Energy-Relevant Decisions in Organisations within Office Buildings

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ABSTRACT

Energy conservation measures are only one – and quite an expensive – way of making the use of energy more efficient. Higher energy efficiency can also be achieved by making sensible decisions about future energy consumption, e.g. when new buildings are constructed, or when energy-consuming equipment is purchased. However, this is rarely done, as the study reported here demonstrates.

The development of electricity consumption within the period 1986–1996 was empirically studied in a Swiss nation-wide survey of office buildings. Data was collected in two ways: via energy audits and in interviews with a sample of building and organisation representatives. The study analyses electric energy intensities, changes in the stock and control of end-use equipment (which I refer to as energy-relevant events) and the decision-making behind these changes.

Energy conservation measures were found to be more frequently implemented in buildings with professional energy managers or where energy was monitored by a director. However, only one seventh of the accumulated effect of all the consumption-decreasing events were caused by explicit conservation measures. In contrast, almost four fifths of the decreasing effect was caused by events where energy savings were not an issue (e.g. centralisation of computer suites). Thus, in this case, a model of purposive action fails to explain energy consequences. In such situations, it is more appropriate to use a model of organisational decision-making and to analyse the enforcing and constraining impact of social institutions and technical infrastructures.

Introduction

Studies of energy consumption have thrown light on a considerable number of cases where energy is used in an inefficient manner. In fact, there is great potential for achieving higher efficiency in energy consumption by adopting better technologies, planning processes and equipment control practices. However, unlike what most simple theories of economic rationality would lead one to expect, very few potentially profitable energy conservation measures are implemented.

In the debate about energy efficiency, it is easily forgotten that explicit conservation measures (i.e. actions specifically undertaken to conserve energy) are only one way of making energy consumption more efficient and are often quite expensive. Higher energy efficiency can also be achieved by making sensible decisions about future energy consumption, e.g. when new buildings are constructed, or when energy-consuming equipment is purchased. The practical difficulty is to recognise the energy-relevance of everyday decisions and to ensure that the crucial decision-makers are provided with appropriate information.

Data on the development of electricity consumption were gathered over a ten-year period in a Swiss nation-wide survey of office buildings. The survey was conducted so as to be statistically representative and comprehensive. The installed end-use equipment (e.g. office equipment, central computing, lighting) was audited, as were recent changes in the stock or control of equipment. I refer to such changes as energy-relevant events. The circumstances and contexts of the decision-making behind these changes were analysed.

In the following, I first take a look at some of the general issues raised in social scientific research on energy consumption. I then describe the methods used for data collection, and the subsequent findings related to consumption levels and their dynamics over time. The decision-making behind energy-relevant events is then discussed. Finally, I discuss methodological issues involved in models of energy consumption.

Social Scientific Research on Energy Consumption

The literature contains a considerable number of studies of the energy awareness and energy-related behaviour of individuals. However, the degree of freedom an individual can exercise with regard to his or her energy consumption in a built environment and a given society is considerably limited. The impact and constraints of social institutions and physical infrastructures on energy consumption has, remarkably, been explored very little. Until now, most research on energy consumption has been dominated by a paradigm of individual, purposive and rational action. Though this approach has been criticised in general, energy is still widely analysed as a commodity, whereas its qualities as an ecological resource, a social necessity and a strategic material (cf. Stern & Aronson 1984, 14 ff.) have been largely ignored. Furthermore, the commodity view is the most problematic, since the end-users do not demand energy, but energy-consuming services. Both the power of infrastructures and institutions and the non-commodity properties of energy are referred to in the literature, but are not taken into account in methods of empirical research on energy consumption. The construction of alternative methodologies to explain changing demand has barely begun to be explored.

Most empirical research on energy use is about private consumption in households. Some studies of energy consumption in organisations (e.g. in private and public-sector firms) do exist, but they are rare. The majority of existing studies are case studies or program evaluations, whose results are difficult to generalise. Representative research on energy-relevant decision-making in organisations is hard to find in the literature.

