Energy Savings and Energy Efficiency through Building Automation and Control

MARTIN BECKER
Prof. Dr.-Ing.
Biberach University of Applied Sciences, Institute for Building and Energy Systems, Germany
becker@hochschule-bc.de

PETER KNOLL
Dipl.-Ing. (FH)
Biberach University of Applied Sciences, Institute for Building and Energy Systems, Germany

In addition to the improvement of building physics/building envelope and building systems (heating, cooling, etc.), the targeted use of room and building automation contributes significantly to the energy-efficient operation of buildings. This potential is based on the application of bus systems and automation technologies. Building automation in particular is a necessary instrument for maintaining the energy-efficient operation of buildings through continuous energy and building management. In order to analyze and advance this topic systematically, Biberach University of Applied Sciences has performed a variety of experimental and theoretical research work.

Keywords: room automation, building automation, energy, efficiency, savings, energy-saving potential, EN 15232, energy management

For the sustainable operation of a building, it is important to understand the interplay between the essential parameters. These parameters can be grouped into four categories.

a) **Aspects of use**
The comfort conditions in the rooms are an essential requirement for the overall planning and operation concept. This includes the thermal conditions (e.g. set-point temperature: 20°C), adequate illuminance (daylight and artificial light) and the possibility of adjusting the parameters.

b) **Energy-efficient operation of buildings**
The focus here is on the efficient use of energy (electricity, heating, cooling). This efficiency can be achieved with suitable functions of room and building automation.

c) **Building envelope**
The envelope is the interface with the environment (e.g. facade systems or building physics).

d) **Building systems**
This includes all technical systems which are used for heating, cooling, ventilation and the power supply of a building.

In the context of the EPBD (Directive 2010/31/EU of The European Parliament and of the Council of 19 May 2010 on the energy performance of buildings), the standard EN 15232 "Energy performance of buildings - impact of Building Automation, Controls and Building" was developed.

This standard divides the functions of room and building automation into four BACS (Building Automation and Control Systems) efficiency classes:

- Class D corresponds to BACS that are not energy-efficient. Buildings with such systems must be retrofitted. New buildings may no longer be built with such systems.
- Class C corresponds to standard BACS.
- Class B corresponds to advanced BACS and some specific TBM functions.
- Class A corresponds to highly energy-efficient BACS and TBM.

The standard provides two basic methods: the detailed and the simplified method (BACS factor method). The simplified BACS factor method allows the use of factors to calculate the final energy demand, depending on the BACS efficiency class.

This approach allows easy explanations, e.g. for owners, of how much the energy demand can be reduced for a given type of building through the functions of room and building automation.

To analyze these standardized methods under real-life conditions, Biberach University of Applied Sciences has performed theoretical research (simulation studies) as well as experimental analyses in seminar rooms in order to demonstrate the possible energy savings.

Measurement campaign

The goal of the measurement campaign is to answer the key question of whether it is possible to determine a potential for savings, in rooms in which different BACS efficiency classes (according to the standard EN 15232) have been realized, during the building's actual operation, and if so, how high the potential savings are.

For that purpose, the University of Applied Sciences Biberach has organized a measurement campaign involving three seminar rooms (G0.02, G0.03, G1.03, **Figure 1**) in the "Technikum G" building with comparable boundary conditions over a longer period of time. These three rooms have different functions in terms of room and building automation according to the norm EN 15232.

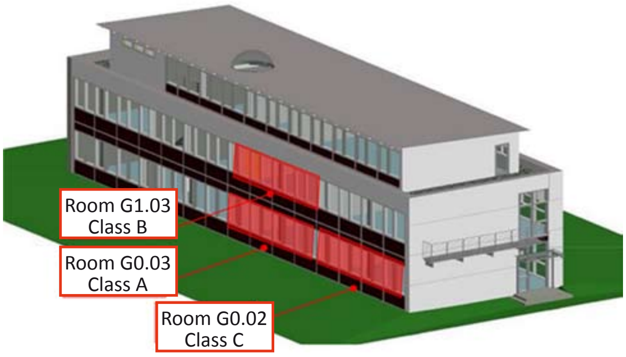

Figure 1. Spatial arrangement of the seminar rooms for the measurement campaign in the "Technikum G" building at Biberach University of Applied Sciences.

