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The economics of energy efficiency: Barriers to profitable investments

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ABSTRACT

Improving energy efficiency is seen as a core strategy for a sustainable energy system, because it may contribute to cost savings for companies and private households, cost-effectively reduces greenhouse gas emissions and other pollutants, increases security of supply for required energy services. The thrust of engineering-economic analyses suggests that there is a large potential for energy efficiency measures that are also profitable, but – because of barriers to energy efficiency – are not being adopted. This paper presents a taxonomy of these barriers, distinguishing between barriers that would warrant policy intervention and those that do not. As a case study, barriers to energy efficiency in the German higher education sector and measures to overcome those barriers are discussed.

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The economics of energy efficiency: barriers to profitable investments

1. Motivation

In October 2006, the European Commission published its Action Plan for Energy Efficiency (European Commission 2006a) to help realise savings in energy use in the European Union of at least 20 percent by 2020 compared to the baseline. The Action Plan outlines a framework of policies and measures for all end-use sectors (residential, tertiary, industry, transportation) and the transformation sector to improve energy efficiency. This was previously called for in the Commission Green Paper on “A European Strategy for Sustainable, Competitive and Secure Energy” in March 2006 (European Commission 2006b) and the 2006 Spring European Council Presidency Conclusions (European Council 2006). Improving energy efficiency, that is, obtaining more energy services such as heat, light or mobility for the same or less energy, is seen as the fastest and often most cost-efficient way to achieve a sustainable energy system.

According to the European Commission (2006a), the 20 percent energy savings by 2020 are in addition to savings induced by price effects, structural change in the economy, natural replacement of technology, and measures already in place. Results from technology-based, engineering-economic (bottom-up) modelling analyses suggest that in total, the energy savings compared to the baseline scenario would mean annual savings of around 390 million tonnes of oil equivalent (Mtoe), most of it in the end-use sectors. The residential and commercial buildings sector exhibits the largest relative cost-effective potentials – 27 percent and 30 percent, respectively. The most important measures include retrofitted wall and roof insulation for residential buildings and improved energy management systems in commercial buildings. Energy savings in industry amount to 25 percent, where measures not specific to the industry concerned – such as high efficient motors, fans, and lighting – offer the most important savings potential. Finally, the estimated savings of 26 percent in the transport sector are – to a large extent – the result of shifting to other modes of transportation.

These savings in energy use correspond to direct energy cost savings of more than €100 billion per year by 2020¹, which the Commission estimates to more than compensate the additional costs for the required investments in energy efficiency over time. Energy cost savings would then translate into improved competitiveness for companies and lower expenses on energy for households, making companies and households less vulnerable to energy price hikes in the future.

The 20 percent potential in 2020 corresponds to reductions in CO₂-emissions of 780 million tonnes, which would be more than twice the reductions required by the Kyoto Protocol by 2012 for the European Union (European Commission 2006a). In general, most other studies also find improved energy efficiency to be the single largest source of fossil fuel-related greenhouse gas emissions savings, at least until 2050. Typically, energy efficiency tends to account for 30-50 percent of all emission reductions in such technology-based models (HM Treasury 2006, IEA 2006a, IPCC 2001).

Ongoing geopolitical crises such as conflicts in the Middle East and recent disputes over gas supply from Russia to Ukraine and Belarus have led to an increased focus on the volatility of international



Joachim Schleich

¹ At \$ 48/barrel.

Higher energy efficiency will reduce import dependency and increase security of supply.

energy markets and the security of supply. By 2030, more than 80 percent of the natural gas and more than 90 percent of the oil used in the EU will be imported, most of it from politically sensitive regions (European Commission 2006b). Obviously, increased energy efficiency will reduce import dependency and increase security of supply for required energy services.

Investments in energy efficiency will bring other benefits, notably a decline in other, local, pollutants such as nitrogen oxides and sulphur. Also, substituting fuel imports for investments in energy efficiency, tends to increase domestic production and employment, in particular in the construction, electrical, and mechanical engineering sectors. Finally, improved energy efficiency at home may also lead to increased export opportunities for new, energy-efficient technologies via first-mover-advantages.

The modelling results, on which the Action Plan for Energy Efficiency is based, suggest that there is a large potential of energy-efficient measures – an energy efficiency gap – which may be realised at low or even negative costs (so called ‘no-regret’ potential). This raises several questions (see also Sorrell *et al.* 2004).

First, do individuals and organisations really ‘leave money on the floor’ by neglecting cost-effective measures to improve energy efficiency? Second, what is the nature of the ‘barriers’ to energy efficiency, that is, the mechanisms which inhibit a decision or behaviour that appears to be both energy efficient and profitable under existing (and expected) economic conditions? Third, do these barriers hinder an efficient resource allocation? And, if so, can these barriers be overcome by adequate policy intervention?

These questions lie at the heart of recent and current policy debates over energy and climate policies and are a focus of continuing dispute within energy economics, with purely technology-based bottom-up modellers on one side of the spectrum, and rather aggregate economic top-down models on the other side. To verify the claims of bottom-up type modelling, it would first be necessary to show that barriers explain the lack of investment in cost-effective energy-efficient technologies; second, that these barriers should be overcome because they inhibit economic efficiency; and third that they could be cost-effectively overcome by non-price measures, which would be the case if the benefits from implementing those measures outweigh the costs.

The remainder of the paper is organised as follows. Section 2 briefly portrays recent historic trends in energy efficiency and the underlying reasons. It also includes a short description of the main differences between bottom-up and top-down models and their implications. Section 3 offers a taxonomy of barriers to energy efficiency based on neoclassical, institutional, and behavioural economics. Barriers that hinder economic efficiency and thus might be addressed by policy intervention will be identified. As an illustration, Section 4 presents results from a case study on barriers to energy efficiency in the German higher education sector and includes suggestions for policies to overcome those barriers. The concluding section points to limitations and future research.

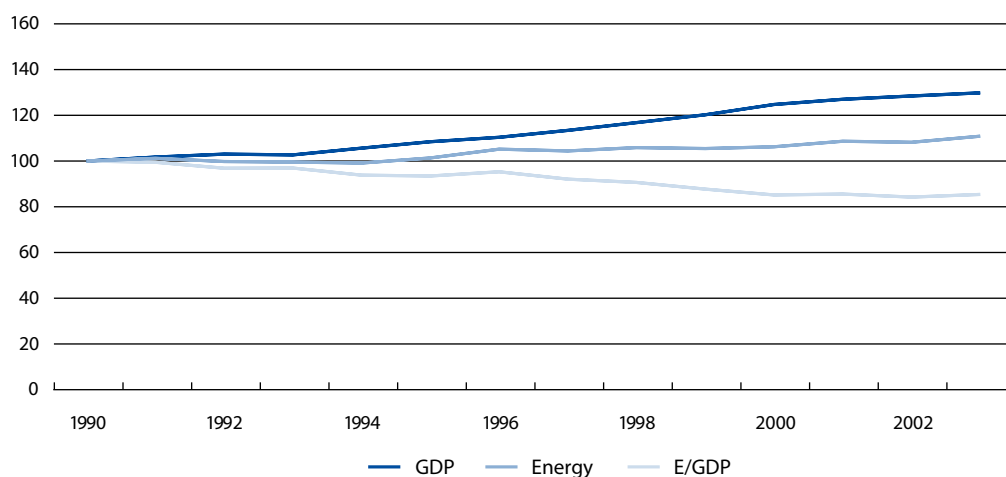
2. Trends in energy efficiency and approaches to energy modelling

A common indicator to portray and compare energy performance over time and across regions at a rather aggregate level is energy intensity, i.e., the quantity of energy use divided by gross domestic product (GDP). Since improvements in energy efficiency in processes and equipment will translate into observed changes in energy intensity, energy intensity is often used as a proxy for energy

efficiency. When there is structural change in the economy – for instance, an increase in the share of the (less energy-intensive) services sectors such as banking or insurance services and a decrease in (energy-intensive) manufacturing sectors such as steel or cement production – the observed energy intensity would change, even if the quantity of energy used to produce one tonne of steel or cement remains unchanged. This should be kept in mind when looking at the development of energy intensities in the EU and the United States in Figure 1 and Figure 2. In both regions energy intensity decreased in the 1990s, but has almost been stagnating since then. For the EU-25, the average annual reduction in energy intensity since 1990 is 1.2 percent compared to 1.8 percent for the United States and 1.6 percent for all OECD countries. Lower reduction rates in the EU may be rationalised by the lower starting level in 1990 and the fact that additional reductions become increasingly more difficult to achieve.

