Opportunities for Energy Savings in Hotels through Bus-technology based building energy management systems

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ABSTRACT

The investigation of a sample of 280 German hotels has provided a detailed insight in the energy consumption structure of hotels and the relevant devices. Electricity accounts for one third of the energy consumption but two third of the energy bill. Yet significant differences between small and large hotels as well as between city and country hotels appear, e.g. saunas can be found both in city and country hotels whereas swimming pools ate mostly located in the country side.

Whereas in large hotels central control systems including also some energy management functions have often been installed in the past, in small and medium-sized hotels in Germany and Europe so far few such systems exist. Here a modular system, based on modern communication bus technologies like LON or EIB, is attractive. Major advantages are: the system can be gradually extended, requiring no high initial investment, wiring is reduced, offering good opportunities for retrofit and energy management for a wide range of applications is feasible.

A particularly attractive application for energy management with bus technologies is the regulation of heating (and occasionally air-conditioning) depending on the booking of teh rooms. Here energy savings of 20 % and more are identified. Furthermore the application of load management is diwscussed which offers additional (cost) saving) opportunities. In the case of lighting both comfort increases and automatic control strategies are major advantages of a building energy management system.

Introduction

In recent years energy and building management systems have undergone a very rapid development. The first management systems for building and energy automation were so called island solutions, i.e. every system got an own controlling or management section. The technology applied for controlling HVAC systems was distinct from the one for fire alarms or key cards. Communication and interaction between these separate systems was hardly possible. Furthermore wiring and installation had to be done for each system separately.

A solution to these problems in the building and energy automation is the usage of modern communication bus technology based systems, like LON, LAN, Ethernet or EIB. With these technologies the connection of numerous applications and integrated systems can be realised, using only a single twisted pair bus wire, a power line or radio frequency. All devices can now communicate with each other and interaction between the different systems can be adapted resulting in an optimized working mode of every single device and of the whole system. By using such a management system a reduction of the overall energy consumption and of costs for energy will be achievable.

To find out the major fields of applications for an energy and building automation system in hotels an empirical survey was done. In this article the most important results of this investigation will be shown and besides the presentation of average numbers for energy and water consumption and resulting costs general concepts about possible solutions for German hotels will be discussed, especially single room control (including heating, cooling, air-conditioning and lighting) and load management.

Results of an Empirical Survey in Germany

Among German hotels in 1996 a detailed survey was conducted investigating not only the electricity and fuel consumption but also the installed equipment and its utilisation (cf. IER, ADEME 1997, Fleissner 1999). A total sample of 281 hotels was obtained who were asked again in 1999 on their equipment with automatic control systems (cf. Sander, Weber 1999). In this second survey a sample size of 140 hotels was reached. Also some basic data on the hotel (number of beds, number of overnight stays, type of hotel etc.) were again investigated in the second survey. The sample may be segmented as described in the following section. Based on this segmentation subsequently major findings of the survey are described.

Segmentation of German Hotels

The considered hotels were classified by their size and the region, in which the hotel is situated. The six different classes of German hotels resulting from this classification and their characteristics are shown in table 1. The size is taken thereby taken as a proxy of the hotel quality standard (see also table 1), since no mandatory classification scheme for hotels exists in Germany. Furthermore the location is taken as a proxy for the predominant type of clients. In the countryside few business travelers may be found, whereas city hotlels (with a few exceptions) are preponderantly frequented by business travellers. This is confirmed by the average duration of stay, which is considerably lower in city hotels (2.3 days vs. 3.4 days). In country hotels also the peak period clearly is in summer, whereas in city hotels it is spring or autumn.

Table 1. Classification of German Hotels

<table>
<tr><th colspan="2">Hotel segment</th><th>Location</th><th>Size</th><th>Number</th><th>Average number of “Stars”</th></tr>
<tr><td rowspan="3">Country</td><td><70</td><td rowspan="3">less than 50,000 inhabitants</td><td>less than 70 beds</td><td>107</td><td>2.9</td></tr>
<tr><td>70/150</td><td>70 to 150 beds</td><td>26</td><td>3.1</td></tr>
<tr><td>>150</td><td>more than 150 beds</td><td>21</td><td>3.8</td></tr>
<tr><td rowspan="3">City</td><td><70</td><td rowspan="3">50,000 and more inhabitants</td><td>less than 70 beds</td><td>27</td><td>2.8</td></tr>
<tr><td>70/150</td><td>70 to 150 beds</td><td>28</td><td>3.3</td></tr>
<tr><td>>150</td><td>more than 150 beds</td><td>37</td><td>3.7</td></tr>
</table>

It will be assumed that the hotels in the country side are receiving preponderantly tourists, whereas the city-hotels will be more frequented by business travellers. The most important characteristics of these segments are summarised in table 2.

