An Evaluation of Energy-Relevant Decision-Making in Office Organisations

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ABSTRACT

This paper is about the decision-making that underlies changes in the operation and stock of technical infrastructure in office organisations. The findings are based on a nation-wide survey of electricity consumption in Swiss office buildings over the period 1986–1996. Changes in the operation and stock of equipment, which I refer to as energy-relevant events, were reconstructed in terms of their impact on the annual electricity consumption, the decision-makers involved and the extent to which energy was considered when the event took place.

Energy is not an issue in most of the decisions related to a change in the operation and the stock of equipment. In terms of a theory of action, energy consumption tends to "happen" rather than being consciously chosen. However, energy programs can influence the way energy-relevant decisions are taken by, for example, ensuring that members of the service staff in the organisation are given technical help when new equipment is purchased and serviced. Energy conservation should focus on making technical infrastructures rather than on end-use.

Introduction

Energy consumption tends to take place without conscious choice. Decisions about technical infrastructures, operational practices and equipment end-use often involve energy, regardless of whether the energy consequences are consciously considered or not (cf. Lovins 1992; Moisander and Kasanen 1993). Since decisions affecting energy consumption tend to be embedded in decisions based on other criteria, analysing them and, *a fortiori*, intervening in energy consuming processes is a difficult and subtle task. In this paper, some past changes in the technical infrastructure which have affected energy consumption are analysed. The data is based on a survey of 62 organisations[1] in Swiss office buildings for the ten years, 1986–1996. The analysis involved studying empirical changes in the stock and the operation of energy consuming equipment, referred to as energy relevant events. For each event, the appliances involved were identified, the impact on the annual energy consumption was reconstructed, the decision-makers involved were identified and the extent to which energy was considered when the event was taking place was retrospectively determined. The survey data was gathered using energy audits, document analyses and face-to-face interviews with decision-makers in the organisations.

Drawing on this analytic approach, this paper advocates indirect measures to improve energy efficiency rather than direct measures. It is argued that it makes more sense to consider energy-efficiency when making decisions about core business matters (e. g. the acquisition of office equipment) than to undertake particular energy conservation actions. If we pursue this argument, then ways of improving energy efficiency will differ somewhat from most of those considered today. To this end, decision-making in

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[1] In this paper, 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, a department or a set of departments in a firm.

organisations would have to be carefully analysed, interventions that target crucial decision-makers rather than the end-users planned and, last but not least, powerful models of energy-relevant decision-making constructed. The results presented here are confined to office organisations, but can easily be applied to different objects, such as industrial organisations or private households.
Little empirical analysis of decision-making processes in organisations has yet been done in energy program evaluations. There have been few investigations into energy-relevant decision-making in architect and engineering firms (Janda 1994, 1996, 1998; Ryghaug 1999) and the housing industry in general (Lutzenhiser 1994; Kasanen & Persson 1997; Reed, Oh & Hall 2000). The method developed here is new in that it seeks to explain energy-relevant decision-making in office organisations in a systematic manner.

A Survey of Energy-Relevant Events in Office Buildings

Before beginning to analyse energy-relevant decision-making, some crucial characteristics of energy consumption in organisations should be mentioned:

- Energy consumption is a derived demand. Humans do not demand energy as such, but rather energy-consuming services. Energy is consumed in technical appliances (air conditioners, light bulbs, computer equipment, etc.). The amount of energy consumed depends on the technology used, the size, the hours of use, etc. of the applications involved. There is no one single direct relationship between any particular energy service and the amount of energy consumed.
- Energy use takes place in organisations. The organisations analysed can be characterised by their formal structure (e. g. legal status) and their organisational framework (organisational goals, hierarchy, division of tasks, etc.).
- Energy-relevant decisions are taken by organisational actors. Decisions are shaped by the organisational role of the decision-maker (employee, technical staff, upper-level manager, etc.) and the kind of responsibility with which they are taken (spontaneously, while in charge, by delegation, etc.).
- The energy impact of an energy-relevant decision strongly depends on the equipment involved and the kind of decision made. The energy consequences of energy-relevant events vary with the sort of equipment (large vs. small energy consumers, controlled by technical staff vs. controlled by end-users, etc.), and whether the decision is about an immediate or future use (end-use, acquisition, planning, etc.).

These features of energy consumption in organisations suggest that it is not only the technical equipment that should be analysed so as to better understand the dynamics of energy consumption but also the social organisation and particular decisions taken.

