# Handbook
## Building Energy Management in Large Shopping Malls and Medium-Sized Hotels

# Imprint

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in Large Shopping Malls and Medium-Sized Hotels

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# 1 Introduction and purpose of the handbook

Commercial buildings account for 11% and 4% of the total final energy demand in Europe and China, respectively[1]. They are major energy consumers with significant saving opportunities. An easy way to save energy is through an appropriate building energy management system (BEMS).

*"Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives"*[2]

Energy management is important for all companies, given the following benefits:

- It results in significant energy savings. In Europe, BPIE[3] estimated that energy management systems bring on average 37% for space heating, water heating and cooling/ventilation and 25% for lighting.
- It reduces greenhouse gas emissions and the energy consumption.
- It improves the image of a company and leads to competitive advantages.
- It helps companies to comply with the legal requirements.[4]

However, there is a lack of awareness and understanding of the potential of energy management systems. In Europe, for example, only 25% of commercial buildings have properly installed energy management systems.

This handbook provides comprehensive knowledge and recommendations about building energy management systems and programmes of commercial buildings. Since SusBuild project targets at small and medium enterprises (SMEs), this handbook focuses on two types of commercial buildings companies most relevant for SMEs:

- **large shopping malls, and**
- **medium-sized hotels.**

The target groups of the handbook are building owners, general managers, and facility managers of large shopping malls and medium-sized hotel buildings:

- Building owners or general managers will have an increased awareness about the importance of building energy management solutions and measures, especially, **key steps of setting up a building energy management programme.**
- Facility managers will have advanced knowledge of building energy management practices such as the different components of the Building Energy Management systems and the approaches for analysis and optimization. Various **technical aspects of a comprehensive building energy management system** are presented in details and illustrated with **good practice examples**

[1] GEA, (2012)
[2] VDI-Guideline, (2007)
[3] BPIE, (2016)
[4] Carbon Trust, (2011)´

The increasing awareness among these actors in large shopping mall is also expected to influence energy consumption behaviour of tenants in SMEs.
In addition, while technologies play a key role in building energy management, its adoption depends on the incentives of different stakeholders, which are addressed by various policies. Thus, the handbook also gives local government an **overview of a prototypical policy package to incentivise companies** to implement an energy management system.

The handbook was developed based on literature review of global experiences, especially those from Europe. This handbook focuses not only on individual technologies, but also on the role of different stakeholders, rational decision-making process, and good practices leading to a holistic approach for energy management. A holistic approach reaps the full benefits offered by different component/part improvements of individual technologies. For example, it is not only sufficient to install efficient lighting system, but also to plan and accommodate corresponding control technologies in both the lamp and circuit technology, as well as in the Building Energy Management system. These decisions should be taken early into the design as they have long-term implications.

# 2 Characteristics and energy consumption of shopping malls and hotels in Europe

## 2.1 Large shopping malls

### 2.1.1 Building characteristics and the relevance of energy efficiency in large shopping malls

Shopping centres have a long history in Europe. In 2013, the Gross Leasable Area of large shopping centre buildings (larger than 5,000 $m^2$) was 112 million $m^2$ in EU-28 and Norway. These are buildings in different sizes and forms containing various functions. According to the International Council of Shopping Centres, shopping centres can be categorised into the following 11 categories (Tab. 1). In this report, the focus is limited to medium and large shopping malls with various functions (traditional and specialised).

Tab. 1: Shopping centres categories by gross leasable area

| Format | Type of scheme | | Gross Leasable Area (GLA) |
|---|---|---|---|
| **Traditional** | Very large | | 800,000 $m^2$ and above |
| | Large | | 40,000 – 79,999 $m^2$ |
| | Medium | | 20,000 – 39,999 $m^2$ |
| | Small | Comparison-Based | 5,000 – 19,999 $m^2$ |
| | | Convenience-Based | 5,000 – 19,999 $m^2$ |
| **Specialised** | Retail Park | Large | 20,000 $m^2$ and above |
| | | Medium | 10,000 – 19,999 $m^2$ |
| | | Small | 5,000 – 9,999 $m^2$ |
| | Factory Outlet Centre | | 5,000 $m^2$ and above |
| | Theme oriented Centre | Leisure-Based | 5,000 $m^2$ and above |
| | | Non-Leisure Based | 5,000 $m^2$ and above |

Source: ICSC (2005)

Fig. 1 shows the share of different sized shopping centres in Europe. Small shopping centres are dominating in Europe (especially in Austria, Belgium, Switzerland, Denmark, Finland, Malta, the Netherlands and Sweden with more than 70%). In Bulgaria, Cyprus, Germany, Croatia, Ireland, Luxemburg, Poland and the UK medium and large shopping malls with more than 20.000 $m^2$ dominate the market with a share of more than 50%.[5]

