaches that need not be industry-specific, and we refer to these policy approaches in Section 4.5.3 below.

First, however, as regards regulation or licensing measures, breweries in Ireland are among the industries that have been required for some time to have IPC (integrated pollution control) licenses from the Environmental Protection Agency. The IPC licensing system requires the licensed activity to use the best available technology not entailing excessive costs (BATNEEC) to prevent or eliminate or reduce emissions from the activity at source through the use of cleaner technology. The IPC system of licensing is now being updated to meet the requirements of the EU Directive concerning Integrated Pollution Prevention and Control (IPPC). This new system specifically requires that the regulated activities should use *energy* efficiently. This approach, therefore, has the potential to push for significant improvements in energy efficiency in brewing and the other targeted industries, although the outcome will depend on the specific licensing conditions that are introduced for individual industries and how these compare with previously existing practice.

4.5.3 GENERAL GOVERNMENT POLICY

The most important barriers to energy efficiency that are found in the Irish brewing industry are those related to access to capital and strict payback criteria, as well as limitations on management time. These types of barriers could occur in many different sectors rather than just the brewing industry alone, although their relative importance could vary across sectors.

As regards the barriers presented by strict payback criteria and the associated constraints on access to capital for investment in energy efficiency, in principle there are a number of different policy approaches available to government in attempting to overcome such barriers. One approach would be to influence the payback calculations so as to favour greater energy efficiency, by means of increasing the benefits to be gained from investment in energy efficiency. This could be achieved by higher taxes on energy inputs, thereby raising their cost, so that the benefits of reducing energy use would be increased. As part of this approach, companies could be compensated for higher energy taxes by reducing other taxes such as taxes on labour or profits, if it is desired not to increase their overall tax burden while still enhancing their incentive to invest in improving energy efficiency.

Another approach would be again to influence the payback calculations so as to favour greater energy efficiency, but to do so by means of reducing the cost of investing in energy efficiency. This could be achieved by greater financial assistance, such as grants, subsidies or low-cost loans, for investments in improving energy efficiency. This would enable a greater number of potential energy efficiency projects to pass the test of the payback criteria.

A third approach would be to impose regulations, such as specifying the energy efficiency standards that must be achieved or the energy efficient measures that must be employed. A fourth approach could involve some combination of elements from the approaches mentioned above.

Recent and emerging policy developments in Ireland amount to a choice of a combination of various approaches. For some time past, Ireland has had grants and free or subsidised services that would reduce the cost of undertaking energy efficiency measures. More recently, the introduction of carbon taxes and emissions trading has been announced. In addition, as mentioned above, the Integrated Pollution Control licensing system, which governs environmental performance for targeted companies including breweries, is being updated so as to include an element focusing specifically on energy efficiency performance.

These types of policies should have the potential to promote significant improvements in energy efficiency, depending on how precisely they are implemented. It seems likely that a combination of policies amounting to a "carrot and stick" approach should be a more effective means of overcoming tight payback criteria than a tax-based approach alone, as well as being more readily acceptable.

As regards the barriers presented by limitations on management time, the various policy approaches mentioned above can again be appropriate. The type of policy measures that give companies cause to invest more in energy efficiency should, at the same time, give them cause to allocate more management time to energy efficiency matters. In addition, there are other measures that can ease demands on management time in improving energy efficiency, such as advisory site visits and energy audits, which already have some place in Irish energy conservation policy.

Finally, there are some other barriers to energy efficiency that were identified above as being of generally low importance in the Irish brewing industry. Of these, heterogeneity generally requires no particular policy response from government, since there would be no good reason to press companies to implement energy efficiency measures that are not appropriate to them. To a somewhat lesser extent, there would also be no particular policy response required from government to address "other" hidden costs (i.e. apart from demands on management time). In addition, to the extent that there is some barrier to energy efficiency arising from split incentives (specifically lack of devolved accountability), this is a matter that needs to be addressed primarily by companies themselves more than by government policy. The remaining barriers of low importance, namely imperfect information and adverse selection (which are related to each other), can be addressed within the framework of existing Irish energy conservation policy.

5. THE HIGHER EDUCATION SECTOR

5.1 Characterising the Sector

The higher education or third level sector comprises the universities, the technological colleges and the teacher training colleges, as well as some non state-aided private higher education colleges that are not covered in this study. There were 119,991 full-time students and a further 32,265 part-time students enrolled in funded higher education institutions in 2000/2001 and the breakdown of enrolment was as follows:

Table 5.1: Number of Students Enrolled in Higher Education Courses in Institutions Aided by the Department of Education and Science in 2000/2001

Institutions	Full-time	Part-time
Universities	69,254	11,313
Technological Colleges	48,360	17,700
Other including Teacher Training	2,377	3,251
TOTAL	119,991	32,265

Source: Department of Education and Science (2002), 2000/2001 Statistical Report.

There are four universities in Ireland, the National University of Ireland, the University of Dublin, the University of Limerick and Dublin City University. Each university is a self-governing body and each receives annual grants from the Higher Education Authority (HEA) to finance operational and capital expenditure. The National University of Ireland, the largest in the state, is a federal university but its constituent colleges have a wide degree of autonomy.

The Technological Colleges comprise principally the Dublin Institute of Technology and a network of eleven institutes of technology throughout the country. The institutes of technology offer a wide range of courses, principally in Science, Technology and Engineering, leading to Certificates, Diplomas and, in some instances, Degree qualifications awarded by the National Council for Educational Awards (NCEA).

The higher education sector is concentrated to a considerable degree in a few large institutions, which, with the exception of the Dublin Institute of Technology (DIT), are all in the universities sector. The largest single higher education institution in the State is University College Dublin (see Table 5.2), which has a total of 14,974 full-time and 2,936 part-time enrolments. The five largest higher education institutions in the state, shown in Table 5.2, account for approximately 48 per cent of full-time enrolments and 44 per cent of part-time student enrolments.

Table 5.2: Number of Students Enrolled in Higher Education Courses in the Five Largest Institutions in 2000/2001

Institutions	Full-time	Part-time
University College, Dublin (UCD)	14,974	2,936
Dublin Institute of Technology (DIT)	9,793	5,747
University College, Cork (UCC)	11,694	1,200
Trinity College, Dublin (TCD)	11,039	2,758
University of Limerick (UL)	9,852	1,457

Source: Department of Education and Science (2002), 2000/2001 Statistical Report.

5.1.1 FUNDING AND GROWTH

Funding for higher education institutions is received either through the HEA (Higher Education Authority) or directly from the Department of Education. The HEA, set up in 1968 and given statutory powers under the Higher Education Authority Act, 1971, has advisory powers over the whole of the higher education sector but its funding role relates mainly to universities. Each year, the Department of Education gives block grants to the HEA to fund recurrent and capital spending by bodies aligned with the HEA. Recurrent funding for each institution is largely determined by the number of students in each organisation and by unit costs, which have to be submitted to the HEA each year by the universities. The HEA does not have any substantial input into the way in which funds are allocated within a particular university. It is therefore left to each individual institution to decide if it wants to invest in energy efficiency and put the savings from its energy bill to other uses. Any energy savings in a given year should not translate into reduced funding in the next year as long as the money saved is spent in the same college year.

Growth in the higher education sector was hampered by constraints on funds during the late 1970s and early 1980s, when Ireland's public finances were under pressure. With rapidly improving public finances in the 1990s and a growing demand for higher education, there has been both a substantial rise in funding and a rise in expenditure by higher education institutions.

Where universities are concerned, the important point to note is that while income has kept pace with recurrent expenditure, they have come under increasing pressure to generate income themselves. An increasing share of income is raised from fees, and also increasingly from "other income".

Of late large capital programmes have come on stream, coming under specific areas such as the Undergraduate Expansion Programme but at the time of this analysis these may not have been accessible for energy efficiency investment. In its reports for 1996, for example, the HEA (1999) pointed to the erosion of the discretionary element of their Capital Building Grant. This grant, it says, would be used for "refurbishment and adaptation of existing buildings to optimise utilisation, improvement to infrastructural services (e.g. replacement of boilers, electrical and other power systems)… such works can, and have, provided a very good return for a modest investment".

We turn now to describe the funding of those institutions, consisting mainly of the institutes of technology, that receive their aid directly from the Department of Education. Each year, the Institutes submit estimates based on the previous year's outturn, rather than on "unit costs" as we saw to be the case for universities, along with their projects. The Institutes do not receive money for discretionary investment (at the time of the interviews), but if by some chance they saved money on foot of installing energy efficiency items, they would re-spend any money saved. Given the inadequacy of many of their buildings, capital grants are directed primarily at satisfying essentials such as space requirements. Given the urgency of these requirements, proposals that reduce energy consumption need to have quite short paybacks, of say three to five years, in order to be funded.

Growth in the higher education sector over the decade has been strong. The number of full-time students in aided institutions has risen over the decade from 64,137 in 1989/90 to 115,696 in 1999/2000 (Department of Education and Science, 2001). Total employment in the month of December in higher education institutions rose from 19,000 to 30,700 over the same period (CSO, 1996, 2001).

There are several reasons for the growth in total student numbers. Demographic change has been one of the principal reasons, with an estimated increase of over 31,000 people in the 15 to 24 age cohort during the years 1991-1996. Increasing returns to higher education may also have contributed to increased participation in higher education. Returns to holding a third level degree are estimated to have risen in the period between 1987 and 1994 (Barrett, Fitz Gerald and Nolan, 2002). In addition to demographic and educational returns another reason for increased student numbers was the depressed state of the economy and shortage of job opportunities in the first half of the 1990s, causing school-leavers to prolong their education.

Although participation rates are predicted to rise slightly over the coming decade or so, the driving force behind changes in total student numbers over that period is likely to be demographic change. The total population in the 15-24 age cohort, from which the bulk of the student population is drawn and which has been rising steadily since the early nineties, is predicted to have peaked at approximately 660,000 in 2000 and to fall to approximately 552,000 by the year 2010 (Duffy *et al.,* 2001). On the basis of these projections, assuming little upward movement in participation rates, pressure from student numbers is expected to slacken.

5.1.2 ENERGY EFFICIENCY POLICY

The principal government intervention in the area of energy efficiency has been through the *Operational Programme for Economic Infrastructure 1994-1999*. Included in the energy element of the programme was a sub-programme on energy efficiency (EI1.2), which mandated the expenditure of £34 million over the life of the programme.

The co-ordination and implementation of the programme was the responsibility of the Irish Energy Centre (IEC, now replaced by Sustainable Energy Ireland) established in 1994. The IEC was a joint initiative of the Department of Public Enterprise and Forbairt, a national agency with responsibility for the development of indigenous industry. The principal schemes set up as a result of the Operational Programme that are of relevance are as follows (Greer, 1998):

- Energy Audit Grant Scheme (EAGS),
- Energy Efficiency Investment Support Scheme (EEISS),
- Steam System Boiler Evaluation Scheme (SSBES), and
- Best Practice Programme (ALERT).

A brief description is given of each in turn. The EAGS provided assistance to organisations that enlisted consultants to carry out energy audits. The scheme, which was also open to all higher education institutions, had a budget of £1.6 million that was fully allocated. The importance of the EAGS scheme was twofold. First, it allowed organisations to identify potential energy cost savings, and second, it encouraged organisations to think strategically about energy management issues.

Under the EEISS, grant aid was available to organisations which undertook to invest in energy saving technologies, having already undertaken an energy audit, like the EAGS, or a feasibility study that was deemed satisfactory to the Irish Energy Centre. The maximum grant available for any particular scheme was 40 per cent of the total cost of the project and was not to exceed £100,000 per site. In addition to the grant aid available under the EEISS, the programme also had a Priority Technology Calls scheme, whereby interested parties could be advised on energy efficient technologies such as building energy management systems, CHP, good practice in boiler houses and the like.

The SSBES scheme aimed to increase awareness of potential energy savings through training schemes, awareness programmes and national boiler awards.

The best practice (ALERT) scheme promoted energy efficient technologies and practices. Information on best practice technologies was transmitted through seminars, workshops, site visits and the publication of best practice guidelines. The ALERT scheme had targeted two of the technologies that are of interest here, namely, Building Energy Management Systems and Boiler Systems.

A number of universities have undertaken energy audits under the EAGS scheme. Some of the largest universities were considering investment, with the help of EEISS, in CHP systems.

In addition to these national schemes, the Irish Energy Centre funded a report entitled "Survey of Energy Usage in Colleges". The report, which was undertaken by Overy and Associates, analysed energy consumption, emissions and expenditure per student and per square foot. The survey results were confidential and provided information to each organisation as to their energy performance, which they can compare against sector benchmarks.

As for so-called voluntary environmental initiatives, any such initiatives that have taken place in the sector so far have been done on an *ad hoc* basis by concerned individuals or groups within the sector. There is little evidence of college authorities systematically taking initiatives and putting energy saving measures in place. Some concerned individuals in the higher education sector aim to promote green campus schemes. These, however, seem to revolve around the (larger) universities rather than the (smaller) institutes of technology.

5.1.3 ENERGY USE

Energy expenditure forms a small part of the budget for higher education institutions, typically less than 3 per cent for the universities. The total energy expenditure, based on the IEC survey of 9 universities and 12 institutes of technology (with approximately 56,800 and 39,800 full-time student equivalents[23] respectively), was £7.6 Million. On a straight averaging basis this works out at just over a third of a million pounds per institution. Table 5.3 breaks this figure down into expenditure on electricity, gas, oil, turf and liquefied petroleum gas (LPG) by universities and institutes of technology.

Expenditure on electricity, at £5.3 million per year, comprises the single largest component of the total energy bill. Gas ranks second, while oil, turf and LPG all constitute very small parts of total energy expenditure. The contrast between the universities and the institutes of technology is marked. Expenditure on gas is proportionately higher in the universities than in the institutes of technology, while for turf, oil and LPG the reverse is true. This is partly due to the fact that many of the institutes of technology are not on the gas grid.

Table 5.3: Total Energy Bill, £ million

	Universities	Institutes of Technology	Total
Electricity	3.7	1.6	5.3
Gas	1.25	0.35	1.6
Oil	0.3	0.25	0.55
Turf	0.0	0.10	0.10
LPG	0.03	0.03	0.06
TOTAL	5.25	2.35	7.6
Average per institution	0.58	0.20	0.36

Source: IEC (1998).

Gas is used mainly for space heat, water heating and cooking. Oil is used for space heat and motive power. LPG is used mainly for cooking and space heat. Electricity, in general, is used for lighting, cooking and other electricity specific uses such as computers.

Table 5.4*: Total Energy Bill, £/Square Metre*

	Universities	Institutes of Technology	Total
	£	£	£

[23] One part-time student = 0.4 full-time students.

Electricity	4.84	4.69	4.80
Gas	1.64	1.03	1.45
Oil	0.39	0.73	0.50
Turf	0.00	0.28	0.09
LPG	0.04	0.08	0.05
TOTAL	6.87	6.89	6.88

Source: IEC (1998).