For the results, only the BACS efficiency classes C, B and A are compared. Class D no longer complies with current technical standards.

The seminar room G0.02 was chosen as the reference room. The functions in this room are based on the BACS efficiency class C. In the other seminar rooms, different functions of room and building automation were realized according to BACS efficiency classes B and A, making it possible to determine potential energy savings through technical measurements.

Table 1 lists the functions which were implemented. BACS efficiency class A has the most extensive functional configuration. Class C is the reference value for the energy savings.

Table 1. Combined functions of the measurement campaign for the three test rooms according to the standard EN 15232.

G0.02 BACS efficiency class C	**G0.03 BACS efficiency class A**	**G1.03 BACS efficiency class B**
Manual lighting on/off, without dimming	Manual lighting on/off, without manual dimming automatic off (presence, daylight), constant light control	Manual lighting on/off, without manual dimming automatic off (presence, daylight)
Temperature control with a thermostatic valve	Individual room control with three different set values: • 14°C night setback/window opening monitoring • 19°C stand-by • 21°C normal mode	Individual room control with three different set values: • 10°C night setback/window opening monitoring • 16°C stand-by • 21°C normal mode

Results of the measurement campaign

Figure 2 shows the electrical energy consumption which was measured in the three previously mentioned rooms with the different functional configurations. The figures have been adjusted to account for the different occupancies of the rooms.

While the lighting in the reference room (G0.02, Class C) is controlled manually, the other rooms have an automatic control which takes occupancy and available daylight into account. In addition to this, there is a constant light control in Room G0.03 (Class A). The clear improvement in the savings for Class A (G1.03) is due to the optimization of the constant light control which took place between the measurements "December 2009 – May 2010" and "October 2010 – March 2011". This optimization was based on experiences made during the first measurement period and involved the correction of sensor placement, among other things.

This illustrates the high importance of continuous improvement during operation.

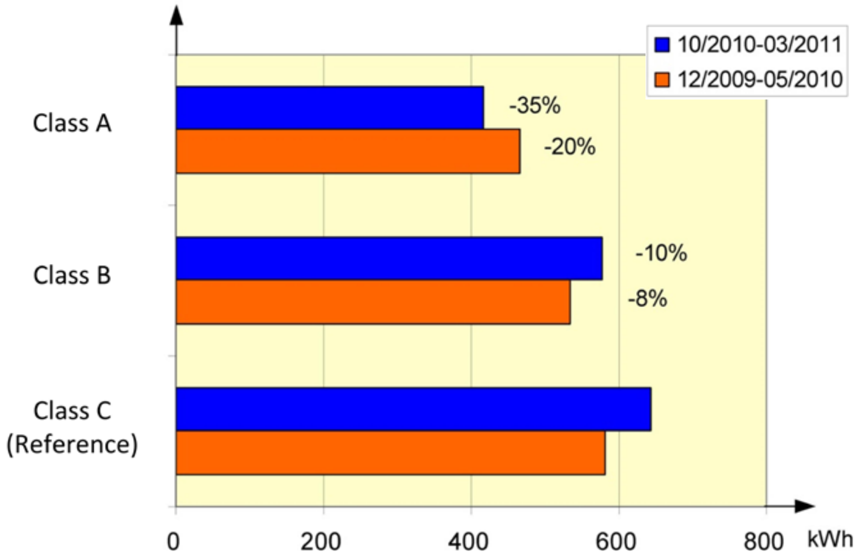

Figure 2. Electric energy consumption with percentage savings of the BACS classes A, B, C