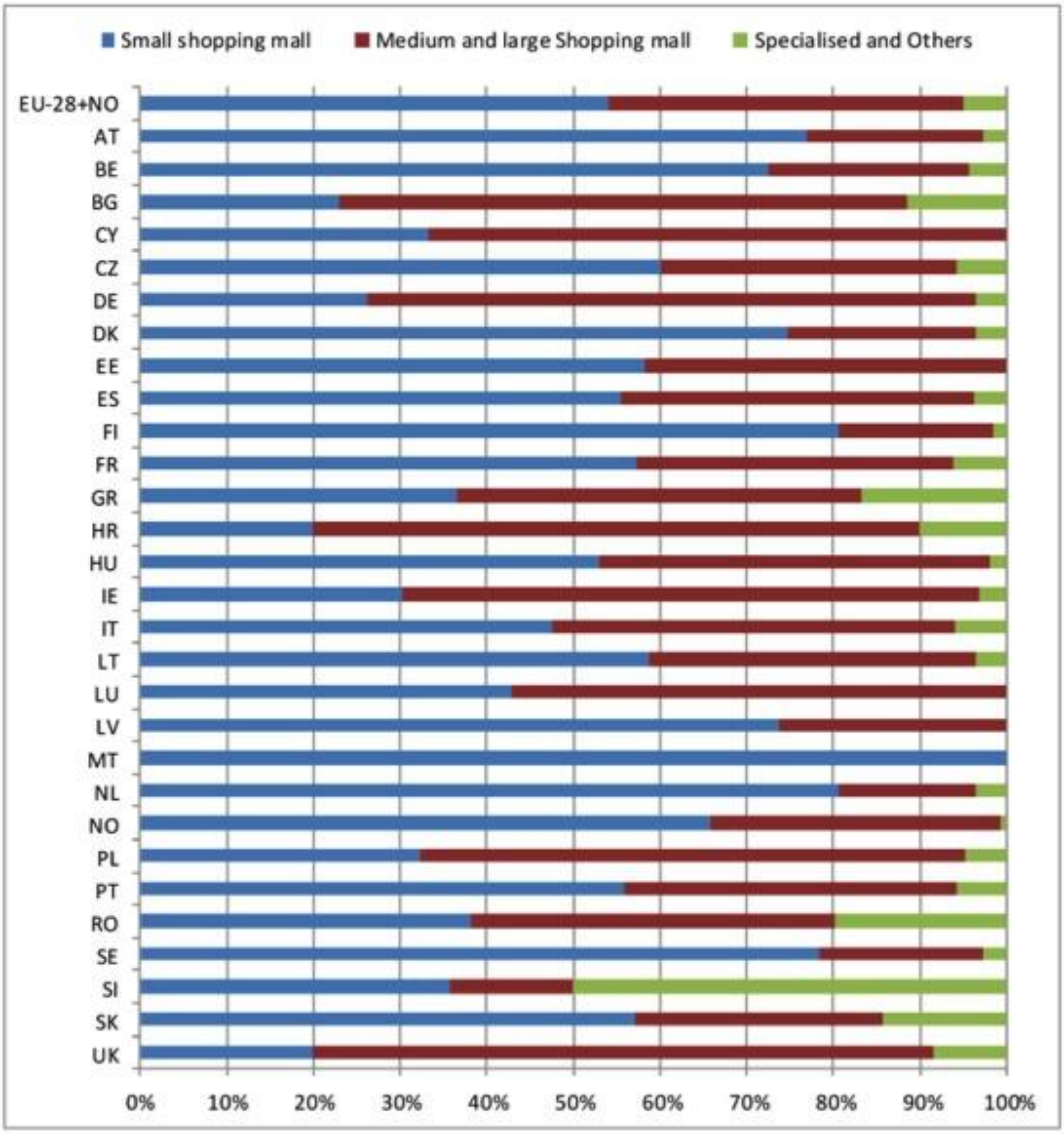


Fig. 1: Share of Small, medium and large shopping malls as well as specialised and other shopping centres in EU-28 + Norway

Source: Bointner & Toleikyte, (2014)

In shopping malls, energy is primarily used for store lighting, ventilation, heating / air conditioning and food refrigeration.[6] In general, due to the high demand for refrigeration, food-driven stores, such as supermarkets, have significantly higher energy consumption than the others, ranging from 500 kWh/m² to 1000 kWh/m². Non-food Stores have energy consumption between 200 kWh/m² (area >

[5] Bointner & Toleikyte, (2014)
[6] Schönberger, et al., (2013)

300 $m^2$) and 270 kWh/$m^2$ (areas < 200$m^2$). Among non-food stores, energy consumption also varies depending on the sizes and functions. Besides, food stores and non-food stores have very different energy consumption patterns. Fig. 2 shows the share of energy demand in food stores and non-food stores.

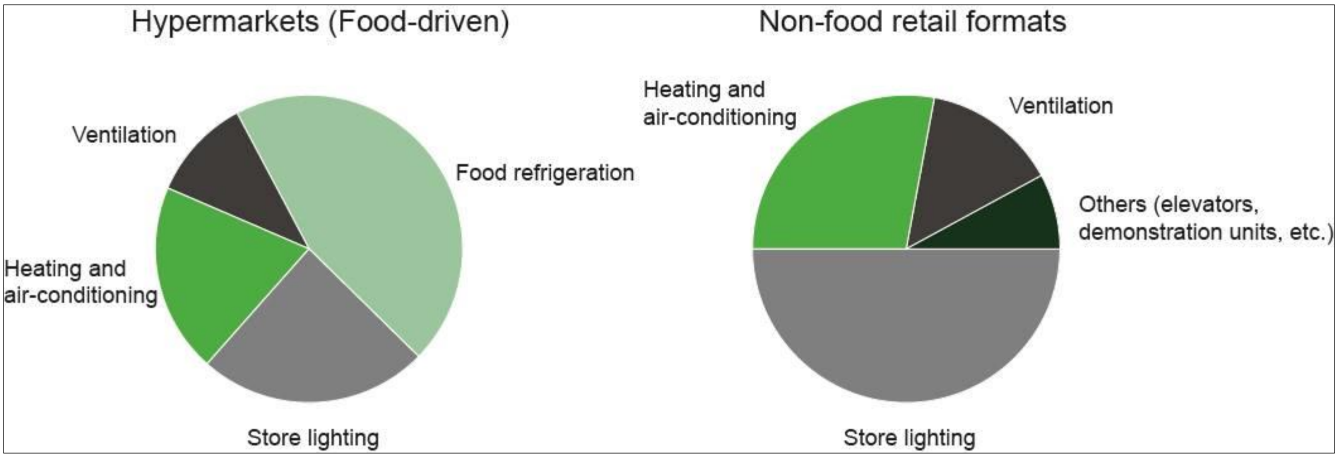


Fig. 2: Share of total energy demand in retail buildings.

Source: adapted from Bointner & Toleikyte (2014)

Due to this high energy consumption and the related energy costs, energy management becomes a key for managing shopping malls. The potentials to increase the energy efficiency and to reduce costs are high.

The following factors foster the implementation of energy efficiency improvements:

- Reducing energy costs, so that the owner and tenants can save money, if proper incentive models are implemented;
- A green image and increasing comfort can attract new customers;
- By accepting the highest legal environmental standards now, firms can anticipate future legislation.

Despite all these benefits, there is still a lack of attention on energy management practices among shopping malls. This is partly caused by various barriers relevant actors encountered.

### 2.1.2 Relevant actors and their roles and barriers in large shopping malls

To understand why the energy saving potentials are not fully exploited, it is essential not only to look at technical aspects but also to analyse different actors and their decision making structures.[7] In general, five major types of actors influence the energy consumption in shopping malls, ranging from building owners, managers, tenants, and facility managers to customers (see Tab. 2). Although large shopping malls are not operated by SMEs, the decision-making by their owners and managers will

[7]Woods, et al., (2015), CommONEnergy

significantly influence on tenants and facility management companies. Tab. 2 presents the roles of the different actors and main barriers they encountered and how this report can support different actors to overcome these barriers.