To compare the energy costs of the universities and the institutes of technology it is necessary to factor in a measure of the total size of the establishments in question. The measure to hand is total floor space, which for the universities surveyed was 764,255 square metres, while for the institutes of technology it was 340,852 square metres. When the total energy expenditure per square metre is calculated as in Table 5.4, a comparison of the expenditures on energy by universities and the institutes of technology yields remarkably few differences. The only major differences in energy expenditures per square metre are that universities tend to be more gas intensive and slightly less oil and turf intensive.

Differences in energy expenditure can be due either to differences in energy consumption and/or to differences in the unit cost of energy. Energy consumption in actual volume terms per square metre in 1996/7 was higher in the universities, at 253 kWh per square metre, than in the institutes of technology that used 228 kWh per square metre, as seen from Table 5.5. This was primarily due to differences in electricity consumption. Fuel consumption (gas, oil, turf and LPG) is marginally higher in the institutes of technology. Total energy cost works out at 2.7p per kWh for the universities and 3.0p per kWh for the institutes of technology, universities being better placed to avail of the cheaper fuel, gas.

Table 5.5: Energy Consumption, kWh per Square Metre

	Universities	Institutes of Technology
Electricity	99	71
Fuel	154	157
TOTAL	253	228

Source: IEC (1998).

5.1.4 OPPORTUNITIES FOR ENERGY EFFICIENCY

The higher education sector is one where potential for quite substantial energy savings is thought to exist. Energy expenditure forms a small part of the expenditure of a higher education institution and as a result until recently relatively little attention seems to have been paid to energy management by higher education institutions. Given the absence of a profit motive, cost minimisation has to take its place but management could generally have other priorities and little personal financial incentive to adopt efficient technologies. The end result may be sub-optimal expenditure on energy efficient technologies.

The energy using technologies employed in the higher education sector are typically generic in type. In identifying relevant technologies we have relied primarily on a study by the then Irish Energy Centre on the energy savings potential in the higher education sector, and the list below of energy saving technologies below draws on this study. The technologies of interest are:

- Building Energy Management Systems (BEMS). A BEMS is a computer-controlled system designed to ensure efficient energy usage. It achieves this by controlling heating, lighting, ventilation systems, air conditioning systems and so forth. It may also be referred to as an Energy Management System (EMS), Building Management System (BMS) or Direct Digital Control System (DDCS). The BEMS may, among other things, monitor and adjust temperature in a building, ensure different heating levels for different sections within a building, and switch heating systems on and off automatically at optimal times.

  The Irish Energy Centre (1996a) has estimated that Building Energy Management Systems installed in new buildings may result in savings of up to 20 per cent of total energy usage. In the case of existing buildings the potential energy savings depend on the type and age of the buildings and on how well energy is being managed at present. The IEC estimate that BEMS may be economically feasible in buildings with energy bills as low as £10,000.

  The payback period of a BEMS varies with the complexity of the system and the current level of efficiency of energy usage. The average payback period for BEMS is thought to be "quite short". Given the average energy consumption of higher education institutions it is likely that BEMS would be economically justified in the majority of higher education institutions.

- Combined Heat and Power (CHP). CHP or co-generation is a process of generating heat and electricity from the same source, usually gas. CHP recovers and uses surplus heat, which is a by-product of electricity generation thus increasing overall efficiency. Hennessy (1994) estimates that the installation of CHP may increase energy efficiency to approximately 80 per cent compared with 30-40 per cent efficiency offered by conventional power generation plants.

  The suitability of CHP depends on a number of factors including: whether the site has a base heat load, especially in the summer months, large enough to absorb heat output; whether the electrical load is sufficient to absorb CHP electrical power; does the site have access to natural gas? In the case of the higher education sector the larger institutions' demands for electricity and heat could be sufficient to justify CHP.

  However, one factor that mitigates against the introduction of CHP is the seasonal demand for electricity and heat output, given that the demand for electricity and heat by the average higher education institution would drop considerably during the summer months. Also, since CHP is most efficient when natural gas is used as the energy source and since the gas grid does not cover all of Ireland, a CHP system will not be economically justifiable for all institutions in the higher education sector.

- Motive Power Applications. The Irish Energy Centre (1996b) has produced a Good Practice Guide on Motive Power Applications. The guide indicates that only 20 per cent of energy consumption in the commercial sector, which would cover the higher education sector, goes on motive power applications. However according to the IEC a reduction of 10 per cent in energy consumed in motive power applications is possible through the implementation of sensible efficiency projects. Thus savings of the order of 2 per cent of the total energy bill of the higher education sector might be possible through good motive power practices.

The IEC pointed out that the electric motor is only one link in the energy chain, the other links being efficient design, efficient purchasing, effective use of tariffs, efficient operation as well as efficient technologies. The IEC suggested prioritising the expenditure on improving links in the energy chain according to respective paybacks.

In addition to BEMS, CHP and motive power applications, the following technologies have been identified by specialists in the energy management field as having large energy savings potential for the higher education sector, under the right conditions:

- Low energy lights
- Energy efficient appliances
- Building related technologies, such as airlocks.

As well as identifying energy efficient technologies, the IEC report on energy usage in higher education institutions identified a number of barriers to energy conservation, including:

- Lack of resources especially financial, manpower and technical expertise;
- Lack of energy management structure and/or management commitment;
- Lack of awareness among students and staff;
- The procurement policies for IT equipment.

Some of these barriers will be covered in the case studies, to which we now turn.

5.2 Case Studies

A brief description is now given of the case studies in the higher education sector and the methodology employed. As with the other sectors covered by this project, interviews were conducted by economists from The Economic and Social Research Institute and, where possible, at least three face-to-face interviews were conducted for each case study. A few interviews were undertaken by telephone. The objective of the interviews was to elicit the opinions of the relevant persons (energy managers, building officers, finance officers, those responsible for purchasing, buildings technicians and so forth) on a wide range of topics relating to energy efficiency in general and their institution in particular. In addition, several interviews were conducted with experts on the sector.

Prior to interview, each institution filled in a short "pre-interview questionnaire". As an example, the pre-interview questionnaire composed for the mechanical engineering sector is given in Appendix 1. There followed a semi-structured interview based on an "interview protocol" composed for the higher education sector to ensure that information was sought on all possible barriers. However, where interviewers thought it appropriate, they were free to deviate from the questions on the protocol in order to obtain a fuller picture of the situation. Appendix 2 gives the interview protocol directed at the energy manager in the brewing industry, as an example.

The case studies were selected in such a way as to obtain a representative selection of organisations. It was decided that medical, veterinary and horticultural schools should be avoided as well as research institutions, as their energy use may differ markedly. Selection also aimed at obtaining a mixture of institutions that are and are not pro-active as regards energy efficiency.

5.2.1 DESCRIPTION OF INSTITUTIONS SELECTED

Interviews were completed with staff members of five institutions out of the seven initially contacted. As each university or institute of technology was assured anonymity in this study, they are not named in this report. For simplicity and in order to preserve confidentiality, the five case studies are referred to as institution A, B, C, D or E.

For the same reasons, we do not present full descriptions of the size, location, and policies of each one in turn as this could reveal its identity. The organisations selected were diverse in terms of size (as measured by either student and/or staff numbers or total floor space). The total number of enrolled students in the selected case studies ranged from a couple of thousand students to over ten thousand students, including both full-time and part-time students. However, the mix of case studies was weighted somewhat towards the larger end of the spectrum, as a higher response rate was achieved with the larger institutions.

The organisations selected were principally campus based, as is the norm in Ireland. A couple of the older institutions selected had a proportion of their buildings located off campus but, in all cases bar one, more than 50 per cent of the floor space was located in one particular site.

For each of the case studies that could provide us with the required information, expenditure on electricity accounts for more than 50 per cent of the total energy expenditure and sometimes substantially more. Those institutions on the gas grid typically spend more on gas than on any other fuel, excluding electricity. Expenditure on oil, coal and turf typically accounts for between 2-15 per cent of energy expenditure. These patterns of energy use are consistent with figures derived in the larger study by the Irish Energy Centre, described above, and in this respect the selection here is reasonable.

The principal mode of heat delivery varied between the institutions studied. Three of the institutions had at least considered or installed CHP. One institution was not on the gas grid yet and thus was not actively considering CHP, while another was considered too decentralised for CHP to be viable and funding was also cited as an issue. For those institutions where CHP did not constitute the principal mode of heat delivery, either centralised and/or decentralised boilers were in operation depending principally on the layout of the institution's premises, that is, on whether it was a campus or metropolitan in layout. One reckoned that the introduction of carbon taxes would make them look at CHP.

Three of the institutions studied are funded under the Higher Education Authority (HEA), which in turn receives a block grant from the Department of Education. The other two institutions are funded directly by the Department of Education. As already described in Section 5.1.1, funding is typically based on student numbers, unit costs or previous outturns and on proposed capital projects, and discretionary funding is small or non-existent as far as energy managers were concerned.

In management structure, the institutions differ quite substantially. In one case the Buildings Officer reports directly to the Finance Officer, while in all other cases the Buildings Officer is separated from the Finance Officer. While the autonomy and position of the "Buildings Office" differs widely some patterns emerge when looking at the structure of the buildings office itself. First, the key individual with respect to energy decisions is typically the Buildings Officer although in larger universities energy decisions are left to a "Technical Services" manager who is in charge of services such as electricity, gas, heating, water and so forth. Second, the person with formal responsibility for decisions on energy matters typically oversees a number of supervisors who in turn supervise engineers, plumbers, electricians *et cetera*, and the number of such staff reflects the size of the institution. Table 5.6 summarises some characteristics of the institutions studied.

Table 5.6: Summary of Characteristics of Five Higher Level Education Institutions Used as Case Studies

Feature	Summary of Case Studies
Size of institution	A wide range of sizes is represented, but the mix is weighted towards the larger end.
Campus/off-campus	In all cases bar one, more than 50 per cent of floor space was located on one site.
Parameters of energy use: Energy per student Energy per cu. m. of floor area	Not forthcoming. The pre-interview questionnaire asked for energy use, floor area and number of students. In general insufficient information was supplied from which *energy per student* or *energy per unit of floor area* could be calculated.
Fuel mix	Over 50 per cent of energy expenditure is on electricity.

5.2.2 POLICIES OF SELECTED CASE STUDIES

None of the five case studies had a formal or written environmental policy and only one had a formal energy policy. Several of the Buildings Officers/Service Engineers reckoned that their particular institution had a *de facto* unwritten energy policy, that is, it is the policy of their particular office to minimise energy usage and cost. None of the institutions was certified to an environmental management scheme but one was considering application for ISO certification.

While there was little indication of formal energy/ environmental objectives being laid down, informal targeting of energy consumption (per person or square metre) was reported to be undertaken by several institutions. However, some institutions, and one in particular which has experienced rapid growth, felt that simply targeting energy expenditure was not feasible as it does not take into account either growth, in terms of campus size or student numbers, or an increase in the energy intensity (owing for example to a higher ratio of computers per student).

Little information relating to the extent to which energy/environmental objectives are integrated into other policy guidelines (e.g. purchasing) was received. In the case of purchasing, one Finance Manager felt that the purchasing guidelines were defined in so far as all tenders for procurements are supposed to go to the "economically most advantageous" option. The individual in question said that the economically most advantageous is, however, typically interpreted as the least cost option and thus energy efficient products that have a higher initial price but save money over their lifetime may not be purchased.

5.3 Evidence of Barriers in Higher Education

The aim of this section is to identify the nature and operation of barriers to energy conservation that were noted during the course of interviewing persons within the higher education sector. Owing to the small size of the sample, evidence to support the existence or otherwise of particular barriers within the sector is primarily… *qualitative* and *anecdotal* but, subject to these limitations, the wide-ranging discussions allowed a comprehensive picture to be formed.

No in-depth energy audits could be undertaken in the conduct of this study and, therefore, we are not certain as to whether energy efficiency opportunities exist within each institution studied and, if they do exist, the extent to which they could be profitably implemented. However, we have received indications from each institution as to their "performance" in relation to the average for the sector with regard to energy usage per square metre or per student. This could be taken as a crude indicator of how energy efficient each institution is.

As we cannot identify for certain which technologies are highly cost effective or not, we rely almost entirely on the opinions of individuals within the institutions to gauge the extent of opportunities available. We also rely on such individuals to provide us with the information necessary to judge whether a hypothesised barrier is a true barrier to investment that is cost effective. Ten potential barriers in the case studies are now investigated.

5.3.1 HIDDEN COSTS

Hidden costs are costs such as staff retraining, potential loss of reliability and the like that may not be taken into account in assessing the cost of introducing a particular technology. If, however, they are taken into account they may very well make the adoption of a particular technology economically unfeasible.

Prior to analysing evidence we first consider what *costs* universities typically do or do not look at in their investment decision-making process that could be *hidden* in the initial feasibility analysis. Responses were received from individuals within three institutions as to what "potential hidden costs" they typically consider, or should consider, when contemplating investments in energy efficient technologies. The responses are shown in Table 5.7. The item of agreement between the three energy managers (including a *de facto* energy manager) is the potential loss of benefit, that is, all three institutions consider the possibility that the benefit may not materialise. Each of the other hidden costs is considered by two out of three institutions – these other costs are overhead costs of energy management, disruption, costs of identifying opportunities and staff replacement/retraining.

Table 5.7: Hidden Costs that are Considered in the Decision Making Process by the Energy Manager in Three Institutions

	Are These Costs Considered? (Yes/No)		
	Institution A	**Institution B**	**Institution D**
Overhead costs of energy management	N	Y	Y
Disruption/inconvenience	N	Y	Y
Cost of identifying opportunities	N	Y	Y
Staff replacement/training	Y	N	Y
Potential loss of benefit	Y	Y	Y

Two institutions (A and B) cited instances where hidden costs were large enough to prevent a project from going ahead. In other cases, hidden costs such as the potential loss of benefit were diverted to a third party so as to ensure that the project went ahead. An example of this would be the attempt to get CHP installed in institution E. The individuals involved in the energy decision-making process here are aware that potential unreliability could cause difficulties in this particular instance and are thus negotiating for a third party to operate the CHP system. Thus only by transferring the hidden costs onto a third party could the project go ahead.

5.3.2 ACCESS TO CAPITAL

Access to capital is a common barrier to energy conservation and lack of access to external funds or lack of a budget from which funds for energy efficient investments could be drawn was an issue for all case study participants. Different organisations had different ways of addressing this. In general, the issue of whether capital constraints were considered to be a binding constraint in the sector hinges on the distinction between the universities and institutes of technology. For example, one university was able to borrow money from campus companies within the college.

Both institutes of technology that were surveyed mentioned finance constraints as being a barrier to the adoption of energy efficient technologies. Key individuals within one institute petitioned for the use of a different fuel rather than the fuel originally specified as the prime fuel source for a new building. The adoption of the different fuel would have been better environmentally but it entailed an upfront cost over and above the cost of using the original fuel. Despite this it would have had a relatively short payback period. The petition was rejected on a cost basis. Another institute mentioned that funding for buildings was so inadequate that they could not, at present, even contemplate energy efficient investments as all their budget went on "fire fighting" measures. The indications suggest that energy managers in the institutes of technology could not access capital for investment in energy efficiency.

