Beyond Energy Conservation: Energy-Relevant Decisions within Office Buildings

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1 SYNOPSIS

The development of electricity consumption 1986–96 in one hundred Swiss office buildings was analysed in order to determine trends in consumption and to characterise energy-relevant decision-making.

2 ABSTRACT

Most energy analysts seek to make energy consumption more efficient. Many adopt a simple theory of economic rationality, in which it is assumed that decisions related to energy consumption in firms will be taken in favour of energy efficiency so long as they are cost-effective. This assumption, however, is wrong, as the research reported here demonstrates.

The development of electricity consumption between 1986 and 1996 was studied empirically in one hundred Swiss office buildings selected at random. The data show that, although managements tended to overestimate energy costs by a factor of three, energy efficiency was taken into consideration in less than a quarter of all decisions related to a change in technical infrastructure or maintenance, which I call energy-relevant decisions. Moreover, only one seventh of the total reduction in electricity consumption was expressly intended to save energy. Most energy savings were a positive side-effect of core business-related activities. The factor found to have the most impact was an increase in computing.

The majority of energy-relevant decisions were about investments. The nominal decision-maker was the management, but in practice we found decisions were mostly taken by specialists inside the firm, e. g. the maintenance staff. Conservation measures that require an extra investment are unlikely to be taken because of their low priority compared to investments in the core business. Successful conservation measures were mostly initiated, decided and realised by a single person fairly low down in the hierarchy.

3 INTRODUCTION

Energy analyses reveal many cases where energy is used in an inefficient way. As far as OECD-countries are concerned, the potential of neglected energy conservation measures that make economically sense amounts to 30% of the total energy consumption (IEA 1987, 63). In fact, there is considerable potential for attaining greater energy efficiency by adopting better technologies, planning processes and operational practices. Unfortunately, many possible energy conservation measures are not taken because they either are, or are said to be, too costly. However, greater energy efficiency could be achieved by making sensible decisions about future energy consumption, e. g. when choosing new technical equipment. Most decisions concerning energy, which I call energy-relevant decisions, are taken without considering energy efficiency. If energy-relevant decisions took energy factors into account, energy efficiency could be achieved in a simple and effective way.

In order to investigate how energy-relevant decision-making in firms works, an empirical study was done on the development of electricity consumption between 1986 and 1996 in one hundred Swiss office buildings. The empirical results are based on documents, energy audits and interviews. The aims of the study were the following:

- To determine typical trends in the development of electricity consumption;
- To identify crucial changes in technical equipment and evaluate their impact on consumption;
- To identify the relevant decision-makers and assess what opportunities they have in order to take energy consumption into account in making decisions;
- To determine what role energy efficiency plays in decision-making and to evaluate the impact of energy conservation measures on energy consumption;
- To evaluate the impact of the way firms are organised on their energy efficiency.

In this paper, some of the main results are presented.[1] First, I introduce energy-relevant decisions, which are a model of change in electricity consumption. I then describe the analysed sample and present some empirical indicators of managements' attitudes to energy. I give a typology of energy-relevant events and exemplify them for the analysed sample. Finally, I describe energy-relevant decision-making in some selected cases in more detail.

4 METHODOLOGY

An analysis of energy-relevant decision-making strongly depends on how decisions are modelled, i. e. which parameters of decision-making are analysed and how they are linked. In this study, the following problems had to be solved:

- The study was retrospective. That is, the development analysed was in the past and could not be directly observed. Decisions had to be reconstructed by means of documents, energy audits and interviews.
- There is no widely accepted definition of "decision". It is not evident what empirically a decision is. Decisions have a technical as well as a social side. Before carrying out the interviews, a model of decision-making was therefore constructed.
- There is no widely accepted definition of "energy-relevant". Energy-relevant decisions can be conceived as either quite close or less close to the technical infrastructure. Before the energy audits were performed, a typology of energy-relevant events was developed.

The employment of additional staff may affect energy consumption, as may the purchase of new computers. Both are energy-relevant, but their effects are different. This study focuses on decisions that can be seen as **close to the technical infrastructure**, because their impact on energy consumption can be assessed in a more definite and precise way than broader decisions.

Infrastructure-related decisions in office buildings are taken at various levels of action: at the level of construction, the level of selection and maintenance of equipment and the level of final use. This study focuses on the middle level, because decision-making concerning the **selection and maintenance of equipment** is formalised and can be reconstructed for the past.

Although there is a very extensive literature about organisations and management, descriptive theories of decision-making in firms are rare and those that exist are too abstract for the purpose of an empirical study. Thus, a model of energy-relevant decisions was constructed. An energy-relevant decision is conceived to have two components, an **energy-relevant event** and some **energy-relevant decision-making** (Figure 1). Energy-relevant events are preferably described in technical terms (e. g. increase in number of computers, shut-down of ventilation, increased use of canteen), whereas energy-relevant decision-making is preferably described in organisational terms (e. g. Who decided? What was the purpose? Did the decision take into account energy efficiency or not?).