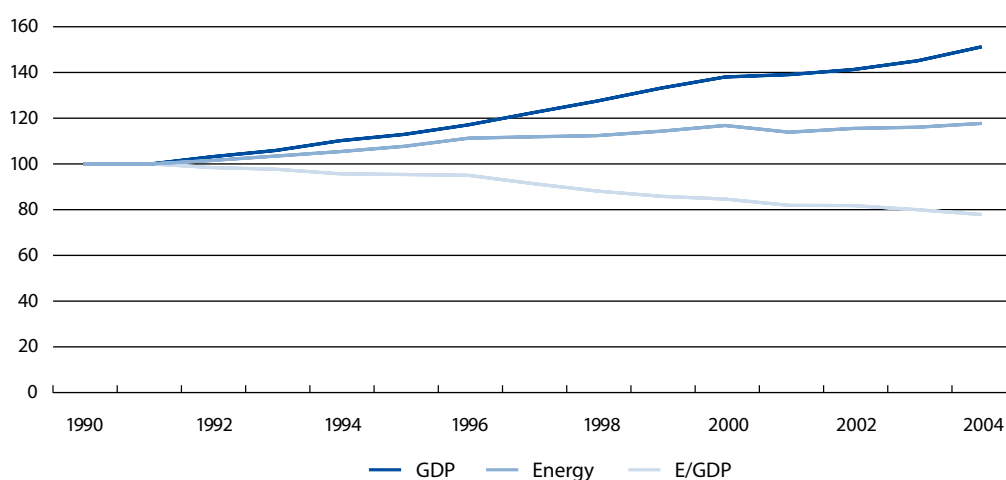
In the 1990s, energy intensity declined in the EU and the United States, but has stagnated since then.

Figure 1. Energy intensity in the EU 25 (1990=100)



Source: Own calculations based on data provided by EUROSTAT

Figure 2. Energy intensity in the United States (1990=100)



Source: Own calculations based on data provided by Energy Information Agency

**The targeted reduction
in energy intensity
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In its latest World Energy Outlook, the IEA (2006b) assumes that until 2030 the average annual reduction in energy intensity in the EU will be 1.3 percent in the baseline scenario, which is based on existing policies to enhance energy efficiency. With an implementation of additional policies currently considered in those countries, the annual average reduction is expected to be 1.6 percent. The estimates by the European Commission as given in the Action Plan for Energy Efficiency (European Commission 2006a) are more optimistic: in the baseline scenario, the rate is 1.8 percent; but with an implementation of the Action Plan and, thus, energy savings of 20 percent compared to the baseline, energy intensity is expected to fall at an annual average rate of 3.3 percent. Thus, in light of historic developments and of estimates by other organisations, the implied reduction in energy intensity in the Action Plan for Energy Efficiency appears to be quite ambitious.

Against this background, it is useful to sketch different approaches to energy modelling. Energy and climate policy makers are typically interested in the influence of proposed policies (for instance, taxes on energy or CO₂ emissions) on individuals' and companies' decisions. In particular, they want to know the effectiveness and the costs of these policies. Historically, two types of models were developed to address these questions: 'bottom-up' models and 'top-down' models.

Conventional bottom-up models are engineering-economic models that describe current and future energy demand and supply technologies in detail. They simulate the ageing and replacement of these technologies, thereby assuming that the cost of meeting the demand for energy services (from all end-use sectors) are minimised. Bottom-up models allow for 'no-regret' opportunities and are able to portray the possibilities for a radically different technology stock in the future. However, bottom-up models have been criticised for their lack of adequately describing microeconomic decision-making behaviour of companies and individuals (for example, they do not allow for transaction costs) and their lack of macroeconomic feedback – such as income effects, price effects, or international trade².

In contrast, macroeconomic top-down models are able to model microeconomic behaviour and macroeconomic feedback mechanisms, but are more aggregate. Rather than including specific technologies, top-down models indirectly reflect production possibilities via production or cost functions, elasticities of substitution (between capital, labour, and energy), and parameters reflecting technological progress over time. As a result, they allow for the decoupling of GDP and energy as shown in Figure 1 and Figure 2. Computable General Equilibrium (CGE) models, which have come to dominate the top-down approach in recent years, typically imply that agents react perfectly rational to prices and also that markets are always in equilibrium (abstracting, for example, from unemployment). By design, CGE models do not allow for no-regret opportunities, which is one of the reasons why top-down models tend to show higher costs of climate policy than bottom-up models.

As summarised by Hourcade *et al.* (2006), conventional bottom-up models perform well in terms of technological explicitness, but they lack microeconomic realism and – in particular – macroeconomic completeness. In contrast, conventional top-down models perform well in terms of macroeconomic completeness, but to some extent lack microeconomic realism and entirely lack technological explicitness. In recent years, substantial modelling efforts have been made to reconcile the bottom-up and top-down approaches via hybrid models. Some top-down models now specifically represent energy-supply and energy-demand technologies, and allow for technological change to be included explicitly – rather than through a time trend or a fixed coefficient. Some bottom-

² For a brief overview see also Hourcade *et al.* (2006).

up models have made considerable progress towards including behavioural parameters to better portray microeconomic decision making.³ Likewise, top-down models and bottom-up models may be linked to get the best of both worlds. For example, the results of a bottom-up model (for example, investments in and prices for energy) enter a top-down model as an input. Ideally, the results of a top-down model are then fed back to the bottom-up model; this process is iterated until convergence is achieved.

Achieving the ambitious targets of the European Commission's Action Plan for Energy Efficiency and the considerable potential for energy savings often suggested by bottom-up models is perhaps less daunting than one may think at first glance if there are easy to remove barriers to energy efficiency. But what is the nature of such barriers, and are they easy to remove? We shall see next.

... but achieving it is perhaps possible if there are easy to remove barriers to energy efficiency.

3. Taxonomy of barriers to energy efficiency⁴

This section develops a taxonomy of barriers to energy efficiency, drawing on concepts from neo-classical economics, institutional economics (principal-agency theory and transaction cost economics), and behavioural economics. These barriers and their implications are described – without formally developing their grounding within the various strings of economic theory, but noting that there is a great deal of overlap between these concepts.⁵ The barriers to be discussed represent potential answers to one or more of the following questions:

- Why do organisations impose very stringent investment criteria for projects to improve energy efficiency?
- Why do organisations neglect projects that appear to meet these criteria?
- Why do organisations neglect energy-efficient and apparently cost-effective alternatives when making broader investment, operational, maintenance, and purchasing decisions?

Table 1 presents an overview of barriers to energy efficiency as developed by Sorrell *et al.* (2004).

In any case though, such barriers are more likely to be found in organisations where the share of energy costs in total production costs is low – such as in the services sectors, public administrations, or in industries like mechanical engineering and the food sectors. In contrast, the considerable importance of energy costs in energy-intensive industries – electric power, iron and steel, and mineral processing, for example – provides a strong economic incentive to find and realise efficiency potentials. Likewise, since investing in energy efficiency directly affects the core production processes in energy-intensive companies, energy use is automatically considered in investment decisions. Bearing this in mind, let us examine various barriers one by one.

³ A Special Issue of *The Energy Journal* (October 2006) is devoted to hybrid modelling of energy-environment policies. Likewise, the Special Issue of *The Energy Journal* (March 2006) presents several innovative ways to model technological change in (long-run) climate policy analyses (Endogenous Technological Change and the Economics of Atmospheric Stabilisation, Special Issue, *The Energy Journal*, March 2006).

⁴ Parts of this section summarise the main concepts and arguments presented in Sorrell *et al.* (2004).

⁵ See, for example, Chapter 2 in Sorrell *et al.* (2004) for a thorough development of these concepts in relation to barriers to energy efficiency.