Table 2. Characteristic Features of Different Hotel Segments (Average Numbers)

Hotel segment		Rooms	Beds	Beds per room	Stays per year	Capacity utilisation [%]	Size [m²]
Country	<70	19	30	1.6	4,447	40	941
	70/150	49	93	1.9	13,529	40	3,008
	>150	130	244	1.9	37,086	42	6,296
City	<70	20	33	1.7	4,690	39	712
	70/150	67	105	1.6	16,252	43	2,845
	>150	179	333	1.9	49,547	41	8,503

The results show that in German hotels a large difference between the available capacity of hotel beds and the used capacity exists. Most of the rooms are unoccupied for a long time during the year. Another important fact is the season in which the most and the least stays occur. It can be shown that in the country-hotels most of the rooms are occupied during the summer months (June through August). Different from this in city-hotels most of the rooms are used during spring and autumn. Nevertheless, in all types of hotels the lowest number of stays appear during the winter. Due to this fact a high potential for energy savings is given by controlling and reducing the power of the heating system.

Energy and Water Consumption

To develop an efficient building and energy automation it is important to understand the structure of the energy and water consumption in German hotels. Therefore the hotels were questioned about the yearly usage of electricity, energy for heating and water, as shown in table 3. The corresponding normalized data are given in figure 1.

From these results it can be seen, that a strong increase of the energy consumption occurs with the size of the hotel. Also the most important part of the energy consumption lies in electricity, as it sums up to about 1/3 of the total consumption and more important to about 2/3 of the total energy costs.

Table 3. Average Consumption and Costs of Energy and Water per year

Hotel segment		Electricity		Oil		Natural Gas		District Heat		Water	
		MWh	DM[1]	MWh	DM	MWh	DM	MWh	DM	MWh	DM
Country	<70	78.1	20,732	92.8	3,335	111.0	5,995	1.1	97	1,202	8,353
	70/150	204.7	56,124	204.3	9,794	344.2	16,821	37.7	2,364	2,966	17,680
	>150	965.6	194,019	335.7	18,924	744.2	55,197	273.3	20,522	14,328	59,856
City	<70	46.7	16,614	39.3	1,745	82.5	3,674	2.9	837	820	3,012
	70/150	302.2	70,551	56.8	3,728	242.8	13,507	205.2	17,115	3,439	21,263
	>150	1,267.6	261,377	171.8	6,230	637.9	32,411	527.8	79,140	16,376	75,896

This table also illustrates that building energy management systems (BEMS) are unlikely to be installed in smaller hotels if they involve a significant fix cost component (independent of hotel size). This may be seen as a major reason why conventional BEMS have so far been mostly applied to large hotels.

To illustrate the correlation between the consumption of energy, the size and the kind of the enterprise figure 1 shows in average the total energy and electricity consumption per bed for the different hotel segments.