Most existing social scientific studies of organisational energy consumption are confined to energy *conservation* behaviour, i.e. actions specifically undertaken to conserve energy (e.g. Goitein 1989; Gruber & Brand 1991; Jochem & Gruber 1990; Komor & Katzev 1988; Train 1988; Widman et al. 1984).[1] However, there are some studies about decisions related to energy consumption in organisations. Most of them have focused on the

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1 A practical problem with surveys based on self-reports is that questions about energy consumption tend to be leading. There are strong normative issues in this field, e.g.: "High energy consumption is bad" or "Energy conservation is good". Hence people often declare actions based on how they think they should be behaving rather than on what they actually do (cf. Milstein 1977, 3; Hackett et al. 1982, 441). If one is not sensitive to this when designing a questionnaire or an interview, then the answers gathered can be biased in expected, but undetermined ways. The risk of biased answers can be lowered if the questions focus on objective facts (which could be checked by a neutral person). However, the risk of biased answers cannot be fully eliminated.

making of physical infrastructures, especially in relation to buildings (Dholakia, Dholakia & Firat 1983; Guy 1998; Janda 1998; Kasanen & Persson 1997; Laat 1997; Lutzenhiser 1994; Ryghaug 1999). Others have analysed energy conservation behaviour in organisations *as* energy consumers (e.g. Cebon 1992; DeCanio 1993, 1998; Haddad, Howarth & Paton 1998). The study reported here is about general energy-relevant decision-making in organisations located in office buildings.

A Survey of Energy Consumption in Office Buildings

The development of electricity consumption in private and public-sector organisations[2] within office buildings[3] was empirically analysed.[4] The period observed was 1986–1996. One hundred office buildings located in the German- and French-speaking parts[5] of Switzerland were randomly selected within five clusters according to building size.[6] In doing so, big buildings were deliberately over sampled, which led to an increase in the analysed floorspace[7] to 2% of the total office building floorspace in Switzerland, amounting to half a million square meters. Within the selected buildings, 65 organisations were analysed.

Both representatives of the buildings – building managers – and representatives of the organisations – managers from the board of directors – participated voluntarily.[8] Since public-sector organisations were more willing to participate than privat-sector ones, the public sector was over represented by about a factor of two. However, self-selection in participation did not bias the result in a recognisable way, since the motives to participate were varied and idiosyncratic.

The dominant building group according to the sector of the largest occupant of the building was public administration (41% of total floorspace), followed by finance and non-profit organisations (38%), the wholesale and retail trade (13%) and industry (8%). About one third (35%) of the buildings were constructed before 1950, whereas 34% were constructed after 1974.

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2 In this study, the term organisation refers to an economic or administrational unit of a private or public-sector firm, occupying a building fully or partly. This is an entire firm or, within large organisations, a branch or a (set of) department(s) of a firm.

3 Office buildings were defined as buildings with an office usage share of 50% or more.

4 The sample and the survey methodology are described in detail in the final report of the empirical analysis. The report is in German and available from EDMZ, 3003 Bern, Switzerland (Lukas Weber, Urs-Peter Menti und Ivan Keller, *Energieverbrauch in Bürogebäuden*, Bern 1999, 121 pages; order no. 805 569 d).

5 The remaining part, which is Italian-speaking and where 4% of the inhabitants in Switzerland live, was excluded because of language barriers.

6 The clusters were defined by equidistant intervals based on insurance sum: 1.5–10, 10–20, 20–30, 30–40, ≥ 40 Million Swiss Francs. The aim was to select 20 buildings out of each cluster (in practice, this aim was only approximately attained). The bias in averaged data caused by the sampling bias was statistically removed.

7 Floorspace (in German *Energiebezugsfläche*) is defined as the heated floor area including floors and walls. This definition is in accordance with that of the Swiss norm, SIA 180/4 (SIA 1982).

8 563 building managers and 1163 boards of directors were asked to participate independently of each other. The response rate was 60%, and 49% of the respondents agreed to participate. Since buildings where both the building manager and a director had responded favourably were preferably selected, the effort involved in finding 100 buildings to survey was considerable.