Tab. 2: Relevant actors, their role in energy management and their main barriers

| Actor | Main interests and role in Energy Management and energy efficiency improvements | Main Barriers | How to overcome the barrier |
|---|---|---|---|
| **Shopping mall owners and investors** | Mainly interested in increasing the attractiveness of the shopping mall and providing sales maximisation. Involved in strategic, tactical and management decisions related to the shopping mall, including energy renovation and energy efficient operation;[8]<br><br>Setting expectations for the facility energy management team. | Lacking information about energy efficiency systems and best practices on energy efficiency | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 3.1.8, 5.3.1, 5.3.3, 5.3.4 |
| | | Uncertain about saving potential | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 5.3.2, 5.3.3, 5.3.4, 5.4.2 |
| | | Lack of interest and motivation for energy efficiency improvements | Please refer to chapter 3.1.2, 3.1.6, 5.3.1, 5.3.3, 5.3.4, 5.3.5 |
| | | Regulatory barriers | Please refer to chapter 5.3.1, 5.3.5 |
| | | Uncertainty about how the investment will perform in terms of revenue and risk | Please refer to chapter 3.1.8, 5.3.2, 5.4.2 |
| **General manager** | Responsible for leasing single shops and primary contact to all tenants ensuring that they comply with the internal policies and regulations. Responsible for the implementation of the energy efficient operation.<br><br>Supporting and monitoring the initiative of all the facility energy management team; Setting goals, approving resources for the team and projects. | Lacking information about energy efficiency systems and best practices | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 3.1.8, 5.3.1, 5.3.3, 5.3.4 |
| | | Lacking financing | Please refer to chapter 5.3.2, 5.4.1, 5.4.2 |
| | | Lacking interest and motivation for energy efficiency improvements | Please refer to chapter 3.1.2, 3.1.6, 5.3.1, 5.3.3, 5.3.4, 5.3.5 |
| | | Regulatory barriers | Please refer to chapter 5.3.1, 5.3.5 |

[8]Woods, et al., (2015), CommONEnergy

| | | | |
|---|---|---|---|
| | | Different expectation from store owners and shopping mall owners | Please refer to chapter 3.1.2, 3.1.5, 5.3.1, 5.3.4, 5.3.5 |
| **Internal facility manager and external facility management companies** | The core business of a facility manager is to plan, develop, manage and use space.[9] This can be done by internal staff member or by an external facility management company.<br><br>In many cases, the facility manager/facility management company is also nominated as energy manager. In this case, his or her main task is to analyse how resources can be used efficiently.[10] Delegating and managing all tasks related to energy management, including the coordination of resources needed to implement energy management and the identification of potentials.<br><br>In addition to monitoring activities and the implementation of energy efficiency measures, a facility manager respectively energy manager has to deal with energy issues in the common places like washing rooms, halls and atria. On the one hand he or she has to implement the requirements of the shopping mall owner or manager but also the interest of the tenants.<br><br>He or she has to report the activities to the management team. | Lacking information | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 3.1.8, 5.3.1, 5.3.3, 5.3.4 |
| | | Lacking management commitment | Please refer to chapter 3.1.2, 3.1.5, 3.1.8 |
| | | Different expectation from store owners and shopping mall owners/manager | Please refer to chapter 3.1.2, 3.1.5, 5.3.1, 5.3.4, 5.3.5 |
| | | Technical barriers, e.g. poor design of existing buildings resulting in energy losses (e.g. through poor insulation) | Please refer to chapter 4 |
| **MSME Tenants** | Managing a single or several shops and concentrating on their core business. Their aim is to realise a pleasant shopping environment for customers and to maximize the sales potential.<br><br>Regarding energy efficiency improvement potentials, it depends on how the tenants are billed for their energy use. In many cases, the store's energy use is included in a basic service charge, which is not consumption-based.[11] If the tenants pay based on their consumption, they would have a higher motivation for energy efficient operation. | Lacking information: Unskilled staff who are not properly trained to run existing energy facilities efficiently | Please refer to chapter 3.1.6, 5.3.3, 5.3.4 |
| | | Lacking interested and motivation for energy efficiency improvements | Please refer to chapter 3.1.2, 3.1.6, 5.3.1, 5.3.3, 5.3.4, 5.4.2 |
| | | The split incentives: The tenants often have no financial incentive when they pay a basic service charge including energy costs | Please refer to chapter 5.3.2, 5.3.5 |
| **Customers** | According to a survey by CommONEnergy (2015), customers are not very interested in energy efficiency / energy management issues of | The investor-user / landlord-tenant dilemma | Please refer to chapter 5.3.2, 5.3.5 |

[9] Woods, et al., (2015), CommONEnergy
[10] Blakstad, et al., (2010)
[11] Woods, et al., (2015), CommONEnergy

| | | | |
|---|---|---|---|
| | the shopping mall. Therefore, they only have a very small role in the implementation of energy management. However, the behaviour of customers can be of high relevance for the energy consumption, e.g. when opening the door of the refrigerator for a long time or when using elevators. | Lacking knowledge/informatio n | Please refer to chapter 3.1.8, 5.3.1 |
| | | Lacking interest and motivation save energy | Please refer to chapter 3.1.8 |

## 2.2 Medium-sized Hotels owned by SMEs

### 2.2.1 Building characteristics and the relevance of energy efficiency in hotels

In the European Union, there are approximately 5,45 million hotel rooms in 200.000 establishments, nearly half of the world's total. Here, the hotel accommodation sector is dominated by small business, which provides around 90% of the total number of rooms. The tourism sector has a huge impact on the environment, after the industry sector and agriculture.[12] 1% of all total $CO_2$ emissions come from hotels and similar accommodations.[13]

Hotels are characterised by a number of activities that collectively exert a significant impact on energy consumption and other resources. Negative environmental effects are an increased demand on energy supply, an increased burden on solid waste management and the pollution of water bodies, soil and air.[14] It is estimated that annual energy consumption of an average hotel ranges between 200 kWh/m$^2$ and 400 kWh/m$^2$, which resulted in 160 to 200 kg of $CO_2$/m$^2$ floor area.[15] Thus, energy efficiency is at the heart of a sustainable hotel.[16] [17]

In many hotels, energy is a substantial proportion of operating cost. After staff costs, energy can be one of the largest elements of expenditure. However, energy is often mistakenly regarded as a fixed overhead although it is actually one of the easiest costs for a business to manage through simple measures such as changing the light bulbs, replacing refrigerators etc.[18] The main energy consuming activities in a hotel are heating and cooling rooms (50%), lighting (10 – 18%), hot water use (up to 15%), preparing meals, and swimming pools. Many rented hotel rooms remain unoccupied for long periods – approximately 60 - 65% during the day – while HVAC systems are left running or in stand-by mode.[19] It was found that typical energy savings from continuous energy management are around 8 – 10% but in some cases such as it can be as high as 30%. To take the example of a hotel in Scandinavia, energy efficiency measures – mostly on energy management, maintenance and staff training – implemented over a seven-year period resulted in energy savings of around 15 – 20% without significant investments.[20] The energy saving potential depends on the age and size of the hotel, the type of equipment installed and the maintenance and operating procedures in use. European studies