Table 1. Taxonomy of barriers to energy efficiency

Barrier	Claim
Risk	Short paybacks required for energy efficiency investments may reflect a rational response to higher technical or financial risk and business and market uncertainty.
Imperfect information	Lack of information on energy efficiency opportunities may lead to cost effective opportunities being missed.
Hidden costs	Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficiency technologies, or the additional costs associated with them. As a consequence, the studies may overestimate the energy efficiency potential. Hidden costs (to observer!) include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing, and applying information.
Access to capital	If organisation cannot raise sufficient external funds, energy-efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules, and the short-term incentives of energy management staff.
Split incentives	Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. For example, if individual departments within an organisation are not accountable for their energy use, they will have no incentive to improve energy efficiency.
Bounded rationality	Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in classical economic models. As a consequence, they may neglect energy efficiency opportunities, even when given good information and appropriate incentives.

Source: Based on Sorrell *et al.* (2004).

3.1 Risk

Although high discount rates are often observed for investments in energy efficiency, they are not a source of the energy efficiency gap per se.

High (implied) discount rates are often observed for investments in energy efficiency. In essence though, high discount rates are merely a restatement and not a source of the energy efficiency gap *per se*. Instead, stringent investment criteria and the rejection of particular energy-efficient technologies may represent a rational response to risk. In particular, they may result from financial risks such as business-specific risk, general economic risk (business cycle, inflation, interest rates, exchange rates, and so on), potential changes in government policy, trends in input and output markets (fuel and electricity prices, for example) or financing risk (an anticipated reaction of capital markets to increases in borrowing, for example). Also, there may be technical risks – unreliability, for instance – associated with individual technologies.

This being said, what matters for the debate about investment barriers is whether or why investments in energy efficiency would carry higher risks than other investments, and therefore would be systematically overlooked. If energy-efficient technologies are unreliable, the risk of breakdowns and disruptions could outweigh any potential benefits from reduced energy costs. Ignoring these

technologies is not only perfectly rational but also avoids inefficient outcomes. However, if these – often new and unfamiliar – technologies are wrongly perceived to be unreliable, government funded demonstration programmes aimed at increasing confidence and disseminating information and awareness among potential adopters might be justified. Interestingly enough though, many of the technologies that are included in engineering-economic models and recommended in energy efficiency publications are well proven, reliable, and widely used. Examples include energy-efficient lighting and motors, condensing boilers, thermal insulation, thermostatic radiator valves, and lighting controls.

Next, since energy efficiency investments are normally embedded within buildings and equipment, costly to remove and with limited scope for subsequent resale, they may carry a higher financial risk (see Sutherland 1991, for instance). For example, they may require higher hurdle rates because compared to stock and bonds they are ‘illiquid’ and irreversible, with limited scope for diversifying risks. While this argument may account for the differing treatment of ‘liquid’ and ‘illiquid’ assets, it fails to account for the differing treatment of comparable assets. For example, it could not explain why cost-saving energy efficiency investments should be subject to more stringent investment criteria than investment in a new production plant, when the latter is equally illiquid and irreversible.

Finally, postponing irreversible investments in energy efficiency may be optimal if future energy prices are uncertain (Hasset and Metcalf 1993; van Soest and Bulte 2001). For example, investing in a more energy-efficient technology may turn out to be unprofitable if energy prices fall after the new technology has been implemented. Hence, there is an option value associated with postponing investments (McDonald and Siegel 1986; Dixit and Pindyck 1994). However, this approach fails to account for the potential costs of delaying energy efficiency investments. For example, it is much more costly to retrofit heat recovery systems than to include them when a plant or building is designed. Since most decisions relevant to energy efficiency involve a choice between efficient and inefficient options within an investment that is being made for other purposes, the scope of this approach to explaining why allegedly viable investments in energy efficiency are not made may be limited.⁶

Postponing irreversible investments in energy efficiency may be optimal if future energy prices are uncertain.

To conclude, the argument that high discount rates can be considered a rational response to risk for all types of energy efficiency investment does not seem plausible. However, depending on the application, business, technical, or regulatory risks might be relevant barriers. If high discount rates are due to business or actual technical risks, they can be taken to reflect an economically efficient response of private decision makers and, thus, there does not seem to be a relevant barrier. If they are due to regulatory or misperceived technical risks, however, there might be relevant barriers that merit a policy intervention.

3.2 Imperfect information

If individuals lack adequate information on either energy efficiency opportunities or the energy performance of technologies, they may underinvest in energy efficiency. Conceptually, information problems possibly hindering energy efficiency investment can be grouped into three broad categories.

⁶ See Howarth and Sanstad (1995) for further criticism of the option-value approach to explaining the energy-efficiency gap.

First, there could be inadequate information on the level and pattern of current energy consumption. The availability of such information depends on the information content of utility bills, the level of sub-metering, the availability of relevant benchmarks, the use of computerised information systems, the time devoted to analysing consumption information, and so on. Gathering and analysing information on current energy consumption is associated with investment, operational, and staff costs, which can be seen as a particular category of transaction costs. Typically, these costs are not taken into account in engineering-economic models.

Second, there could be imperfect information on specific energy-saving opportunities – such as the retrofit of thermal insulation. Information on energy-specific investment opportunities within an organisation consists of two components. One concerns the extent to which organisations have evaluated energy efficiency opportunities, for example through energy audits. Since the value of an audit becomes known only after the audit has been carried out, it can only be judged with hindsight whether an audit was actually useful or not. In this sense, it is unlikely that the market produces an efficient outcome (Goldstone 1995). The other component refers to the availability of information on the costs and performance of specific energy-saving technologies. Since the search costs for energy-efficient technologies are likely to be much greater than those for energy commodities (electricity, gas, fuel oil, and so on), individuals' and organisations' choices may be systematically biased against energy efficiency. For example, the performance of technologies such as control systems, motors, and variable-speed drives may be difficult to evaluate even after purchase because detailed metering is not feasible. Thus, feedback on the performance of the energy-efficient technology is not available. Similarly, information on the performance of new energy-efficient technologies rests with the investor, but would be of value to others too. In this case, markets undersupply such information (because of the public-goods character of information), potentially justifying publicly funded information programmes and demonstration schemes.

Third, information on the energy consumption of new and refurbished buildings, process plants, and equipment and machinery could be asymmetric, resulting in adverse selection and thus inefficient outcomes. For example, among many aspects, the value of a house should reflect its energy efficiency. While this information may be available to the seller, potential buyers have difficulty in recognising and evaluating the potential energy savings. As a consequence, their bids on the house will be too low. In the end, only energy-inefficient houses (or other technologies) may be on the market and investment in improving the energy efficiency of houses is lower than it would be with symmetric information.

Problems of imperfect information are likely to pervade energy service markets and could potentially explain a substantial proportion of the efficiency gap.

To sum up, problems of imperfect information are likely to pervade energy service markets and could potentially explain a substantial proportion of the efficiency gap. If private markets do not provide adequate information, policy interventions (such as energy labelling) could be justified. Information programmes appear to be the most obvious policy approach, but minimum energy efficiency standards might be more effective in some instances. If information programmes are to be employed, both the manner in which information is presented and the credibility of the source need to be taken into account. There is some overlap between the barrier 'imperfect information' and 'hidden costs' – the barrier to be addressed next.

3.3 Hidden costs

If engineering-economic studies fail to account for either the reduction in utility associated with energy-efficient technologies or the additional costs associated with their use, the cost-efficient potential may be overestimated (Nichols 1994). Hidden costs are only hidden to the observer, but

not to the decision-making individual or organisation. As Table 2 shows, three broad groups of hidden costs can be distinguished.

Table 2. Hidden costs of energy efficiency investment – main categories and examples

Sub-category	Examples
Loss of utility associated with energy-efficient choices	Problems with safety, noise, working conditions, service quality, and so on (e.g., lighting levels). Extra maintenance, lower reliability.
Cost 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. Additional staff cost for maintenance. Cost for replacement, early retirement, or retraining of staff. Cost of disruptions and inconvenience.
General overhead cost of energy management	Cost of employing specialists (e.g., energy manager). Cost of energy information systems (including gathering of energy consumption data; maintaining sub-metering systems; analysing data and correcting for influencing factors; identifying faults; and so on). Cost of energy auditing.