Methodology

Time series data for each building's annual electricity consumption within the period 1986 to 1996 and detailed data about the energy consumption and energy-related features of the buildings in 1997 were gathered by means of document analysis and audits[9]. Data about each organisation's characteristics and energy-relevant decision-making were gathered additionally via either telephone or face-to-face interviews. Annual changes in electricity consumption were reconstructed on the basis of changes in the stock and control of end-use equipment, referred to as energy-relevant events (Fig. 1). An average of four energy-relevant events per organisation were revealed for the analysed period, 1986–1996.

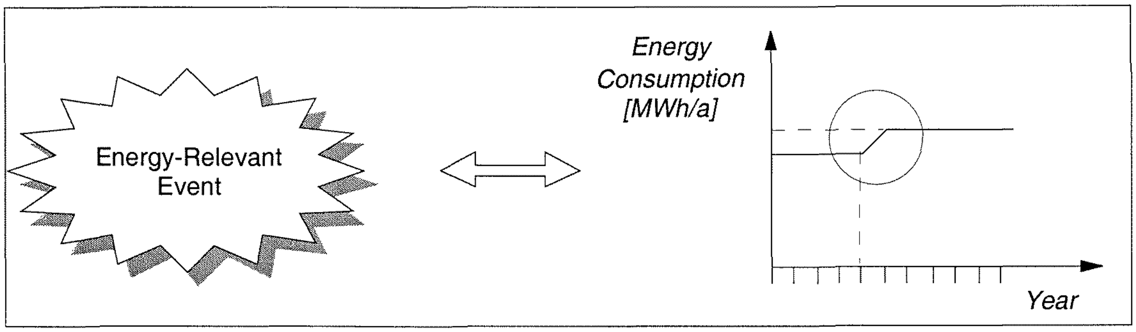

Figure 1. Energy impact model of an energy-relevant event

Energy-relevant events. Each energy-relevant event was dated by year, indicating that, from then on, it had affected energy consumption, and its impact on energy consumption level was estimated. These estimations were based on technical information and engineering experience.

A three-dimensional typology of energy-relevant events was constructed in order to group technically similar events. The dimensions were: 1. the end-use equipment involved (e.g. office equipment, central computing, lighting); 2. the change involved (e.g. installation, replacement, shut-down); 3. the character of the change (change in the stock or in control).

Energy-relevant decision-making. The process of decision-making was subdivided into three stages: initiation, preparation and final decision. For each energy-relevant event, a set of variables were gathered.

- Initiation: The individual or group who initiated the event to be decided on.
- Preparation: The individual or group who technically prepared the decision, i.e. who chose the technology or the way the equipment control changed.
- Final decision: The formal decision-maker.
- Purpose: The formal reason that justified the event to be decided on (not necessarily the initiator's motive!).

[9] For each piece of equipment, the electric power demand and the annual hours of operation were audited, as were floorspace areas according to usage. The audit method complies with the Swiss norm, SIA 380/4 (SIA 1995).

- Extent of energy-consideration: Measure describing to what extent energy efficiency was considered when the decision was made ("energy conservation", "energy-related" or "non-energy-related". The measure is discussed further below).
- Year: The year from which time on the event affected energy consumption.
- Description: Technical specification of the event.
- Energy impact: The assumed increase or decrease in electricity consumption caused by the event (in MWh/a).

Of course, this set of variables can characterise energy-relevant decision-making only in a rather rough way. However, it was possible to gather complete data sets even for events that the interviewees found difficult to remember.

Findings

Since buildings as well as organisations were analysed, some data refer to buildings, and other data refer to organisations. All data related to an annual consumption (i.e. energy intensities, consumption by end-use) refer to a sample of buildings, while data related to energy-relevant events or energy-relevant decision-making refer to a sample of organisations (cf. the specifications within figure legends).

Static consumption (1997). The electric energy intensity amounted to 300 MJ/m^2a on average (1997).[10] It varied from 70 to 1230 MJ/m^2a, mainly according to extent of air conditioning. Fully air-conditioned buildings consumed three times as much electricity as buildings without air conditioning.