While capital availability was also a consideration for universities (which tended to have undertaken more energy efficient investments), it appears to pose less of a constraint to them than it does for the institutes of technology. For example, one university recently put up several thousands of pounds of its own money to help co-fund an energy efficiency investment. In addition, the recurrent buildings budget is often used by the three HEA-funded universities surveyed to implement energy saving projects that have a payback period of less than one year. It appeared that a higher status is bestowed upon energy management activities in the universities than in the institutes of technology that were interviewed, which makes it easier for the universities' energy management staff to obtain the funds necessary for energy efficient investments.

In sum, the organisations surveyed generally fund some energy efficient investments from their recurrent budget, which necessitates a short (typically one year) payback on investments. The ability of organisations to find funding for larger projects with longer payback periods varies substantially but, from the cases studies, energy managers in the universities had less difficulty in accessing capital.

5.3.3 RISK

The standard calculations that predict whether a particular energy efficiency investment is cost effective may not fully take account of the inherent riskiness of the project. In some cases, even if a technology is *thought* to be cost effective, an individual or organisation may not take on the project because the return is considered to be too low given the risk. Thus for reasons of risk, it may be rational to decide against investing in a particular energy efficient technology.

In setting up the investment criteria, the riskiness of a particular project may be reflected in either (a) high discount rates, or (b) short payback periods. The use of either may reflect rational risk averse behaviour.

During the course of interviewing the cases, no evidence pertaining to the use of stricter investment criteria as a result of the risk associated with energy efficient investments was uncovered. Each of the five institutions typically use simple payback as their investment criterion, although one institution uses life-cycle costs in its assessment of some types of plant. Three of the institutions use a short payback period, of less than a year, for investments in energy efficiency. This was, however, principally due to budget constraints, which dictated that energy efficiency investments can only be undertaken out of the recurrent budget and provided their payback was within the year, rather than as a result of the inherent riskiness of energy efficient projects.

Although there is no evidence that the riskiness of a project manifests itself in terms of higher discount rates or shorter payback periods, there is evidence that risk is a factor in the decision-making process relating to energy efficiency. Two institutions in particular noted that CHP brought a sizeable risk in terms of potential loss of reliability. These sought to minimise risk by taking on a partner who would take on at least part of the risk by financing and running their CHP plant.

It could be maintained that the short length of payback period that was required was in fact evidence of perceived risk. However, the payback period required for energy efficiency was not, as far as one can tell, any shorter than for any other type of investment.

5.3.4 IMPERFECT INFORMATION

The previous barriers are thought of as "non-market" barriers, that is, they are economic barriers to entry that are not predicated on the failure of markets to allocate resources optimally. The next barriers analysed (imperfect information, its form and trustworthiness, split incentives, and principal-agent issues) are what are commonly referred to as "market barriers"; these barriers are predicated on the failure of, or absence of the conditions required for, markets to work properly.

The first such market barrier we analyse is imperfect information. If one or more of the parties to a transaction does not have full information then a sub-optimal level of energy efficient investment could result. The information in question can be separated into three different categories, which will be discussed in turn, namely:

- information on current energy consumption,
- information on energy specific investment opportunities, and
- information on the energy consumption of new buildings/equipment purchases.

The level of information available to each organisation on current energy consumption varies widely between institutions. The larger institutions have access to a wide range of data (daily or monthly consumption, degree days data etc.) on energy consumption broken down by building. All major buildings have BEMS systems installed. These institutions monitor and target energy usage. The constraints seem to be more in the nature of availability of personnel and time to monitor energy usage rather than a lack of information relating to energy consumption. The quantity and quality of information available to the smaller institutions was adjudged to be not as good. Another institution can get detailed information with regard to the buildings in which BEMS has been installed, if information is monitored and logged. Most though not all of their buildings have BEMS installed. Consumption is compared with the sector benchmarks that are available from the study sponsored by the IEC.

Energy management staff in two institutes of technology expressed dissatisfaction at the level of information available relating to energy consumption. One has BEMS systems installed in only 50 per cent of the building area and cannot get adequate information on energy consumption elsewhere. The other only has information relating to the organisation's annual energy consumption and expenditure, and the Buildings Officer considered that sub-metering would be needed to monitor energy trends adequately.

As regards the information sources on energy efficient opportunities, the individuals in charge of energy management in all five institutions surveyed considered that adequate information was available on energy efficiency opportunities. A wide range of sources of information relating to energy efficient opportunities is used within the sector, including:

- the Irish Energy Centre,
- City of Dublin Energy Management Agency (CODEMA),
- Energy Research Group, University College Dublin (ERG),
- Chartered Institute of British Services Engineers (CIBSE),
- American Society of Refrigerating and Air Conditioning Engineers (ASHRAE),
- European Commission – THERMIE projects,
- Electricity Supply Board (ESB),
- an Bord Gais (BGE), and
- informal networks and energy manager groups.

It is noted that those institutions that have implemented the most energy saving measures tend to use a more diverse array of sources of information relating to energy efficient opportunities. In addition, these institutions give more weight to the importance of informal networks and energy manager groups.

Turning to the level of information available on energy consumption in new buildings, three out of five institutions surveyed specify stringent energy targets in the design specifications for new buildings. The extent to which designers take energy consumption seriously in designing new buildings was questioned by a number of individuals involved in the energy management process. The Buildings Officer in one university felt that new building designs should include independently validated predictions of energy consumption which should be certified on commission and penalties should be included in contracts to ensure performance as projected.

Energy management staff were not forthcoming as to their satisfaction with the available information on energy performance of new equipment. In some cases, as in an institute of technology where the Buildings Office does not have a formal role to play in equipment purchases, such information is typically not sought prior to purchase.

In sum, the quality of energy information available to each institution varied widely. In general it was found that the larger more pro-active institutions had a range of information available at a disaggregated level, while the smaller and less pro-active organisations tended to have less precise information.

5.3.5 THE FORM OF INFORMATION

The form that information takes may influence its effectiveness. If information is presented in a manner that is not conducive to clear interpretation, the information may be discarded or not interpreted correctly. As regards barriers to investment in energy efficiency, two questions arise:

- what form of information is generally preferred, and
- what form does generally available information take?

Referring to the first question, it became evident from the case studies that the preferred form of information is through the provision of *clear* and *concise* case study seminars of individual technologies, in which individuals can impart their own experiences and the audience can comment and ask questions. This concurs with their earlier indications that a preferred source of information is informal networks/energy manager groups.

As regards the second question, information presently available takes a wide array of forms including:

- leaflets,
- case study seminars,
- internet websites,
- brochures,
- information sheets,
- conference/workshop papers,
- books,
- posters and,
- published reports.

The manner in which information is, at present, disseminated *may* constitute a sizeable barrier to energy conservation in so far as much of the information is conveyed through booklets/ papers/websites which do not afford easy interaction with the audience.

5.3.6 CREDIBILITY AND TRUST

While the form that information takes could constitute a barrier to energy efficiency, it is also possible that the credibility, and trust in, the source of information is equally important. If the source of information is not trusted, the information passed on by the source could be discounted. The issue at stake is whether the individuals involved in energy management in the higher education sector discount valid information for reasons of trust or credibility, which therefore represents a barrier to investment in energy efficiency.

Table 5.8: Sources of Information Used (Yes/No) and the Source that is Most Trusted

	Institution				
Sources of Information Used?	**A**	**B**	**C**	**D**	**E**
Irish Energy Centre	Y	N	Y	Y	N
Energy manager networks	Y	Y	N	N	Y
Electricity Supply Board	N	N	N	Y	Y
An Bord Gais	N	N	N	N	Y
CIBSE	Y	N	N	N	Y
Web sites	Y	N	N	N	N
ESCOs	N	N	N	N	N
The most trusted source	IEC	No View	IEC	ESB	Bord Gais

Note: CIBSE is the Chartered Institute of British Services Engineers.
ESCOs are Energy Service Companies.

Table 5.8 shows which sources of information relating to energy efficient investment are used by the institutions surveyed. It is apparent that the most commonly used sources of information are the Irish Energy Centre and energy manager networks. The least trusted source of information is Energy Service Companies (ESCOs).

None of the individuals surveyed who were involved in energy management thought that ESCOs were a reliable source of information. Individuals in two institutions expressed strong misgivings about ESCOs in the light of past experiences. Both had taken on an ESCO to negotiate tariffs on their behalf but felt that they were charged too much for the service provided. None of the institutions surveyed was thinking about participating in projects with energy service companies except perhaps as third party financiers of CHP.

5.3.7 SPLIT INCENTIVES

The problem of split incentives may cause a party to fail to undertake an action that would normally be considered beneficial. This may be because the party would not be able to appropriate the ensuing benefits. The classic example of split incentives is the landlord-tenant relationship. The tenant has little incentive to improve the dwelling he is living in as he may not reap the long-term benefits of his actions. The landlord in turn may not wish to undertake new investments unless he can extract a higher rent from the tenant.

Here we consider the forms of split incentives that could prevail in the higher education sector, namely:

- leasing of buildings or equipment, and
- lack of accountability for energy costs.

If an institution leases buildings or equipment, it may well not have the incentive to undertake energy efficient investments as the benefits of reduced energy bills only accrue to them for the duration of the lease, which may not be long enough to render the investment worthwhile. The improvement to the asset is foregone on relinquishing the lease unless, that is, they have entered into some arrangement with the owner. Buildings are leased by three of the five institutions. The individuals responsible for energy management in these institutions by and large felt that only minor work (typically with a payback of less than one year) would be undertaken in leased buildings. However, the proportion of total floor space leased was generally small. The institution with the highest proportion had only 16 per cent of floor space leased.

The leasing of equipment was generally thought to create even less of a problem of split incentives than the leasing of buildings. We were only informed of three cases where some equipment was probably leased and in the words of the Buildings Officer this just consisted of "bits and bobs" from various departments. No individual surveyed conveyed a belief that equipment leasing represented a major barrier to energy efficiency.

The problem of split incentives can also be seen not just in terms of leasing but also in terms of purchasing of equipment such as low energy computers – with individuals having little incentive to purchase energy efficient equipment. Only one institution had formal structures to ensure purchase of energy efficient equipment where possible. In three other cases, energy management staff had some degree of influence over equipment purchases made within their own institution. However, with computer procurement typically devolved to either individuals or departments who are unlikely to seek out or possess information relating to energy efficiency prior to purchasing equipment, it is likely that energy efficiency criteria are ignored in the purchase of new equipment, by and large.

The second possible form of split incentives investigated here was accountability for energy costs. For example, if a particular individual or department has no incentive to reduce energy expenditure then they may use more energy than is optimal. As shown in Table 5.9, of the five institutions surveyed not one had in place a system for billing individuals or departments for their energy usage, as shown in Table 5.11. Energy management staff were generally of the opinion that such a system would prove difficult to set up. The most often cited difficulty was the need to sub-meter each department separately, which could prove difficult in some cases with departmental offices scattered over several buildings. Thus even though energy management staff were in favour of the principle of giving incentives to energy efficiency in this way, in general they expressed reservations as to how viable such a system would be.

In sum, not one of the institutions had in place a formal system of charging departments for their energy usage. While the desirability of such a system tended not to be questioned, the feasibility was challenged in some cases.

Table 5.9*: Accountability for Energy Usage in the Institutions Studied*

	Institution				
Does the Institution…	**A**	**B**	**C**	**D**	**E**
Charge departments for energy usage? (Yes/No)	N	N	N	N	N
Ensure that all equipment is energy efficient? (Yes/No)	N	Y	N	N	N

It is worth noting, however, that the one institution that was relatively pro-active on energy efficiency also had an arrangement in place whereby any savings gained through energy efficiency were allowed to be retained by the energy manager's department.

5.3.8 PRINCIPAL-AGENT

Principal-agent relationships may inhibit energy efficiency when the interests of one party (the principal) are affected by the actions of another (the agent) and the incentives facing the two parties diverge. In delegating responsibility to the agent, the principal necessarily sacrifices a measure of control over the activities delegated. In order to counteract this, principals are likely, for example, to impose strict or simple investment criteria in an effort to play it safe and ensure that only definitely profitable projects are undertaken.[24] Thus the principal-agent problem could manifest itself in either of two ways:

- discount rates that are higher than warranted, or
- required payback periods that are shorter than warranted.

No direct evidence was uncovered in support of the existence of the principal-agent problem as a barrier to energy efficiency within the higher education sector. Each of the institutions questioned did use strict payback rules for investment criteria, some with payback less than one year, but these were applied for reasons of capital scarcity. No explanation was received to the effect that this was for reasons *other* than capital constraints, which generally require investments in energy efficiency to be undertaken out of the recurrent budget.

That said, it is possible that capital constraints indirectly reflect the principal-agent relationship at several levels. In addition to the relationships within the institutions, there is the relationship between the ultimate funding body, the Department of Finance, the Department of Education and Science, and in the case of the universities the Higher Education Authority, and finally the institutions themselves. In sum the decision-making criteria used are likely to be at variance with principles for public investment decisions as laid down, for example, in the Department of Finance's guidelines[25] for evaluating projects.

While we saw in the section on split incentives that decision-making processes with respect to equipment purchases were wanting, the situation in relation to buildings is more positive. Three of the five institutions (two universities and one institute of technology) include energy targets in building specifications. The Buildings Officer in one of the other institutions says that he works closely with the design team to ensure that energy is considered in the design process. This is not to say that the final buildings turn out to be energy efficient however. Several individuals were strongly of the opinion that energy consumption targets do not get taken seriously by the building consultants. Several suggestions were put forward to remedy this situation including:

- life-cycle costs of buildings should be analysed rather than the simple construction cost,
- design of new buildings should include independently validated predictions of energy consumption, and
- penalties should be imposed on the design team if the building fails to meet certain energy targets.

5.3.9 VALUES AND ORGANISATIONAL CULTURE

[24]The idea is best summed up by De Canio "…the underlying idea…is that the owner's general problem of acquiring information and exercising control leads to the imposition of second-best expedients that may maximise profits subject to organisational constraints but are not first-best solutions that would optimise allocations of resources .." (De Canio, 1993, p. 910).

[25]Guidelines drawn up in partnership with the European Commission, for evaluating projects under the Community Support Framework (CSF Evaluation Unit, 1999).

The issues of personal values and organisational culture are now investigated. Those individuals responsible for energy management in each institution were asked whether they were influenced by environmental concerns and whether environmental concerns were more important than cost savings.

All responded that they were personally motivated by environmental concerns but that, at organisational level, environmental concerns were low. Their answers to three other questions were also recorded. They were asked how the importance of environmental performance compared with that of cost saving, and did they perceive any internal pressures from colleagues and students, or external pressures from the government, media, NGOs, local community, funding councils *et cetera*? Energy managers gave the responses listed in Table 5.10.

Table 5.10: Importance of Environmental Concerns and of Internal and External Pressures

Institutions	Responses of Energy Managers
A	The internal environment, such as heating, is a priority. An external stimulus would be the comparisons of energy performance with other institutions in the higher education sector.
B	The quality of the internal environment is important but the quality of the external environment has not arisen. There are pressures to improve the internal environment. External pressures or public perception are important and it is nice to be seen as being green.
C	Environmental performance is a factor in the decision-making process. No real internal pressures, but being seen externally as being green is a good PR exercise.
D	Cost saving would be more important and saving of expenditure on energy might need to be over £20,000 for the investment to be considered. There are no internal or external pressures to improve environmental performance.
E	Environmental performance is not important. There are no internal pressures, only external pressures owing to resentment of construction activity and planning applications.