Survey Method and Surveyed Variables

Changes in the stock and the operation of energy-consuming equipment within office buildings[2] in private and public-sector organisations were empirically analysed.[3] The observation period was 1986–1996. One hundred buildings located in the German and French-speaking parts[4] of Switzerland were ran-

2 Office buildings were defined as buildings with an office usage share of 50% or more.
3 An overview of the survey data is given in Weber (2000).

. One hundred buildings located in the German and French-speaking parts[4] of Switzerland were randomly selected within five classes according to building size.[5] In doing so, large buildings were deliberately over-sampled, which led to greater variation in the variables surveyed and an increase in the analysed floorspace[6] to two percent of the total office building floorspace in Switzerland, amounting to half a million square meters. Within the selected buildings, 235 energy-relevant events in 62 organisations were analysed.

Both representatives of the buildings – building managers – and representatives of the organisations – upper-level managers – participated voluntarily.[7] Since public-sector organisations were more willing to participate than private-sector ones, the public sector was over-represented by about a factor of two. The bias in the sampled data caused by the building classes and the over-representation of public-sector organisations was removed.

The data about energy-relevant events and their decision-making was gathered using audits and face-to-face interviews). Energy-relevant events describe larger (1MWh/a)[8] durable changes in electricity consumption. The set of events was sampled so as to be comprehensive for the organisations sampled. Organisational energy measures (e. g. the introduction of an energy manager) and changes in the behaviour of end-users were not termed energy-relevant events since their impact on annual consumption could not be precisely determined. Nevertheless, if the presence of an energy manager or the behaviour of an end-user led to a change in the stock or in the operation of energy-consuming equipment, their impact was part of the collection of energy-relevant events.

Energy-relevant events were characterised by the end-use equipment involved («equipment_involved»), the change involved («change_involved») and the character of the change («change_character») (Table 1). Every event was dated by year («year»), indicating that, from then on, it had affected energy consumption. For each event, the impact on the annual energy consumption was quantified by engineering estimations («energy_impact»). The process of decision-making was subdivided into three stages: initiation, preparation and final decision. For each stage, the main decision-maker was determined («subject_initiation», «subject_preparation» and «subject_decision»). The complexity of the decision-making process was measured by an index, indicating the length of the path from the subject who initiated the event to the subject who finally decided on the realisation of the event («decision_path_length»)[9]. Finally, the extent to which energy was considered when the event was being realised was surveyed («energy_consideration»). This variable differentiates between energy conservation measures, events intended for a different purpose than energy conservation, but decided on with energy efficiency in mind

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4 The Italian-speaking part, where 4% of the inhabitants in Switzerland live, was excluded because of language problems.

5 The classes were defined by equidistant intervals based on the insurance sum (1.5 – 10, > 10 – 20, > 20 – 30, > 30 – 40, > 40 Million Swiss Francs). It was the aim to select 20 buildings out of each class; in practice, this aim was only approximately attained.

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

7 563 building managers and 1163 upper-level management units were asked to participate independently of each other. The response rate was 65%, and 49% of the respondents agreed to participate. Buildings where both the building manager and the upper-level management had responded favourably were preferably selected.

8 A change of 1 MWh/a means that from the year in which the event took place, the annual electricity consumption was 1 MWh/a higher.

9 The path length was measured in terms of number of passes, where a pass could be from employee to service staff, service staff to upper-level management, or upper-level management to board of directors, as well as from any subject within the organisation to a contractor or from a contractor to any subject within the organisation. The index is the sum of the path length from the subject who initiated the event to the subject who prepared its realisation plus the path length from the subject who prepared the realisation of the event to the subject who finally decided on the realisation of the event.

(energy-related) and events designed neither to conserve energy nor with energy efficiency in mind (non-energy-related).