[12] Hotel Energy Solutions, (2011)
[13] neZEH, (n.a.)
[14] Mbasera, et al., (2016)
[15] Hotel Energy Solutions, (2011)
[16] Han, et al., (2010)
[17] Hotel Energy Solutions, (2011)
[18] SEI, (n.a.)
[19] Hotel Energy Solutions, (2011)
[20] Hotel Energy Solutions, (2011)

estimated that the saving potential is 15 – 20% for heating, 5 – 30% for cooling, 40 – 70% for hot water and 7 – 60% for lighting.[21] In addition to energy savings and reduced costs, energy efficiency improvements can also for example ensure high standards of indoor environmental and thermal quality and minimize temperature fluctuations and improved air-ventilation systems. Furthermore, environmental-friendly hotels offer better public relations and the opportunity to enter new markets. A business that demonstrates environmental commitment by cutting energy use is likely to gain positive customer opinion and market share.[22] According to a publication in 2013, 75% of all travellers would consider ethical or environmental impact of their main holiday during that year.[23] This was confirmed by a TripAdvisor study which showed that 81% of travellers prefer hotels implementing eco-friendly practices.

### 2.2.2 Relevant actors, their barriers and their interactions

The most relevant actors in terms of energy management are the hotel owner/general manager and the energy manager/facility manager. The implementation of energy efficiency measures depends on the commitment of the hotel owner and/or the top management. There is a growing attention among hotel owners and managers to communicate sustainability performance to all relevant stakeholders as quality feature. The hotel facility manager plays a central role in this field as he or she is the one who implements and controls energy saving measures. Other actors like employees and hotel guests also have a strong influence on the energy consumption of the hotel.

A study of the roles and authorities in more than 100 European hotels finds a mixed picture in decision autonomy, depending on the individual's experience and education, as well as whether the hotel is independent or chain managed.[24] Mostly, the staff structure is hierarchically organized: with the general management at the top, who is assisted by the executive assistant manager to whom report the line managers, consisting of the rooms' divisional head. The roles of the different key actors are presented in Tab. 3.

Tab. 3: Relevant actors, their role in energy management and their main barriers

| Actors | Role in Energy Management and energy efficiency improvements | Main Barriers | How to overcome the barrier |
|---|---|---|---|
| **Hotel owner** | Managing all responsibilities connected with the ownership of the hotel property itself. The main task of the hotel owner is to reduce costs (e.g. energy costs) and to generate profits. In small family hotels, most owners perform building operation, including energy management, themselves. In large hotels, the owners hire staff such as a facility manager for energy management. The owner decides the future development plans and targets of the hotel. | Lacking information about energy efficiency systems and best practices on energy efficiency | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 3.1.8, 5.3.1, 5.3.3, 5.3.4 |
| | | Lacking financing (over 90 per cent of | Please refer to chapter 5.3.2, 5.4.1, |

[21] Hotel Energy Solutions, (2011)
[22] SEI, (n.a.)
[23] Blue and Green Tomorrow, (2013)
[24] Hodari & Sturman, (2014)

| | | | |
|---|---|---|---|
| **General hotel manager** | The general hotel manager is usually responsible for the day-to-day management. Some responsibilities are promoting and marketing the business, managing budget and maximising profit, maintaining statistical and financial records, setting and achieving sales, and ensuring compliance with existing laws.<br><br>He or she is the connection between the heads of department and the hotel owner. The manager may report to the hotel owner about the developments of energy efficiency and energy management on a regular basis. Depending on the role of the hotel owner, the manager either fulfils the requirements of the owner or decides future plans and targets. In the second case, the hotel manager sets targets, develops a strategy plan, and evaluates the development in terms of energy management. | hotels have difficulty obtaining financing for any types of investments) | 5.4.2 |
| | | Lacking interest and motivation for energy efficiency improvements | Please refer to chapter 3.1.2, 3.1.6 |
| | | Regulatory barriers | Please refer to chapter 5.3.1, 5.3.5 |
| | | Uncertainty about how the investment will perform in terms of revenue and risk | Please refer to chapter 3.1.8, 5.3.2, 5.4.2 |
| **Facility manager** | In contrast to hotel management, facility managers are responsible for planning, designing, constructing and managing space. In most cases, the facility manager performs the role of an energy manager and is the primary contact in terms of energy efficiency improvements. He or she is responsible for the implementation of the energy management system. Facility managers are expected to be knowledgeable and to master a board range of administrative and leadership skills. | Lacking information | Please refer to chapter 3.1.1, 3.1.3, 3.1.4, 3.1.7, 3.1.8, 5.3.1, 5.3.3, 5.3.4 |
| | | Lacking management commitment | Please refer to chapter 3.1.2, 3.1.5, 3.1.8 |
| | | Technical barriers: E.g. poor design of existing buildings resulting in energy losses (e.g. through poor insulation, draughts, etc.) | Please refer to chapter 4 |
| Employee | Activities of employees include room service, food and beverage, font desk, security, marketing and sales, or purchasing. Employees can play an active role in the implementation of an effective energy management system. For instance, housekeepers should be motivated to turn off all lights and set temperature to minimum level after cleaning each room. Front desk employees like registration staff should be educated that they can help save energy costs by booking rooms in clusters, so that only occupied building areas or wings need to be heated or cooled to guest comfort level. For example, rooms on top floors, at building corners, and facing west (in summer) or north (in winter) can be the most energy intensive. Front desk employees should consider that and renting them last.[25] | Lacking information: Unskilled staff who are not properly trained to run existing energy facilities efficiently | Please refer to chapter 3.1.6, 5.3.3, 5.3.4 |
| | | Lacking motivation for energy efficiency improvements | Please refer to chapter 3.1.2, 3.1.65.3.3, 5.3.4 |

[25] National Grid, (2004)

| | | | |
|---|---|---|---|
| Guest | Hotel guests have a very small role in the implementation of the energy management system. They have no influence on the technical developments and the monitoring systems. However, the behaviour of hotel guests is of high relevance for the energy consumption. Hotel guests are frequently given full control over thermostat settings and individual air conditioning units, and they often adjust these with little or no concern for energy conservation. Often windows and doors are opened simultaneously to the operation of the cooling or the heating system. [26] | The investor-user dilemma | Please refer to chapter 5.3.2, 5.4.2 |
| | | Lacking knowledge/information | Please refer to chapter 3.1.8 |

[26] Hotel Energy Solutions, (2011)

# 3 Developing a Building Energy Management Programme (BEMP) in Shopping Malls and Hotels

The application of energy efficiency measures to a large number of shopping malls and hotels requires a good management and the mobilisation of resources.[27] One option to reduce energy is the implementation of a building energy management programme (BEMP). Its benefits for building owners include long-term cost reductions, competitive advantages, the growth of brand value and the acquisition of a positive image, sustainability, compliance with legislation, and the satisfaction of customers and guests seeking green services.[28]

The US EPA's ENERGY STAR Guidelines for Energy Management provides a proven strategy for creating a BEMP. The Guidelines follow seven main steps (Fig. 3).