As the table shows, while individuals within the institutions may be committed to the idea of environmental performance, at the level of the organisation environmental concerns and internal pressures, other than for warmth, are low. External pressures rather than internal pressures would have some influence on environmental performance.

5.3.10 STATUS

If the status of energy management is low this could be a barrier to energy conservation. The institutions generally rated to be top performers with respect to energy conservation considered that the status afforded to energy management activities was either high now or high in the past when the bulk of energy efficient investments took place.

The relatively high status of energy management activities within those organisations that had taken action was thought to have helped them to fund energy conservation projects. One of the staff remarked that their unit had taken a lot of initiatives a while ago, after the OPEC-induced fuel price increases, presumably because the bigger value of potential savings imparted higher status. The Buildings Officer felt that the dominant barrier at present was "without doubt" low energy tariffs. The three other institutions, where the status of energy management was rated as low, generally find it more difficult to fund energy efficient investments.

This completes the summary of replies about the importance of the potential barriers to investment in energy efficiency from the five organisations in the higher education sector that were interviewed. It is clear that many of the barriers apply to some extent and that several are related, such as access to capital and short payback rules laid down under principal-agent relationships. The next section will classify the barriers and proceed to investigate the policy implications.

5.4 Possible Policy Responses

The case studies have shown that a wide range of barriers exist. These are now summarised in Table 5.11, which shows instances of each barrier and comments on them. As described, some of these barriers are related and could reinforce each other. For example, the principal-agent relationship results in the use of simplified investment rules that have the effect of restricting access to capital. This range suggests that, if the energy efficiency of the higher education sector is to be significantly improved, a wide range of policy measures is likely to be required.

As is common in a sector in which funding is at arm's length and is determined at several removes from the ultimate source, the Department of Finance via the Department of Education, energy managers have limited discretion on energy efficiency investments. Universities, however, which are even further removed, have in fact more devolved responsibility and more scope for manoeuvre.

It is paradoxical that educational institutions, which have assured longevity and have long-term societal returns as their *raison d'être*, are not required routinely to use social long-term investment criteria. These criteria would require analyses to cover a longer horizon, using societal costs of resources (of water, for example) and emissions (e.g. the estimated greenhouse gas penalty), and some energy efficiency projects would by consequence not appear so unfavourable. As things stand, access to capital, hidden costs, compounded by small returns on foot of low energy prices, split incentives and the like, militate further against energy efficiency investment and require strong personal commitment on the part of energy managers in order to achieve results.

Measures to combat these barriers can be applied at three levels: (1) at the level of the organisation, (2) at the level of the sector and (3) at the level of national policy. This chapter concludes with a brief investigation of key policy initiatives for each of these levels in turn.

Table 5.11: Barriers Found to be of High Importance in the Higher Education Sector

Barrier	Specific Instance	Comments
Access to capital	Availability of capital to the institution or energy manager. Short payback requirement by the institution.	Inadequate funding, especially in the institutes of technology, is a barrier. Application of short payback rule (sometimes one-year) meant no funds for longer projects. Third party finance could help but it is only applied to certain projects, such as CHP.
Hidden costs	Loss of benefit. Managerial time. Disruptions. Cost of identifying options. Staff replacement/training.	Perceived hidden costs can prevent a project from going ahead. Shortage of time, especially time to investigate energy efficiency, was stressed repeatedly. Low energy prices were cited forcefully by two institutions.
Imperfect information	Information on organisational energy use.	Lack of information relating to energy consumption results in reduced level of energy management generally.
	On equipment's energy use.	Efficient equipment may be overlooked.
	On energy specifications of new building.	Possible barrier (also a problem of enforcement, see split incentives, below).
	The form of information may not be suitable, given scarcity of managerial time.	Information that requires further investigation on the part of energy managers can constitute a barrier to investment.
Split incentives	Departments not accountable for energy costs.	Perceived as a barrier, but the costs and difficulties associated with introducing devolved budgeting make it difficult to overcome this barrier. Where energy cost savings could be kept, this was an incentive.
	Purchasers of equipment not accountable for energy costs.	Purchasers of new equipment sometimes take account of energy use but this was by no means universally the case. There are some attempts, sometimes successful, at integrating energy concerns into purchasing criteria.
	Designers and contractors for new buildings are not accountable for their running cost.	It could prove very difficult to enforce the incorporation of energy efficient standards in new buildings and hard to make designers and builders take energy efficiency instructions seriously.
Principal-agent relationship	Short payback rules rather than full appraisals seemed to be the principals' means of control. Principal uses wrong rule.	Investment criteria are over-simplified to the detriment of investments that are good when considered over their lifetime. The principals involved are the Departments of Finance and of Education, the Higher Education Authority. Institutes of technology in particular had little devolved responsibility for energy efficiency.
Credibility and trust as regards ESCOs	ESCOs could in theory help overcome many barriers.	Suspicion, bad track record, difficulties with supervision and desire to hold on to control inhibit resort to this means of overcoming barriers.
Values and culture	The attitude of actors in the institution and of the energy manager in particular.	There was little by way of internal values, except emanating from pressure for warmth etc., though external pressure such as to "be seen to be green" was in general a possible stimulus at least. Commitment on the part of the energy manager seems to matter.
Power	Energy management has low status, though this can be countered by personal motivation.	Academic priorities can predominate, energy prices are low and the energy manager may not get sufficient staff or have sufficient say to get funding.

5.4.1 POLICY AT THE LEVEL OF THE INSTITUTION

There is good literature on measures that the higher education sector can implement to improve its energy efficiency. In order to set the framework for such action, adoption of an energy policy and an effective information system, alongside the conduct of regular energy audits, are useful starting points. Routine energy numeracy, and access to key numbers, such as energy use per student or per square (or cubic) metre in various departments, should be made easy.

Purchasing guidelines should include energy efficiency standards for equipment, such as computers, copiers and the like.

Where investments in new buildings are being considered, estimates of discounted values of energy expenditure entailed in various options should be a requirement prior to decisions on investment. Institutions should make decisions relating to lifetime cost of the building including energy use, rather than mainly the initial cost of building and refurbishment.

Other measures that ought to be implemented at the level of the institution include the introduction of departmental charging for energy costs (where feasible), establishing energy awareness campaigns and, where appropriate or necessary, considering external financing.

Methods for giving staff incentives for efficient, expenditure-saving, investment are notoriously difficult to implement in grant-aided institutions. If staff cannot be rewarded and the fruits of such effort accrue to central administration or beyond, then there is little incentive. Some method of reward needs to be established as it appears to be worthwhile, as was seen in the mechanical engineering sector for example. If part of the savings could be kept for the person or department that makes the savings in order to counter some of the hidden costs, involving extra personal effort in many cases, this could help.

5.4.2 POLICY AT SECTORAL LEVEL

There are three areas where initiatives could be undertaken at the level of the higher education sector as a whole:

- *Information*: Provision of more targeted information of an interactive nature would help break down the information barrier. Sustainable Energy Ireland, previously the Irish Energy Centre, would be well placed to undertake this and to help produce benchmarks of energy use. Regular provision of information on current technologies and examples in the form of case studies of like institutions could be provided. Also user-friendly calculation packs or seminars could be supplied for estimating lifetime costs and NPVs of proposals. Similarly, institutions should be required to undertake pre- and post-investment assessments of any projects that they undertake. This could be set up and made mandatory where public funding is involved and will provide a record of "like case studies" for other institutions, enabling lessons to be learned.
- *Funding requirements:* Somewhere along the chain of funding (from the Department of Finance through the Department of Education and, where applicable, the Higher Education Authority, to the institution) the attitude to investment becomes transformed into the inimical and unsound short payback rule. This is probably because it was felt that only "recurrent" funds could be accessed. There is now a framework

in place that enables universities to borrow. Where the institutes of technology are concerned funds can be accessed through the annual "Programmes and Budget Submissions" or from discretionary amounts. The important task for the institutions is to draw up a programme of energy efficiency investments that have good NPVs, using societal costs where items such as water are subsidised, and accounting also for other externalities where these are known, in the manner recommended by the CSF Evaluation Unit (1999).

Encouragement to build up internal expertise is needed, combined with mandatory internal reporting requirements on energy consumption and energy efficiency. Reporting should form part of the management process, for automatic comparison with benchmarks, ideally. The qualification "ideally" is added because there are differences in circumstances that would need to be taken into consideration, which may be complicated by the need for quick and easy reporting.

- *Purchasing*: Advice on standards for equipment that is being purchased would help institutions to avoid locking themselves in to inefficient technology. New buildings ought to have BEMS installed, where feasible. Energy performance targets should be specified in the design specifications for new buildings and refurbishment, and Sustainable Energy Ireland could help with a user-friendly procedure to document and report actual performance afterwards in a disciplined manner.

  Given the difficulties mentioned in relation to ensuring that standards are incorporated in new buildings, the scope for application and monitoring of enhanced building regulations in this sector needs to be given serious consideration or even, perhaps, fiscal measures are needed (OECD, 2003).

5.4.3 NATIONAL MEASURES

The above measures will only be effective in the context of a broadly based commitment to reducing energy-related emissions. Fiscal, regulatory and information measures all have a role to play.

Universities now have a framework for borrowing and the institutes of technology can submit projects for funding or avail of discretionary funds. Therefore, proposals for investment in energy efficiency need to be drawn up using standard NPV techniques with prices that reflect societal costs. Those techniques for appraising investment proposals recommended by the evaluation unit of the Community Support Framework, for example, ought to become routine and Sustainable Energy Ireland might help to make them specifically applicable to investments in energy efficiency.

The lack of enthusiasm for engaging Energy Service Companies (ESCOs) needs to be confronted. Measures that would engender trust on the part of those institutions that could benefit and that would otherwise avail of their services could help.

In the field of fiscal policy generally, the failure to account for the external damage of greenhouse gas emissions in the prices of fuels needs to be corrected. A carbon tax is now official policy and respending of the revenues in the form of reduced labour taxes, for example, could on balance benefit the institutions.

The rate of VAT is an area of concern, in so far as higher education institutions are exempt VAT. This exemption means that they pay non-reclaimable VAT on their inputs. The different levels of VAT rate mean that the institutions' energy purchases are subject to VAT at 12.5 per cent, while energy efficiency services such as audits are subject to 21 per cent VAT. This represents a penalty to energy efficiency investment because its relative price is disadvantaged to the tune of nearly 8 per cent. A removal of the difference in rates is evidently desirable.

The rating of new buildings by energy use, with follow up to document the outturn, would be worthwhile. Funding ought to be closely tied to adherence to standards. The National Development Plan has a measure devoted to energy conservation under the Sustainable Energy priority, of the Economic and Social Infrastructure Operational Programme. The energy performance of tertiary buildings is one of the areas of focus, including energy rating and the programme states "Public sector leadership in procurement and demonstration will play a role in market transformation" (Department of the Environment, 2000).

6. Conclusions and Policy Issues

This chapter draws together findings from earlier chapters and aims to provide answers to a number of the issues raised in the Introduction. Three representative sectors have been studied, namely, mechanical engineering, brewing and higher education and the key issues that we need to address here are the following. Is it the case that many cost-effective opportunities to improve energy efficiency are being neglected? What is the relative importance of each type of barrier to energy efficiency and how does this vary between different sectors? Is there a legitimate role for public policy intervention? What would be the most effective and appropriate forms of policy measures for overcoming the identified barriers?

6.1 Existence of Energy Efficiency Opportunities

First we consider the question whether many cost-effective opportunities to improve energy efficiency are being overlooked. Cost-effective in this context means that, considering the measurable costs such as capital costs and energy costs (i.e. ignoring hidden costs or risk), the investment has a significantly better rate of return than the cost of capital to the organisation.

The findings from the organisations in the three sectors studied suggest strongly that there are many cost-effective opportunities available in most of the organisations concerned. A majority of interviewees in each of the sectors agreed that there were many energy efficiency opportunities available in their organisations that would have quite short payback periods (namely three years, or five years in the case of brewing). This suggests that there would be even more opportunities that would have a better rate of return than the cost of capital.

As mentioned in Chapter 1, our research on barriers to energy efficiency in three sectors in Ireland was conducted as part of an international project that was carried out simultaneously on the same three sectors in the United Kingdom and Germany. The overall findings from the three countries also concluded that there were many cost-effective opportunities to improve energy efficiency that were not being taken up in most of the organisations studied (Sorrell *et al.*, 2000, Chapter 8).

In the UK, large postal surveys were conducted of wide samples of organisations in higher education and brewing, in addition to smaller numbers of more in-depth case studies. In the higher education postal survey undertaken for the UK, 79 per cent of respondents either agreed or strongly agreed that there were many opportunities with four-year paybacks, with 14 per cent neutral and only 7 per cent disagreeing. The corresponding results from the UK brewing industry postal survey were 48 per cent agreeing, 19 per cent neutral and 33 per cent disagreeing. This suggests that somewhat fewer opportunities were perceived in the brewing sector than in higher education – a result that was backed up by the case study interviews in the UK and is also consistent with the case study interviews in Ireland. Since brewing is a more energy-intensive sector, which should cause it to pay more attention to energy efficiency, it is not surprising that the brewing industry would already have taken up more of the available energy-efficiency opportunities (see also Section 6.2.2 below).

6.2 The Relative Importance of Different Barriers

Next we consider what is the relative importance of the different types of barriers to energy efficiency and how does this vary between different sectors. This is a question that cannot be answered with great quantitative precision. For one thing, as indicated in Section 2.6, there is a degree of overlap and interdependence between the various barriers, while the case study results are also partly qualitative and require some interpretation.

For each of our three sectors, it was attempted as far as possible to rate the importance of the individual barriers. The chapters on the three sectors have discussed this in some detail, and Table 6.1 identifies those barriers that were considered to be of high importance in each sector. The barriers are listed in descending order of the frequency with which they were reported.

Table 6.1*: Barriers Considered to be of High Importance in the Different Sectors*

Barrier	Mechanical Engineering	Brewing	Higher Education	Total
Access to capital	*	*	*	3
Hidden costs	*	*(1)	*	3(1)
Imperfect information	*		*	2
Split incentives			*	1
Principal-agent			*	1
Form of information, credibility and trust			*	1
Values and organisational culture	*			1
Power			*	1

Notes: * The asterisk means that the barrier is identified as being of high importance.
(1) Hidden costs can be of high importance for smaller brewing firms, but not for large firms.

6.2.1 THE MOST IMPORTANT BARRIERS

It can be seen from Table 6.1 that eight barriers have been identified as being of high importance in at least one of the sectors studied. But within this group of eight barriers that appear at least once in Table 6.1, two stand out as being particularly important, namely access to capital and hidden costs. These two are very important in all three of the sectors studied. Imperfect information is very important in two of the sectors studied, while the other five barriers are of high importance in only one sector. It is also worth noting that a number of other potential barriers were identified in Chapter 2, and although these are not included in Table 6.1, they are all of some importance in some sectors.