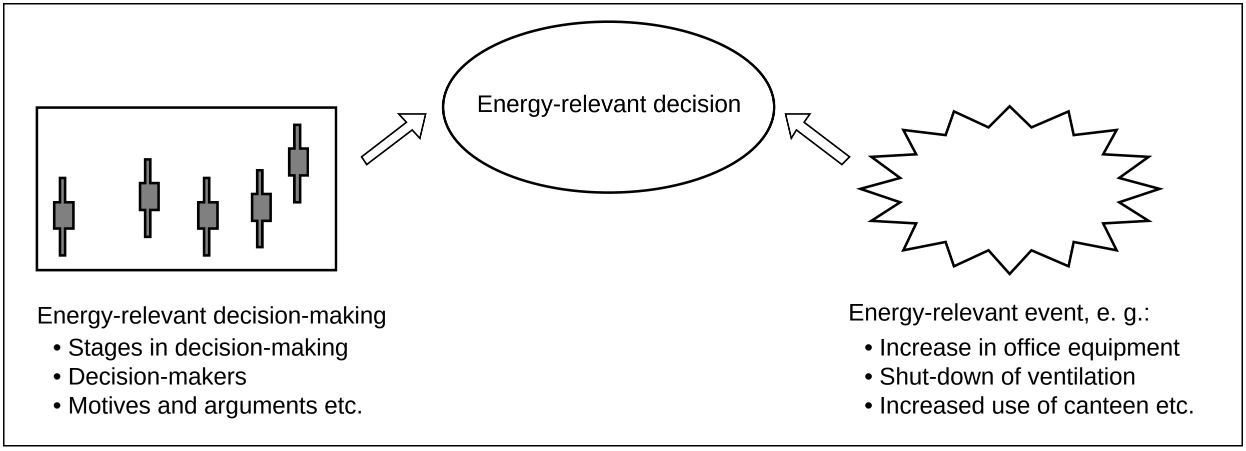

Figure 1 ***Construction of a model of energy-relevant decisions***

4.1 Energy-Relevant Decisions

In this study, a decision is called energy-relevant if it changes energy consumption directly and endurably. Whether the decision was made on the basis of energy efficiency or not is irrelevant. Nor does it matter whether a formal decision-maker or an informal one was involved. What counts is only whether the decision affected energy consumption or not. An energy-relevant decision is therefore defined as follows:

1. The decision is deliberately taken;
2. The decision is autonomously taken (i. e. it is taken independent of any other energy-relevant decision);
3. The decision leads to a endurable change in energy consumption;
4. The decision can be technically reconstructed (i. e. there are potentially various technical ways of reaching the same goal).
5. The impact on energy consumption is estimated to be ≥ 1 MWh/a.

Each energy-relevant decision was dated by year, indicating that, from then on, it had affected energy consumption. The impact on energy consumption was estimated in megawatt hours per year (MWh/a). The estimation was based on technical information and engineering experience. For example, “+23 MWh/a in 1990” means that an event was estimated to have increased electricity consumption by 23 MWh from 1990 on (Figure 2).

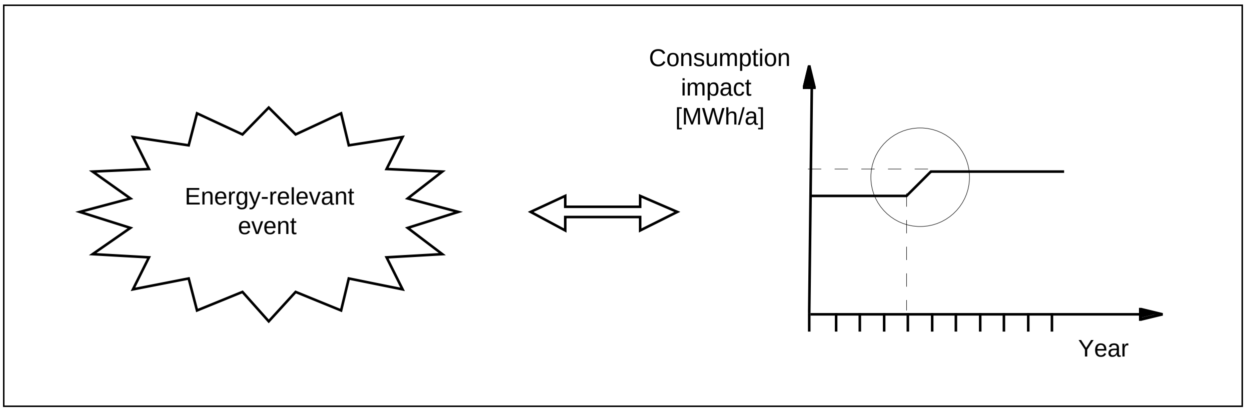

Figure 2 ***Impact model of an energy-relevant event***

One object of the study was to reconstruct the annual development of electricity consumption in firms on the basis of energy-relevant events, i. e. to explain all increases and decreases in consumption in terms of the collection of events previously identified. Ideally, the collection fully explains the development; i. e. each increase or decrease in real consumption can be traced back to one or several events. It is obvious that the performance of the model depends on how complete the collection of events is, and how accurate the dating and the estimation of the impact are. Supplementary annual data on surface, staff and office equipment were collected to catch gradual processes, which are easily lost in an event-based model.

1.1.1 A Typology of Energy-Relevant Events

A three dimensional typology was developed to order energy-relevant events. Three categories were: the equipment and the kind of change involved, and the character of change (Table 1).

- **The equipment involved:** Office equipment, central computing, telephone switchboard, UPS (= uninterrupted power supply), kitchen/restaurant, special equipment (powerful copy machines, cold-storage chambers, circulation pumps etc.), lighting, ventilation, cooling, lift, electric heating, and the floor area (this means office equipment, lighting, ventilation and cooling);
- **The change involved:** Installation, increase, replacement, decrease, shut-down, expansion and reduction;
- **The character of the change:** change in equipment, change in maintenance (M).

Table 1 Typology of energy-relevant events (possible types shadowed; "M" is for a possible change in maintenance)

Equipment	Installation	Increase	Replacement	Decrease	Shut-Down	Expansion	Reduction
Office equipment							
Central computing		M		M			
Telephone switchboard							
UPS							
Kitchen/Restaurant		M		M			
Special equipment		M		M			
Lighting		M		M			
Ventilation		M		M			
Cooling		M		M			
Lift							
Electric heating		M		M			
Floor area							

1.1.2 A Model of Energy-Relevant Decision-Making

For each energy-relevant event, decision-making was analysed (Figure 3). The process of decision-making was subdivided into three stages. For each stage, the main decision-maker, who can be an individual or a group, was determined.

- **Initiative:** Individual or group who initiated the decision.
- **Preparation:** Individual or group who technically prepared the decision, i. e. who chose the technology or the way of change in maintenance.
- **Final decision:** The formal decision-maker.

It is conceded that this is a rough model of decision-making. However, it is practicable even for events far back in the past. Further data was collected for each decision:

- **Purpose:** The formal reason that justified the decision (not necessarily the initiator's motive).
- **Energy-relation:** Status which describes whether energy efficiency was a criterion or not when the decision was prepared ("energy-related" or "non energy-related").
- **Year:** The year when the event began to affect energy consumption.
- **Description:** Technical specification of the event.
- **Impact:** The estimated increase or decrease in energy consumption (in MWh/a).