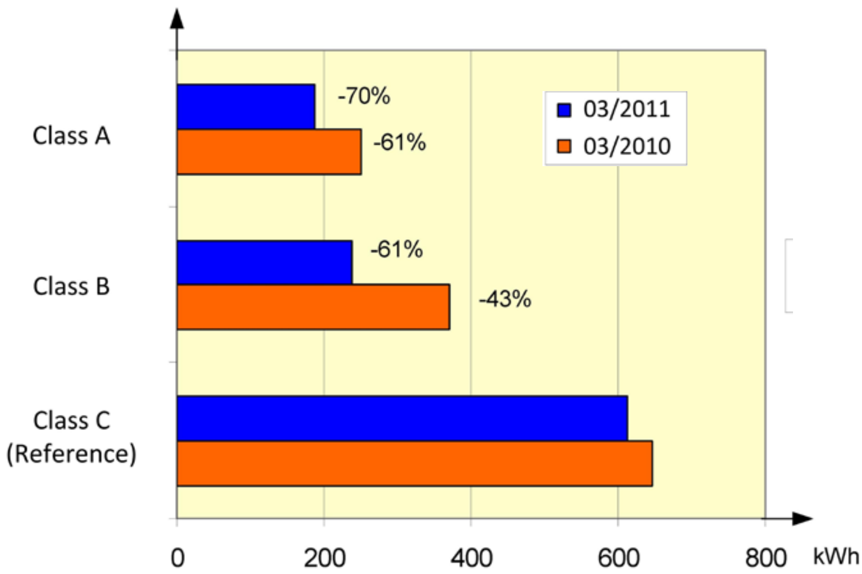

Figure 3. Comparison between the months March 2010 and March 2011; reduced consumption of heating energy (adjusted)

The data for heating energy consumption was analyzed analogously to the method used for electrical energy consumption. While the control in the reference room (G0.02) is realized with thermostatic valves, the room with the BACS class C (G1.03) has an individual room control with a zone valve which is blocked if a window is open. In addition to this, room G1.03 (BACS class A) has an optimized set point if the room is unoccupied.

Figure 3 shows the comparison between the measurement data for heating energy consumption. For the analysis, it was necessary to adjust for internal loads (e.g. lighting, occupancy), geometrical dimensions and building physics during the measurement periods.

The savings are based on the reference room G0.02. The data for March was very well suited for the analysis, because the weather conditions were similar in both years. You can see high energy savings between the reference room and the rooms with constant light control. While the savings in Room G0.03 were similar in both years, Room G1.03 shows clear improvements between March 2010 and March 2011. The reason for this is the realization in the first measurement period that the installed valve didn't fit to the valve gear. As a result, the control behavior was very bad.

This optimization process which was identified with the installed energy monitoring made it possible to achieve a huge improvement in energy efficiency. This example shows once more that continuous monitoring is very important. Continuous monitoring is the basis for straightforward optimization during building operation.

Importance of continuous energy monitoring

A major advantage of integrated building automation systems lies in the ease with which different types of data on the building and its systems can be analyzed. These possibilities are more than the usual error messages and energy analyses. For example, it is possible to check whether the automation strategy suits the room (occupancy) profile.

The following section contains an example which demonstrates how differently users can control the lighting of a room.

So-called carpet plots were used for the illustration. A carpet plot is a type of chart which is very well suited for concentrated information analysis. The abscissa of the chart is used for the day in a month or year and the ordinate for every hour of a day. This makes it possible to display a mean value (e.g. temperature) for data which is color-coded, allowing the analysis of electrical power or the runtime of components such as pumps or fans over a longer period of time at a glance.

A very clear example is shown in **Figure 4** and **Figure 5**. The electrical power for the lighting and the occupancy of Room G0.02 are color-coded. As noted in **Table 1**, the lighting in this room can only be switched on and off manually (BACS class C). The occupancy sensor is only used to determine occupancy, not control the lighting.

Figure 4 shows that the users switched the lighting on and off in a fairly exemplary fashion in December 2010. During this period, users switched off the lighting as soon they left the room. An occupancy sensor would not result in any energy savings in this case.