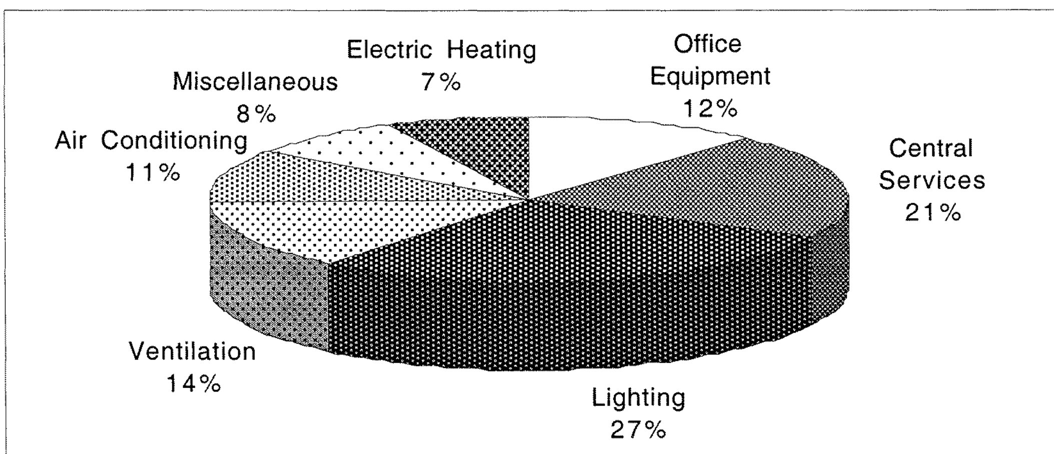

Figure 2. Electricity consumption by end-use (n = 100 buildings, average values 1997, weighted by consumption level)

The most energy-intensive end-uses were found to be lighting, central computing (the main part of the *central services* category), ventilation and air conditioning (Fig. 2). These

[10] For comparison, the electric energy intensity in US office buildings amounts to 729 MJ/m^2a on average (1995, cf. EIA 1998).

together accounted for about 70% of the total electricity consumption. Most equipment related to this type of consumption can hardly be selected or controlled by the end-user. In contrast, office equipment, which indeed can be controlled by the end-user, amounted to just 12%. The direct influence of the end-user on electricity consumption in office buildings is actually quite low. Consumption levels in office buildings are predominantly determined by the building owners, architects and engineering contractors when decisions about the building shell and the equipment are taken.

The average thermal energy intensity amounted to 390 MJ/m^{2}a. It varied from 176 to 882 MJ/m^{2}a, mainly according to the thermal quality of the building shell. Surprisingly, the extent of electrical end-use equipment barely influenced the thermal index, despite the fact that electrical equipment dissipates heat. This small influence is due to the fact that, until the early 1980s, the electrical equipment and the heating system were planned independently, which led, very often, to the heating systems being over-dimensioned.

Changes in consumption (1986–1996). Within the observed period, the electric energy intensity reached a peak in 1992 (354 MJ/m^{2}a). The index increased continuously before 1992, and decreased afterwards (Fig. 3). Private-sector buildings consumed about twice as much as public-sector buildings due to higher amount of equipment in private-sector buildings, especially air conditioning. In fact, every third private-sector building was air-conditioned, whereas only every twentieth public-sector building was air-conditioned. Bank and insurance company buildings were found to have the highest share of air-conditioning (about 50% of the buildings).