Source: Sorrell *et al.* (2004)

The first category concerns the potential loss of utility associated with energy-efficient choices. In essence, there are costs that result from inferior performance of energy-efficient technologies with respect to dimensions other than energy services. For example: an energy-efficient production process may lead to increased noise; the installation of cavity wall insulation in an old building may encourage damp; a variable-speed drive may require extra maintenance and training for new skills and tools. While these considerations clearly apply to energy-specific investment opportunities, they are likely to be even more important for investments where energy efficiency is only one of many attributes to consider. Incorporating these costs in engineering-economic models is feasible, in principle, but difficult to achieve in practice. Since taking into account costs related to inferior performance is necessary for a rational technology choice, they do not justify policy interventions.

Hidden costs in the second category can be considered part of the production costs of energy efficiency. They are specific to an individual investment in energy efficiency or the choice of an energy-efficient option. Examples include design fees for large items of a plant, the civil engineering costs of installing a combined-heat-and-power (CHP) unit and of connecting it to the grid, the costs of re-routing pipework, the costs of new light fittings to accommodate compact fluorescents, and the cost of production interruptions during equipment installation. In principle, these costs can be included in engineering-economic models (Ostertag 2003), but as they are site-specific and difficult to estimate, they may be easily overlooked. Arguably, they represent real costs, and organisations can be expected to take them into account when appraising investment opportunities. In any case, these types of barriers do not result in inefficient choices and, consequently, do not provide a rationale for policy intervention.

A rational choice of energy efficiency measures needs to account for a loss of utility possibly associated with them.

A third group of hidden costs relates to general overhead costs of energy management, and it corresponds to the search costs discussed in the context of the 'imperfect information' barrier. On the one hand, these costs partly depend on factors outside the control of the organisation adopting or considering the energy efficiency investment – such as the existence of standardised labelling schemes. On the other hand, these search costs also depend on factors internal to the organisation such as organisational procedures for information gathering, specification, purchasing and procurement. Within the broader category of transaction costs, they include all the organisational costs associated with establishing and maintaining an energy management scheme, investing in specific energy-saving technologies, and implementing specific energy-efficient options within broader investment programmes (for example, choosing an energy-efficient motor rather than a standard one). In contrast to the production costs and loss of utility discussed above, transaction costs depend closely on organisational and contractual structures, procedures, incentives, and routines. This makes them much more difficult to incorporate in models that represent costs purely in relation to individual technologies (Ostertag 2003). Nevertheless, these types of market or organisational transaction costs could be reduced through public policy or changes in the internal organisational structure.

All in all, claiming that hidden costs can explain the entire efficiency gap seems to be a tautology, but asserting that hidden costs are unimportant seems to be equally wrong. Sorrell *et al.* (2004) conclude that the truth lies somewhere between the two and the relative importance of different categories of cost is likely to vary between technologies and between organisations.

3.4 Access to capital

Imperfect access to capital may prevent the implementation of profitable energy efficiency projects.

The literature on barriers to energy efficiency usually discusses lack of access to capital in the context of private households. If low-income households have limited access to credit and can only borrow at high interest rates, this may prevent energy efficiency projects with a high rate of return from being undertaken. From the perspective of neoclassical economics, the inability to access capital may well constitute a barrier, but it need not imply a failure in capital markets. If low-income households are considered high-risk borrowers, potential lenders may demand a high risk-adjusted rate of return (Sutherland 1996). In this case, the market outcome is efficient and policy interventions are not justified. From the perspective of transaction costs economics, it may be that transaction costs necessary to investigating the creditworthiness of individual households are sufficiently high to diminish the economic viability of such loans (Golove and Eto 1996). Thus, overall efficiency may be improved if transaction costs to assess households' creditworthiness could be lowered.⁷ In practice, policy interventions to overcome this barrier in the household sector are usually justified primarily on equity grounds.

As for the enterprise sector, lack of access to capital as a barrier to energy efficiency is more complex. Here, the 'access to capital' problem has an external and an internal dimension. To start with possibly insufficient access to external finance, in principle, firms should invest in all projects that have a rate of return exceeding the average cost of capital. However, there may be several reasons why a firm might fail in raising additional debt or equity. For example, external funding for a highly profitable investment in energy may be denied simply because of business risk.

The internal 'access to capital' problem stems from neglect of energy efficiency within internal capital budgeting procedures, combined with other organisational rules such as strict requirements

⁷ A similar argument could be made for small and medium-sized companies.

on payback periods. Two observations are commonly made in this context. First, since energy efficiency investments tend to be classified as discretionary maintenance projects, they are usually given a lower priority over essential maintenance projects or strategic investments. Second, energy efficiency projects tend to be evaluated based on payback periods rather than discounted cashflow analyses. The (implicitly) required rate of return implied by short payback periods exceeds those for business development projects. In practice, such short payback periods may be required for all (not just energy efficiency) projects by central or upper management as a safeguard to managerial slack at the lower management levels, because they cannot perfectly observe or assess the lower management's abilities or the project's profitability. Similarly, relatively high hurdle rates may be required for smaller projects – and many energy efficiency projects fall into this category – since the transaction costs of determining the profitability of such investments are likely to represent a larger portion of the expected savings.

In addition, top management does not consider energy-cost savings as a strategic priority. Thus, given the constraints on time and attention (see also sub-section 3.6 on bounded rationality), it may be overlooked by top management. This bias towards strict investment criteria may be worsened by individual managers' incentives to favour large, strategic projects, which are more prestigious than energy management activities.

In sum, there may be good reasons for imposing strict investment criteria or restricting capital budgets for energy efficiency investments within organisations. Empirical research would have to identify the rationale for such behaviour, the extent to which this is reproduced in other comparable organisations, and whether such behaviour is a contingent feature of particular organisational arrangements, which may be altered.

3.5 Split incentives and appropriability

If a company is renting office space, neither the landlord nor the company (tenant) may have an incentive to invest in energy efficiency because the investor cannot appropriate the energy-cost savings. On the one hand, the landlord may not invest in energy efficiency if the investment costs cannot be passed on to the tenant, who will benefit from the investment through lower energy costs. On the other hand, the tenant may not invest if he is likely to move out before fully benefiting from the energy-cost savings. In principle, this so-called investor/user or landlord/tenant dilemma could be avoided if the investor were able to credibly transmit the information about the benefits (that is, future cost savings) arising from the investment and to enter into a contract with those benefiting from the investment. Such a contract would have to secure the appropriation of cost savings so that the investor can cover the investment costs. However, the costs of verifying energy-cost savings and the costs for the contractual arrangements are often prohibitive. Thus, asymmetric information and transaction costs are at the root of this investor/user dilemma problem (Jaffe and Stavins 1994).

Asymmetric information and transaction costs are at the root of the split incentives problem.

Similarly, if managers – because of job rotation – remain in their post only for a short time, they may not have an incentive to invest in energy-efficient projects that have a longer pay back time. Further, if departments (in larger organisations) are not accountable for their own energy costs, they may have no incentive to invest in energy efficiency because the benefits in terms of cost savings accrue elsewhere. Finally, the purchaser of equipment may have a strong incentive to minimise capital costs, but may not be accountable for operating costs (including energy costs). This type of problem may also arise with users of buildings, operators of process equipment, and designers and contractors in the case of construction projects.

To conclude, various types of split incentives are likely to explain part of the energy efficiency gap. Policies that can be implemented at low costs – labelling, for instance – are likely to be economically efficient.

3.6 Bounded rationality

When faced with a complex decision structure, agents may not be able to optimise because of lack of time, attention, or the ability to adequately process information. Instead, bounded rationality may result in using routines or rules of thumb (Simon 1957, 1959), thus neglecting opportunities for improving energy efficiency – even when information is perfect and incentives are appropriate. For example, small motor end-users tend to consider only delivery time or price instead of life-cycle costs when buying a new motor to replace an old one (de Almeida 1998). Similarly, when making decisions about investment priorities, firms are likely to focus on the core production process rather than on ways to save energy costs. Likewise, in cases where investments in energy-efficient technologies are being considered, the same profitability or payback criteria may be required as for the core production technologies although the economic risks associated with the former are much lower.