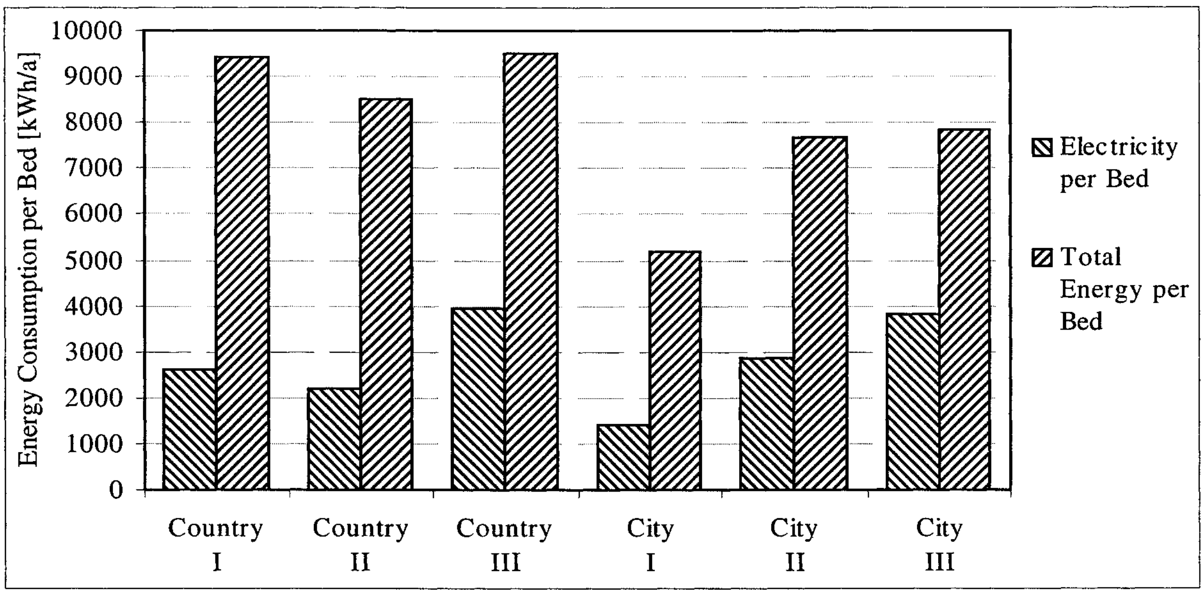

Figure 1. Average Total Energy and Electricity Consumption per Bed

It becomes evident that in city-hotels the consumption of electricity depends highly on the size of the hotel, with the total energy consumption for medium sized and large city-hotels remaining nearly the same. Different to this in country-hotels the lowest total energy and electricity consumption appear in the medium sized segment.

Furthermore, it can be stated that for a comparable size of the enterprise the city-hotels require a lower amount of energy per bed. This is certainly due to a lower surface to volume ratio of city hotels, as building space in cities is more expensive than in the country side and therefore rooms in a city-hotel are smaller in average leading to a lower specific demand for heating.

Further Results of the Survey

In the following a short overview about other relevant results of the empirical survey in Germany, i.e. the installed applications for heating, cooling, air-conditioning, lighting, load management and single room control, will be given.

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[1] DM = Deutsche Mark. In 1999 on average 1 DM = 0.545 US $

Load shape. An interesting potential for cost savings in hotels is given by load management, meaning the controlled reduction of the electrical peak load. To quantify the existing potential for such an application figure 2 shows the average peak load for the surveyed hotels. Also the number of hotels, in which a load management is already installed, is indicated.