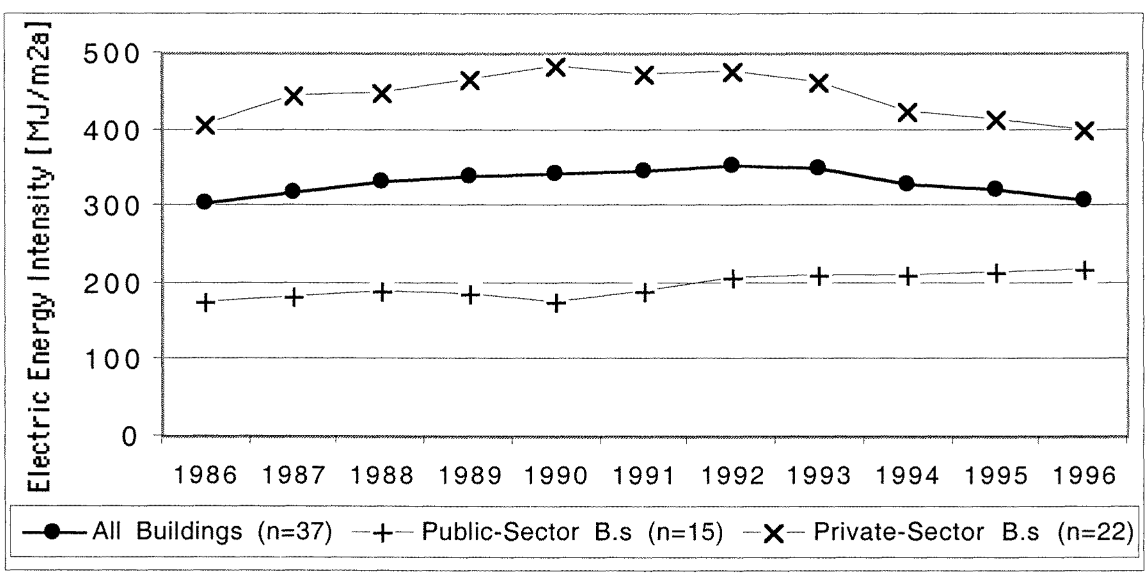

Figure 3. Electric energy intensities over the period 1986–1996 (average values, weighted by floorspace)[11]

[11] The sample size is smaller here than the total, because complete time series data were not available for all buildings.

The rise in electric energy intensity within public-sector buildings after 1990 was due to the increasing number of office equipment devices (Fig. 3). The decrease in intensity in private-sector buildings after 1992 was caused by the centralisation of computer suites.

Most of the dynamics of electricity consumption could be explained by innovations with central computing (computer suites, servers, etc.). A graph of the annually cumulated energy impacts of all revealed energy-relevant events – gathered independently from the time series data – illustrates the dominant role of central computing in the evolution of electricity consumption (Fig. 4).

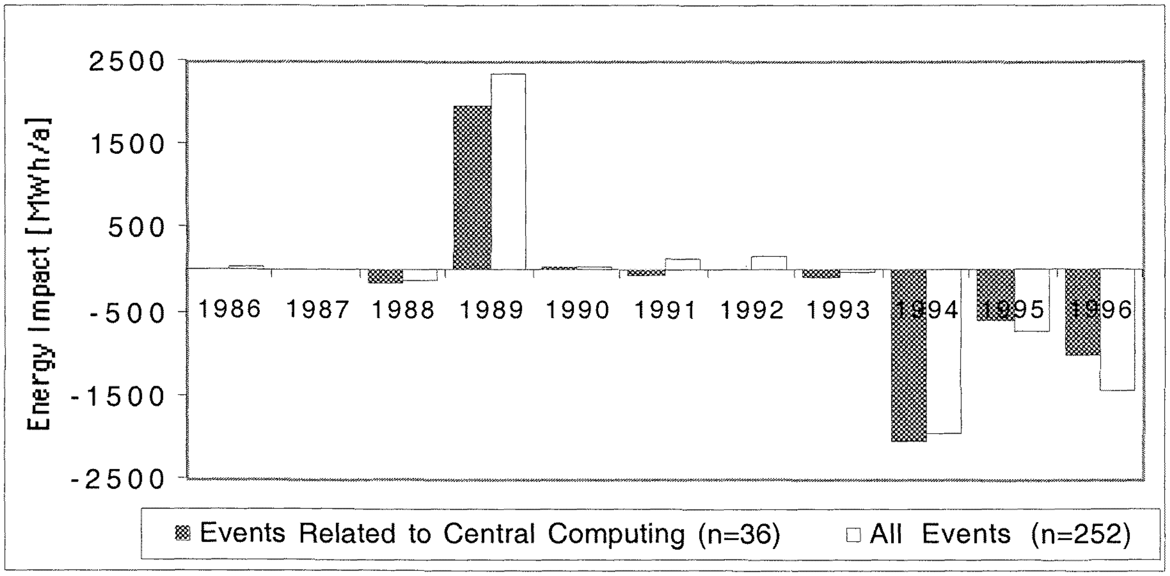

Figure 4. Annually cumulated energy impacts caused by energy-relevant events over the period 1986–1996 (revealed in 65 organisations)

Since computer services do not necessarily need to be housed within the building where they are needed, energy-relevant events related to central computing have to be analysed cautiously. While it was not possible to show that central computing was being replaced by personal computers, there was a significant centralisation of computer suites within big companies and company networks. In 10 out of 65 organisations, computer suites had been shifted out, while 3 organisations showed an increase in central computing caused by the same process. The net energy effect of computer centralisation was obviously negative, thanks to the efficiency gains arising from technical progress and more optimal size. That is, centralising computer suites can save a considerable amount of energy. However, the sample is too small to quantify accurately the size of the energy effect for Switzerland as a whole.