For each decision a complete set of data was collected. It was gained in face-to-face interviews with representatives of the management, mostly with senior members of the service line or with directors. The interviews were based on checklists.

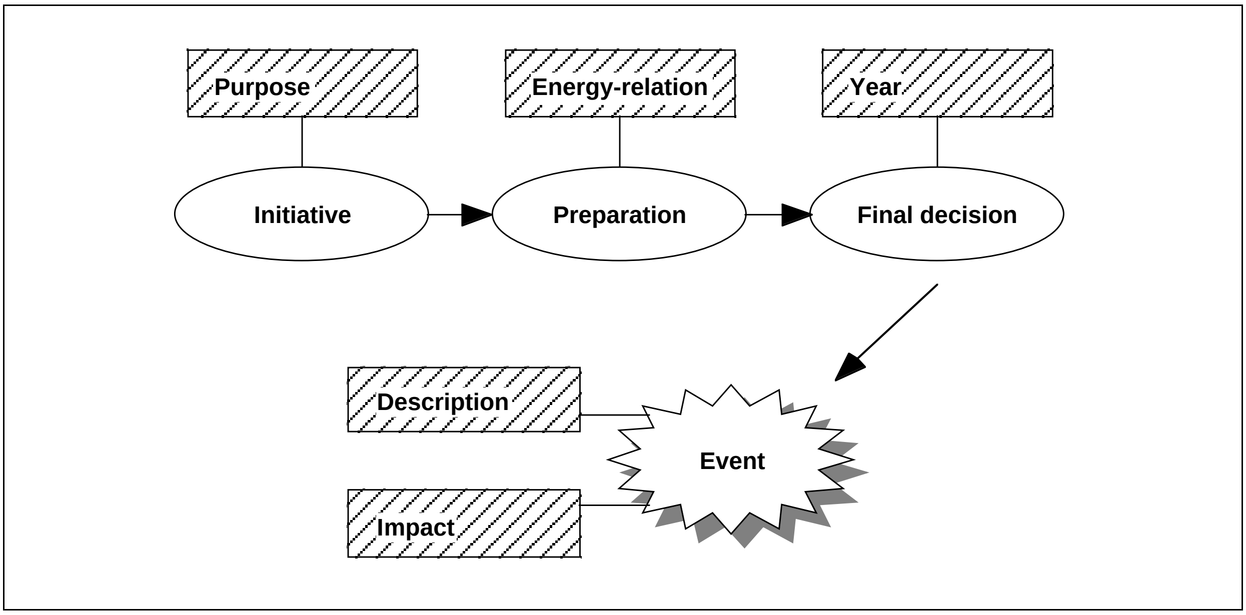

Figure 3 Model of energy-relevant decision-making

The distinction between energy-related and non energy-related decisions was fundamental. One of the primary research questions was to find out whether energy-relevant decisions take energy consumption into account or not. Energy conservation measures are then a special case of energy-relevant decisions, i. e. decisions intended to improve energy efficiency (Figure 4).

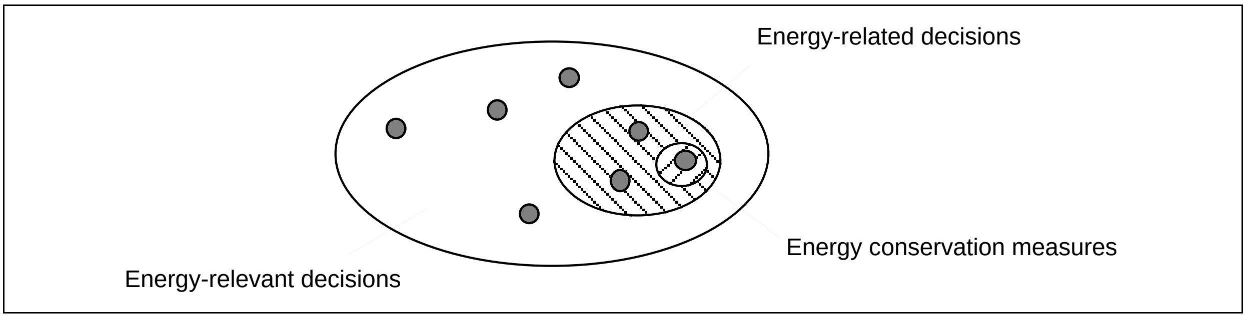

Figure 4 Classification of energy-relevant decisions

5 THE SAMPLE

Half a million square meters were analysed, which make up about 2% of the total Swiss floor area in office buildings[2] or 0.1% of the floor area in buildings generally. In 1992, the Swiss building stock as a whole covered an energy-related floor area (EBF)[3] of 555 million square meters (BUNDESAMT FÜR ENERGIEWIRTSCHAFT 1994).

One hundred office buildings were selected at random.[4] They were situated in the German- and French-speaking parts of Switzerland. Remote areas, e. g. the Alps, were weakly represented as their density in office buildings is low. The Italian part of Switzerland, where 4% of the inhabitants live, was excluded because of language barriers. Big buildings were preferably selected in order to catch a sufficiently large number of energy consumers.[5]

All the firms analysed participated voluntarily.[6] Public institutions were more willing to participate than private ones, which meant that the public sector was over-represented by a factor of two (Table 2). Finance companies were sampled quite accurately. So were industry and the service sector, which means that, all in all, the sample represents the sample space fairly satisfactorily.

Table 2 Percentage of floor area (EBF) according to sector
(empty fields: data not available; source: BUNDESAMT FÜR ENERGIEWIRTSCHAFT 1994)

Sector	Sample	Sample Space
Industrial Sector	7 %	10 %
Mining and quarrying	0 %	
Manufacturing, recycling	2 %	
Electricity, gas and water supply	5 %	
Building and construction	0 %	
Service Sector	93 %	90 %
Wholesale and retail trade, repair of vehicles and pers. household goods	15 %	12 %
Transport, communication	0 %	
Finance	30 %	24 %
Real estate, computers and related activities, R&D, other business activ.	2 %	
Public administration, defence, compulsory social security	36 %	17 %
Health and social work	1 %	
Other community, social and personal service activities	8 %	
Extraterritorial organisations and bodies	1 %	

The analysis was limited to the consumption of electricity. It was focussed on non-heating applications because electric heating is relatively rare (4% of the total electricity consumption), and the demand for electricity for heating fluctuates predictably, in accordance with the weather. The dynamics of other forms of electricity consumption are more varied and more idiosyncratic.