These findings from Ireland are similar in significant respects to the overall results from the studies conducted in the UK and Germany. In particular, access to capital and hidden costs were found to be the most important barriers overall, since they were identified as being very important in all three sectors studied in all three countries (Sorrell *et al.*, 2000, Chapter 8). In addition, imperfect information, together with risk, were found to be the next most commonly occurring barriers, being very important in six of the nine sector/country studies. The remaining barriers were found to be of high importance in smaller numbers of the sector/country studies, but they were all important in some of the studies. Sorrell *et al.* (2000) concluded that problems associated with access to capital and hidden costs appear to be the primary reasons for not investing in energy efficiency in the case study sectors.

6.2.2 DIFFERENCES BETWEEN SECTORS

Problems with access to capital and hidden costs are common to all sectors. But there are differences between sectors with respect to the other barriers. In particular, it is noticeable in Table 6.1 that the number and range of barriers of high importance varies between sectors, with the widest range occurring in higher education and the narrowest occurring in brewing. It is perhaps understandable that interviewees in the brewing industry perceived only one or two really important barriers to energy efficiency while those in the other sectors identified more, since this is probably a reflection of the fact that brewing is more energy-intensive. Since energy accounts for a larger part of total costs in brewing, the benefits that brewing can gain by investing in energy efficiency would amount to savings of a greater proportion of total costs than in the case of less energy-intensive sectors. Compared to these relatively large benefits, most potential barriers to energy efficiency would appear to be quite small and it would be considered worthwhile undertaking the effort and expense required to overcome such barriers. In less energy-intensive sectors, however, the benefits that can be gained by investing in energy efficiency would amount to savings of a less significant proportion of total costs. Consequently, a range of barriers that would be overcome in a more energy-intensive sector may appear sufficiently great in less energy-intensive sectors actually to prevent investments in energy efficiency. Hence such barriers would be rated as very important. For example, imperfect information is found to be a barrier of high importance in both higher education and mechanical engineering, but not in brewing.

It is also worth noting that a number of barriers are found to be of high importance in higher education although they are less important in the other sectors. For example, the power or status of energy management tends to be rather low in higher education due to the dominance of academic priorities such as research and teaching, so that energy managers may not get sufficient staff or have sufficient funding. Split incentives are also a significant problem in higher education, but appear to be of less importance in brewing and mechanical engineering. In higher education, the importance of split incentives results to a considerable extent from a combination of the large size of universities and the significance of individual departmental decisions for energy consumption (including equipment purchasing), together with a lack of devolved accountability for energy costs. The resulting application of simple rules in the principal-agent relationship with the funders was particularly constraining in the case of the institutes for technology.

A final point worth noting here is that it might have been expected that business risk would play a substantially more important role as a barrier to energy efficiency in the private sector (brewing and mechanical engineering) than in higher education. Although business risk is not identified in its own right as a barrier of high importance for any sector in Table 6.1, it is in fact quite a significant contributory factor that helps to explain the importance of the access to capital barrier in the two private sectors, as will be discussed below.

6.2.3 CAPITAL CONSTRAINTS

A strong general message from the research is the importance of *limited access to capital* as a barrier to energy efficiency. This can apply at two levels: an overall limitation on access to capital for the organisation as a whole; and restricted access to capital for energy efficiency within internal capital budgeting procedures. The result of either or both of these factors, from the perspective of those responsible for energy management, is that they lack sufficient capital to invest in energy efficiency improvements.

The limitation on access to capital tends to take different forms in the different sectors. In the higher education sector, there were constraints associated with public sector funding, as well as internal budgeting constraints. But in mechanical engineering and brewing, the firms in principle have access to commercial capital markets. There was practically no evidence that the case study firms had difficulties in obtaining capital at reasonable rates – as would be the case if there were capital market failures. Instead, the restrictions on access to capital were largely self-imposed through a reluctance to take on additional borrowing. This was manifested primarily in the use of tight payback criteria for assessing proposed investments, including investments in energy efficiency as well as other types of investments.[26]

As was discussed in Chapter 2 (especially in Section 2.3.4) and later in the chapters on the sectors, there are a number of possible explanations for companies' use of stringent investment criteria. In particular:

- *Risk*: Projects could be required to have a rapid payback to allow for current business and market risk, including the possibility of closure. There are also risks associated with increased gearing (increasing the ratio of loan finance to equity), and there can be technical risks that are specific to individual projects.

[26] It could be the case at times that potential energy efficiency projects fail the test of tight investment criteria because there is inadequate accounting for the full benefits of such projects and there is exaggerated estimation of the costs. In such cases, it could be said that barriers such as imperfect information are part of the problem. Nevertheless, the widespread use of stringent investment criteria is a common barrier in its own right, and would continue to be so even if there were no information problems or other difficulties in applying the criteria.

- *Principal-agent*: Monitoring and control problems can lead principals to impose stringent investment criteria to ensure that only unambiguously high value projects are undertaken.
- *Hidden costs*: Projects could be required to have a rapid payback on capital cost alone, to accommodate the significant salary and other costs associated with energy management.
- *Strategic priorities*: Top management may have strategic goals that have priority over internal investment when using whatever capital is available to the company, such as mergers and acquisitions or expansion into new activities.
- *General capital constraint*: If the organisation has a difficulty overall in borrowing money, it may use stringent payback criteria for discretionary cost-cutting projects as a method of rationing capital.

The information available from the case studies is not really sufficient to determine the relative importance of each of these hypotheses or to draw definitive conclusions as to which hypothesis is most important. However, we can say with some confidence that most of the case study companies did not appear to experience a general capital constraint with an overall difficulty in borrowing money.

Risk was a common concern, with the area of business and market risk generally being more significant than technical risk with respect to energy efficiency investments. However, we can also make the observation that stringent investment criteria were common even in those case study organisations where business seemed very healthy, as well as being a generally widespread phenomenon throughout all sectors of industry. This makes it unlikely that business or financing risk alone would provide an adequate explanation for the general reluctance to borrow for non-essential cost-saving investments.

Therefore, it seems likely that principal-agent relationships and the desire to cover hidden costs are quite commonly part of the explanation, while other strategic priorities are undoubtedly significant in some cases. The precise explanation must vary somewhat depending on the circumstances of the individual organisation. For some companies, it may be the case that all these factors apply to some extent, making the decision to impose stringent investment criteria over-determined by good reasons.

It is not clear to what extent the general reluctance to increase borrowing represents rational behaviour. Firms could be reacting quite rationally to factors such as risks, concerns about gearing, and hidden costs. But assessment of whether the firms are behaving rationally lies outside the scope of our study. To the extent that firms are not behaving rationally, the use of stringent investment criteria would represent a form of internal organisational failure, perhaps resulting from monitoring problems in principal-agent relationships or other factors.

6.2.4 HIDDEN COSTS

A second strong general message from the research is the importance of *time constraints* as a barrier to energy efficiency. The general importance of hidden costs as a barrier as shown in Table 6.1 is primarily a reflection of the aspects of hidden costs that involve putting demands on management time. Many interviewees across the different sectors emphasised that there were great demands on their time. This caused difficulties for them in keeping fully up to date with technical information, in identifying energy efficiency opportunities and in implementing energy efficiency projects.

Salary costs for energy management staff represent a form of hidden costs, as does the operation of energy information systems and the time spent on specification and tendering for capital works. In each case, time constraints on the relevant staff are an indication that these costs are important. Unfortunately, however, it was generally not possible to quantify these costs. This was commonly because the relevant duties were only part of the broader duties of key individuals, and they were also spread between a number of staff.

We can think of the time spent by energy management staff as being divided into: (a) time spent specifically on identifying, assessing and implementing projects to improve energy efficiency; and (b) time spent on other necessary and more general tasks such as negotiating with energy suppliers, controlling the Building Energy Management Systems and overseeing maintenance. If it were possible to quantify the hidden costs of the time spent specifically on energy efficiency projects (category a), it would be justifiable to count those as part of the cost of such projects. It is possible that the stringent payback criteria used for investment projects might be at least partly justified as a means to recover these hidden costs. However, it should be said that recovery of these hidden costs was never an *explicit* rationale for stringent investment criteria in the organisations studied. Investment criteria were generally identical for all forms of cost saving investment and the reasons given for the choice of criteria usually centred most on the area of business and market risk. In no case were hidden costs relating to management time explicitly quantified and included in investment appraisal.

As regards the time spent on other more general energy management tasks under category (b) above, much of this can be seen as an *essential* overhead, involving work that is necessary for the functioning of the organisation and the comfort of employees. It would not be appropriate to treat this as a cost to be recovered from savings from energy efficiency projects.

Energy Service Companies (ESCOs) can save management time as well as provide third party finance and shoulder risk. Some institutions in higher education had unsatisfactory experiences with the use of ESCOs while the breweries on the other hand tended to have an open mind. Many firms engaged in mechanical engineering would, by dint of low energy use, be unattractive to ESCOs. Overall the ESCO solution to barriers has variable potential and low take-up, at least at present.

6.3 The Rationale for Policy Intervention

As indicated above, the most important barriers to energy efficiency were identified as being: *access to capital* (in the private sector, specifically a reluctance to borrow as manifested in the use of stringent payback criteria); and *hidden costs* (specifically demands on management time). A feature of both of these barriers is that they may imply that organisations are behaving rationally to a great extent in allowing such barriers to deter them from investing in energy efficiency. Such barriers may not necessarily be a result of market failure. If so, such barriers do not *in themselves* provide grounds for governments to intervene to correct market failure.

However, as discussed in Section 2.6, there is another form of market failure that can provide good grounds for government intervention. The basic reason why governments would wish to improve energy efficiency is because of the need to reduce greenhouse gas emissions so as to combat undesirable climate change. If energy users cause environmental damage through greenhouse gas emissions, thereby imposing costs on society at large that are not reflected in a commensurate cost or penalty attached to the use of energy, this is called an environmental externality and it is a form of market failure. In this situation, there is a good case for policy intervention to improve energy efficiency and reduce energy consumption – even if the most important barriers to energy efficiency are not in themselves market failures.

For example, the access to capital or hidden cost barriers can be reduced by the use of revenue neutral energy taxation (such as higher taxes on energy offset by lower taxes on labour, for instance as described in Bergin *et al.* (2002). By increasing energy costs and at the same time decreasing labour costs, the benefits of greater energy efficiency would be increased relative to the costs of installing energy efficiency measures. Such a policy can be justified on the grounds that it internalises the external costs of energy use.

Apart from access to capital and hidden costs, many of the other barriers to energy efficiency identified in this report provide an even clearer justification for government intervention. This is because they stem from either neo-classical market failures or from some form of organisational failure, as discussed in Chapter 2. For example, in the case of imperfect information, the energy service market produces and transmits insufficient information about the energy performance of different technologies (Section 2.1.1). This is a form of market failure and it leads energy consumers to make sub-optimal decisions based on provisional and uncertain information, and consequently to underinvest in energy efficiency. In addition to standard market failures, there are also examples of organisational failures, as in the case of principal-agent relationships that can impede profit maximising behaviour.

It is also clear from our case studies that many individuals who have a role in energy management are subject to severe constraints on their time. They may habitually overlook, or at least give relatively limited attention to, matters that are seen as secondary or peripheral, such as energy efficiency. This indicates that the concept of bounded rationality (discussed in Section 2.4.1) is of real significance, meaning that decision-making in organisations is often less than optimal – aiming to make quick and fairly satisfactory decisions rather than expending a great deal of time in order to make optimal decisions.

These observations can provide a rationale for government intervention. The objective of such intervention is both to overcome neo-classical market failures and to strengthen internal organisational decision-making. The rationale for the latter is that, as a consequence of bounded rationality and organisational failure, there is scope for governments to help individuals and organisations to help themselves. One example of a government policy measure to help overcome organisational failures and bounded rationality could be an information programme. However, there may be a limit to what can be achieved by such measures since it may be more difficult to modify the behaviour of actors who are heavily preoccupied with other priorities. In that case, shortcomings in individual and organisational decision-making can be bypassed through the use of regulatory standards, such as minimum levels of energy efficiency in energy-using equipment.

6.4 Policy Measures

One conclusion from the research is that there are considerable variations in the nature of the barriers to energy efficiency that apply to different sectors or organisations. While some barriers are very significant in most contexts as indicated above, the importance of other barriers varies considerably across sectors or companies. Therefore, effective policy solutions need to address the particular circumstances of energy-using sectors and organisations. It is unlikely that there will be a single best policy solution for all. Instead, a variety of approaches is likely to be required, addressing the features of individual circumstances.

For each of the individual sector studies, we have indicated possible policy interventions at three levels: organisational, sectoral, and national. This gives a range of suggestions that are based on the circumstances in each sector, but these suggestions are indicative. It is not possible within the constraints of this study to identify an "optimal" policy mix for each sector. The results do, however, illustrate the diversity of approaches that are likely to be required.

However, there are certain broadly-based approaches to policy at national level that influence many or all sectors, such as policies that affect energy prices. In Ireland the introduction of carbon taxes and emissions trading should work in the right direction by raising energy prices generally. In addition, as mentioned in Chapter 4, the Integrated Pollution Prevention and Control (IPPC) licensing system requires an increasing number of selected industries to use energy efficiently, as well as control their emissions of pollutants in general. The scheduled industries are quite wide-ranging and would include nearly all those that are relatively energy-intensive, such as brewing. These broad national-level policies should have the potential to achieve significant improvements in energy efficiency, depending on how precisely they are implemented.

These types of measures are suited to addressing the two most pervasive barriers to energy efficiency, namely the access to capital barrier resulting from tight payback criteria or capital budgeting, and the hidden costs barrier associated with constraints on management time. These measures would have the effect of increasing the incentive to invest in energy efficiency as compared to other potential investments, while at the same time giving organisations cause to allocate more management time to energy efficiency matters. Companies can be compensated for higher energy costs through reduced taxes on other things such as taxes on labour or profits, if it is desired not to increase their overall tax burden while still enhancing their incentive to invest in energy efficiency.

The experience of the UK shows how powerful an energy tax measure can be. The climate change levy there was introduced with a corresponding reduction in employers' national insurance. Even before its introduction the levy transformed the level of attention given to energy efficiency. The effect appeared to be out of proportion to the size of the cost changes alone, because the high public profile of the levy effectively captured top management attention.

While carbon taxes, emissions trading and IPPC licensing can address the access to capital and hidden costs barriers, these measures would also help to overcome some of the other barriers at the same time. For example, these measures should increase the importance of the energy management function within organisations, thereby helping to overcome the barriers associated with values and organisational culture and the power or status of energy managers.

In addition to these broad national-level measures, we have also indicated in the individual sector studies how other more specific measures can address other barriers to energy efficiency that arise. Such measures include, for example, various industry-specific or technology-specific information programmes in user-friendly formats, energy audit schemes, appropriate subsidies for energy efficiency measures or for research and development on energy efficiency, and support for new or emerging mechanisms to deliver energy efficiency such as ESCOs.