In contrast to this, the situation with the same boundary conditions is shown for October 2010. **Figure 5** shows that the lighting was almost never switched off from 14 October 2010 onwards, even if nobody was in the room. The light green color shows an electrical power consumption of about 500 W. This amount may represent a single light-band in the room which users forgot to switch off. In this example, an occupancy sensor would save a lot of energy by deactivating the light-band as soon as no one is in the room.

Summary

Along with good building physics and building systems, building automation is the third pillar in the energy-efficient operation of a building. Building automation combined with energy monitoring is a particularly important tool for showing potential for optimization in regard to users' behavior.

As a basis for this, it is necessary that building automation be considered during the planning process. The standard EN 15232 with the defined BACS efficiency classes provides a foundation for planning which has to be considered for the realization of new and modernized buildings in order to arrive at energy-efficient solutions.

Biberach University of Applied Sciences has analyzed the energy consumption of three seminar rooms with different BACS efficiency classes in order to determine the possible energy savings in the norm.

The analysis shows high potential energy savings through the use of room and building automation. An additional insight is that a process (e.g. a building) which has changing boundary conditions (e.g. the weather) or different disturbances (e.g. user behavior) can only be operated with an automation system which includes every building system.

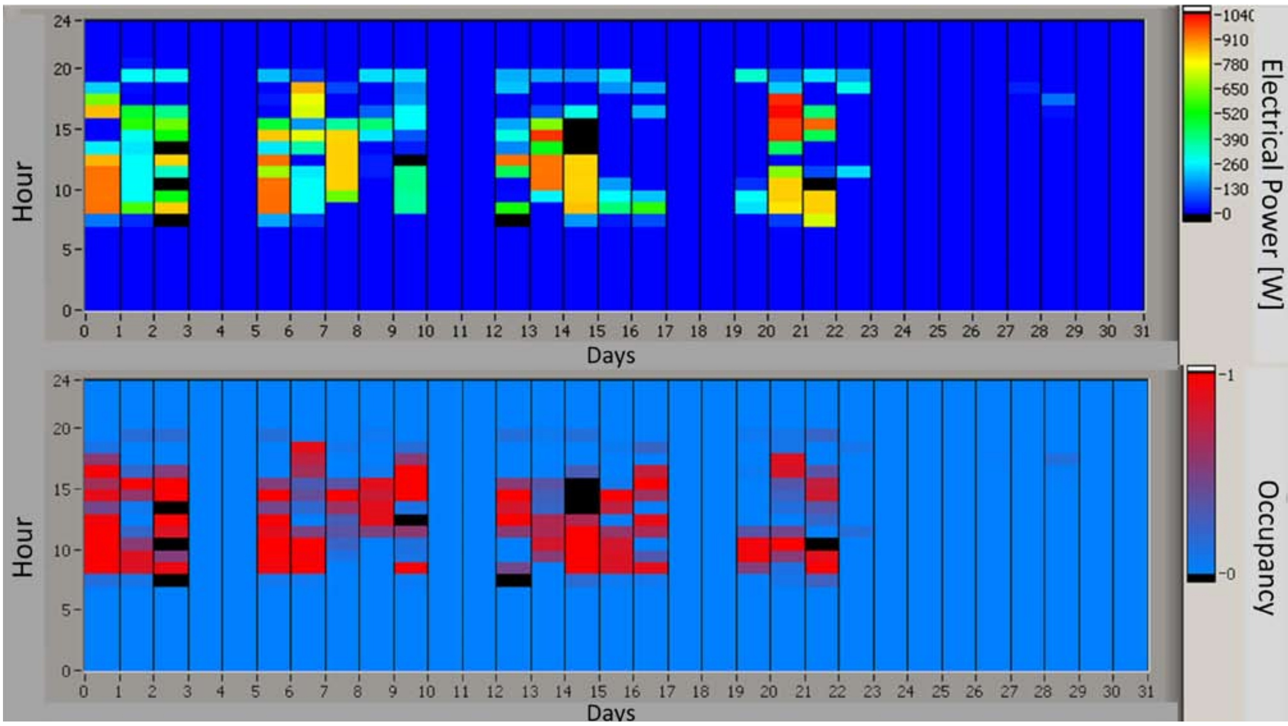

Figure 4. Carpet plot with an example of energy-efficient user behavior (December 2010)