4. Case study on German higher education sector

4.1 Overview

The German higher education sector (HE) consists of about 370 institutions for about 1.8 million students (Federal Ministry of Education and Research 2005), but only a few are private. Operating expenses for higher education institutions are largely financed through the budgets of the federal states (*Länder*). Investment costs for large equipment, new buildings and the building extensions are evenly split between the state and federal budgets.

When energy expenditures account for only a small share of energy users' overall spending, there is little financial incentive to reflect on energy efficiency.

Total energy consumption in the German higher education sector is significant and accounts for about 0.4 percent of German final energy consumption. The majority of this is for generic uses, notably heating, ventilation, air conditioning, and lighting (see Table 3). Since individual institutions only spend around 2 percent of their budget on energy, there is little financial incentive to pay attention to energy efficiency in university decision making, which is dominated by research and teaching concerns.

Table 3. Energy use in the German higher education sector

Share of electricity consumption	40 percent
o/w Ventilation and air conditioning	30-50 percent
o/w Lighting	20-40 percent
o/w Office equipment	20-30 percent
Share of thermal energy consumption	60 percent
o/w Space (and process) heating	> 90 percent
o/w Hot water	< 10 percent
Total energy costs	€500 million
Share of electricity costs in total energy costs	60 percent
Share of energy costs on total budget	2 percent

Source: Sorrell *et al.* (2004)

The technical and economic potential for energy efficiency in the German higher education sector is estimated to be substantial. Government analyses suggest that organisational measures in the public sector may save 5-15 percent while technical measures could reduce thermal energy consumption by 25-60 percent and electricity consumption by at least 10 percent (*Umweltbundesamt 1999, Energieverwertungsgesellschaft 1999*). Energy efficiency opportunities in the higher education sector are typically of a general nature (that is, they are not specific to the higher education sector, but may be implemented in other sectors too) rather than process specific (see Table 4). These represent established and low-risk technologies widely recommended in the best-practice literature.

Energy efficiency opportunities in the higher education sector are typically of a general nature rather than process specific.

Table 4. Selected measures for the rational use of energy

Space heating
Thermostatic radiator valves
Programming heating and ventilation controls to match occupancy patterns and/or temperature
Use of building energy management system (BEMS)
Lighting
Replacement of 38mm fluorescents with 26mm
Use of high frequency electronic ballasts
Use of compact fluorescents
Use of photocell, acoustic or movement sensors
Plant room
Insulation of pipes, valves and flanges
Use of boiler sequencing controls
Replacement of oversized boiler plant
Installation of condensing boilers
Installation of CHP
Building fabric
Draught proofing of windows and doors
Retrofitting insulation to walls and roofs
Use of secondary or double glazing on refurbishment
Electrical equipment
Specification of high efficiency office equipment
Specification of high efficiency motors
Use of variable speed drives in pumps, fans and other applications
Automatic switch off of fans & pumps

Source: Sorrell *et al.* (2004)

Like almost all publicly funded projects and institutions, higher education in Germany has suffered from tight federal and state budgets. Since many institutions need new equipment for research and teaching and many buildings need to be refurbished, the budget situation constitutes a major challenge. Further challenges arise from current reforms of the higher education sector, including increased autonomy from the state authorities, the introduction of global budgeting and business accounting, new funding schemes, tuition payments in some states, rankings and evaluation, increased competition from other public or private universities, new forms of teaching such as virtual universities, and new designs for bachelors' and masters' degrees. Since the German constitution

grants authority over education largely to the *Länder* (rather than the federal government), these challenges vary across institutions. As will be described below, some of these reforms may be beneficial for energy efficiency.

In this section, barriers to energy efficiency in the German higher education sector will be explored and some recommendations on how these could be overcome will be identified. The section draws on results from six in-depth case studies of individual universities and a number of additional interviews carried out under the EU research project “Barriers to energy efficiency in public and private organisations”, published in Sorrell *et al.* (2004). At these universities, up to six people (top administrators, energy managers, technical managers, finance managers, purchasing officers, buildings officers, and so on) were interviewed in person and, where necessary, follow-up telephone interviews were conducted. The interviews were semi-structured and used detailed protocols based on the theoretical framework developed in the previous section. The next sub-section briefly summarises the energy management practices observed in the German higher education sector.

4.2 Summary of energy management

A variety of factors shape energy management practices in Germany's higher education sector.

The energy management practices at the six case-study universities in German higher education may be summarised as follows.

Organisation: universities are large institutions with complex decision-making structures, where energy consumption is influenced by several departments and institutes, individuals and groups from within and outside the university; the university administration is primarily responsible for measuring and controlling energy consumption and costs, setting investment priorities, purchasing equipment, space planning, and to a limited extent also for construction planning and maintenance; typically, there is no energy manager; instead a department for technical services is responsible for the supply of heat and electricity services, while a construction department participates in the planning of buildings and is in charge of their maintenance; many universities exhibited a lack of coordination, clear delegation, and clear responsibilities for energy management.

Energy/environmental policy: formal environmental or energy policies are an exception; no university had a certified environmental management scheme in place; teaching and research are the top priorities.

Energy costs and specific energy consumption figures: the share of energy cost in the budget ranged from 1.7 percent to 2.4 percent (including third-party funding); final thermal energy consumption was between $0.56 \text{ GJ}_{\text{th}}/\text{m}^2$ and $1.5 \text{ GJ}_{\text{th}}/\text{m}^2$, while final electricity consumption was between $0.28 \text{ GJ}_{\text{el}}/\text{m}^2$ and $0.66 \text{ GJ}_{\text{el}}/\text{m}^2$; annual energy costs per student ranged from €110 to €350.

Energy information systems and energy consumption control: energy consumption is measured and controlled regularly at the level of individual buildings, but no targets exist; energy management systems for buildings are usually in place, but mostly only for some of them and often outdated; energy costs are paid out of a central budget and unknown to individual departments or institutes.

Capital budgeting and investment criteria: separate budgets for energy efficiency measures do not exist; typically a share of 6 percent of the maintenance budget is required by law to be spent on energy saving measures, but this is not sufficient to realise all measures; quantity and quality of profitability and risk analyses for energy efficiency measures vary considerably across universities; for investments, payback periods of 5 years tend to be required, but they may be longer for equipment with a long lifetime.

New buildings and refurbishment: for construction of buildings and most refurbishment, a state construction agency is responsible for planning and carrying out the work, with limited influence of the universities; often, prestige and design dominate; there is lack of coordination between planners, various engineering firms, and trades.

Purchasing and policy integration: specifications for new equipment are provided by individual departments, and equipment is ordered by central purchasing offices, where energy efficiency is taken into account; but usually initial outlays (and not life-cycle costs) are most important; existing laws and guidelines for integrating environmental performance into the purchasing specifications are not very powerful and usually not enforced.

Awareness and culture: a general lack of awareness for energy performance was prevalent; where educational programmes aimed at increasing energy efficiency awareness exist, research and teaching staff tend to abstain; support for rational-use-of-energy measures from the top administration is important, but the personal motivation of those in charge of energy management seems to be crucial for finding and realising rational-use-of-energy potentials; some of the interviewees would like to see universities to lead by example (that is, do what they preach); but the concept of 'sustainability' had only started to enter the curricula.

4.3 Barriers to energy efficiency in the German higher education sector

The case-study interviews confirmed that there are numerous opportunities for improving energy efficiency in a cost effective way, but many are not being realised. Most interview partners agreed with the following statement from a pre-interview questionnaire:

"There is a wide range of energy-efficiency measures that could be implemented in my university that would yield paybacks of less than four years at current energy prices".

This section assesses the importance of various barriers to energy efficiency in the German higher education sector using the theoretical framework presented earlier. When interpreting the results, it is important to note that the barriers represent perspectives that highlight particular aspects of a complex situation and that there is much overlap and interdependence between the different categories. The barriers found to be of particular importance are split incentives, lack of capital, hidden costs, and imperfect information. These are discussed in turn below. Table 5 specifies how these barriers operate, with the final column identifying potential policy measures to remove or lower them.

To start with split incentives, the case studies suggest that these are the most important barriers to energy efficiency in Germany's higher education sector. Three key split-incentives problems are worth highlighting.