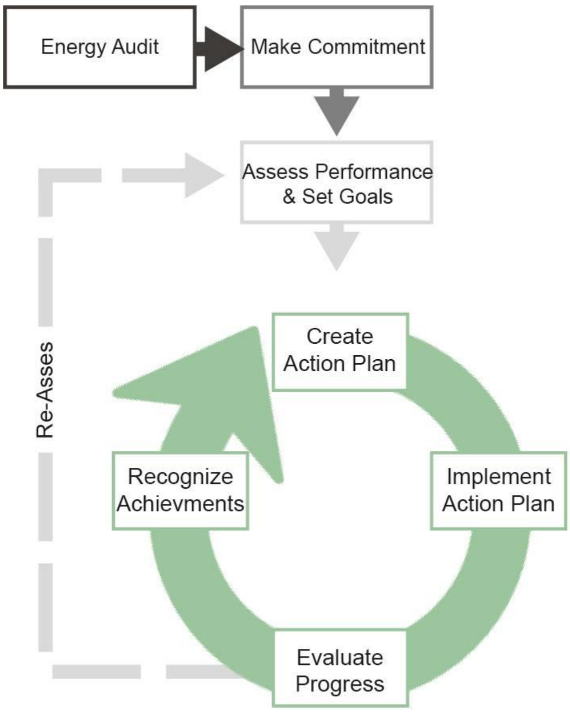


Fig. 3: Guidelines for Energy Management. Source: adapted from neZEH (2016)

## 3.1 Precursor: Energy audit

The precursor of any energy management programme should be an energy audit. Focusing on technology more than delivered value is misguided at best. One can find many examples of projects that failed because they threw a bucket load of advanced technology at a "problem" only to find that it either didn't solve the original problem, created additional problems, and didn't result in more efficient buildings. Energy audit, made by an energy expert, identifies energy consumption and produc-

[27] Schönberger, et al., (2013)

[28] Hays & Đurđana, (2014)

tion of a building and gives quantitative information about the energy consumption of heating, cooling, ventilation and domestic hot water supply system among other factors. Moreover, energy audit identifies short- and long-term energy saving solutions taking into consideration the initial situation of the building, the financial investment, the local factors such as energy price, climate as well as main factors, which affect energy consumption. Thus, it is highly recommended to perform energy audit at the outset.

Once all data collected is analysed, appropriate energy saving measures shall be identified, tackling the aspects of:

- Energy management
- Reduction of heating and cooling demands
- Equipment efficiency
- System efficiency
- Renewable energy.

Financial investment necessary for an energy audit can be classified as medium, because usually it is only a few per cent of the annual energy cost, but the potential energy saving even in a relatively modern hotel and shopping mall can be high.

The second step of the assessment should be a feasibility study to consider the results of the energy audit. Energy audit results indicate that often there are measures that could be quickly taken to reduce energy consumption, the most common being energy management and the installation of management systems early in the renovation process. Such measures require a relatively low investment, but quickly yield large savings, which can help to motivate the building owners to quickly start an energy efficiency programme.

*This step addresses the barrier "Lack of information about energy efficiency system" and the "Uncertainty about saving potentials"*

## 3.2 Step 1: Commit toward continuous improvement

A conscious and continuous effort is needed to achieve the desired savings using an energy management system. To achieve this goal, it is important to spell out clear objectives and goals, allocate responsibilities among the staff and establish accountability. Then a dedicated energy team with at least one person from each of the end uses that account for significant energy consumption (or the heads of the operational level) should be appointed. Furthermore, an internal energy manager should be nominated, e.g. the facility manager. A plan for monitoring energy consumption should be put in place.

*This step addresses the barriers "Lack of management commitment, "Different expectations from store owner and shopping mall owners" and "Lack of interest and motivation for energy efficiency improvements".*

## 3.3 Step 2: Assess energy consumption

The assessment of energy consumption creates a quantifiable evidence for clients, investors and other stakeholders that the project goals are met (see next step). That is why a firm measurement and verification plan should be put in place to analyse and evaluate energy consumption and to enable continuous (technical and financial) assessment and optimization.

For monitoring and measurement of the energy consumption, advanced metering techniques including appropriate sub-meters and smart meters are needed. Typical utility meters consist of electricity, natural gas, steam, water and condensate, compressed air meters and data loggers. However, a single utility meter per fuel source cannot be able to give a breakdown of energy use per end use. Therefore, adopting a measurement and verification plan with sub-meters per end-use helps to create baselines and benchmarks, identify areas of energy wastage, make improvements and measure the savings incurred due to optimization.

Besides sensors, a sophisticated Building Energy Management Programme (BEMP) also employs an appropriate measurement and verification (M&V) plan and involves deploying of sub-meters and data loggers for various groups of end uses. For example, in a shopping mall or a hotel building, electrical sub-metering means installing separate meters for lighting, HVAC, appliances and equipment, hot water, parking etc. These meters can be further grouped per floor, or per block or per user group etc. based on the M&V plan. All the data is then fed into the monitoring unit of the BEM system.

In comparison, sophisticated facility monitoring and control systems allow monitoring of various end uses in real time if the necessary hardware is in place. Electricity consumption, temperature, pollutants in space (e.g., $CO_2$ levels etc.) can be monitored using the required combination of software and hardware within the BEM. Adequate data storage capacities should be provided, as the amount of data generated can be enormous. Easily comprehendible post processing technologies should be developed to decipher the raw data generated from the BEM system into meaningful information that can be used for M&V purposes. Training the professionals for continuous facility BEM operation is mandatory along with ensuring data privacy and security of the system. The Efficiency Valuation Organization (EVO)[29] publishes the International Performance Measurement and Verification Protocol (IPMVP), which lays special emphasis on the use of Building Energy Management Systems and allows building owners, energy service companies, and financiers of energy efficiency projects to quantify the energy savings performance of energy conservation measures[30].

For further information on how to assess the energy consumption, please refer to chapter 4.