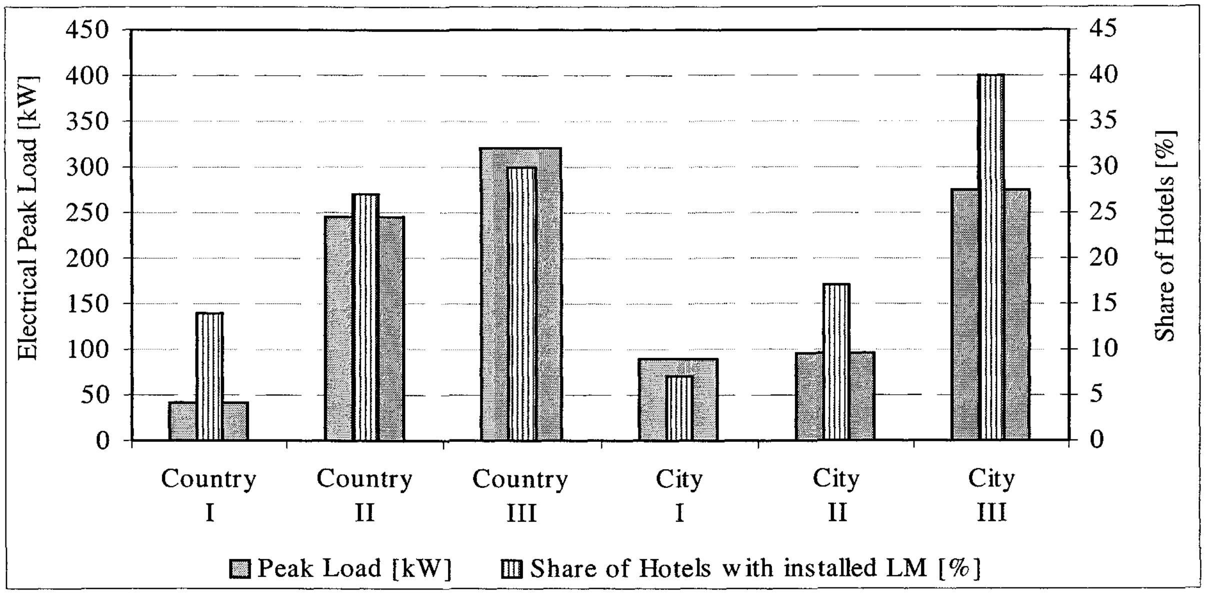

Figure 2. Average Electrical Peak Load and the Share of Hotels with a Load Management System (LM) installed

The diagram shows that especially in smaller hotels only few load management systems are actually installed. On the other hand the average peak load in the small hotel segment is probably too low for an installation of a load management system to be cost effective. But even in larger hotels 40% or less of the enterprises have a load management installed.

Heating, cooling, air-conditioning and tap water. In almost 100% of the considered German hotels heat is provided by a central system. The used energies for heating are mostly fuel oil and natural gas, whereas in medium sized and larger city-hotels the shape of natural gas and district heat are increasingly important.

In general, hot tap water is produced in combination with the heating system. Only about 20% of small city-hotels generate the hot tap water with separate water heaters, based on natural gas or electricity.

Exhaust air ventilators are installed in most of the considered buildings, mainly in the bath rooms, the kitchens and the restaurants. 2/3 of these ventilators are coupled with the lighting, the others are operated manually.

Large differences appear in the installation of central ventilation and air-conditioning systems. In the city-hotel segment only 4% of small enterprises have such systems installed, whereas in about 78% of the larger hotels a ventilation and air-conditioning system is used.

An individual room control for heating, cooling and air-conditioning is installed in 2/3 to 4/5 of all considered hotels. For heating usually thermostats in combination with an outside temperature controlled central heating system are used, the regulation of ventilation and air-conditioning devices occurs particularly by dynamic digital control (DDC).

Lighting. Another interesting application for the energy management is lighting. By using bus technology it is possible to regulate the luminosity depending on daylight and/or on other requirements, e.g. lighting in floors is only switched on in case of occupancy.