First, at the university level, there was no incentive to save energy costs since the savings were generally not allowed to be used for other purposes and – even worse – may lead to reduced budgets in the future. At the root of this problem are public accounting principles in Germany (*Kameralistik*) that limit the transferability of funds across the separate budgets for capital expenditures and administrative expenditures as well as within those budgets. Unused funds designated for a particular purpose can neither be spent on other purposes nor transferred across budgeting periods. In particular, savings in energy costs must not be spent on investment in energy efficiency, buildings maintenance, or office equipment. Historically, this was the case in all universities. Recently, most federal states have started to change budgeting principles, but

The barriers found to be of particular importance are split incentives, lack of capital, hidden costs, and imperfect information.

Incentives for German universities to save energy are likely to improve, but will remain constrained.

the policies and future plans on how to allocate savings differ across states. For most universities, partial transferability of unspent funds to other purposes within the same budgeting period is being planned for the near future in connection with the introduction of 'global budgeting'. Similarly, for savings at the university level, some type of cost-sharing arrangements with the state administration is being considered, but universities will not be allowed to fully keep the savings made in one period for future periods. Thus, incentives for the university to save energy costs are likely to improve, but remain constrained.

Table 5. German higher education sector – barriers to energy efficiency and policies to overcome them

General category	Specific instance	Policies
Split incentives	Departments not accountable for energy costs.	Devolved budgeting with new business accounting system.
	Limited transferability of funds.	Global budgeting (degree of implementation varies by Federal State).
	State construction agency responsible for the planning of new buildings and refurbishment.	Increase universities' planning and financial authority; put operating/facility/space management company in charge; privatisation of all facility/space, building codes.
	Contractors, etc. for buildings not accountable for operating costs.	Targets for energy performance and operating costs to be included in tender; integrated design process, building codes.
Access to capital	Availability of capital to university.	Energy service contracting.
	Allocation of capital within university.	Conduct profitability analyses; life-cycle costing; make university funding a function of energy performance or energy audits; environmental/energy management schemes; subsidies for energy audits; raise awareness at top administration level via voluntary agreements, etc.
Hidden costs	Lack of time, management costs.	Energy service contracting; full-time energy manager; targeted information programmes; co-operative procurement; subsidies for energy audits.
	Complex and time-consuming decision-making process.	Change responsibilities and shorten process through laws; devolve financial and decision-making responsibility to individual institutions; involve ESCOs.
Imperfect information	Information on energy use and needs.	Invest in information systems and Business and Environment Management Schemes; energy manager to improve co-ordination of energy management; improved communication with top management; energy committee; best practice programmes.

Second, energy consumption was not always metered for individual departments, and historically there had been no arrangements for decentralised accountability of energy costs. Instead these costs were paid out of the university-wide budget for operating costs. Since energy budgets and the

responsibility for energy management were not devolved to individual departments, these had no incentive to save energy through purchasing efficient equipment, office and space management, or behavioural measures. Again, these are typical split-incentives problems and they were encountered in all the universities studied. With the introduction of the business accounting system in most universities, it is planned to allocate energy costs in future, most likely using some proxy such as floor space. Although this represents an imperfect second-best to directly charging for energy consumption, it should nevertheless create stronger incentives than the existing mechanisms to manage office and room space. One interviewee noted that:

“... so far the use of space is considered free and not associated with any costs, ... and the status of a professor is also determined by the office space he manages to seize,... Institute managers will be stunned once they actually have to face costs, especially energy costs.”

Third, as already pointed out, for all new construction and to some extent for building maintenance too, a state construction agency and not the university was responsible for planning and implementing projects. Thus, those planning the projects were not the same as those who had to pay the operating costs. Except for one university, which for historical reasons was also in charge of construction planning, all universities complained that the state construction agency did not adequately take into account future energy and other operating costs. Instead, other motives like prestige and design appeared to be more important. Quite often, this situation caused friction between those responsible for energy management at the university level and state planners, as indicated by the following statements from interviewees:

“... decision makers have the power, but they do not have the relevant knowledge and information about the actual needs at the university level.”

“... planners at the state construction agency are utterly incompetent and haven't a clue about what is going on.”

“Often, one hand does not know what the other hand is doing, or why it is doing what it is doing. ... input from the universities is not always appreciated at the state construction agency.”

“... it is not important to save energy or energy costs, but rather to comply with regulations.”

In the past, these problems were exacerbated by external designers and contractors, who were commissioned by the state construction agency and reimbursed according to the Ordinance on Fees for Architects and Engineers (HOAI). Since their fees depend on the financial size of the projects, designers and contractors have an incentive to choose larger heating, ventilation, and cooling equipment than necessary, leading to needlessly high energy consumption. Similarly, until recently, efforts on the part of designers and contractors to improve energy efficiency were not incentivised or rewarded. In 1994, the German Federal Government modified the HOAI to provide financial incentives for improved energy efficiency or the inclusion of renewable energy sources. Although higher fees can now be charged if the services provided exceed those usually required, the reimbursement may not fully cover the costs.

Even with these additional incentives, split-incentives problems remain since architects, engineers, sub-contractors, and consultants are accountable for capital cost but not for future operating costs. For them, meeting deadlines and staying within the budget are vital. Lack of coordination between different trades tends to aggravate this problem⁸.

⁸ For details, see Chapter 7 in Sorrell *et al.* (2004).

Until recently, efforts on the part of building designers and contractors to improve energy efficiency were neither incentivised nor rewarded.

In contrast, other potential forms of split incentives – landlord-tenant relationships in leased buildings and the lack of long-term incentives created by rapid job rotation, for example – were not found to be significant in the German higher education sector.

Turning then to the ‘access to capital’ problem, for the case-study universities, this was a major barrier to improving energy efficiency – reflecting both lack of funds for universities and an allocation of funds within universities that shows low priority for energy efficiency investments.

The access-to-capital problem has been a major barrier to improving energy efficiency in Germany's higher education sector.

Financing for larger investments comes from the state and federal budgets, which have been very tight for years. The situation is seriously aggravated by the fact that, historically, universities have not been allowed to borrow on the capital market. Thus, borrowing for investments in energy efficiency has not been an option, no matter how profitable the investment may have been. Likewise, in some states, third-party financing through an energy services contract was considered illegal. Hence, in universities, the funding situation for investments in general is difficult, which tends to restrict funding to small projects with payback period of less than five years. Investments in energy efficiency will at best be delayed, as in the case of one university where the implementation of a highly cost-effective lighting system took eleven years! This delay resulted from the combination of lack of capital in the public sector as a whole and the complex decision-making structures in the higher education sector.

While investment in energy efficiency suffers from aggregate capital restrictions, the lack of funding for these investments is also a consequence of priority setting inside and outside the university. The primary criteria are quality of research, quality of teaching, urgency, and design prestige. Energy efficiency – and in some cases even profitability – are only of minor importance. Hence, it does not come as a surprise that none of the universities had a specific budget for energy efficiency investment. Instead, small investments had to be financed through unused funds from other areas, in particular through the maintenance budget, where laws require that a certain percentage be spent to improve energy efficiency. But in most cases the amount of money available from this source is both small and insufficient.

As for hidden costs, the case studies considered all three main categories discussed above: general overhead costs of energy management; costs specific to a technology investment; and loss of utility associated with an energy-efficient technology.

The overhead costs of energy management (including expenditures on staff salaries, energy audits, information systems, sub-metering, and so on) were usually not included in profitability analyses of possible energy efficiency projects – if such analyses were conducted at all. Typically, only investment costs, direct personnel costs, and maintenance and fuel costs were considered. Accounting for overhead costs of energy management in profitability assessments would require calculating their magnitude. This is no easy task, and leads to additional costs of its own. The prevalence of severe time constraints on university employees was suggestive of the importance of salary costs, in that it may be uneconomic to increase staff resources for energy efficiency improvements. However, not only were such calculations not made, but hiring new staff was often prohibited by rigid public employment schemes (*Stellenplan*) that fix the number of university staff.

As outlined above, the costs associated with complex and time-consuming decision-making processes constituted a major barrier to all types of investment, including energy efficiency investments. For example, the installation of a CHP-plant would have to be planned 5 to 7 years in advance – a period during which energy markets and CHP-technology may change significantly.