Within offices, the most energy-intensive usage groups[7] were central services (mostly central computers) and lighting, which consumed a quarter of the electricity each (Figure 5). Ventilation and cooling together consumed another quarter. Office equipment used only 12% of the total electricity consumption.

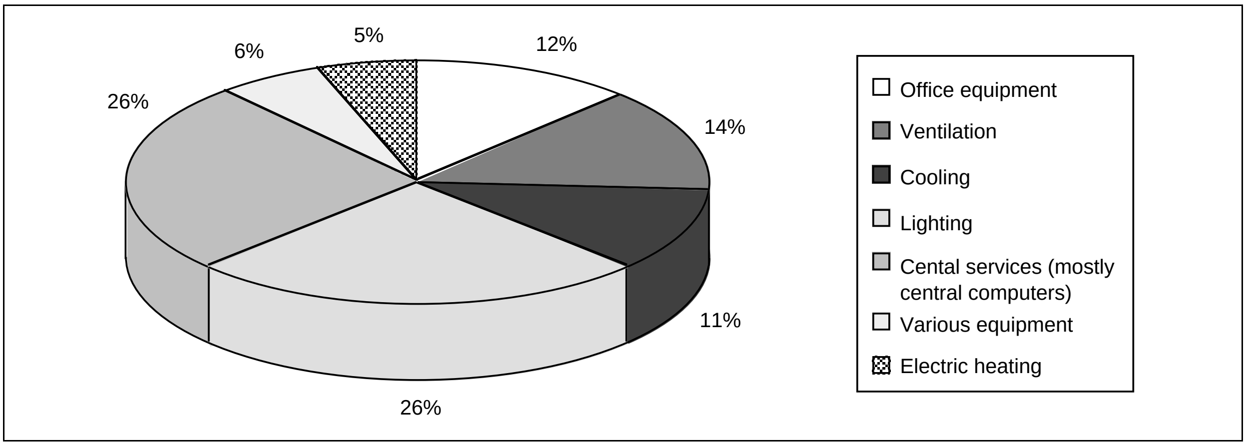

Figure 5 Electricity consumption in office buildings according to usage

6 RESULTS

Energy-relevant decisions are special. Energy is a derived demand, i. e. it is not energy itself that is demanded, but an energy-consuming service. When the stock or the maintenance of energy consuming equipment is changed, energy efficiency is not the main selection criterion, but probably a secondary criterion as well as comfort or aesthetics.

6.1 Managerial Attitudes To Energy Consumption

Much empirical research has been done on attitudes to the environment and how attitudes relate to actions. Unfortunately, many of the findings of existing studies are week because the effect of social desirability on the answers to ecological questions was largely ignored. People like to call themselves environmentally aware, and tend to respond to questions about what they do according how they think they should act rather than how they actually behave. In a field that is as normatively strong as ecology, it is difficult to ask about personal behaviour without using leading questions. This methodological problem can be avoided by not asking the research questions directly, but by transforming the questions into non-normative ones. This consideration led to the development of a methodology focussing on energy-relevant decisions.

Several indicators were evaluated to determine the energy awareness of the management and the importance of energy costs in firms. Two of 73 interviewees spontaneously claimed ecology to have been one of the biggest challenges either in the past or in the future. One interviewee in local administration referred to “ecology in building constructions”, and a manager of a bank noted that “ecological products” presented a challenge. No interviewee spontaneously discussed energy efficiency or any related subject. Energy is obviously not on the top of managers’ priority lists.

Managers generally tended to overestimate energy costs by a factor of three. Compared to the total costs in an office building including all salaries and operational costs, the average share of energy was actually 0.9%, yet estimated to be on average 2.6%. In industry, the overestimation was even higher. The average share of energy costs in office buildings was 0.7%, yet estimated at 3.5%.

In the interviews, the decision-makers were asked to assess several statements about energy consumption (Table 3). Two fifths of the managers approved of the statement “energy costs in the office building can be ignored”. Approval or disapproval correlated highly with the share of energy costs.

One fifth of the managers assessed the end user's influence on energy consumption to be negligible. These managers did not typically distinguish themselves according to which sector they worked in, the technical equipment or the energy consumption in the building they worked in. Thus each manager's assessment was judged to be his or her personal opinion, and independent of energy policy.

Only 4% of the managers agreed with the statement "energy conservation results in a reduction in comfort". These managers worked in firms that were either highly equipped with information technology, or the interviewee judged the enterprise to be already extraordinarily energy-efficient.

Table 3 Statements assessed by managers

Thesis	"Agree"	"Do not agree"
"Energy costs in the office building can be ignored."	38 %	62 %
"The influence of the end users on energy consumption is negligible."	21 %	79 %
"Energy conservation results in a reduction in comfort."	4 %	96 %

In a quarter of the firms (25%), energy consumption was periodically checked by the management. Checking the energy consumption means that the management at least knows whether and how much their annual electricity consumption has changed. In firms without energy checks, energy consumption is of course part of the annual budget, but it is not perceived as a value in its own right.

Almost half of the firms had a professional energy controller (47%). Energy controllers were usually in a position with little power to instruct or decide. They periodically check energy consumption, draw up energy statistics, propose conservation measures and topicalise the rational use of energy inside the firm. Energy controllers were more frequent in big enterprises[8] (65%) and in the public sector (68%).

Energy checks were not directly evaluated. Nevertheless some indicators were constructed to assess the success of monitoring energy consumption. Energy conservation measures were undertaken in 18% of the firms in the period 1986–96 (Table 4). They were more frequent in enterprises with a professional energy controller (26%) and even more in firms where energy consumption was monitored by the management (50%). If the specific power of installed office lighting is taken as an indicator of energy efficiency, the picture is similar, but less distinct. The median of the full sample was 16.5 watts per square meter. The specific power in enterprises with a professional energy controller was slightly lower (16.3 W/m^2) and even lower in firms were energy consumption was monitored by the management (15.0 W/m^2). If floors lighting is considered, the picture is different. The specific power in firms where energy consumption was monitored by the management was then the highest (7.9 W/m^2), even higher than the median of the full sample (6.8 W/m^2). The lowest specific power was in enterprises with a professional energy controller (6.0 W/m^2).