Table 1. Variables concerning energy-relevant events

Variable	Explanation	Values/Dimension
Equipment_involved	End-use equipment involved	{office equipment, central computing, telephone switchboard, uninterrupted power supply, canteen, special equipment, lighting, ventilation, cooling, lift, electric heating}
Change_involved	Change involved	{installation, increase, replacement, decrease, shut-down}
Change_character	Character of the change	{change in the stock, change in the operation}
Year	Year in which the event took place	#
Energy_impact	Energy impact of the event	[MWh/a]
Subject_initiation	Subject who initiated the event	{employee, service staff, upper-level management, board of directors, contractor}
Subject_preparation	Subject who prepared the realisation of the event	{employee, service staff, upper-level management, board of directors, contractor}
Subject_decision	Subject who finally decided on the realisation of the event	{employee, service staff, upper-level management, board of directors, contractor}
Decision_path_length	Length of the path from the subject who initiated the event to the subject who finally decided on the realisation of the event	{0…6} (index)
Energy_consideration	Extent to which energy was considered when the event was being realised	{non-energy-related, energy-related, energy conservation}

Findings

Within the sampled organisations, data on 235 energy-relevant events were collected and analysed. For 214 events, a value for the energy impact could be estimated.

Energy Impact of Energy-Relevant Events. The values of the energy impact of the events varied considerably (Figure 1). The values could be positive (indicating a consumption-increasing event) as well as negative (indicating a consumption-decreasing event). The median of the energy impact was +1 MWh/a, while the mean amounted to -4.2 MWh/a. Thus, the level of electricity consumption remained about constant within the observed period.

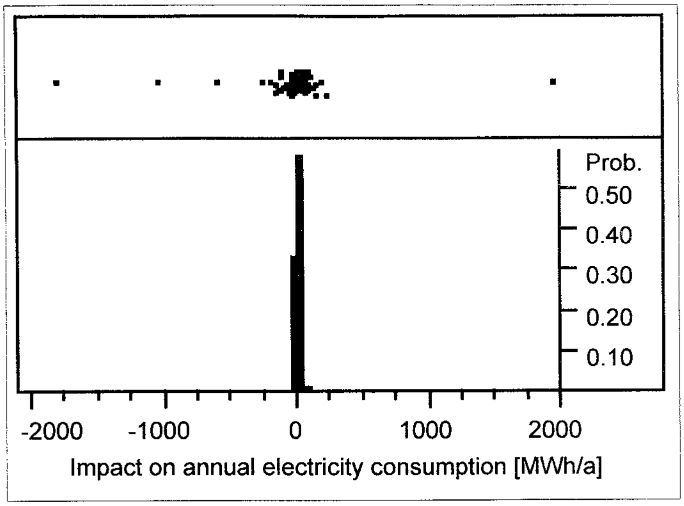

Figure 1. Distribution of the energy impact of energy-relevant events (with outliers shown, n = 214 events)

Events related to central computing (mainframes, servers, etc.) had by far the highest energy impact. Since central computer services do not necessarily have to be housed within the building where they are needed, these events must be analysed with caution. In fact, there was a considerable move to centralise computer services during the period analysed. The net energy effect was negative, thanks to efficiency gains arising from technical progress and more optimal size. However, the sample of organisations was too small to accurately quantify the energy effect for Switzerland as a whole. If the energy-relevant events related to the centralisation of computers services are excluded, the median of the energy impact of the events was +2 MWh/a, while the mean amounted to -1.2 MWh/a.

Not surprisingly, central computing had the highest accumulated impact on energy consumption among all end-use equipment (63%), followed by office equipment (11%), cooling and lighting (8% each) (Fig ure 2).