By contrast, hidden costs specific to a technology investment – such as disruption, hassle, and inconvenience – were found to be much less important. Major construction or equipment replacement can always be carried out during the relatively long winter or summer breaks. Likewise, loss of utility associated with energy-efficient technologies was not considered to be important. However, in many cases the costs for additional energy services were not considered when buying new equipment. For example, at one university, a new transmission microscope was estimated to increase annual operating costs by €1,600. However, the microscope significantly added to cooling and ventilation loads, and when the fixed, operating and maintenance costs for cooling and ventilating the equipment were taken into account, the additional costs exceeded €6,000 a year. Hence, when indirect costs are neglected, as is typically the case, total costs may be seriously underestimated, with the result that inefficient investment decisions are made.

In summary, hidden costs associated with identifying savings potentials, finding appropriate energy efficiency measures, conducting profitability analyses, and preparing public procurement processes were important barriers to energy efficiency in the case-study institutions. But the evidence does not support the hypothesis that these hidden costs are significantly higher for energy efficiency measures than for standard (i.e., non-energy efficiency) measures.

This takes us to imperfect information – the last barrier to energy efficiency investment found to be of particular importance in case-study universities. Two categories of information were considered: information on the volume and pattern of universities' energy use and on opportunities for dedicated energy efficiency investments.

Information on current energy use at the level of individual buildings or departments was poor and the end-use split of energy consumption was generally unknown, particularly for electricity. Data on energy costs, energy consumption, and user needs were collected by individual departments rather than a central organisational unit, and there was no evidence of comparison with either generic or sector-specific benchmarks. Similarly, the needs of end users were often neither known nor well communicated within the institution. The case-study results thus suggest problems of decentralised information and lack of both knowledge and coordination of user needs throughout the higher education sector. But they also suggest that these problems are less pronounced in universities with a full-time energy manager.

While lack of information on the volume and pattern of energy use was considered to be an important barrier to energy efficiency, the quality and quantity of information available on energy-specific investment opportunities was generally judged to be good. Information on investment opportunities appeared to depend on the competence and motivation of the staff in charge of energy management. With regard to sources of information on energy efficiency measures, the media used included the internet, informal networks, meetings of energy managers, the information system for the higher-education sector (HIS-Higher Education Information Systems GmbH, Hannover), special seminars and workshops, and energy service companies (ESCOs). If used at all, informal networks were considered to be excellent and trusted sources of information. By contrast, there was considerable suspicion of ESCOs.

Lack of information on the volume and pattern of energy has been an important barrier to energy efficiency.

4.4 Policy implications

The empirical research demonstrates a wide range of barriers to energy efficiency in the German higher education sector that also inhibit economically efficient outcomes. It follows that significant improvements in energy efficiency are likely to require a similarly wide range of initiatives at the organisational, sectoral, and national level. A general observation from the case studies is that

successful energy efficiency policy has to encompass more than just fiscal measures. It must also take into account the communicative, organisational, and cooperative challenge that energy efficiency creates for individual institutions (Ostertag 2003).

Energy service contracts may provide an effective route for overcoming barriers such as lack of capital, time, staff, and expertise ...

In addition to public policy measures, energy service contracts may provide an effective route for overcoming barriers such as lack of capital, time, staff and expertise. Likewise, the involvement of ESCOs (see Box 1) may avoid the time-consuming and complex decision-making structures within the higher education sector. Since the potential – and limitations – of ESCOs in the German higher education sector have been discussed in detail elsewhere (Schleich *et al.* 2001), the remainder of this section will focus on potential measures at the organisational, sector and national level (see the last column in Table 5). It should be noted, however, that it is beyond the scope of this paper to assess the efficiency of these measures, that is, whether the benefits of implementing them outweigh their costs.

At the organisational level, creating the position of an energy manager would have considerable potential to reduce information deficits, improve the coordination of energy management and user needs, and encourage vertical and horizontal communication – thereby reducing barriers to energy efficiency. Along with other tasks, an energy manager could assume the role of ‘product champion’

Box 1. The energy services concept with application to the higher education sector

Energy services represents a new and rapidly growing business model in which suppliers offer a single contract to minimise the total bill for the services that energy provides – such as heating, lighting, and air conditioning. This contrasts with the traditional approach in which energy consumers contract separately for energy commodities (fuel oil, natural gas, electricity, and so on) and for a range of conversion equipment that delivers energy services (heating, lighting, air conditioning, and so on). In its simplest form, an energy services contract guarantees supplies of heat and power at reduced cost, but in a more sophisticated form the contract may guarantee particular levels of service provision (for example, lighting levels and room temperatures).

By focussing on better performance and solutions to customer needs rather than commodity sales, energy service companies (ESCOs) have a strong incentive to improve energy efficiency. ESCOs typically offer energy management, energy information systems, energy audits, installation, operation and maintenance of equipment, competitive finance, and fuel and electricity purchasing. The contract allows the host organisation to lower risk, avoid capital expenditure, reduce energy costs, and concentrate attention on core activities. Energy services contracts could provide a cost-effective route to overcoming barriers to the diffusion of both established and innovative low-carbon technologies in the public, commercial, industrial, and household sectors. The model is applicable to both energy-use and energy-supply technologies and is, in many countries, the primary mechanism for the diffusion of CHP technology. It is also consistent with energy market liberalisation and the broader trend towards the outsourcing of non-core activities.

As for ESCOs’ potential in the higher education sector, it is useful to point out that they may be reluctant to offer their services in this sector. One of the typical reasons in the higher education sector is the long negotiation process before a contract can actually be made: the decision making at universities involves administrative procedures and budgeting laws, is highly complex, and rather inflexible. Also, some universities compare new offers from ESCOs with the variable costs of providing the same services internally. This incorrect procedure renders offers by ESCOs, which calculate on

for energy efficiency, which has proven to be instrumental for improving energy efficiency in the industrial sector (Ramesohl 1998). Likewise, bundling information and competence for energy use and consumption within a single department saves coordination costs and helps identify and solve internal conflicts of interest. This means that responsibility for planning, maintenance, technical services, space management, heat and electricity supply, and buildings energy management systems should be under the same roof. In any case, clear delegation and responsibility for energy management is crucial.

Certified environmental management schemes might also be an effective measure, especially for poor performers. These schemes not only organise environmental management, but are also designed to motivate staff and students and to get energy and environmental issues high on the administration's agenda. For large universities, implementing such schemes at the level of the institution requires considerable effort in coordination and hence may be difficult to achieve. Environmental management schemes for individual schools or institutes should therefore be considered as an alternative. Getting key administrators' attention may also be achieved via voluntary or negotiated agreements, either at the level of the institution or for the entire higher education sector. Given the crucial role of the state administrations, voluntary agreements may be most effective for organisations at the state level. Instead of using payback periods, profitability

... and certified environmental management schemes might also be an effective measure.

the basis of full costs, (seemingly) unprofitable. Outsourcing or privatisation is often associated with the loss of jobs in the public sector, which tends to create a political problem. Furthermore, at least historically, because of public budgeting laws, the budget for energy costs could not easily be used for financing contract energy management. In particular, universities had problems getting the investment part of the contracting fee 'reimbursed' by the state administrations. Likewise, some state administrations have denied approval of contract energy management because it was regarded as a type of unauthorised 'hidden credits'.

On the other hand, ESCOs may find conditions in the higher education sector particularly beneficial. Since energy consumption (and costs) of universities is rather high, projects for contract energy management are of sufficient size for ESCOs to recover overhead and transaction costs. Moreover, energy supply and demand technologies in the higher education sector are fairly homogenous (generic), which encourages strategies by ESCOs to focus on particular customer groups and to realise economies of scale and scope. What is more, since institutions of higher education usually belong to the public sector, they carry a very low financial risk. Since contract energy management for investments in energy efficiency typically requires long contract periods, a low financial risk is crucial for such projects. At the state level, several administrations have pushed contract energy management as a strategy to overcome financial restrictions in the public sector. Furthermore, ESCOs are expected to benefit from more recent developments towards increased autonomy in terms of decision making and financial resource allocation for universities – developments that are expected to speed up the decision process and reduce uncertainty stemming from hierarchical administrative structures. Likewise, the introduction of global budgeting and business accounting systems (rather than separate budgets for capital and administrative expenditures under a *Kameralistik* system) should facilitate contract energy management via ESCOs and help to correctly assess the costs of contract energy management vis à vis other alternatives.