*This step addresses the barriers "Lack of information about energy efficiency systems" and "Uncertainty about saving potential".*

## 3.4 Step 3: Set goals

It is important to set tangible and measureable energy performance goals based on the detailed M&V plan with a clear timeframe and to conduct periodical audits to reflect upon the data from M&V plan to rectify any shortcomings.

A checklist of possible energy saving improvements should be made, which includes the recommendations from energy audit and/or the feasibility study. The checklist should include: operational is-

[29] EVO, (2017)

[30] IPMVP, (2002)

sues such as checking temperature and humidity levels, checking lighting levels, and usage levels, equipment operation times etc.; maintenance issues such as checking ductwork and airflow, checking the condition of windows and doors, checking refrigerant levels, checking lamps and luminaires, and equipment for faults and cleanliness; procedural issues that account for how, when different energy end uses are being used, ensuring purchasing of certified and labelled energy efficient products. The responsible staff should be added to the checklist to clearly define responsibilities.

*This step addresses the barriers "Lack of information about energy efficiency systems" and "Uncertainty about saving potential".*

## 3.5 Step 4: Create an action plan

A roadmap to continuously improve the energy performance needs to be prepared. An action plan should be developed and updated periodically. The plan should suit the M&V plan to reflect on the achievements, changes in performance and shifting priorities. It is important to first define technical steps and targets to identify current gaps, develop necessary steps for fulfilling and upgrading, and to define renewed performance targets by establishing a tracking system. Furthermore, the allocation of roles and responsibilities should be streamlined accordingly, secured and allocated necessary financial resources.

*This step addresses the barrier "Different expectations from store owner and shopping mall owners" and "Lack of management commitment".*

## 3.6 Step 5: Implement the action plan

Ensuring support and cooperation of staff and other stakeholders like customers and guests is key towards the fulfilment of the established goals. The way staff and management carry out daily work will have a huge impact on hotel energy consumption. Support can be built at all levels within and beyond the organization by conducting awareness rising programmes and carrying out capacity building activities for staff through training, knowledge transfer programmes, etc. This should be organised by the person in charge of the energy management system, i.e. the facility manager. For the training to be adequate, training and awareness rising must also be relevant to the target groups and be related to their daily activities (see chapter 5.3.4). Awareness raising and training can be implemented in the different departments of the hotel and in the different shops of the shopping mall. Practical demonstrations increase the effectiveness of the training. This should take place as a yearly exercise and can be held at the beginning of the season for hotels or in off-peak periods for shopping malls.

Customers and guests can also become involved. They shall be informed about the rational use of energy. For instance, the information can be distributed to hotel guests when they arrive in the hotel or it can be posted in the guest rooms. Customers can receive information when entering the shopping mall or single shops. By communicating clearly about its efforts in the field of environmental protection, shopping malls and hotel can increase the approval and loyalty of demanding guests. Nevertheless, it is important to communicate well and get the message across without being sanctimonious.[31]

EuroFM is the European Facility Management platform organization that brings educators, researchers and practitioners in the field of Facility Management together.[32] They further motivate the staff to improve energy performance through incentives.

*This step addresses the barriers "Lack of information: Unskilled staff" and "Lack of interest and motivation".*

## 3.7 Step 6: Evaluate progress

Monitoring and verification plan is key to evaluate progress. A through evaluation includes measuring results, reviewing energy and cost data, comparing baselines and achieved results, comparing the performance against established goals in terms of environmental and financial performance.

Further information how to evaluate the process can be found in chapter 4.

*This step addresses the barriers "Lack of information about energy efficiency systems" and "Uncertainty about saving potential".*

## 3.8 Step 7: Recognize achievements

Last but not least, it is essential to provide incentives and recognise achievements of individual and teams that account for correct implementation of established objectives and goals. Building owners can also seek out recognition from government agencies, media and other organisations.

The implementation of a building energy management system is a great opportunity to market the investment. It helps to differentiate from the competitors, to address new customers, to nurture the customer relationship and to build a positive, green image. For this purpose, a communication strategy is needed to raise awareness and to inform your stakeholders about the targets and their benefits.

Not only the guests and customers but also the media play a significant role . In general, the media is very interested in new ideas and innovative concepts. Successful public relation activities can lead to competitive advantages and increase revenues. Communication tools include, for example, printed material, websites, social media channels, smart phone applications, newsletter and videos.

To communicate your efforts, certification and labels can also be a helpful tool. Green branding plays a significant role in the decision making process about energy efficiency investments (for more information, please refer to chapter 5.3.1.)

*This step addresses the barriers "Uncertainty about how the investment will perform in terms of revenue and risk", "Lacking management commitment" and "Lack of interest and motivation"*

[31] SBA, (2008)
[32] EuroFM, (2017)

# 4 Building Energy Management System (BEMS) Technologies

## 4.1 Introduction

Building Energy Management System (BEMS) is "Intelligent" microprocessor-based controller networks, which represent a wide range of hardware and software. They monitor control and benchmark energy consumption of a building and sometimes optimise the operation of the building in order to minimise energy use over time. More specifically, they link the functionality of individual pieces of building equipment so that they operate as one integrated system. Current generation of BEMS is based on open communications protocols and WEB enabled, allowing integration of systems from multiple system vendors and access from anywhere in the world.

**Major benefits of deploying BEMS**

- Energy saving: By complying to 'Class A' (high energy performance) classification of the standard EN 15232 (Energy performance of buildings - Impact of Building Automation, Controls and Building Management), there can be potentially up to 30% energy and cost savings with added benefits of thermal comfort and safety.[33]
- Being green pioneers: Contemporary green building rating systems also recognize the energy saving potential of such systems and award points towards the use of sophisticated lighting, shading and heating, cooling and ventilation system controls.
- Cost-effective: Other studies show that by employing building automation and energy management techniques 60% of annual energy savings could be obtained with a payback period of 2-10 years in commercial buildings.[34]
- Occupant comfort: Intelligent building control systems ensure energy optimization in commercial buildings while ensuring individual occupant comfort and security.

This chapter addresses the barriers "Lacking information about energy efficiency systems" and "Technical barriers". It gives further insights on how to implement step 2 and step 6 of the Building Energy Management Programme (see chapter 3).

Fig. 4 shows four groups of different functions a BEMS can offer. The functional complexity of BEMS increases along with its desired function. Not all buildings need to adopt the whole range of functions. For examples, a small hotel would fully benefit from a BEMS systems targeted at "fault detection and diagnostics" instead of opting for more functional "optimization" services which increases both technological and capital cost requirements.