For sectors where enterprises are not particularly energy intensive, such as in the mechanical engineering sector, keeping informed on energy matters takes up management time that is scarce. Informative energy labelling, meters and bills as well as demonstration case studies and encouragement to undertake audits could be targeted at enterprises through their industry association. These associations could also be helped with organisation and with provision of generic or technology-specific information, mentioned above.

Enterprises that are bigger energy users, like breweries, could also be helped to make investment in energy efficiency less demanding of management time. There is scope here for ESCOs, which are specialists in energy matters, to provide advice and finance for investments in energy efficiency, or else provide energy services on an agency basis. For their potential to be realised ESCOs would need to develop a track record, with certification probably, and develop an interest in energy efficiency relating to buildings and not just to equipment and energy supply. ESCOs' engagements with SMEs, such as smaller firms in the mechanical engineering industry, would be best directed through industry associations.

More widespread use of sectoral guidelines and benchmarks of energy use needs promotion. These could be supplied on a regular basis with assistance from the new agency Sustainable Energy Ireland and would enable enterprises to judge whether their plant or buildings are wanting or to satisfy themselves that ESCOs are proposing genuine improvements. The types of contract drawn up between enterprises and ESCOs need careful attention. The rewards of energy saving activities should ideally be reaped by the investors who undertake them, and take-or-pay contracts for energy, for example, should be avoided. A possible model is for the contract to fix an annual price below the current fuel bill, and then to share any larger than expected annual savings.

Higher education is a particularly interesting case, where funding arrangements exemplify the principal-agent barrier. Though the sector's objective is the long-term gain to society, the institutions studied tended to operate a one-year payback criterion for investment in items such as energy efficiency. Calculation of Net Present Value or Internal Rate of Return should be made easy and widespread, using societal costs of externalities and resources that are subsidised. More widespread calculation of Net Present Value or Internal Rate of Return should be encouraged generally and help should be forthcoming for recording prior and follow-up information to provide future demonstration studies.

APPENDIX 1

Pre-Interview Questionnaire for the Mechanical Engineering Sector

Thank you for participating in this international research project funded by the European Commission (DG-XII). Within this project, research teams from the UK, Ireland and Germany aim to identify why organisations do or do not make cost effective energy efficiency investments. This project looks at both public and private sectors and aims to identify how government policy can encourage energy efficiency.

In this questionnaire, we would like to ask a few general questions on your company, its current level of energy consumption, and the energy efficiency measures that have been realised. **The questionnaire should take no more than 10-15 minutes to complete**. If the information is not known or not readily available then please leave the section blank.

We guarantee the confidentiality of all data and information. The draft results of this research will be sent to all participating organisations and full opportunity will be given for comment. The anonymity of the participating organisations will be preserved in all resulting reports and publications.

Thank you very much for taking the time to answer this questionnaire. Please send the completed forms back in the attached envelope.

1. Identification

Company...

Name..

Position..

2. The Company

Total employees..

Approximate annual turnover (i.e. sales, £ million)..

Approximate number of shifts per 24 hours...

Approximate floor area (m^2)..

(leave blank if information not known)

3. Annual Energy Use

Please indicate your company's approximate annual consumption of:

Fuel.. Electricity...

(please indicate units)

Please indicate your company's approximate annual expenditure on:

Fuel.. Electricity...

(leave blank if information not known)

4. Contract Energy Management

Do you use contract energy management? Yes θ No θ

If Yes, could you briefly indicate the coverage of the contract:

....

....

....

5. Energy Information Systems

At what level is energy use generally metered?

	Site?	Building?	Individual equipment?
Electricity	θ	θ	θ
Other energy	θ	θ	θ

How frequently is energy use generally recorded?

	Annually?	Monthly?	Weekly?	Daily?
Electricity	θ	θ	θ	θ
Other energy	θ	θ	θ	θ

Do you monitor trends in energy consumption?	Yes	θ	No	θ
Are consumption records adjusted for weather conditions?	Yes	θ	No	θ
Is a monitoring and targeting scheme employed?	Yes	θ	No	θ
Is consumption compared with sector benchmarks?	Yes	θ	No	θ
Has an audit of your energy use been undertaken?	Yes	θ	No	θ

6. Energy Efficiency Opportunities

How much do you agree with the following statement:

"There are a wide range of energy efficiency measures that could be implemented in my company that would yield paybacks of less than three years at current energy prices"

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
θ	θ	θ	θ	θ	θ

7. Information Sources on Energy Efficiency Opportunities

Please rank the usefulness of each of the following information sources on energy efficiency opportunities:

Source	Excellent	Good	Average	Poor	Don't Use
Colleagues within the company	θ	θ	θ	θ	θ
Network of contacts in the sector	θ	θ	θ	θ	θ
Energy manager groups/networks	θ	θ	θ	θ	θ
Irish Energy Centre schemes	θ	θ	θ	θ	θ
Professional associations	θ	θ	θ	θ	θ
Trade/Technical journals	θ	θ	θ	θ	θ
Technical conferences/seminars	θ	θ	θ	θ	θ
Energy supply industry	θ	θ	θ	θ	θ
Equipment suppliers	θ	θ	θ	θ	θ
Consultants	θ	θ	θ	θ	θ

8. SELF ASSESSMENT PROFILE OF ENERGY MANAGEMENT

This page is a "self assessment" exercise developed by the UK Energy & Environmental Management Division.

Reading down each column in turn, could you please circle the box that corresponds most closely to current practice in your company.

Policy	Organising	Information Systems	Awareness	Investment
No explicit policy	No energy management or formal delegation of responsibility for energy consumption	No information system. No accounting for energy consumption	No promotion of energy efficiency	No investment in energy efficiency
Unwritten set of guidelines	Energy management the part-time responsibility of someone with only limited authority or influence	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency	Only low cost measures taken
Unadopted energy policy set by energy manager or senior departmental manager	Energy manager reports to *ad hoc* committee, but line management and authority are unclear	Monitoring & targeting reports based on supply meter data. Energy unit has *ad hoc* involvement in budget setting	Some *ad hoc* staff awareness training	Investment using short term payback criteria only
Formal energy policy, but no active commitment from top management	Energy manager accountable to energy committee representing all energy users in the organisation	M&T reports for individual premises based on sub-metering, but savings not reported effectively to users	Programme of staff awareness and regular publicity campaigns	Same payback criteria as for all other investment
Energy policy, action plan and regular review with commitment of top management	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption	A comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking	Marketing the value of energy efficiency and the performance of energy management both within and outside the organisation.	Positive discrimination in favour of "green" schemes with detailed investment appraisal of all new-build and refurbishment opportunities

9. Implementation of energy efficiency measures

The following list contains some measures for reducing energy consumption. Could you please indicate whether your company has either:

1. **implemented** each measure ***on a significant scale***; or
2. **considered** the measure, but not yet implemented on a significant scale.

	Implemented?	Considered?	Comments
Space Heating:			
Use of Building Energy Management System (BEMS)?	θ	θ	____________
Programming HVAC controls to match occupancy patterns and/or outside temperature?	θ	θ	____________
Thermostatic radiator valves?			
Ensure adequate lagging/insulation?	θ	θ	____________
Lighting:			
Use of 26 mm compact fluorescents?	θ	θ	____________
Use of high frequency electronic ballasts?	θ	θ	____________
Photocell, acoustic or movement sensors?	θ	θ	____________
Compressed air:			
Inspection & elimination of leaks?	θ	θ	____________
Generation of compressed air at appropriate pressure?	θ	θ	____________
Consideration of energy consumption when purchasing new compressors?	θ	θ	____________
Heat recovery?	θ	θ	____________
Heat treatment:			
Furnace insulation?	θ	θ	____________
Furnace heat recovery?	θ	θ	____________
Accurate control of temperature, pressure and fuel air ratio?	θ	θ	____________
Boiler plant:			
Insulation of distribution pipes, valves and flanges?	θ	θ	____________
Use of energy efficient burners?	θ	θ	____________
Use of condensing boilers?	θ	θ	____________
Building fabric:			
Retrofitting insulation to walls and roofs?	θ	θ	____________
Reduction of draughts from loading bays?	θ	θ	____________
Specification of high standards of energy			____________

efficiency in new buildings?	θ	θ	

Electrical equipment:

Purchase of energy efficient computers and office equipment?	θ	θ	________
Use of variable speed drives (VSD) for motors	θ	θ	________
Automatic switch off of fans & pumps when the equipment they serve is not in use?	θ	θ	________

10. Barriers to Energy Efficiency Improvement

Studies by technology researchers commonly identify energy efficiency opportunities that appear to be highly cost effective. The following have been suggested as reasons why such investments are not made. In your view, how important is each suggested reason:

		Often important	Sometimes important	Rarely important
1	Technology inappropriate at this site	θ	θ	θ
2	Cost of production disruptions/hassle/ inconvenience	θ	θ	θ
3	Cost of identifying opportunities, analysing cost effectiveness and tendering	θ	θ	θ
4	Cost of staff replacement, retirement, retraining	θ	θ	θ
5	Possible poor performance of equipment	θ	θ	θ
6	Lack of capital	θ	θ	θ
7	Strict adherence to capital budgets	θ	θ	θ
8	Other priorities for capital investment	θ	θ	θ
9	Technical risk	θ	θ	θ
10	Business/market uncertainty	θ	θ	θ
11	Lack of information/poor quality information on energy efficiency opportunities	θ	θ	θ
12	Difficulty/cost of obtaining information on the energy consumption of purchased equipment	θ	θ	θ
13	Lack of time/other priorities	θ	θ	θ
14	Lack of technical skills to analyse/operate	θ	θ	θ
15	Lack of staff awareness	θ	θ	θ
16	Department/individuals not accountable for			θ

	energy costs	θ	θ	
17	Energy objectives not integrated into operating, maintenance or purchasing procedures	θ	θ	θ
18	Conflicts of interest within the company	θ	θ	θ

Do you have any further comments on barriers to energy efficiency improvement?

....

....

....

....

Thank you very much for completing this questionnaire!

Please return this questionnaire in the enclosed pre-paid envelope

APPENDIX 2: INTERVIEW PROTOCOL FOR ENERGY MANAGER (BREWING)

IDENTIFICATION

Name of Brewery..

Name ....

Job Title...

Date of Meeting ....

QUESTIONS

Background

- What are your principal ***responsibilities*** within the brewery?
- What proportion of your ***time*** is devoted to energy compared to other issues?
- How ***long*** have you been in this post?
- What is your professional background?

Energy policy

- Does the brewery have an ***Energy/Environmental Policy?*** What form does it take (e.g. use of targets; action plan; designated responsibility and accountability etc.)?
- How ***long*** have these policies been established?
- What ***impact*** has this policy had on energy decision making and the brewery's energy performance?
- What have the energy/environmental policies ***achieved?***
- Is the brewery certified to an ***environmental management scheme***? ISO 14001 or European EMAS? Does it intend to certify?
- Are provisions for achieving energy/environmental policy objectives included in other ***policy documents***, such as purchasing or maintenance?

- Is your company a **subsidiary** of another company? National? International? If yes, what impact does it have on energy management and decision making? Do the same rules apply to all subsidiaries?

Energy management

- Could you please draw a simplified version of the corporate ***organisation diagram***, showing key individuals and departments/divisions with responsibility for energy decision making.
- Does the brewery have a ***committee*** wholly or partly responsible for energy matters? If so, what is the ***membership*** of this committee? How does it function?
- Who do you ***interact*** with on a regular basis?
- Is energy management an in-house activity or are ***energy service companies*****,** consultants or energy suppliers used? What is the rationale for this choice?

Status

- How would you assess the ***status*** of energy management within the brewery (high/medium/low)?
- How does this status ***affect*** energy management activities?
- How much does status depend on ***formal authority*** and how much does it depend on other factors such as the support of key individuals (a lot/a bit/not at all)?
- Are there areas where you would like to have ***influence*** but do not (e.g. equipment purchasing, building specification)?
- Are there ***conflicts of interest*** within the brewery that inhibit energy management activities?

Capital

- Is there a separate ***budget*** for energy efficiency investment?
- If yes: How large is it? (percentage of utility spend) How is it set? How has this changed over time?
- If no: How is energy efficiency investment funded?
- How has this budget been ***spent*** over the last financial year?
- Is this budget allowed to be ***carried forward*** if unused at year end?
- How does capital availability affect the ***type of projects*** that can go ahead?
- Do you ***borrow*** for the purposes of investment in energy efficiency?

Investment

- Could you describe the ***decision-making process*** for investments in energy efficiency? Who are the key individuals/committees involved? What is the impact of the parent company (if applicable)?
- What are the biggest ***obstacles*** in this process? How could it be improved?
- What ***criteria*** are used for appraising energy efficiency investments? How do these differ from other categories of investment? What are the ***reasons*** for this choice of criteria?
- Are the investment criteria ***feasible*** or restrictive?
- Is there a ***portfolio*** of properly justified and costed projects that could be implemented?

- How are investment projects ***prioritised***? What factors are taken into account?
- Who has the final say?

Energy information systems (relate to answers in PIQ)

- What ***information*** is available to you on organisational energy consumption?
- To what extent is energy ***sub metering*** used in the brewery?
- Is information available on ***trends*** in energy consumption?
- Is information available on the performance of previous ***efficiency investments*** and the savings achieved?
- Is the energy performance of the brewery compared against sector or generic ***benchmarks***? Where are these used?
- Is a ***monitoring and targeting*** scheme in operation? How is it used?
- What information is disseminated to top management and other individuals? How effective are these ***reporting requirements***?
- Are you happy with the ***quality*** of current information systems? How could they be improved? What are the obstacles to such improvement?

Information on efficiency opportunities

- Do you consider that you have adequate information on energy efficiency ***opportunities***?
- Have any energy ***audits*** been conducted? Are any planned?
- Do you consider that you have adequate information on the ***needs*** of building and equipment users?
- Is the primary problem a ***lack of information***, or constraints on using existing information (e.g. lack of technical ability; lack of time)?
- Which ***information sources*** on energy efficiency opportunities are used and why? (**see PIQ**)
- Which information sources do you place the greatest ***trust*** in and why?
- Are you aware of any government sponsored ***information programmes***? How ***useful*** are they?
- How could the quality of information be ***improved***?

Accountability

- What are the arrangements for ***charging*** energy costs? Are subdivisions (e.g. brewing filling, packaging) charged individually?
- To what extent can individual subdivisions ***influence*** their own energy costs?
- Are energy budgets and the responsibility for energy management ***devolved*** to individual divisions?
- How are the ***benefits*** from efficiency investments distributed?
- Are ***targets*** for energy budgets identified?
- Are there any ***incentives*** created for subdivisions and staff? How effective are they?

Performance

- Do you know the energy ***savings*** achieved by your brewery over the past five years or so?

- Have energy savings measures been taken up for ***other reasons*** than to save energy (e.g. environmental reasons, such as emissions, odour).
- What types of energy efficiency ***measures*** have been implemented.
- How would you rate your brewery's ***performance*** on energy efficiency?

Overhead costs of energy management

- Which people are engaged in energy management activities? What is the estimated annual ***person-hours*** devoted to energy management?
- Do you know the estimated annual **costs** devoted to energy management activities?