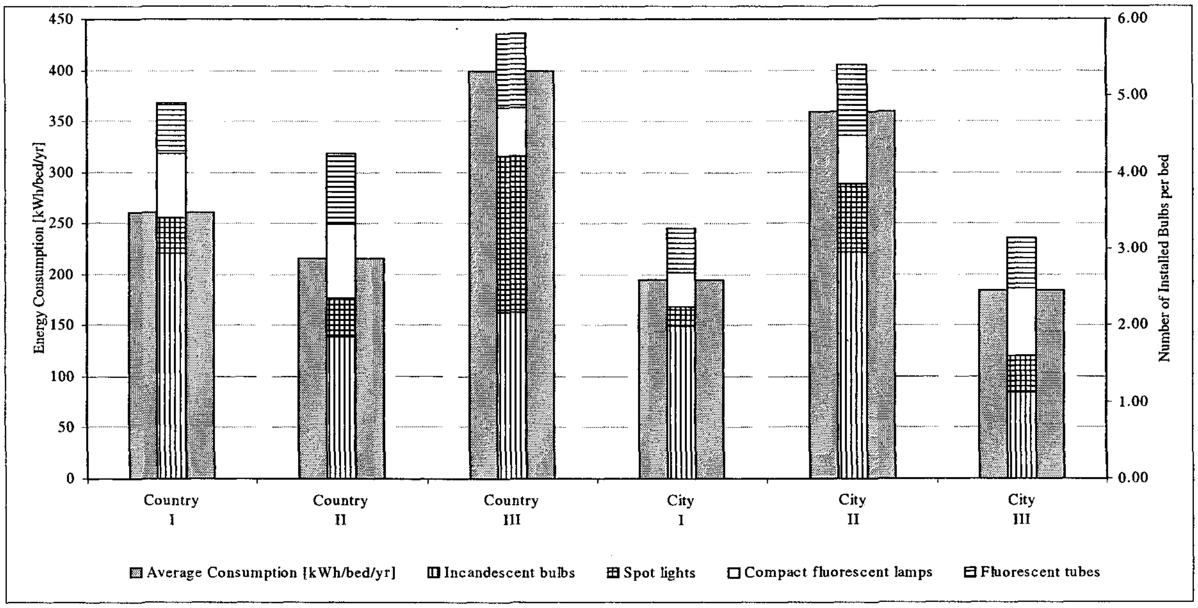

Figure 3. Electricity Consumption and Number of Installed Bulbs

An overview about the installed lighting is given in figure 3; it can be seen that a substantial saving potential exists. Furthermore it can be seen that in all hotels most of the lights are incandescent bulbs or spot lights; the share of energy saving lamps is relatively low. In comparison with other hotel segments in large country-side hotels the consumption of electricity is over proportionally high. These are mostly high-quality tourist hotels which offer numerous conveniences to their guests (e. g. swimming pools). These hotels also have substantial outdoor areas.

Further analyses indicate that most of the bulbs in the building are installed in the guests' rooms, the lobby and the restaurant. Lighting in the sanitary, the kitchen and the office area play only a minor role.

Other results. Some further results of the survey, which are relevant for the installation of a bus technology based building and energy management system, are summarised in table 4.

It can be seen that in numerous hotels alarm and security systems are installed, i.e. smoke and fire detectors, which can also be integrated in a bus technology based building and energy management system[2].

2 Currently German insurance companies envisage to accept also bus-based systems as fire alarms.

Table 4. Share of Hotels with Installed Systems [%]

Hotel segment		Security / alarm systems	Hotel reservation systems	Key systems	Other automatic control systems
Country	<70	38	21	13	5
	70/150	53	67	13	7
	>150	73	91	73	9
City	<70	43	36	43	13
	70/150	54	92	38	30
	>150	93	100	88	50

Another important fact is that especially medium sized and larger hotels are equipped with hotel reservation and key systems. These can be used for a single room control to take account of the state of occupancy of a hotel room. In any cases, a reservation system is required for an efficient regulation of the heating, ventilation and air-conditioning system.

Opportunities for Energy Savings through Bus Technology

Based on the results of the empirical survey key opportunities for a building and energy management system based on a bus technology are described. The basic advantage of the bus technology compared to conventional BEMS is thereby that an integration of different measures within one technology framework is possible. This reduces the costs for sensors and actors in addition to the reduced wiring requirements. Furthermore conventional BEMS have so far been mostly restricted to large hotels with integrated HVAC systems. Bus technology based systems are on the contrary more flexible and better scaleable, so they may also be applied to medium sized hotels as described in the following. Especially energy saving potentials for Single Room Control (SRC) and strategies for Load Management (LM) will be discussed.

Single Room Control (SRC)

Aim of a Single Room Control (SRC)-system is to reduce energy consumption and energy costs for heating, ventilation, air-conditioning and lighting. This is realised by control and regulation of the conditions in a single room depending on several parameters like the room occupancy, the individual needs of the guests, the room climate (temperature, humidity, luminosity), the time of the day (day or night) and other influences. For example it is feasible to reduce the performance of the heating and/or air-conditioning system while a room is unoccupied. Power reduction or even switch-off of these systems can also be realised as windows are opened.

To control and regulate the different applications depending on the room conditions some basic information about the status of the systems are necessary. This information can be given by sensors (window contact, occupancy sensor), timers or the reservation software.

In the following some more detailed information about the structure and the function of a Single Room Control is given.

The main applications for a SRC in hotels should be control of the heating, the ventilation and the air-conditioning system, the illumination (lights and Venetian/roller blinds) and the electrical devices of a room. The structure and functionality of a SRC will be demonstrated with a simple example. It is assumed that the heating and air-conditioning system for this example is combined with the ventilation, as such an integrated system would be required for fast temperature changes in a room (warm air or cold air will be blown into the room by the ventilation). It is then possible to realise four different working modes for the heater:

- **Anti-freeze mode** — about 5°C
only to prevent the heater from damage by frost
- **Economic mode** — about 12°C to 14°C
temperature in rooms unoccupied for a few days
- **Standard mode** — about 16°C to 18°C
temperature in rooms unoccupied for only some hours and at night-time
- **Comfort mode** — 20°C and more
wellness temperature in occupied rooms