Table 4 Assessment of energy monitoring

Energy efficiency indicators	Full sample	Professional energy controller	E. consumption monitored by the management
Firms with energy conservation policies 1986–96	18 %	26 %	50 %
Installed specific power of lighting in offices	16.5 W/m^2	16.3 W/m^2	15.0 W/m^2
Installed specific power of floors lighting	6.8 W/m^2	6.0 W/m^2	7.9 W/m^2

Over all, energy checks seem to have a quantifiable impact on energy consumption. The energy awareness of the management appears to have more effect than the existence of a professional energy controller.

6.2 Energy-Relevant Events

About four energy-relevant events per enterprise were identified, totalling 252 altogether. In the following, energy-relevant events are presented ranked according to frequency and the average impact per event.

6.2.1 Energy-Relevant Events Ranked According to Frequency

The most frequent event was an increase in office equipment (61 items). The observed period 1986–96 can indeed be characterised by an increase in office equipment. Today, most modern work-places in an office building are equipped with a PC, a monitor and often an individual printer. The reasons why there was an increase in office equipment were the same everywhere: employees were taking over tasks previously performed by secretaries and software was becoming much more powerful. It was not always easy to quantify changes in office equipment, because these take place gradually. People do not usually remember when equipment was purchased and how many workstations are in use. In big enterprises with several branches it is often not known how equipment is distributed in the different buildings. In order to find a practicable way of modelling changes in office equipment, it was treated as one event, measured over a period of years.

Second place was held by the replacement of an almost invisible piece of infrastructure: the telephone switchboard (30 items). During the period under observation, most analogue switchboards were replaced by digital ones. The reasons for the replacement were diverse and independent of the specific activities carried out in the building: the need for more direct lines, the introduction of a multi-functional communication net inside the firm, extra functions provided by digital switchboards and the termination of maintenance by the supplier.

In third place was the replacement of lighting, mostly lamps or light fittings, often in combination with further architectural changes (23 items). Lighting in office buildings was occasionally replaced for aesthetic reasons or because PCs, which require low-glare light, were introduced. Lighting was sometimes replaced in order to save energy, and this was the most frequent energy-conservation measure.

6.2.2 Energy-Relevant Events Ranked According to Average Impact

Frequent events do not necessarily affect energy consumption in a major way. There are frequent events which have a low impact and, vice versa, rare events with a high impact. For example, telephone switchboards were frequently replaced, but they caused a relatively low decrease in consumption of about 5 MWh/a per event. Yet the installation of a kitchen caused a relatively high increase of 78 MWh/a, but rarely occurred, in the same period.

The most influential event was when central computing was shut down, which mostly meant that mainframes were shut down along with corresponding cooling systems and UPS (roughly one third of the impact). When central computing was shut down, computer services were not, of course, stopped, but the equipment was moved out and/or centralised in another building. Thus, a decrease in one building often corresponded with an increase in another, although the overall consumption was usually less due to more efficient technologies and the economies of scale.[9]

The event to have second greatest impact was an increase in central computing. This was the most influential event leading to an increase in consumption and was complementary to the former.

6.2.3 Energy-Relevant Events Ranked According to Accumulated Impact

If all events were separated by the direction of their impact ("+" is for more consumption, "-" for less), a total positive impact of 4606 MWh was set off by a negative one of 6192 MWh in the period 1986–96. The net impact was -1586 MWh/a, which meant that consumption in 1996 was about 5% less than that in 1986.

Two thirds of the total decreasing impact, -4071 MWh/a, was due to shutting down central computing (Figure 6). The increase in central computing represented +2333 MWh/a or half of the total consumption-increase. In third place came an increase in office equipment, which had a total impact of +687 MWh/a, constituting 15% of the total consumption-increase.

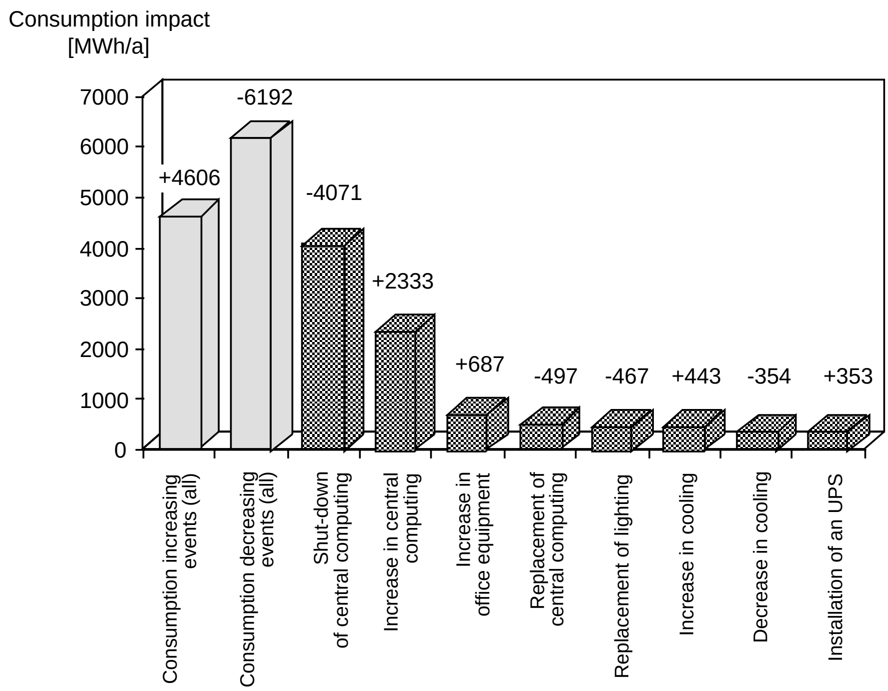

Figure 6 Energy-relevant events with the largest accumulated impact, irrespective of wether they led to more consumption (+) or less (-)

6.3 The Development of Electricity Consumption from 1986 to 1996

The development of electricity consumption from 1986 to 1996 can be evaluated on the basis of changes in annual electricity bills ("top down") and the totals for the estimated annual impacts of energy-relevant events ("bottom up"). There is a significant correspondence between "top down" and "bottom up" data for the whole period 1986–96. The data "top down" was -2124 MWh/a compared to -2190 MWh/a "bottom up" (Table 5).[10] This correlation does not prove that the model fits to the data excellently because, with aggregated data, random residuals tend to be compensated.