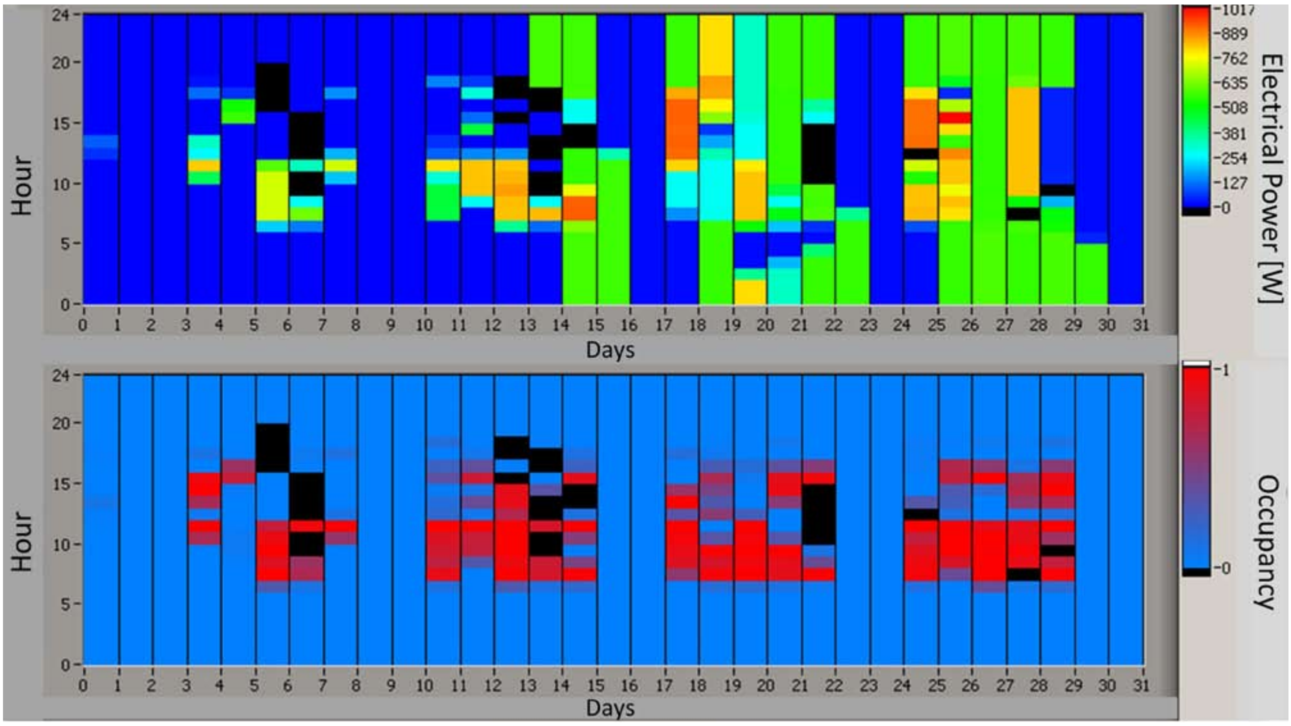

Figure 5. Carpet plot with an example of inefficient user behavior (October 2010)

The results of the analysis show very well that user behavior has a huge influence on measurements during the actual operation of a building. Even the prediction of the possible energy savings and the analysis of the results are dependent on this user influence.

Another important insight for practical applications is the high influence that the positioning of the sensor systems and the correct use of actuators have on the potential energy savings. ■