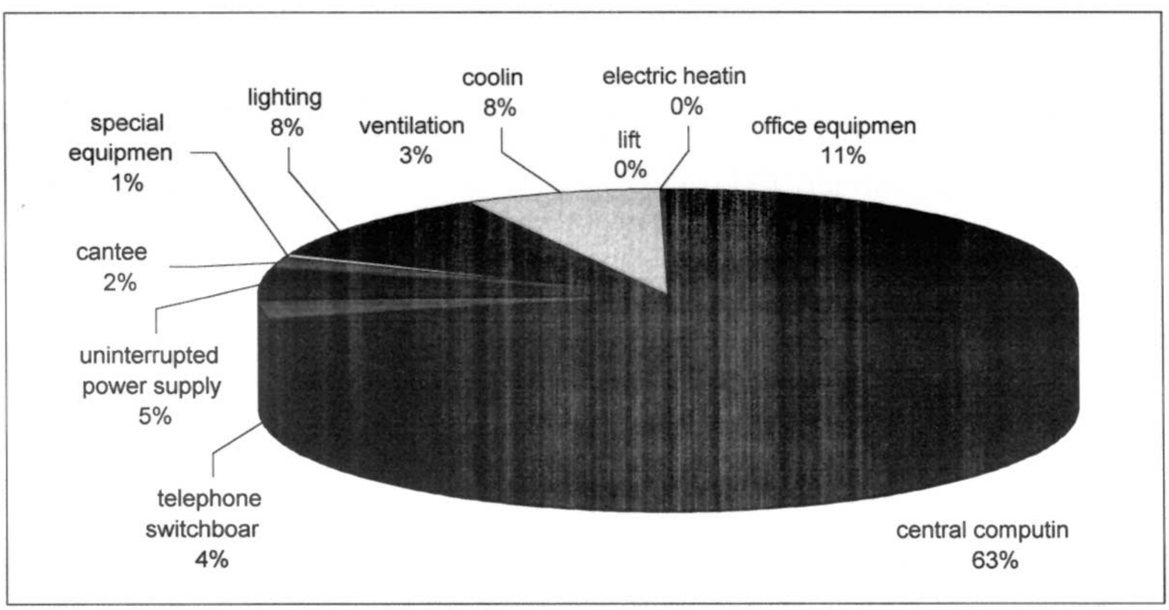

Figure 2. Accumulated absolute values of the energy impact of energy-relevant events by end-use equipment (n = 214 events)

A regression analysis of the energy impact according to the different variables concerning the energy-relevant event and its decision-making indicated a strong correlation of the energy impact with the end-use equipment involved (Table 2). A strong correlation was also observed with the extent of energy-consideration. Energy conservation measures had the highest energy impact (37 MWh/a on average taking the absolute values), followed by energy-related events (26 MWh/a). Non-energy-related events had an energy impact of 10 MWh/a on average. Another significant correlation was the subject who finally decided on the realisation of the event. Events where the final decision-maker was a service staff member had the highest energy impact (33 MWh/a on average for absolute values), whereas events finally decided on by the upper-level management had a mean energy impact of only 12 MWh/a. The service staff, although low in the organisational hierarchy, had a high influence on energy consumption. Conversely, other non-management employees turned out never to take a final decision on the realisation of an energy-relevant event. Their influence on energy consumption is therefore quite low.

Table 2. Statistical sensitivity of absolute values of the variable «energy_impact» (R^2 and significance at the 0.05 level;[10] events related to a centralisation of computer services excluded, n = 190…196 events)

Technical variables		**Behavioural variables**	
Equipment_involved	0.13 **	Subject_initiation	0.03 (n. s.)
Change_involved	0.05 *	Subject_preparation	0.03 (n. s.)
Change_character	0.00 (n. s.)	Subject_decision	0.06 **
Year	0.04 (n. s.)	Decision_path_length	0.03 (n. s.)
		Energy_consideration	0.06 **

Extent of Energy-Consideration in Energy-Relevant Decision-Making. Energy conservation applied to 7% of the energy-relevant events, while 13% of the events were designed for a different purpose than energy conservation, but were decided with energy efficiency in mind.[11] The remaining part, 80% of the events, though affecting energy consumption, were decided without a consideration of the energy consequences.

The extent of energy-consideration was strongly correlated with the end-use equipment involved (Table 3). Events related to ventilation had the highest share of energy conservation measures (35%), followed by events related to lighting (26%). Conversely, events related to central computing and office equipment had high shares of non-energy-related events (88% and 83%, respectively). While limited choice could explain the low energy-consideration related to central computers, this cannot explain failure to consider energy when choosing office equipment. Thanks to labels on office equipment such as energy star®, it would be easy to consider energy efficiency. However, this option was actually seldom taken up.

[10] Significance classes according to the „stars" convention:

(n. s.)	P > 0.05	not significant
*	0.05 P > 0.01	slightly significant
**	0.01 P > 0.001	highly significant
***	0.001 P	most highly significant

[11] These numbers may sometimes be different from those published in earlier papers because, in the latter, the bias in the sampled data was not removed.

Table 3. Statistical sensitivity of the extent of the variable «energy_consideration» (R^2 and significance at the 0.05 level, n = 214...235 events)

Technical variables		Behavioural variables	
Equipment_involved	0.08 ***	Subject_initiation	0.04 **
Change_involved	0.12 ***	Subject_preparation	0.05 *
Change_character	0.01 (n. s.)	Subject_decision	0.06 ***
Year	0.03 *	Decision_path_length	0.03 *
Energy_impact	0.00 (n. s.)		