As a guest checks in at the hotel reception the ventilation will be switched on. Also the heating/cooling procedure will be turned on at maximum power. When the guest enters the hotel room lighting and the electrical circuit are switched on. Now a temperature controller regulates the room temperature in comfort mode. As a window is opened (window contact) the heating system shifts to the anti-freeze mode, in case of cooling a room the systems merely stops. After closing the windows the system changes back to the comfort mode. During winter season the heating mode at night is also changed from comfort to standard. When the guest leaves the hotel (check out at the reception desk) the ventilation system for that room can stop and heating changes to economy mode.

If the heating/cooling system is flexible enough for fast temperature changes a switch from comfort to standard mode can be realised even when the guest leaves the room for only some hours. This is particularly the case for ventilation-coupled heating systems or mixed heating systems where water filled radiators provide the base heating and ventilation provides the peak load. In any case the information about the status of the room (occupied/unoccupied) has to be given by a occupancy sensor.

If such a rapidly working heating system is not installed in the hotel the regulation of the heating/cooling system depending on the rooms occupancy is only feasible in times when a room is not reserved (reservation software). Control via presence detection can not be realised, as the increase of the room temperature using a conventional heater is not fast enough for sufficient comfort. However, a change of the working mode during night-time and with opened windows should be possible.

Nevertheless guests have to be able to influence the regulation of the room conditions by changing the room temperature at a control panel at any time.

As the room temperature is also influenced by the intensity of solar radiation control of possibly installed Venetian or roller blinds has to be integrated in the regulation of the heating system. For example it is not necessary that the Venetian blinds are completely closed on a clear and sunny winter day with the light and the heater running with full power. Moreover the solar radiation should be used to reduce the heating demand and the demand for lighting.

Another application for a SRC is the regulation of the illumination. It should be practicable to switch or dim the lights depending on the inside luminosity. If luminosity of a single room is too high lamps are dimmed automatically. On the other hand if luminosity in a room is not sufficient the Venetian blinds are opened. In case of missing or already opened Venetian blinds or the guest does not want the blinds to be opened the intensity of the lights will be increased. When the guest leaves the room the SRC switches off all lamps. Considering that about 40% of the total electrical costs of a hotel due to lighting a substantial potential for energy and costs reductions becomes evident that.

A further application to be mentioned in short is the interruption of electrical circuits in a hotel room as the room is not in use.

Energy saving potentials, an example. In the following the results of an estimation of the substantial energy saving potentials will be discussed. Therefore the heating energy demand for a selected German hotel was estimated based on the following characteristics:

- 81 rooms, 121 beds, 2,780 m² total area
- Central heating system, warm water generation combined with heating
- No single room control, no load management, no heat recovery system.
- Consumption of district heat currently approximately 680,00 kWh/yr

Following the calculation methodology propoesd by (VDI 1993) and (DIN 1983) (a static balancing method for the heating season) an estimation of possible energy savings was done with the following assumptions:

- about 20% of the heating energy is used for warm water generation,
- hotel rooms are situated on the upper floors only,
- no consideration of internal heat transfer.
- the room temperature of an occupied room is 20°C.

With these assumptions and under consideration of the basic data given above the results shown in figure 4 were obtained.