When all the events related to central computing are excluded from the sample, the types of equipment with the largest positive (increasing) impact on energy consumption were office equipment (33% of the cumulated positive energy impact), air conditioning (25%), uninterrupted power supply (19%), and a kitchen/restaurant (12%). If central computing were excluded again, the types of equipment with the greatest negative (decreasing) impact on energy consumption were lighting (37% of the cumulated negative energy impact), air conditioning (25%), ventilation (16%), telephone switchboard (11%), and an uninterrupted power supply (10%).

The group of consumption-decreasing events deserves special attention because such events saved energy, whether they were actually intended to do so or not. In fact, only 14% of the total consumption-decreasing effect was due to genuine conservation measures, while 79% was caused by events where energy conservation was not considered. Even if all events related to computer centralisation are excluded, 58% of the total consumption-decreasing effect was due to changes that were not of an energy conservation type.

Decisions behind changes in consumption. The ensemble of energy-relevant events was divided into three classes according to extent to which energy was considered when the decision was made:

- Energy conservation measures: Actions specifically undertaken to conserve energy,
- Energy-related events: Energy-relevant events intended for a different purpose than energy conservation, but decided with energy efficiency in mind (i.e. energy efficiency was not the central reason for the decision, but was also explicitly taken into account when the decision was made),
- Non-energy-related events: Energy-relevant events designed neither to conserve energy nor with energy efficiency in mind (= remaining).

Nearly every tenth energy-relevant event (9%) was of an energy conservation type. Their energy impact was negative, i.e. energy conservation measures all led to a decrease in energy consumption.

Every seventh energy-relevant event (14%) was decided with energy efficiency in mind. The direction of the changes in energy consumption was principally open: some events led to an increase in energy consumption; others led to a decrease.

By far the most energy-relevant events, 77%, were decided without respect to their impact on energy consumption. That is, the majority of events affecting energy consumption were decided without reference to any consideration of energy. However, with other buildings or within another period, the total effect could have been a consumption-increase. Hence, the decrease in consumption was an unintended side-effect, mostly due to technical efficiency gains related to central computing, telephone switchboard and lighting equipment.

Presumably the energy-relevant events most interesting to someone who seeks to make the use of energy more efficient were those which potentially *could* have been decided with energy efficiency in mind, but were not. The saving potential of these events (which is, properly speaking, rather an efficiency potential) is probably much greater than the potential of specific energy conservation measures if all related institutional and organisational barriers are considered. Energy-related decision-making can, therefore, be a true alternative to energy conservation measures.

In principle, each decision related to an installation, an increase in equipment or an equipment replacement could have been decided with energy efficiency in mind; however, only 35 out of 198 actually were (Fig. 5). The proportion of energy-relevant events that took energy efficiency into account varied with the type of equipment, but never exceeded 40%. While the freedom of choice related to the equipment used in central computing, telephone switchboards, uninterrupted power supplies and kitchens/restaurants is severely limited by technical requirements, the range of possible choice related to office equipment, lighting, ventilation and air conditioning is large. Technical help for decision-makers inside the organisation (e.g. building managers, computer departments, and technical services) as well as outside (e.g. architects or engineering contractors) might help re-define decisions as energy-related decisions. Surprisingly, the selection of those items of equipment for which target values for consumption have been established,[12] i.e. office equipment, lighting, ventilation and air conditioning, was not more frequently decided on with energy efficiency in mind than other items.