Table 5 Annual changes in electricity consumption (consumption in MWh/a)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1986–96
# of events	1	10	12	19	17	25	35	27	23	26	195
Σ Energy-relevant events	1	-136	2083	20	103	60	-111	-2027	-741	-1442	-2190
Δ Measured consumption	621	898	1163	614	-9	-555	-481	-1627	-773	-1975	-2124

The correlations between the annual "top down" and "bottom up" data were most marked after 1991 (Figure 7). Data on energy-relevant events for the previous years is generally less reliable because the remoter in time the events are, the more difficult it is for the interviewee to recall them. The small number of events reported prior to 1992 supports this assumption (Table 5).

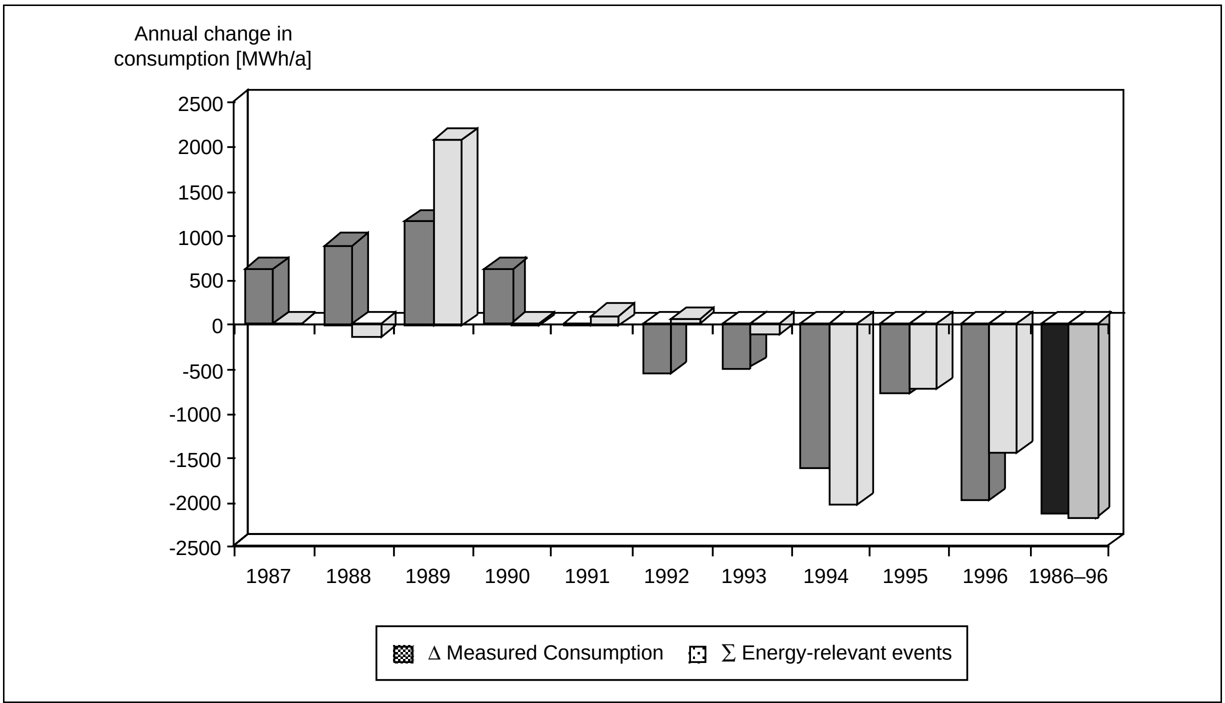

***Figure 7** Annual changes in electricity consumption, "top down" vs. "bottom up" data*

The development of energy-relevant events shows two main trends: an increase up to 1992 and a decrease afterwards (Figure 7). The most influential form of energy consumption for both trends was computing (Figure 8). Prior to 1992 there was a huge growth in the number and size of mainframes, PCs, monitors and printers. Between 1992 and 1996 the number of computers still grew, but there was a considerable efficiency gain due to technical innovations in computer technology.