Thus, ESCOs may help overcome important barriers to energy efficiency in the higher education sector such as lack of sufficient internal or external capital to finance profitable measures, know-how, manpower, and time to realise such measures internally.

Introducing global budgeting with unrestricted transferability of funds within and across budgeting periods has considerable potential to encourage energy savings.

analyses using life-cycle costs should be carried out, so the net benefits of energy efficiency measures can be demonstrated. With modern software tools, the transaction costs of this should not be prohibitive. Similarly, when deciding on new equipment, the indirect costs for additional energy services should be considered. Since indirect costs can sometimes be a multiple of the direct investment costs, neglecting them might result in inefficient investment decisions.

Creating positive incentives for universities to invest in energy efficiency implies that institutions should be able to keep the cost savings from these investments and use them for other purposes now or later. Reforms to this end would constitute one of the crucial measures at the sectoral level. In essence, universities should be able to shift funds between budget headings and they should not be punished for lower energy costs by receiving less funding overall in subsequent financial periods. Thus, global budgeting with unrestricted transferability of funds within and across budgeting periods should be introduced in all organisations. To make incentives for planning and operating buildings compatible, individual universities should be given more planning (and financial) authority at the expense of the state planning agencies. Alternatively, the operation and management of facilities and estates could be outsourced to private companies.

If a portion of university funding were to be made a function of prior performance (such as achieved energy savings or performance against some kind of benchmark), the incentive to realise energy efficiency measures within the university would be much stronger. This kind of funding system would also force energy costs onto the top administration's agenda. Alternatively, a portion of state funding could be dependent on the universities having carried out an energy audit within the last year or two or on having an environmental/energy management system in place.

Similarly, individual departments should have individual budgets and be held accountable for their energy costs as far as possible. Clearly, allocation of costs based on the space used would only be a first step. At the same time, the business accounting system, which is currently being introduced in many universities, is expected to lead to a better allocation of financial resources and to provide better incentives for energy-saving measures than the obsolete *Kameralistik* system. Business accounting systems are also expected to provide opportunities for incorporating data on environmental performance.

Future operating costs should be an integral part of the procurement specifications for new buildings and major refurbishments. Likewise, integrated planning should be implemented as a rule. Since integrated planning involves all the relevant actors (notably architects, specialist engineers, sub-contractors, and the energy manager), the content of the individual work-packages can be better coordinated and designed so that split incentives are accounted for and a more efficient solution emerges.

Other possibilities at the sectoral level include training seminars for those in charge of energy management and targeted information programmes on specific topics (for instance, contract energy management). Both are expected to reduce information and other transaction costs. In the same way, informal networks can be a cost-effective tool to reduce information-related barriers.

Benchmarking at the sectoral level is an important tool to get the attention of top administrators and it may help improve the status of energy management. However, for meaningful comparisons across different institutions, proper benchmarking would have to differentiate between a wide range of buildings types and uses.

Finally, cooperative procurement of energy-efficient equipment by several higher education institutions provides another route to reduce transaction costs and obtain price reductions on equipment through bulk purchases. For example, primary and secondary schools in the city of Hamburg have successfully used such a procurement process for more energy-efficient lighting.

To conclude with key measures at the national level, it should be stressed that the effectiveness of measures at the organisational and sectoral levels will be enhanced if they are embedded in a broad-based, long-term national programme to address the climate-change challenge. In particular, allowing energy prices to reflect external environmental costs will render measures improving energy efficiency more cost-effective and raise awareness among higher administration. In Germany, such policies include the continuation of the ecological tax reform, which was implemented in 1998. Increasing tax rates on fuels and electricity reduces the financial risk associated with investments in energy efficiency and allows for long-term planning. The introduction of the EU CO₂-emissions trading scheme (EU ETS), which started in 2005 for about 11,500 installations from the power and most energy-intensive industry sectors in the EU, has led to a substantial increase in the costs of electricity. Companies subject to the EU ETS receive more than 95 percent of allowances for free, but in particular power producers were able to pass on a large part of the full (opportunity or marginal) costs to consumers.⁹ If the cap on CO₂ emissions is chosen so that climate change targets are met, energy prices could increase significantly, creating additional incentives for energy efficiency.

A national programme addressing climate change challenges will enhance the effectiveness of energy efficiency measures at the organisational and sectoral levels.

National policies in support of CHP plants may affect universities either directly, as operators of CHP plants, or indirectly as end users who bear the costs of national subsidy programmes. Other policies at the national level include the continued tightening of the standards in the Energy Conservation Ordinance; the re-examination of technical standards for heating, ventilation, air conditioning, and cooling services (to avoid over-sizing); and the introduction of minimum efficiency standards and labels for energy-consuming equipment such as personal computers. Moreover, public programmes subsidising energy audits and the implementation of energy management systems could be extended to make public institutions eligible. Finally, the recently formed Federal Energy Agency could initiate, coordinate, or develop information and education programmes targeted at the higher education sector, together with best-practice programmes, pilot projects, support networks (such as eco-campus net – a network for an environmentally sound development of universities), and ‘energy-cocktails’. At such energy cocktail, top university administrators would be invited for food and drinks and to listen to a short keynote presentation on the importance of energy costs and energy efficiency, similar to the Swiss RAVEL programme (Bush 1996). Top administrators may have strong incentives to participate in such events, since – as a side benefit – they also provide a stage for networking among top administrators where other relevant topics may also be discussed.

5. Conclusions

The case-study results presented in this paper for the higher education sector in Germany confirm the notion that there are barriers to energy efficiency. That is, there are mechanisms that inhibit the adoption of profitable energy-efficient measures. The main barrier found were various forms of split incentives, which – apart from preventing higher energy efficiency – lead to economically

⁹ Note that the logic of emissions trading requires opportunity costs (rather than actual costs) to be passed on to consumers. Otherwise, product prices would not reflect true environmental costs. Of course, a free allocation of allowances may result in substantial windfall profits for companies. Auctioning off allowances would reduce those windfall profits.

The case study on Germany's higher education sector supports – at least to some extent – the presumptions of technology-economic type modelling and the call for policy interventions.

inefficient outcomes. The findings support – at least to some extent – the presumptions of technology-economic, bottom-up type modelling and the call for policy interventions. For example, policy measures such as global budgeting at the level of universities and devolved budgeting at the level of departments may be implemented at relatively low costs. Barriers that would not have justified policy interventions, like hidden costs of production interruption, were not found to be relevant for the German higher education system. For other sectors, however, such as the brewing or mechanical engineering (see Sorrell *et al.* 2004) hidden costs such as production interruption and loss of quality were found to be significant, but did not provide a rationale for policy intervention either. This illustrates that barriers to energy efficiency will vary across applications, and judgment on whether policy measures should be implemented is likely to be case specific. The case studies also suggest that multiple, possibly reinforcing, policies may be necessary to address the different types of barriers.

However, since the number of observations in a case-study analysis – as the one presented for the German higher education sector in this paper – tends to be small (by definition), the findings cannot be generalised in a statistical sense. Nevertheless, case studies are well suited to gain insights into complex decision-making processes and structures within organisations – even if their findings are usually limited to an analytical generalisation, where observed outcomes of decision-making processes are explained by identifying relevant causal mechanisms (Yin 1994). Although all these qualifications are sensible, existing econometric analyses based on large samples tend to support the general findings of analyses based on case studies (see for example, Scott 1997, Schleich 2004, and Schleich and Gruber 2007).

Finally, cost-benefit analyses ought to be conducted with a view to assessing the economic efficiency of the proposed policies. Likewise, thorough methodologically sound *ex-post* evaluations of existing energy-efficiency programmes are vital. With increased data availability, using econometric techniques to evaluate such programmes may become more popular. Such analyses could also help reduce the uncertainty about just how many kilowatt hours and CO₂ emissions were saved by a particular policy intervention.

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