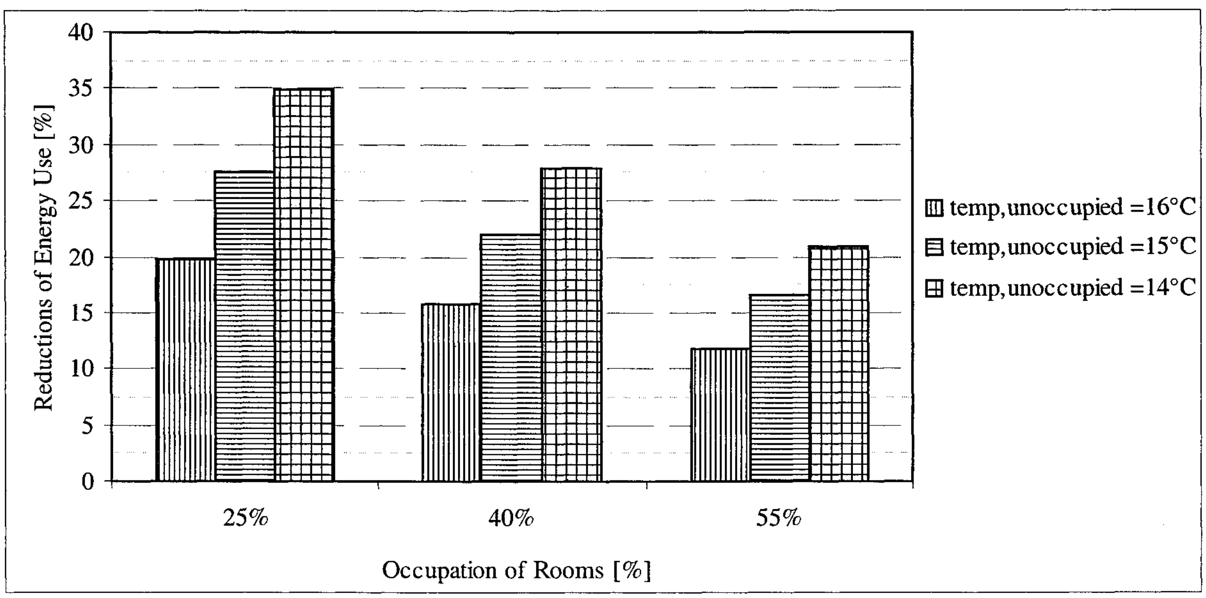

Figure 4. Energy Saving Potentials for an Example-Hotel

These figures indicate an important potential for the reduction of energy use. In table 2 it was presented that in German hotels approximately 40% of the total room capacity is used. For this occupancy rate an energy saving of up to 27% would be possible, if the room temperature is decreased from 20°C to 14°C when the room is not in use.

One should thereby note that a room temperature of about 20°C is only a recommended figure. Probably, the average room temperature in a hotel will be closer to 21 or 22°C. For a room temperature of 21°C an energy saving potential of up to 30% exists.

Load Management

Load management systems are in Germany not primarily designed to reduce energy consumption, but rather present the possibility to decrease the costs for electrical peak load consumption.

The focus has therefore been on electrical appliances with high energy consumption, that can be scheduled in time and therefore offer a chance to avoid peaks in energy consumption by changing times of operations. By using modern bus technologies the integration of a high number of devices with comparably low energy consumption becomes possible. If these devices are combined into one group an electrical load occurs useful for load management, for example electrical appliances in the kitchen.

Typical tariffs for electrical peak consumption in Germany use the 3 or 4 highest peaks in electricity consumption per year as the average peak load. However the everyday peak consumption is lower than the defined reference value, so that most of the enterprises pay a higher fee than necessary. The aim of a load management system is to avoid these short time peaks, resulting in a more constant consumption over a day.

Basically there are two main strategies to reduce electrical peak consumption. One is to change the structure or organisation of the working day, which means that energy intensive procedures not linked to a defined day time can be reorganised to times where costs for electrical energy are lower. An example can be the night time use of washing machines, dryers or irons.

Secondly costs for electrical peak consumption are reduced by switch off electrical devices for a short period of time (up to 5 minutes). To avoid disturbances in working procedures the switched electrical devices have to be sorted by priorities. Equipment with lower priority, e. g. cooling machines and freezers[3], can be switched off more often and for longer periods than for example a grill or a frying pan. Other devices like microwaves, hair dryers or personal computers can not be included into a load management system, as well as security related equipment.

In figure 5 the total amount of installed electrical peak load consumption and possible numbers of switchable peak loads divided by different priorities are shown. These priorities are assigned as follows:

- **Priority 2** — devices that can often be turned off without impact on the daily working process
  i.e. refrigerators, cooling and freezing machines, mini-bars, Rechauds

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3 Here the bus technology offers the additional opportunity to couple the switch on of freezers to measurements of inside temperature instead of using predefined maximum switch off times.