Hidden costs

- Are the following considered when evaluating efficiency investments? How do you take account of them?:
- overhead costs of energy management
- disruptions/hassle/inconvenience
- cost of identifying opportunities, analysing cost effectiveness, tendering and seeking approval for expenditure
- staff replacement, retirement, retraining
- potential loss of benefit (e.g. unreliability, extra maintenance, **beer quality**)
- Have there been cases when such additional costs were the reason for ***rejecting*** a project?
- Which ***technologies*** are particularly associated with such hidden costs?

Risk

- What, in your opinion, are the ***main risks*** facing your brewery (e.g. business economic trends; political decisions, take-overs)?
- What ***impact*** have these had on energy efficiency investment (e.g. through strict investment criteria)?
- Have there been cases where ***technical risk*** has inhibited the adoption of energy efficient technologies?

Equipment purchasing

- What influence do you have over ***equipment purchasing*** decisions? How does this vary between different types of equipment?
- In situations where you have an influence, what ***level of information*** is typically available on the energy performance of equipment? How difficult is it to obtain additional information on energy performance?
- In situations where you do not have an influence, do you think energy efficiency is considered? If not, why not?
- How important are written ***rules & procedures*** in purchasing decisions? Does energy efficiency feature in these rules?

Culture

- How important is ***environmental performance*** compared to cost saving in organisational decision-making on energy efficiency?

- Do you perceive any ***internal pressures*** to improve environmental performance (e.g. colleagues etc.)? How important are these pressures?
- Do you perceive any ***external pressures*** to improve environmental performance (e.g. government, media, NGOs, local community, industry sector etc.)? How important are these pressures?
- Is senior ***management aware*** of the potential for cost effective investment in energy efficiency?
- Is senior management ***seriously committed*** to improving the environmental performance of the brewery? How widely is this commitment shared throughout the brewery?
- How important have ***changes*** in management and other key posts been in changing organisational performance on energy efficiency?

Inertia/Previous Experience

- How is current practice influenced by the experience of ***previous attempts*** to improve energy efficiency?

Awareness

- Have there been any actions taken regarding energy ***awareness campaigns***, energy training and incentive schemes? If yes, how effective have these been?

Perceptions of barriers

- Many studies have suggested that there are a large number of energy efficiency opportunities that are ***highly cost effective*** at current prices. Do you think that this is the case with your brewery? If not, why not? If so, why are these opportunities not taken up?
- What do you see as the ***biggest obstacle(s)*** to improving energy efficiency in your brewery?
- Which energy savings opportunities are currently not taken up but could be profitably taken up in the future? (***wish list***)

Government Policy & ESCOs

- Do you consider ***contract energy management*** to be an attractive option for your brewery? If not, why not? If yes, then for which functions are they most appropriate?
- What are your views on the effectiveness of ***government policy*** on energy efficiency, as this impacts on your brewery?
- Do you benefit from **governmental programmes** (information, subsidies, tax breaks etc.) **in other areas**, like environmental performance?
- How should the ***government act*** to improve energy efficiency in the brewing sector? What do you consider to be the best ***instruments*** for improving energy efficiency?

Personal

- How ***long*** do you expect to remain in your current position?
- How is your ***performance*** in this position rewarded?
- Do you personally benefit from energy savings?
- What ***influence*** does this have on your choice of investment projects?
- Do you think that ***making money*** gets more recognition in this brewery than saving an equal amount of money?

- Are you motivated by ***environmental values***?

Final

- Are there any ***important points*** about this topic which we have not discussed?

REFERENCES

AKERLOF, G., 1970. "The market for lemons", *Quarterly Journal of Economics*, Vol. 84, No. 3, pp. 488-500.

ANTLE, R. and G.D. EPPEN, 1985. "Capital Rationing and Organisational Slack in Capital Budgeting", *Management Science*, Vol. 31, No. 2, pp. 163-174.

ARROW, K., 1969. "The organisation of economic activity: issues pertinent to the choice of market versus non-market allocation", *The Analysis and Evaluation of Public Expenditure: The PPB system: Vol. 1*, US Joint Economic Committee, 91st Congress, 1st Session, Washington D.C., US Government Printing Office, pp. 59-73.

BARRETT, A., J. FITZ GERALD and B. NOLAN, 2002. "Earnings Inequality, Returns to Education and Immigration into Ireland," *Labour Economics,* Vol. 9, No. 5.

BARRY, F., J. BRADLEY and E. O'MALLEY, 1999. "Indigenous and Foreign Industry: Characteristics and Performance" in F. Barry (ed.), *Understanding Ireland's Economic Growth*, London: MacMillan.

BERGIN, A., J. FITZ GERALD and I. KEARNEY, 2002. "The Macro-Economic Effects of Using Fiscal Instruments to Reduce Greenhouse Gas Emissions" paper read at conference *The Sky's the Limit: Fair and Efficient Policies on Global Warming,* December, Dublin: The Economic and Social Research Institute.

BUILDING RESEARCH ESTABLISHMENT, 2000. *Market Analysis of Energy Service Providers for Small and Medium-sized Enterprises.* Report prepared for the Energy Savings Trust, UK.

BURNS, T. and G.M. STALKER, 1961. *The Management of Innovation*, London: Tavistock Publications.

BURREL, G. and G. MORGAN, 1979. *Sociological Paradigms and Organisational Analysis: Elements of the Sociology of Corporate Life*, London: Heinemann.

CEBON, P.B., 1992. "Twixt cup and lip: organisational behaviour, technical prediction and conservation practice", *Energy Policy*, September.

CER (Commission for Electricity Regulation), 2002a. *Discussion Paper on Market Pricing.* CER/02/32, 19 March.

CER (Commission for Electricity Regulation), 2002b. *Review of Electricity Trading Arrangements – A Draft Consultation Paper.* CER/02/33. 19 March.

CHANEY, P.K., 1989. "Moral Hazard and Capital Budgeting", *The Journal of Financial Research*, Vol. 12, No. 2, pp. 113-128.

CIBSE, 1991. *Contract Energy Management, Applications Manual.* Paper AM6: 1991. The Chartered Institution of Building Services Engineers, London.

COASE, R., 1960. "The problem of social cost", *Journal of Law & Economics*, Vol. 3, No. 1, pp. 1-44.

COGEN Europe, 1999. *European Cogeneration Review 1999.* European Association for the Promotion of Cogeneration, Brussels. www.cogen.org.

CRAIG, C.S. and J.M. McCANN, 1978. "Assessing communication effects on energy conservation", *Journal of Consumer Research*, Vol. 5, pp. 82-88.

CSF Evaluation Unit, 1999. *Proposed Working Rules for Cost Benefit Analysis.* Department of Finance in Partnership with the European Commission.

CSO, (Central Statistics Office) 2000. *Census of Industrial Production 1997.* Dublin: Central Statistics Office.

CSO (Central Statistics Office), 1996, 2001. *Statistical Releases: Public Sector Employment and Earnings*, Dublin: Central Statistics Office.

DeALMEIDA, E.L.F., 1998. "Energy efficiency and the limits of market forces: The example of the electric motor market in France", *Energy Policy*, Vol. 26, No. 8, pp. 643-653.

DeCANIO, S.J., 1993. "Barriers within firms to energy efficient investments", *Energy Policy*, September, pp. 906-914.

DeCANIO, S.J., 1994. "Agency as control problems in US corporations: the case of energy efficient investment projects", *Journal of the Economics of Business*, Vol. 1, No. 1.

DeCANIO, S.J., 1998. "The efficiency gap: bureaucratic and organisational barriers to profitable energy saving investments", *Energy Policy*, Vol. 26, No. 5, pp. 441-454.

DELG (Department of the Environment and Local Government) 2000, *National Climate Change Strategy, Ireland*, Dublin: Stationery Office.

DEPARTMENT OF EDUCATION AND SCIENCE, 2002. *Statistical Report 2000/2001*. Dublin: Stationery Office.

DEPARTMENT OF ENERGY, 1983. *Energy conservation investment in industry: an appraisal of the opportunities and barriers*', by Armitage Norton Consultants, Energy Paper No. 50, London: HMSO.

DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT, 2000. *National Climate Change Strategy,* Dublin: Stationery Office, October.

DPE (Department of Public Enterprise) 1999. *Green Paper on Sustainable Energy,* Dublin: Stationery Office.

DOSI, G. and R. R. NELSON, 1994. "An introduction to evolutionary theories in economics", *Evolutionary Economics*, No. 4, pp. 153-172.

DUFFY, D., J. FITZ GERALD, J. HORE, I. KEARNEY and C. MacCOILLE, 2001. *Medium-Term Review 2001-2007*. Dublin: The Economic and Social Research Institute. (Background tables.)

EC (European Commission), 1997. *Communication from the Commission to the Council and the European Parliament, A Community strategy to promote combined heat and power (CHP) and to dismantle barriers to its development*. COM(97) 514 final, Brussels 15.10.97.

EC (2000), *Excise Duty Tables, DG Taxation and Customs Union Tax Policy* (Excise duties and transport, environment and energy taxes), Brussels: European Commission.

EEO (Energy Efficiency Office), 1993. *Organisational Aspects of Energy Management*, Good Practice Guide no. 167, London: Energy Efficiency Office.

EEO (Energy Efficiency Office), 1995. *Aspects of energy management,* General Information Guide Report 12, BRECSU, Watford.

ERM, 1998. *Limitation and Reduction of CO_2 and Other Greenhouse Gas Emissions in Ireland.* Report to the Department of Public Enterprise and to the Department of the Environment and Local Government, Dublin: Stationery Office.

EYRE, N., 1997. "Barriers to energy efficiency: more than just market failure", *Energy & Environment*, Vol. 8, Issue 1, pp. 25-43.

FAHEY, T. and J. FITZ GERALD, 1997. "The Educational Revolution and Demographic Change", in D. Duffy *et al.*, *Medium-Term Review, 1997-2003,* Dublin: The Economic and Social Research Institute.

FAWKES, S.D. and J. K. JACQUES, 1987. "Approaches to energy conservation management in beverage related industries and their effectiveness", *Energy Policy*, December.

FISHER, J., W. BLYTH, S. COLLINGS, S. BOYLE, J. WILDER, G. HENDERSON and M. GRUBB, 1998. *Prospects for Energy Saving and Reducing Demand for Energy in the UK*, paper prepared as background to the study on Energy and the Environment by the Royal Commission on Environmental Pollution. Available from http://www.rcep.org.uk.

FRIEDMAN, M., 1953. "The methodology of positive economics", in M. Friedman, *Essays in Positive Economics*, Chicago: University of Chicago Press.

FUTURE COGEN, 2001. *The Future of CHP in the European Market – The European Cogeneration Study: Ireland.* Future COGEN Country Report. Co-ordinated by ESD Ltd. http://tecs.energyprojects.net.

GALBRAITH, J. R., 1971. "Matrix organisation designs: how to combine functional and project forms", *Business Horizons*, No. 14, pp. 29-40.

GLADWIN, T.H., 1992. *Building the Sustainable Cooperation: creating environmental sustainability and competitive advantage*, Washington D.C.: National Wildlife Federation.

GOLOVE, W.H. and J.H. ETO, 1996. Market barriers to energy efficiency: a critical reappraisal of the rationale for public policies to promote energy efficiency, LBL-38059, Lawrence Berkeley Laboratory, Berkeley: University of California.

GREER, H., 1998. Personal Communication. Network Resources Limited (NRL), Dublin.

GRUBER, E. and M. BRAND, 1991. "Promoting energy conservation in small and medium-sized companies", *Energy Policy,* April.

HADDAD, B.M., R.B. HOWARTH and B. PATON, 1998. "Energy efficiency and the theory of the firm", Proceedings from the 1998 ACEEE Summer Study on Energy Efficiency in Buildings, Washington D.C.: American Council for an Energy Efficient Economy.

HAITES, E. F. and A. ROSE (eds.) 1996. "Energy and greenhouse gas mitigation: the IPCC Report and beyond", *Energy Policy (special issue)*, Vol. 24, Nos 10/11, October/November.

HARRIS, P.S., 1979. *Energy Audit Series, No. 8 – The Brewing Industry*, issued jointly by the UK Department of Energy and Department of Industry, London: HMSO.

HARRIS, R, and J. CARMAN, 1983. "Public regulation of marketing activity: Part 1: institutional typologies of market failure", *Journal of Macromarketing*, Spring, pp. 49-58.

HASSETT, K.A. and G.E. METCALF, 1993. "Energy conservation investment: Do consumers discount the future correctly?", *Energy Policy,* June, pp. 710-716.

HATCH, M.J., 1997. *Organisational Theory: Modern, Symbolic and Postmodern Perspectives*, Oxford: Oxford University Press.

HEA (Higher Education Authority), 1999. *Reports, Accounts 1995 and 1996*. Dublin.

HEIN, L. and K. BLOK, 1994. "Transaction costs of energy efficiency improvement", Proceedings European Council for an Energy-Efficient Economy.

HENNESSY, M., 1994. "The Economics of CHP projects in the private sector" in Commercial and Industrial Small Scale CHP, proceedings of a THERMIE seminar, Dublin: Irish Energy Centre.

HERRING, H., 1996. "Is energy efficiency good for the environment: some conflicts and confusions?" Published in Gordon MacKerron and Peter Personas (eds.), *The UK Energy Experience: a model or a warning*? (Imperial College Press) March, pp. 327-338.

HEWETT, M.J., 1998. *Achieving energy efficiency in a restructured electric utility industry*, Report prepared for Minnesotans for an Energy Efficient Economy, Minneapolis, MN.: Center for Energy and Environment.

HIGHER EDUCATION FUNDING COUNCIL FOR ENGLAND *et al.*, 1996. *Energy management study in the higher education sector: management review guide*, HEFCE, Bristol.

HIRST, E. and BROWN, M., 1990. "Closing the efficiency gap: barriers to the efficient use of energy", *Resources, Conservation and Recycling*, Vol. 3, pp. 267-281.

HODGSON, G.M., 1988. *Economics and institutions: a manifesto for a modern institutional economics*, Cambridge: Polity Press.

HOLTI, R. and D. NICOLINI, 1998. *Understanding the take up of advanced energy technology*, publishable final report for the project "Social & organisational issues in the adoption of advanced energy technologies in manufacturing", London: Tavistock Institute.

HOWARTH, R.B. and B. ANDERSSON, 1993. "Market Barriers to Energy Efficiency", *Energy Policy*, Vol. 21, No. 8, pp. 262-272.

HOWARTH, R.B. and A.H. SANSTAD, 1995. "Discount rates and energy efficiency", *Contemporary Economic Policy*, (ISSN 1074-3529), Vol. XIII, July, pp. 101-109.

HOWARTH, R.B., B.M. HADDAD and B. PATON, 2000. "The economics of energy efficiency: insights from voluntary participation programmes", *Energy Policy*, Vol 28, No. 6-7, June.

HUNTINGTON, H.G., 1994. "Been top down so long it looks like bottom up to me", *Energy Policy*, Vol. 22, No. 10, pp. 833-839.

HUNTINGTON, H.G., L. SCHIPPER and A. H. SANSTAD, 1994. "Editor's introduction", *Energy Policy*, Vol. 22, No. 10, pp. 795-797.