On the other hand, significant savings can be achieved in larger buildings through a fully functional BEMS with "optimization" technology.  Owners of large buildings would also have the required resource for BEMP including BEMS. The choice depends on the step 4 of the 7 steps of energy man-

[33]Siemens, (2010)

[34]Becker, et al., (2010)

agement as explained in section 3.1.5 to 3.1.8. Medium-sized buildings between 2500 and 150000 $m^2$ and 100 – 500 employees may still have limited resources. Here an adequate energy audit is needed. Each company must go through a process to determine which system is appropriate for their needs, resources, and financial position. This may be a dedicated task for one or more trained or skilled individuals.

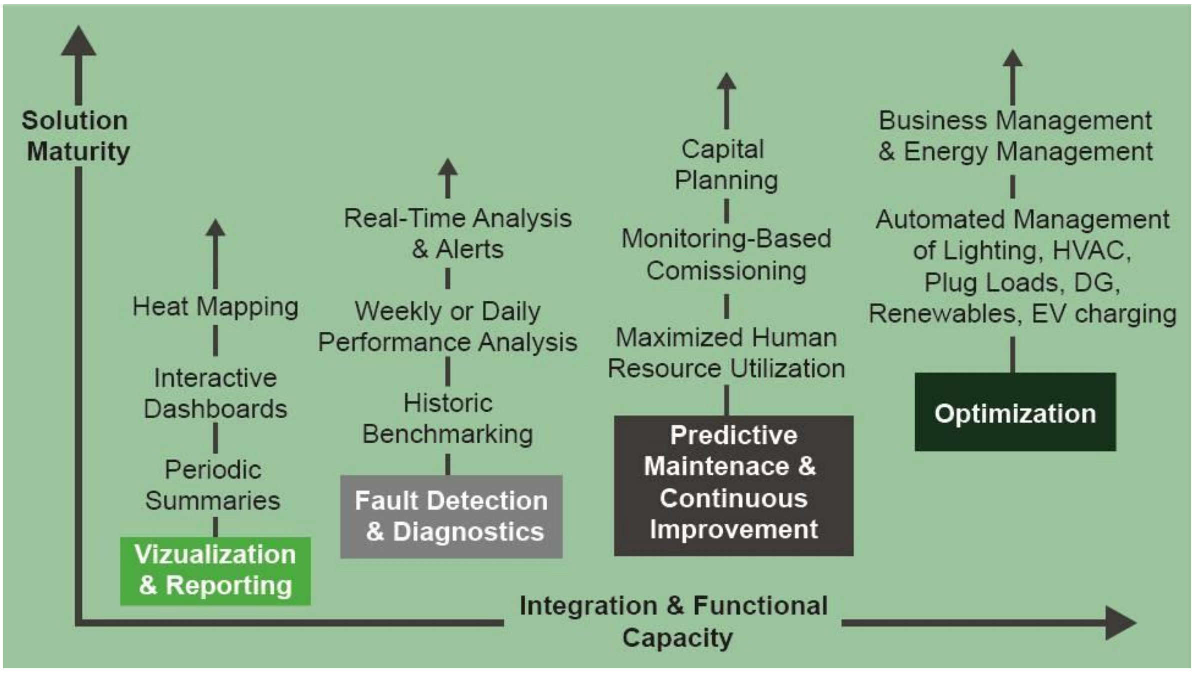


Fig. 4: BEMS Offerings Roadmap

Fig. 5 illustrates the operation of a BEM system, which is a three-step process with three key components: sensors, a logical monitoring and control unit, and actuators. Sensors (Component 1) are attached to all the systems that need to be monitored and controlled and the data is relayed to monitoring and control system. Monitoring and control (Component 2) system continuously evaluate the performance of various systems and sends out signals to actuators to take any necessary action. This enables live controlling of devices through actuators and also enables to continuously monitor energy consumption data by its end use. Component 1 and 2 are required for all levels of functional complexity as sown in Fig. 4. However, for "visualization and reporting" and "fault detection and diagnostics", Component 1 may be replaced by meters or sub-meters connected to various end-uses. For more advanced functional outputs from a BEMS system all three components as shown in Fig. 5 are required. More information on these various components is explained in the following sub sections.

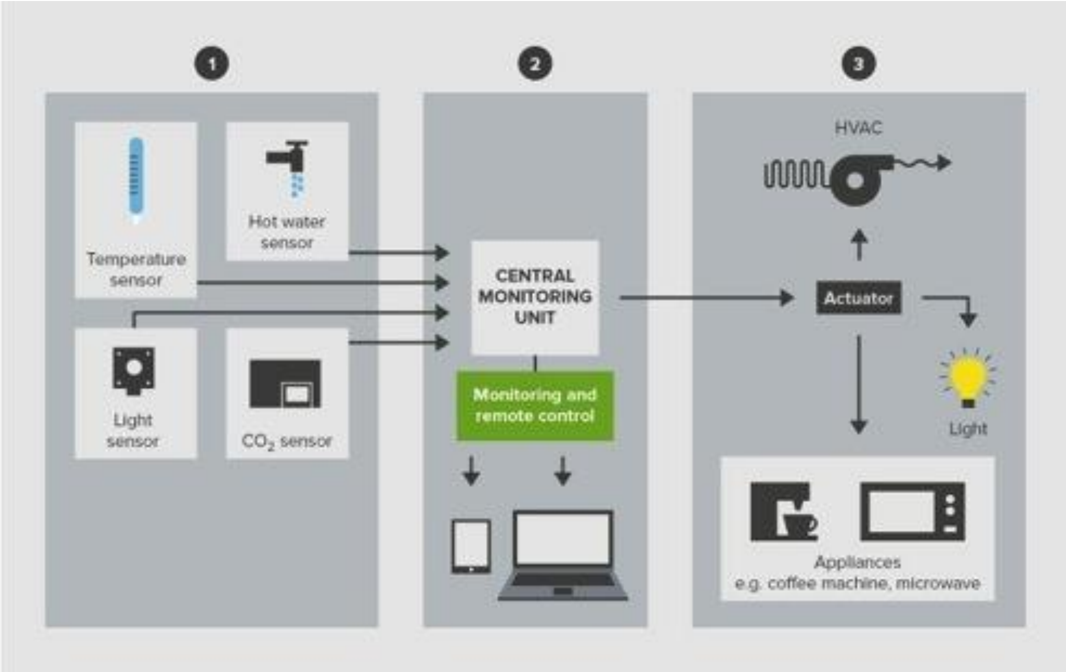


Fig. 5: Components of a BEM system.