The extent of energy-consideration was further strongly correlated with the change involved (Table 3). Energy conservation measures were relatively frequent when equipment was replaced (17% of all replacements). In turn, events related to the installation of equipment were mostly decided on without energy-efficiency in mind (91% of the events).
Interestingly, the extent of energy-consideration did not correlate with the amount of energy impact (Table 3).
Most of the energy conservation measures were initiated and also finally decided on by members of the technical staff (12 out of 22 conservation measures). Energy conservation measures were more frequent the shorter the path of decision-making (Figure 3, picture on left). Most of the energy conservation measures were initiated, prepared and finally decided on by one single decision-maker, mostly a member of the technical staff. Thus, energy conservation measures that required the approval of several decision-makers (especially measures which involved a financial investment) were unlikely to be implemented, even if they had been successfully initiated (cf. Sassone & Martucci 1984).

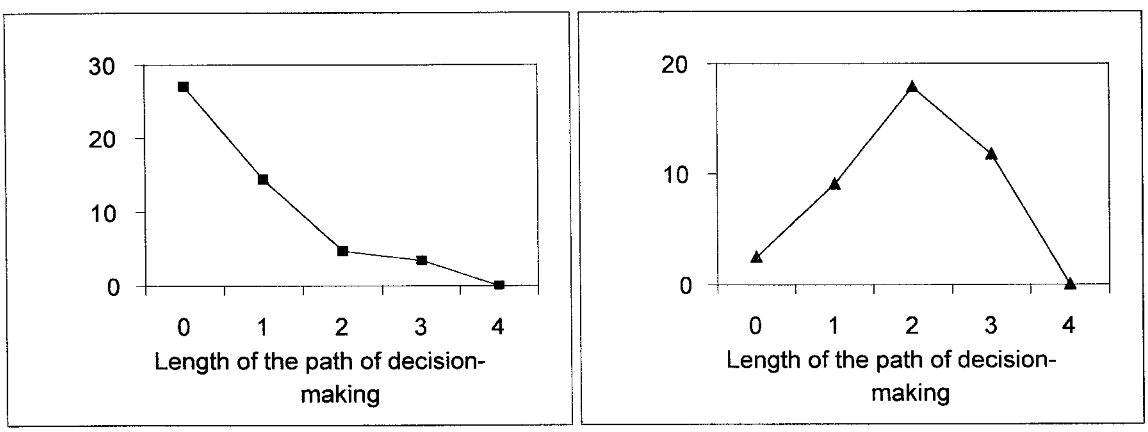

Figure 3. Share of energy conservation measures (left hand picture) and share of energy-related events (right hand picture) by length of the path of decision-making (n = 235 events)

Decisions that took into account energy efficiency were most frequently implemented when the length of the path of decision-making equalled two (Figure 3, picture on right). In contrast to energy conservation measures, energy-related events often do involve a large financial investment, which makes the length of the path of decision-making longer.
Energy Costs Relative to Total Expenses. The representatives of the upper-level management interviewed estimated the share of the energy costs relative to the total costs including salaries within the

analysed organisations to be 3.2% on average.[12] The high variability of the estimated values could indicate that the interviewees were uncertain about their estimates (Figure 4). Many interviewees even refused to give a number at all.[13]

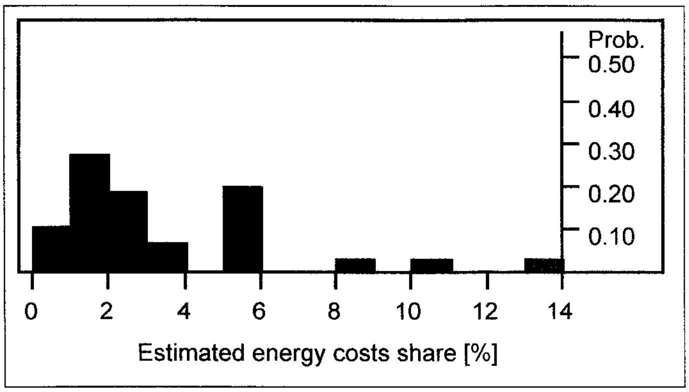

Figure 4. Distribution of the estimated values of the share of energy costs (n = 55 organisations)

However, the actual mean share of energy costs amounted to only 0.74%, which was less than a quarter of the estimated number (Figure 5). The level as well as the variation of the values were far below those of the estimated values.