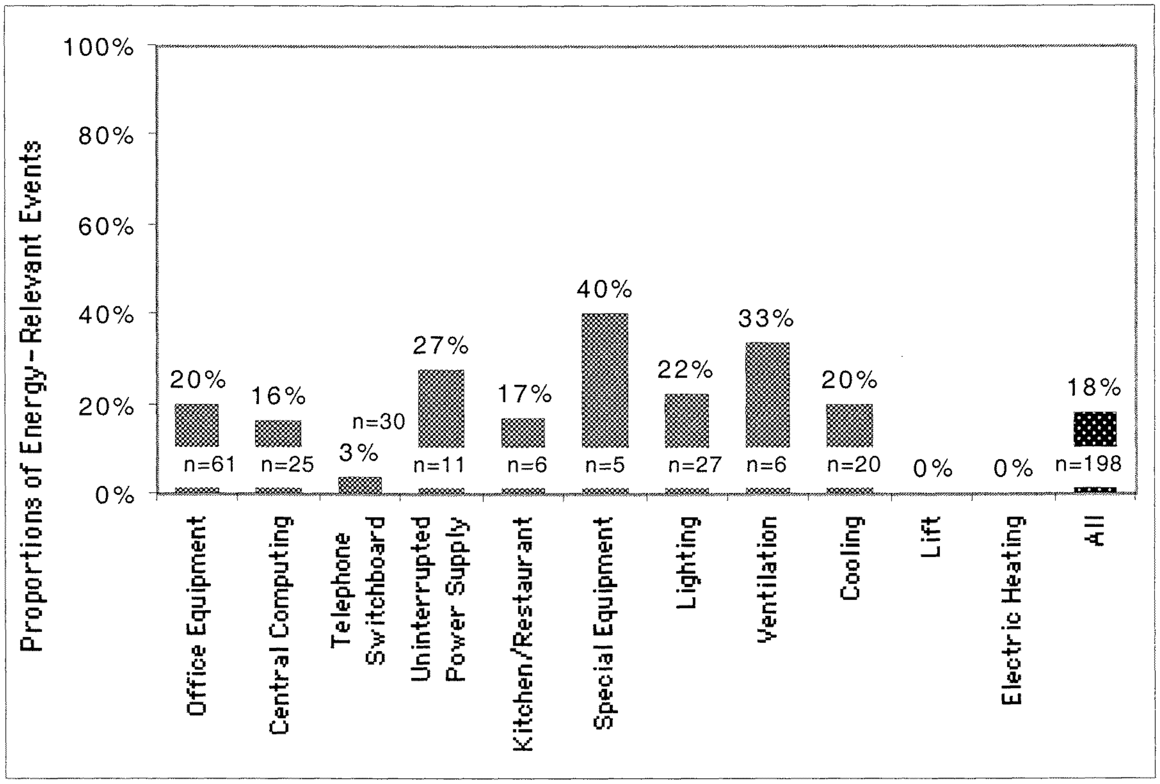

Figure 5. Proportions of energy-relevant events in which decisions took energy efficiency into account (n = 198 energy-relevant events[13])

Explicit energy conservation measures took place in 11 out of 65 organisations. They were more frequent in organisations with professional energy managers or where energy was monitored by a member of the board of directors. About two fifths (9 out of 22) of all conservation measures took place in bank and insurance companies, which also had a high share of either professional energy managers or of energy monitoring by a director, but also considerably higher electric energy intensities.

Energy cost may serve as a rough indicator of the economic value of energy in a firm. In interviews, directors generally tended to overestimate energy costs in their office buildings by a factor of about three. Compared to the total costs (including all salaries and operational costs), the average share of energy costs in office buildings was actually 0.87%, yet it was estimated by the directors to be on average 2.4%. Despite the rather low contribution of energy to the total costs, just 27 out of 65 directors assessed the energy costs to be negligible.

[12] For instance equipment labels or the Swiss norm, SIA 380/4 (cf. SIA 1995).

[13] All energy-relevant events related to an installation, an increase in equipment or an equipment replacement.

Both this overestimation and the very high valuation of the energy costs indicate that directors take energy issues seriously.