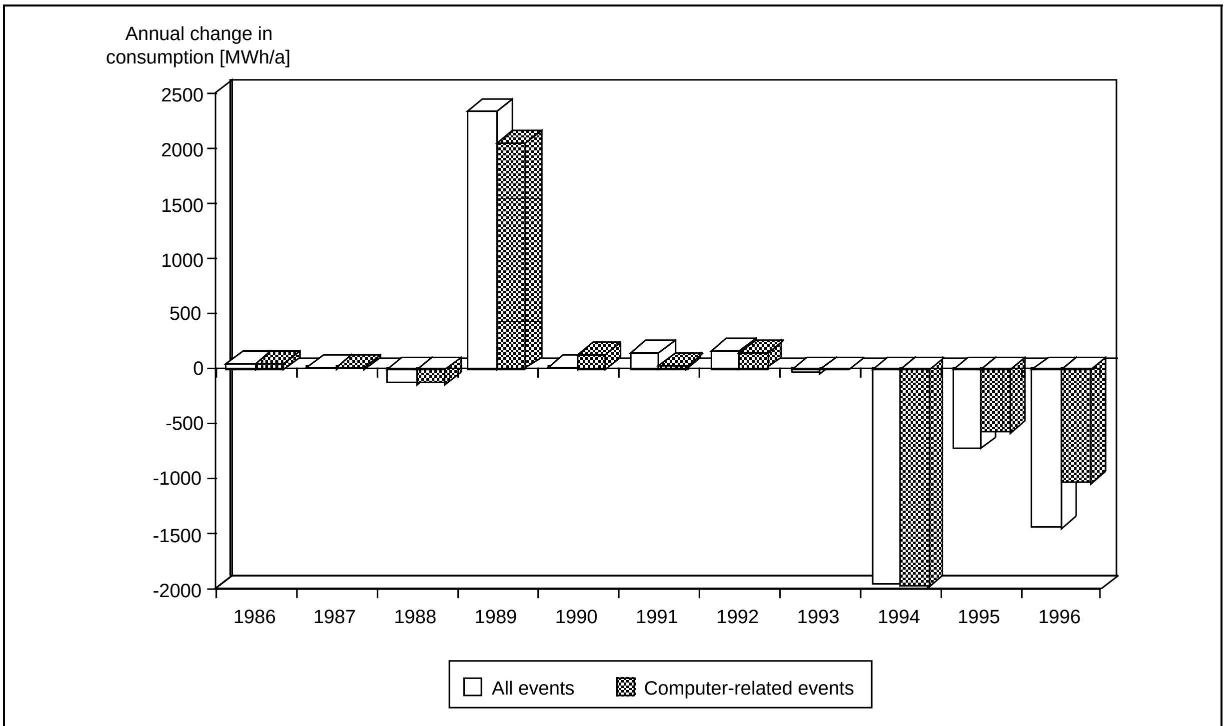

***Figure 8** Annual changes in electricity consumption, all energy-relevant events vs. computer related events*

1.4 Energy-Relevant Decision-Making

Energy-relevant decision-making was analysed according to the model shown in Figure 3. For each event and each stage of decision-making, decision-makers were identified. In order to make decision-making comparable for all events, a typology of decision-makers was developed.[11] It follows the hierarchy inside the firm from the bottom to the top.

- **Staff:** Employees independent of their function in the firm.
- **Services:** Individuals or groups appointed to deliver services inside the firm, e. g. caretakers, maintenance staff or the computer acquisition group.
- **Management:** managers.
- **Headquarters:** Services or management at the central office (in big enterprises), or the supervisory board, or in the case of public institutions, parliament[12].
- **Outside:** External organisations assigned for well-defined tasks by the firm, e. g. suppliers, consultants, or architects.

1.4.1 Increases in Office Equipment

An increase in office equipment was the most frequent event in the sample. Its impact varied considerably according to the size of the firm; it was between +1 and +70 MWh/a. An increase in office equipment means that more terminals were installed or were replaced by PCs, or that the number of PCs, monitors and individual printers increased. One fifth of the events were the result of decisions related to energy efficiency.

Nearly half of the events were initiated by the staff (Figure 9). The preparation for acquisitions was mostly done by an internal computer group. Increases in office equipment were usually decided as a part of the annual budget.

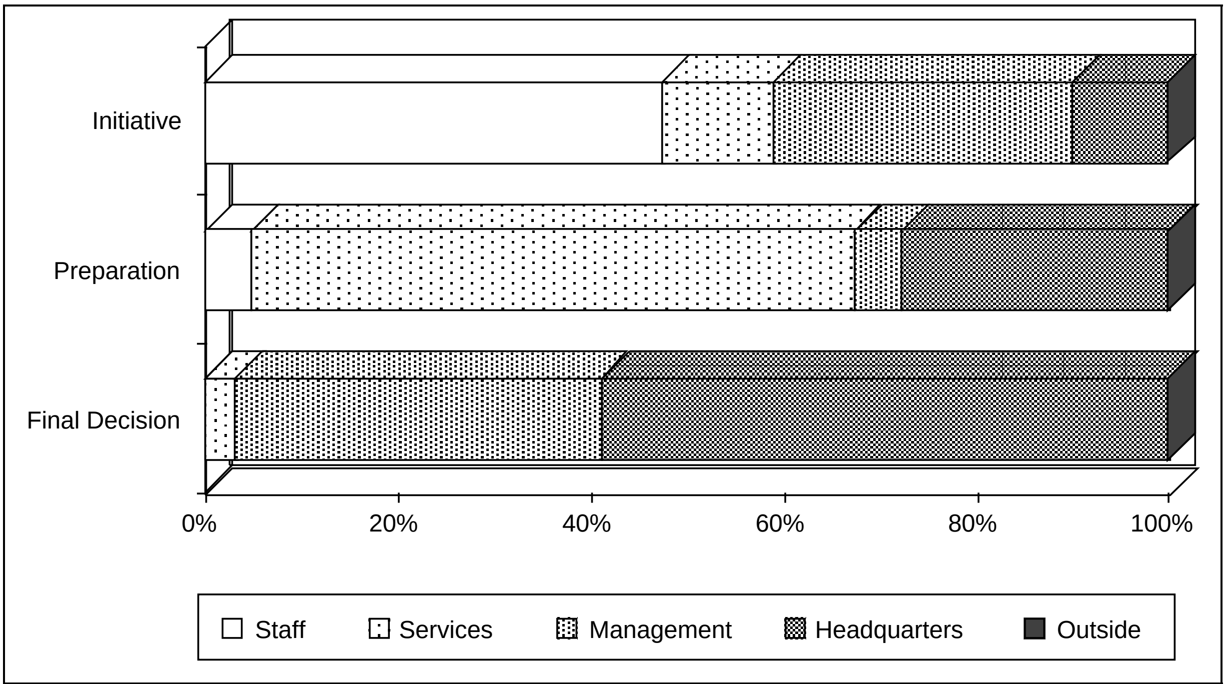

Figure 9 Decision-making about increases in office equipment

1.4.2 Energy Conservation Measures

Energy conservation measures are actually not a type, but a special case of energy-relevant events. They affected lighting (56% of the accumulated impact), ventilation (22%), cooling (22%) and electric heating (almost zero). The impact varied from -1 to -180 MWh/a. The impact of all energy conservation measures amounted to -878 MWh/a, which was 14% of the total decreasing impact of the energy-relevant events altogether. This means that 86% of all consumption-decreasing events were not the result of conservation measures, i. e. they were not based on decisions to save energy.