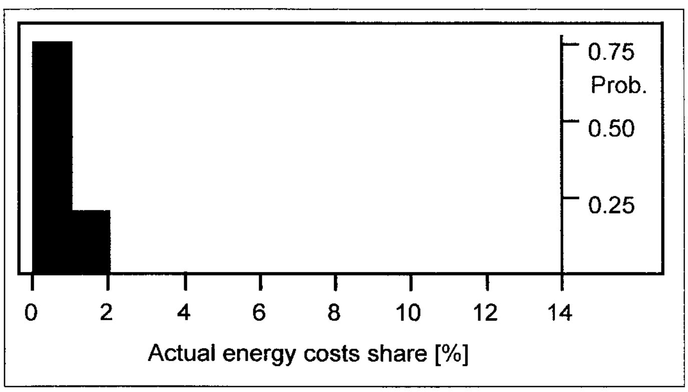

Figure 5. Distribution of the actual values of the share of energy costs (n = 54 organisations)

There was hardly any correlation between the actual and estimated values ($R^2 = 0.02$, not significant at the 0.05 level). This suggests that upper-level managers tend not to know much about the energy costs of their organisation.

The high estimations of the share of energy costs could point to the fact that managers tend to value energy highly, which could mean that they would actually seek to use energy in an efficient way. Conversely, their unrealistic estimates indicate a lack of knowledge, which could mean that they place little value on energy. The overall picture is contradictory. However, since we can assume that a single cost factor (e. g. energy costs) is generally over-estimated when explicitly tested, the over-estimation may

12 Cf. previous footnote.

13 The rate of non-response amounted to 25%, which was the highest in the survey.

well be based on survey-technical reasons rather than on objective reasons. Energy consumption probably has a low priority in upper managers' minds.

Conclusions

A few energy-relevant events, mainly to do with a centralisation of computer suites, had an extremely high impact on electricity consumption in office buildings. In fact, these events dominated the development of consumption within the observed period. They led to considerable decreases in electricity consumption, though energy conservation was not an issue when decisions were implemented. On the other hand, the average energy impact of those events that had been decided on taking energy efficiency into consideration was relatively low. The energy consequences of energy-relevant events are seldom considered, even if there is technical help for decision-makers available (e. g. energy labels). Thus, energy consumption tends to be a side-effect of business activities rather than the result of a purposive choice. Efficiency advocates may be upset by this, but they cannot change it. Rather than advocating particular conservation actions, they would be better put identifying the pivotal moments in decision-making and who the crucial decision-makers are, and then trying to technically influence the energy impact of those changes that are going to happen anyway.

Once an office building is constructed, the members of the service staff (the computer department, the construction department, the facility engineers, etc.) are probably the most influential decision-makers. A great number of energy-relevant events are initiated and prepared by them, and those events that are finally decided on by them have the highest energy impact. Further, almost all energy conservation measures were initiated, prepared and finally decided on by the service staff. Thus, energy programs should focus their activities on the service staff members. They are normally few in number and, after having been identified, are easy to address. Activities directed to the end-users are less promising, since there are so many of them, and they tend to know little about energy issues and to be of limited influence.

The study showed that explicit energy conservation rarely takes place and if it does, then only if no financial investment is required. As soon as several decision-makers are involved, energy conservation measures become very unlikely. Rather than stimulating isolated actions, energy programs should encourage efficiency measures as a part of the regular service, maintenance and purchasing policy. This could be done by providing technical help in decision-making and by giving the service staff basic and further training.

Upper-level management turned out not to be very knowledgeable about how much energy costs their organisations. Energy programs that primarily appeal to cost-saving principles will probably have little success. Financial incentives may help, but as a trigger rather than as a variable in a rational calculation Nevertheless, upper-level managers can support energy efficiency by demanding energy-efficient solutions from the service staff and contractors when they make decisions about energy-relevant investments.

Theories of rational choice obviously fail to explain the energy consequences of energy-relevant decisions. This study found that energy consumption was more often an unintended side-effect than the result of the implementation of a purposive decision. It is difficult to develop a theory of unintended side-effect since there is no link between the energy consumption outcome and the purpose of an action and thus, no empirical predictions can be made. Nevertheless, the fact that energy-relevant decisions are often made without considering energy consumption helps us to see that many of these decisions are probably not made in an "irrational" manner, but within a rationality that does not take into account the efficient use of energy.

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