Nevertheless and despite existing saving potentials, energy conservation measures rarely took place, and those that did were either free of investment or were primarily undertaken in pursuit of non-energy-related goals, e.g. the improvement of the lighting quality. None of the organisations sampled invested exclusively in order to save energy. Directors are generally not willing to invest in energy efficiency even if the investment is profitable. Directors tend to concentrate on the core business, in which domain they are knowledgeable and powerful. Energy conservation measures are actually considered to be outside the scope of rent-seeking actions in firms, whether private or public sector.

Discussion

Up to now, descriptive theories of general energy-relevant behaviour have been rare in the literature and relatively underdeveloped. The mainstream theory of economic behaviour, according to which the demand for energy is often modelled as a function of price, can easily be applied to empirical analyses. Yet it fails when applied to energy-relevant decisions. The reason is that the majority of energy consumption choices are embedded in decisions related to technical infrastructure, which are strongly determined by the existing infrastructure, social consumption standards and individual consumption patterns. In western societies, energy is just a marginal factor and is usually treated as less important than other marginal factors, such as safety, convenience and comfort (cf. Morell 1981, 8).

Other theories are needed if we are to understand the patterns in energy consumption behaviour. McClelland & Canter (1981) provide a rich overview of psychological research on energy-relevant behaviour. These authors define energy consumption as a "by-product of a wide variety of actions […]. Energy use is […] virtually never an end in itself but rather a means toward many ends." (*ibid.*, 1) This sounds rather trivial, but in fact, most models of energy consumption indeed view energy-use as an end in itself in incorporating human choice in the model. Perhaps this is because psychological, economic and sociological theories of decision-making offer many more models of purposive choice than of unintended side-effects and the like.[14]

Apart from *a priori* considerations, the study reported here provides empirical evidence that energy is generally not an issue when energy-relevant decisions are taken. About three quarters of all energy-relevant events were found to be decided without explicitly taking into account the energy consequences. If these are not considered, they are *a fortiori* not assessed, neither in economic calculations nor in any kind of conscious evaluation. They rather "happen", which speaks for their side-effect character (cf. Olsen 1981; Schuster 1997). Of course, disregard for energy consequences may be motivated by an economic or similar assessment (e.g. the consideration of opportunity costs). However, such an assessment will, by its nature, be idiosyncratic rather than systematic, so that it cannot explain energy-relevant behaviour in a definite way.

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[14] Thus, this methodological preference for models of purposive action has to do with pragmatics of research rather than with the inherent nature of the subject. Actually, standard models are often applied to empirical cases for which they are not made. This sometimes leads to impressive, yet potentially misleading results.

The systematic analysis of built environments and their making offers a practical way to investigate energy consumption as an unintended side-effect. For example, Lutzenhiser (1994) sheds light on the organisational networks' shaping and constraining character related to energy-efficiency innovations. Kasanen & Persson (1997) perform an analysis of complex decision-making processes behind window purchase choices, recognising interaction between the involved parties (building owner, architect, municipality, etc.) as well as within them. Janda (1998) has interviewed architects and engineers in order to identify the organisational characteristics of building design firms that determine the adoption of energy-efficiency in the building design. Ryghaug (1999) has reviewed energy-related articles in architectural journals in order to identify attitudinal attributes of architects that favour or disfavour energy efficiency in their work. All these studies applied approved social science methods and organisational theories.

The study reported here was also based on an organisational approach. However, it was difficult to apply existing theories to our case. Although there is an extensive literature about decision-making in organisations, descriptive theories are rare, and those that exist are either so abstract that they are difficult to apply to empirical research (e.g. a garbage can model, cf. Cohen, March & Olsen 1972), or they are so specific that it is hard to apply them to a different case (e.g. the subjective expected utility model in Enste 1998). The methodology developed here has proved to be useful and could be further developed both empirically and theoretically. The method of energy-relevant events could be applied to different empirical objects, for instance personal decisions about where to settle or where to spend holidays, or to inter-organisational decisions related to the construction of new buildings. Furthermore, hypotheses could be tested about the energy impact of particular features of a national infrastructure (e.g. the availability of public parking areas in cities, the quality of a public transport system, etc.) or features of governmental policies (e.g. direct or indirect subsidising of private housing, taxation of energy resources, etc.). The analysis of energy-relevant actions has just begun.

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