Four fifths of all energy conservation measures were initiated by the caretaker or the maintenance group and mostly prepared and finally decided by the same person or group (Figure 10). The vast majority of the successful energy conservation measures did not require a large investment. They were technical measures that cost little, involving people at a low level in the hierarchy with little participation of formal decision-makers.

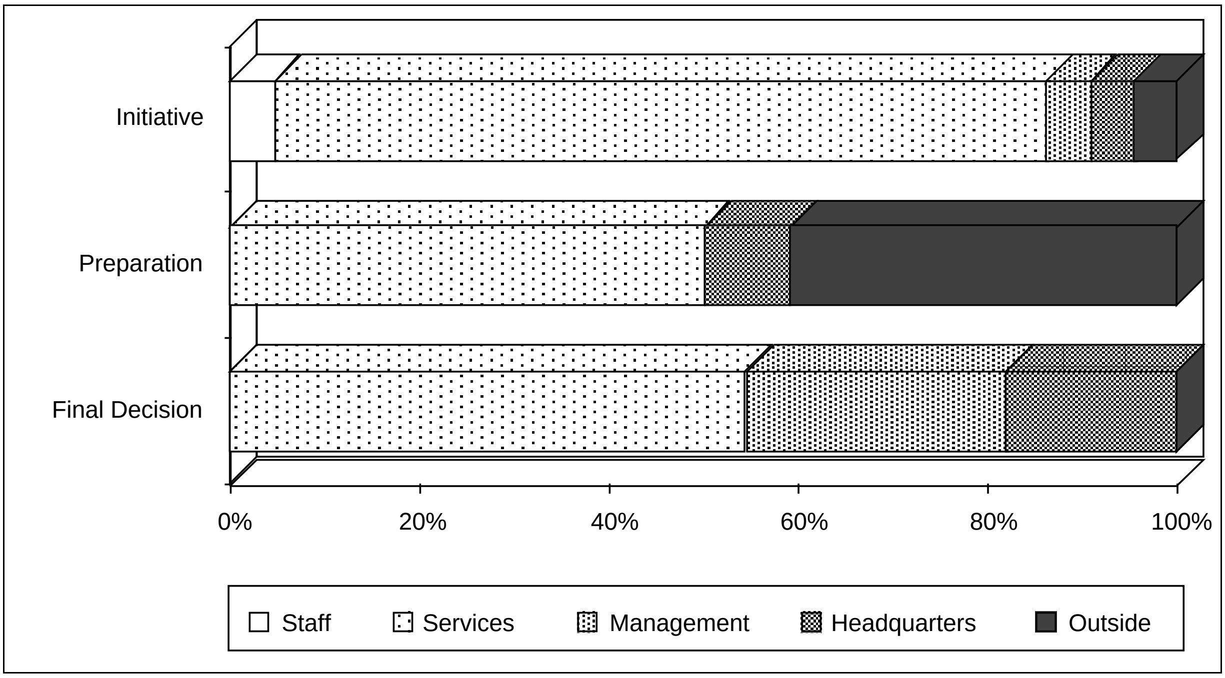

Figure 10 Decision-making about energy conservation measures

7 CONCLUSIONS

This study presents statistical data about electricity consumption in Swiss office buildings. It gives insights into the dynamics of electricity consumption, identifies the key technologies and shows how changes in the stock and the maintenance of equipment are decided.

Managers tend to estimate energy consumption in office buildings in a qualified way, but usually overestimate energy cost. Cost estimations are not good indicators of the value of energy in an enterprise. Correspondingly, meeting the need for a more rational use of energy includes other factors as well as economic rationality, e. g. lifetime cycles of equipment.

Firms with an institutionalised form of energy monitoring are more energy-efficient than firms without. However, the success of energy monitoring is difficult to evaluate. A systematic method of evaluation has to be developed.

The small impact of energy conservation measures with respect to all consumption-decreasing events is disillusioning. In contrast, the efficiency gains arising from technical innovations in computer technology is pleasing. They will probably continue to lead to further reductions in electricity consumption in office buildings in future years.

8 ACKNOWLEDGEMENTS

This study was done in co-operation with a Swiss engineering company, Amstein und Walthert AG*, and the German* Fraunhofer Institut für Systemtechnik und Innovationsforschung *at Karlsruhe. The author would like to thank PSEL, EWZ and VSE for their financial support.*

Thanks to Mithra Moezzi (LBNL) for many useful notes and to Silvia Dingwall who improved the English.

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[1] A detailed report of the study is available from the author.

[2] Office buildings are defined as buildings with an office usage share of ≥ 50%.

[3] Energy-related floor area = heated floor area including floors and walls, in German *Energiebezugsfläche (EBF*). The EBF is defined in the Swiss norm SIA 180/4 (SCHWEIZERISCHER INGENIEUR- UND ARCHITEKTEN-VEREIN 1982).

[4] Randomness was restricted by voluntary participation.

[5] All buildings were classified into five groups according to their fire insurance. Each group was represented by 20 buildings if possible. The selection defined in this way resulted in an over-representation of large buildings, but this was what was wanted.

[6] Caretakers and managers were separately asked to participate. Buildings where both agreed to participate were selected preferably. In the end 73 firms were analysed, located in 67 buildings. The remaining 33 buildings were audited, but no interviews were performed. The sample was sometimes 73 firms, sometimes 65, depending on the available data.

[7] Usage groups are defined in the Swiss norm SIA 380/4 (SCHWEIZERISCHER INGENIEUR- UND ARCHITEKTEN-VEREIN 1995).

[8] Defined as firms with ≥ 50 employees.

[9] Nevertheless, the analysed sample remained representative because it contained buildings with an increase in central computing as well.

[10] Data in this comparison partly differ from the rest because annual bills were not available for the full sample. The sample was exceptionally reduced from 65 to 46 enterprises. Within the reduced sample, the total change in consumption 1986–96 amounted to -2190 MWh/a (versus -1586 MWh/a for the full sample), which was about 9% of the total consumption (versus 5%).

[11] When several decision-makers were involved, the lowest in the hierarchy determined the indicated type.

[12] Private firms and public institutions were analysed and modelled in the same way. Nevertheless there are differences; e. g. private firms are supervised by a supervisory board, whereas public institutions are supervised by a legislative body.