➢ **Priority 1** devices that can sometimes be turned off without impact on the working process
i.e. Bain-marie, ovens, washing machines, clothes dryers, ventilators

➢ **Priority 0** devices that should only be turned off in exceptional cases and only for a short period of time
i.e. frying pans, grills

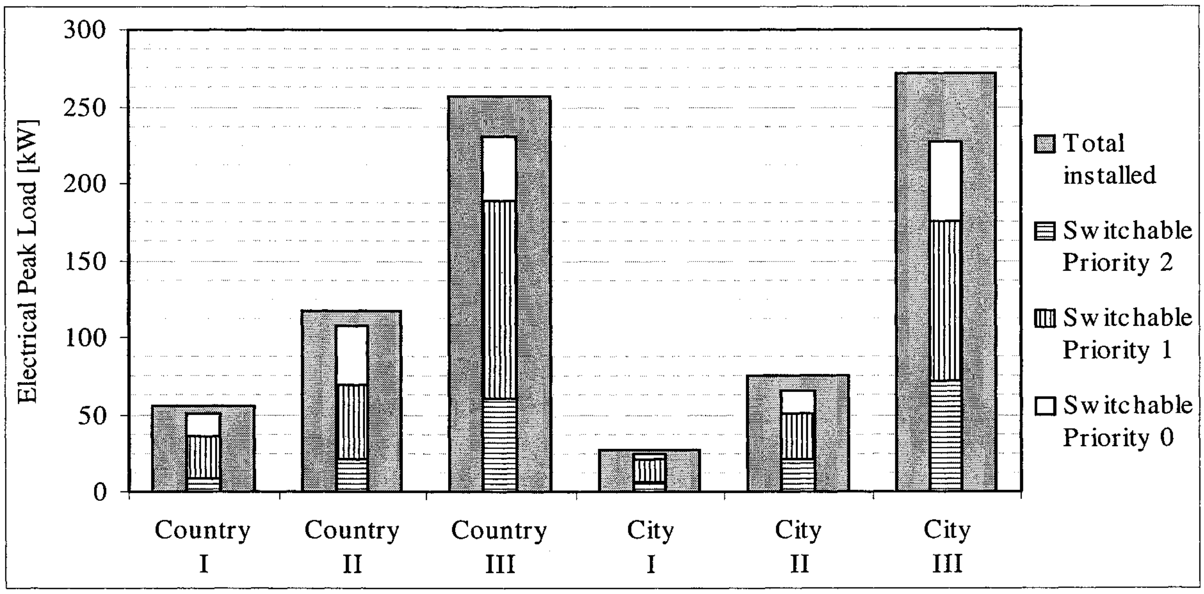

Figure 5: Average Amount of Total Installed Electrical Load and of switchable Electrical Load

Lighting

The third main application of a bus technology based building and energy management system is lighting. In addition to the given information in context to the single room control the installation bus simplifies the conception of light scenarios. For example, a general regulation of different lamps or of groups of lamps by switching one single button becomes possible. With this the illumination in i.e. conference rooms can be controlled very easily. Furthermore change of the working state of lamps will be realised by only one push on a button. During a conference or a business meeting where several kinds of presentations are given an optimised degree of illumination can always be achieved, and the comfort for the participants of the meeting may even be increased.

Furthermore in larger hotels with often more than one conference room the state of the lamps can be supervised at a central place, for example at the reception desk. It is then possible to avoid lighting in times when the room is not in use.

Another possible application for an installation bus controlled lighting is on floors or in elevators, where lights are usually turned on continuously. In combination with occupancy sensors lights can be switched or dimmed automatically depending on the occupancy of an area, such that lights are only working when they are needed.

Also the outside area of a hotel can be controlled and a sunshine dependent illumination may be realised.

Conclusions

The empirical analysis showed that electricity accounts for about one third of the energy consumption in German hotels but for about two thirds of the costs. The major singele energy use is room heating and heare substantial energy savings of 20 % or more have been identified through occupancy-dependent single room control.

For electricity significant cost savings are possible through loaed managemeet. Also lighting is an attractive field for bus technology applications since increased comfort and more efficient energy use may be combined.

Although bus technology besed BEMS are better scaleable than conventional systems, we think that thes systems are hardly economically viable in small hotels (less than 70 beds). Since the energy costs are too low to cover the fixed cost component of the installation. However with the past and still ongoing cost reductions, the bus technology becomes attractive for medium-sized hotels (70 to 150 beds). Therefore application a consortium, in which we are involved, wants to prove both the technological feasibility and the cost effectiveness of an integrated BEMS using bus technologies.

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