IEA (International Energy Agency), 2000. *Concept paper – Performance Contracting Task,* IEA Technologies on p. 4 of website http://dsm.iea.org/.

IEC (Irish Energy Centre), 2001. *An Examination of the Future Potential of CHP in Ireland.* Consultation report commissioned by the Government.

IEC (Irish Energy Centre), 2002. *CHP and District Heating – Research, Development and Demonstration Programme Strategy.* Consultation document.

INTERLABORATORY WORKING GROUP, 1997. *Scenarios of Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond*, Office of Energy Efficiency and Renewable Technologies, Department of Energy, Washington D.C.

IPTS (Institute for Prospective Technological Studies), 2000. *Preliminary Analysis of the Implementation of an EU-Wide Permit Trading Scheme on CO_2 Emissions Abatement Costs – Results from the POLES Model*, Brussels: Directorate-General Joint Research Centre.

IRISH ENERGY CENTRE, 1996a. *Building Energy Management Systems*, Good Practice Guide 1.

IRISH ENERGY CENTRE, 1996b. *Motive Power Applications*, Good Practice Guide 2.

IRISH ENERGY CENTRE, 1998. *Final Report – Survey of energy usage in Ireland*, March.

JACAARD, M. and W. D. MONTGOMERY, 1996. "Costs of reducing greenhouse gas emissions in the USA and Canada", *Energy Policy*, Vol. 24, Nos 10/11, pp. 889-898.

JAFFE, A.B. and R.N. STAVINS, 1994a. "Energy-efficiency investments and public policy", *The Energy Journal*, Vol. 15, No. 2, pp. 43-65.

JAFFE, A.B. and R.N. STAVINS, 1994b. "The energy-efficiency gap: What does it mean?", *Energy Policy*, Vol. 22, No. 10, pp. 804-810.

JOCHEM, E. and E. GRUBER, 1990. "Obstacles to rational electricity use and measures to alleviate them", *Energy Policy*, May, pp. 340-350.

JOHNSON, B.E., 1994. Modelling energy technology choices: which investment tools are appropriate?, *Energy Policy*, Vol. 22, No. 10, pp. 877-883.

KAHNEMAN, D. and A. TVERSKY, 1979. "Prospect theory: an analysis of decision making under risk", *Econometrica*, Vol. 47, pp. 263-291.

KATZEV, R. and T. JOHNSON, 1987. *Promoting energy conservation: an analysis of behavioural research*, Boulder: Westview Press.

KEMPTON, W., C. K. HARRIS, J. G. KEITH and J.S. WEIHL, 1984. "Do consumers know what works in energy conservation?", in J. Harris and C. Blumstein (eds.), *What works: encouraging energy conservation in buildings*, Washington D.C.: American Council for an Energy Efficient Economy.

KEMPTON, W. and L. MONTGOMERY, 1982. "Folk quantification of energy", *Energy*, Vol. 7, No. 10, pp. 817-827.

KOMOR, P.S. and R. KATZEV, 1988. "Behavioural determinants of energy use in small commercial buildings; Implications for energy efficiency", *Energy Systems and Policy,* Vol. 12, pp. 233-242.

KOMOR, P.S. and L.L. WIGGINS, 1988. "Predicting conservation choice: beyond the cost-minimization assumption", *Energy*, Vol. 13, No. 8, pp. 633-645.

KOOMEY, J.G. and A.H. SANSTAD, 1994. "Technical evidence for assessing the performance of markets affecting energy efficiency", *Energy Policy*, Vol. 22, No. 10, pp. 826-832.

KOOMEY, J.G. *et al.,* 1996. "Energy-efficient lighting: Market data, market imperfections, and policy success", *Contemporary Economic Policy* (ISSN 1074-3529), Vol XIV, July, pp. 98-111.

KRAUSE, F., 1996. "The costs of mitigating carbon emissions: a review of methods and findings from European studies", *Energy Policy*, Vol. 24, No. 10/11, pp. 899-915.

LAWRENCE, P. R. and J. W. LORSCH, 1967. "Differentiation and integration in complex organisations", *Administrative Science Quarterly*, Vol. 12, pp. 1-47.

LEVINE, M.D., E. HIRST, J. KOOMEY, J. McMAHON and A. SANSTAD, 1994. *Energy efficiency, market failures and government policy*, Lawrence Berkeley Laboratory and Oak Ridge Laboratory, LBL 35376, ORNL/CON-383.

LOVINS, A.B. and L.H. LOVINS, 1997. *Climate: Making Sense and Making Money*, Colorado: Rocky Mountain Institute, CO.

LUTZENHISER, L., 1993. "Social and behavioural aspects of energy use", *Annual review of Energy and the Environment*, Vol. 18, pp. 247-289.

OECD (Organisation for Economic Co-operation and Development), 2003. *Environmentally Sustainable Buildings – Challenges and Policies.* Paris: OECD.

McCOY, D. and S. SCOTT, 2002. *Green and bear it? Implementing market-based policies for Ireland's environment*, Conference proceedings, Dublin: The Economic and Social Research Institute.

McLANEY, E.J., 1994. *Business Finance for Decision Makers*, 2nd Edition, London: Pitman Publishing.

MARCH, J. G., 1978. "Bounded rationality, ambiguity and the engineering of choice", *Bell Journal of Economics*, Vol. 9, pp. 587-608.

MARCH, J. G. and H. SIMON, 1958. *Organisations*, New York: John Wiley & Sons.

METCALF, G.E., 1994. "Economics and rational conservation policy", *Energy Policy*, Vol. 22, No. 10, pp. 819-825.

MILGROM, P. and J. ROBERTS, 1992. *Economics, Organisation and Management*, New Jersey: Prentice Hall.

MODIGLIANI, F. and M.H. MILLER, 1958. "The cost of capital, corporate finance and the theory of investment, *American Economic Review*, Vol. 48, pp. 261-297.

MOHLO, I., 1998. *The Economics of Information: lying and cheating in markets and organisations*, London: Blackwell.

MORGAN, G., 1986. *Images of organisation*, London: Sage.

NARAYANAN, M.P., 1985. "Observability and the payback criterion", *Journal of Business*, Vol. 98, No. 3, pp. 309-323.

NELSON, R. and S. WINTER, 1982. *An Evolutionary Theory of Economic Change*, Cambridge: Belknap Press.

NICHOLS, A.L., 1994. "Demand-side management: Overcoming market barriers or obscuring real costs?", *Energy Policy*, Vol. 22, No. 10, pp. 840-847.

OECD, 2003. Environmentally Sustainable Buildings – Challenges and Policies. Paris: OECD.

OLSON, M., 1971. The Logic of Collective Action: public goods and the theory of groups, Cambridge, MA: Harvard University Press.

PIATTELLI-PALMARINI, M., 1994. *Inevitable illusions: how mistakes of reason rule our minds*, New York: John Wiley & Sons.

PINDYCK, R.S., 1991. "Irreversibility, uncertainty and investment", *Journal of Economic Literature*, Vol. 29, No. 2, pp. 1110-1148.

PINDYCK, R.S. and D.L. RUBINFELD, 1998. *Microeconomics*, USA: Prentice Hall.

PRENDERGAST, C., 2002. "Consumers and Agency Problems", *Economic Journal*, Vol. 112, No. 478, March.

RIGHTER, R., 1998. "Visionary banker sets free powerless poor", *The Times*, October 31st.

ROBINSON, J.B., 1991. "The proof of the pudding: Making energy efficiency work", *Energy Policy*, September, pp. 631-645.

ROSS, M., 1986. "The capital budgeting practices of 12 large manufacturing firms", *Financial Management*, Vol. 15, No. 4, pp. 15-22.

ROWLINSON, M., 1997. *Organisations & institutions: perspectives in economics and sociology*, Basingstoke: Macmillan Business.

SANSTAD, A.H., C. BLUMSTEIN and S.E. STOFT, 1995. "How High Are Option Values in Energy Efficiency Investments?", *Energy Policy*, Vol. 23, No. 9, pp. 739-743.

SANSTAD, A.H. and R.B. HOWARTH, 1994a. "'Normal' markets, market imperfections and energy efficiency", *Energy Policy*, Vol. 22, No. 10, pp. 811-818.

SANSTAD, A.H. and R.B. HOWARTH, 1994b. *Consumer Rationality and Energy Efficiency*, ACEEE Summer Study on Energy Efficiency in Buildings, ACEEE.

SCHEIN, E.H., 1985. *Organisational culture and leadership*, San Francisco: Jossey-Bass.

SCOTT, S., 1995. "LRMC and charging the polluter", in *UTILITIES POLICY,* Vol. 5, No 2, Butterworth-Heinemann Ltd.

SCOTT, S., 1997. "Household energy efficiency in Ireland: A replication study of ownership of energy saving items", *Energy Economics*, Vol. 19, pp. 187-208.

SCOTT. S., 1999. "Fiscal Measures for a Sustainable Energy Economy – Ten Fears about a Carbon Tax", Chapter 5, *Sustainable Energy and the Environmental Imperative,* Dublin: Institute for European Affairs.

SCOTT, W. R., 1987. *Organisations: rational natural and open systems*, Englewood Cliffs: Prentice Hall.

SELIGMAN, C., L. J. BECKER, and L. J. DARLEY, 1981. "Encouraging residential energy conservation through feedback", in A. Baum and J. E. Singer (eds.) *Advances in Environmental Psychology,* Vol. 3*,* pp. 93-113.

SHOVE, E., 1995. "Gaps, barriers and conceptual chasms", *in The Energy Efficiency Challenge for Europe*, proceedings of the European Council for an Energy Efficient Economy, 1995 Summer Study 6-10 June.

SIMON, H.A., 1957. *Models of Man*, New York: Wiley.

SIMON, H.A., 1959. "Theories of decision-making in economics and behavioural science", *The American Economic Review*, Vol. XLIX, No. 3, June, pp. 253-283.

SIMON, H.A., 1986. "Rationality in psychology and economics", *Journal of Business*, No. 59, pp. 209-224.

SMITH, P. G., 1993. *Obstacles to the uptake of energy efficiency measures in the UK light industrial sector.* Unpublished M.Sc. Thesis, Science Policy Research Unit (SPRU), University of Sussex.

SMITH, A. and S. SORRELL, 2000. "Interaction between environmental policy instruments: carbon emissions trading and Integrated Pollution Prevention and Control", *International Journal of Environment and Pollution*, Vol. 13, No. 4, June.

SMYTH, D., 2000. Personal communication, derived from the data bank of the Energy Policy Research Centre at The Economic and Social Research Institute, Dublin.

SORRELL, S., 1999. *BARRIERS – Work Package 2B: Interview protocol for the higher education sector*, a report to DG XII under the JOULE project "Barriers to energy efficiency in public and private organisations", SPRU, February.

SORRELL, S., 2000a. *Barriers to energy efficiency in the UK higher education sector,* a report to DG Research under the JOULE project "Barriers to energy efficiency in public and private organisations", SPRU, August.

SORRELL, S., 2000b. *Barriers to energy efficiency in the UK brewing sector,* a report to DG Research under the JOULE project "Barriers to energy efficiency in public and private organisations", SPRU, September.

SORRELL, S., 2000c. *Barriers to energy efficiency in the UK mechanical engineering sector,* a report to DG Research under the JOULE project "Barriers to energy efficiency in public and private organisations", SPRU, October.

SORRELL, S., J. SCHLEICH, S. SCOTT, E. O'MALLEY, F. TRACE, U. BOEDE, K. OSTERTAG and P. RADGEN, 2000. *Reducing Barriers to Energy Efficiency in Private and Public Organisations – Final Report*, a report to DG XII (Science, Research and Development) of the European Commission under the Non-Nuclear Energy *JOULE* program of the Fourth Framework Program. http://www.sussex.ac.uk/spru/publications/reports/ barriers/final.html.

STATIONERY OFFICE, 1999. *Electricity Regulation Act, 1999*. Dublin: Stationery Office.

STATIONERY OFFICE, 1999a. *Ireland – National Development Plan 2000-2006*, Dublin: Stationery Office.

STATIONERY OFFICE, 2001. *Electricity (Supply) (Amendment) Act, 2001,* Dublin: Stationery Office.

STATMAN, M., 1982. "The persistence of the payback permit: a principal agent perspective", *The Engineering Economist*, Winter, Vol. 27, No. 2, pp. 95-100.

STATMAN, M. and J.F. SEPE, 1984. "Managerial incentive plan and the use of the payback method", *Journal of Business Finance & Accounting*, Spring, Vol. 11, No. 1, pp. 61-65.

STERN, P.C., 1984. *Energy use: the human dimension*, New York: W.H. Freeman.

STERN, P.C., 1986. "Blind spots in policy analysis: What economics doesn't say about energy use", *Journal of Policy Analysis and Management*, Vol. 5, No. 2, pp. 200-227.

STERN, P.C., 1992. "What psychology knows about energy conservation", *American Psychologist*, Vol. 47, pp. 1224-1232.

STERN, P.C., E. ARONSON and J.M. DANLEY, 1987. "Answering behavioural questions about energy efficiency in buildings", *Energy,* Vol. 12, No. 5, pp. 339-353.

STIGILITZ, G. and A. WEISS, 1981. "Credit rationing in market with imperfect information", *American Economic Review*, Vol. 71, pp. 393-409.

SUTHERLAND, R.J., 1991. "Market barriers to energy efficiency investments", *The Energy Journal*, Vol. 12, No. 3, pp. 15-34.

SUTHERLAND, R.J., 1994. "Energy efficiency or the efficient use of energy resources?", *Energy Sources*, Vol. 16, pp. 257-268.

SUTHERLAND, R.J., 1996. "The economics of energy conservation policy", *Energy Policy*, Vol. 24, No. 4, pp. 361-370.

THALER, R.H., 1991. *Quasi Rational Economics*, New York: Russell Sage Foundation.

THOMPSON, P. B., 1997. "Evaluating energy efficiency investments: accounting for risk in the discounting process", *Energy Policy*, Vol. 25, No. 12, pp. 989-996.

TIETENBERG, T., 1996. *Environmental and Natural Resource Economics*, 4th edition, New York: Harper Collins.

TRAIN, K., 1985. "Discount rates in consumers' energy related decisions: A review of the literature", *Energy*, Vol. 10, No. 12, pp. 1243-1253.

WARREN, A., 1987. "Saving megabucks by saving megawatts", *Energy Policy*, December, pp. 522-537.

WEBER, L., 1997. "Some reflections on barriers to the efficient use of energy", *Energy Policy*, Vol. 25, No. 10, pp. 833-835.

WELFORD, R., 1997. *Corporate Environmental Management* 2, London: Earthscan.

WILLIAMSON, O., 1985. The Economic Institutions of Capitalism, New York: Free Press.

WINETT R.A., I.N. LECKLITER, D.E. CHINN and B. STAHL, 1984. "Reducing Energy-Consumption – The Long-Term Effects of a Single TV Program", *Journal of Communication*, Vol. 34, No. 3, pp. 37-51.

YIN, R.K., 1994. *Case study research: design and methods*, second edition, London: SAGE publications.