Source: bigEE (n.a)

## 4.2 Sensory instruments

Sensors are used to monitor various aspects such as temperature, light levels, humidity levels, occupancy, air quality etc. They are made up of thermostats, electro-mechanical/chemical devices, pneumatic devices, photosensitive devices etc. Sensors continuously gather the data and relay it to the central monitoring and control unit. Depending on the type of sensor it can either be directly integrated into the field wiring and can communicate with the control or include a special microprocessor and transmitter to convert the sensor information into industry standard signals for communication. For example, thermostats are integrated into the wiring as a part of the circuit while photo sensors include a special microprocessor to transmit relay signals. Information can be conveyed to the controller via wired or wireless connections. Accuracy of the sensor and the quick response time are the major indicators of the efficiency of a sensor.

Tab. 4: Various sensory instruments used in BEM systems and their location

| Sensory | Typical equipment used | Location/usage in a building or service systems |
|---|---|---|
| **Temperature** | Thermo couples, thermistors and resistance thermometers | Indoor temperature, outdoor temperature, surface temperature, radiant temperature, fluid temperature in pipes and ducts etc. |
| **Electrical power** | Current clamps (generally used when sub-metering to dedicated end uses is absent; sub-metering, however, is pref- | Used to gauge electrical energy consumed for lighting, equipment and appliances, fans, pumps, lifts and escalators, machine tools, |

| | | |
|---|---|---|
| | erable) | compressors etc. |
| **Air movement** | Rotating vane anemometer, hot wire anemometer, pilot tubes | To measure indoor and outdoor air movement, ventilation or infiltration rates, air movement through ducts etc. |
| **Indoor air quality ($CO_2$ sensors)** | Non-dispersive Infrared sensors, chemical sensors | Used to measure $CO_2$ build up in the space to enhance ventilation |
| **Water flow** | Impeller type rotary mechanism | Water flow in pipes connected to chillers, boilers, AHUs etc. |
| **Relative humidity** | Capacitive sensors, resistive sensors, thermal conductivity humidity sensors, wet-and-dry bulb humidity sensors | To measure Indoor and outdoor humidity levels, to predict chances of condensation |
| **Occupancy/motion sensors** | Infrared sensors, ultrasonic sensors | Detects presence of occupants within the space |
| **Daylight sensors** | Photodiode sensors, analogue photo sensor | Determines lighting levels in space |

## 4.3 Monitoring and control: Network & communications hardware and protocol

A monitoring and controller unit is responsible for receiving signals from a sensor, analysing the signal and sending an appropriate control action to the actuator to perform. This process can be automated or can be overridden by manual control. Controllers generally consist of a pre-programmed microprocessor device capable of carrying out the relay transmissions. Local control devices could be wall mounted within the space and controls for large facilities typically consist of large display panels showing various components of the building management systems. Advanced monitoring systems also work with multi-purpose remote controls and via Internet Protocol through smartphones and laptops.

A central monitoring and controller unit is responsible for monitoring and measurement in a BEMS system. It consists of IT networking and corresponding hardware elements such as bus units and submeters linking to various end uses (both sensors and actuators) such as HVAC, lighting, hot water, security, etc.

### 4.3.1 Hardware and controls

Controller unit usually consists of a pre-programmed microprocessor device capable of carrying out the relay transmissions by using modular bus units with digital and analogue input/output channels. The bus devices are configured as per the desired application into bus couplers and bus terminal controllers with embedded PC. The bus terminal controllers communicate with room controller units. Room controller units typically receive analogue input to sense temperature, air flow and quality, lighting levels and send out analogue output to the control devices such as fans, heater elements, flow control dampers, window shutters etc. to initiate necessary action.

Depending upon the complexity they are configured in various hierarchal levels. Simplest systems have field level room controllers directly connected to bus terminals with embedded PCs with or without display devices. Complex systems have field level room controllers connected to bus terminals at floor or system level (central HVAC), which in turn are connected to a central building management system with sophisticated display units and control features. In complex systems controls are available at both local level and central level. The hierarchy of operation depends on the configuration of the automation systems to suit building usage.

### 4.3.2 Data transfer and exchange

The input and output data transfer between sensors to controllers and controllers to devices takes place in a single or different standards such as DALI, Zigbee, EnOcean, LONWorks, KNX, MODBUS etc. This includes both wired and wireless connections. When multiple standards are used within a system, it is bridged using bus couplers within a network.

The data communication between various bus terminal controllers and bus couplers take place in standard platforms such as BACnet, DMX, PROFINET, and Ethernet etc. The latest technologies also use Internet Protocol based control systems that work in conjunction with multiple Building Automation Control (BAC) platforms.

All the data from various modular bus units is relayed to a central building management and automation system. There are a variety of building energy management software that comprehend the data received from bus units (in single or multiple standards) and represents it in a user-friendly environment facilitating monitoring and controlling.

## 4.4 Actuators and end uses: Energy management systems in various building systems

An actuator is a device that physically controls the end use system. A simple actuator could be a remotely operated on/off switch. The data from the sensors is conveyed to the controller. The controller analyses and provides an output command signal to an actuator, which locally controls the physical movement of the target systems and components. Actuators are typically electrical, mechanical or pneumatic. Actuators perform tasks like tuning on & off the end use, increasing or decreasing the speed of end use motors, fans etc.

Different kind of controls can be implemented at various systems and sub-system levels of HVAC systems, lighting, equipment, etc. Some of the important control functions used in shopping malls and hotels have been listed here. Although most of the HVAC, lighting, hot water and other systems are similar in most commercial buildings such as shopping malls and hotels, what varies are the individual end use controls which are either connected to the BEMS or left to the end user to adjust, or a provision for both.

### 4.4.1 Heating, Ventilation and Air Conditioning controls

Heating, Ventilation and Air conditioning (HVAC) controls are used to precisely control space temperature and ventilation airflow. Using specialized sensors and controls that respond to space demand and external weather conditions save considerable energy. Studies have shown that by the use of building automation and control systems the potential savings for heating energy would be approximately 5-50% and for cooling it would be about 10-80%.[35]

[35] Becker, et al., (2010)

HVAC controls consist of a series of sensors and controllers relaying information over a network. Sensors are typically equipped to measure temperature, humidity, air flow and air quality at various points in the building, within the thermal and air distribution network, heating and cooling plants (e.g., chillers and boilers) and also on the exterior of the building. The information from the sensors is relayed to the automation system and appropriate control sequences are activated.

HVAC systems can be divided into two components, the supply side and the demand side. The main control purpose on the demand side is to sense and maintain the room set point temperature, humidity and minimum level of fresh air. The demand side needs to identify the load on the supply side system and operate to meet the load.

The demand side typically consists of all air systems or air water systems. Sensors are placed to monitor the room air set point temperature, humidity and ventilation levels at the zone level. In all air systems corresponding controls are located at the Air Handling Unit (AHU) level. Chilled water or hot water supply temperature, flow and mixing or air is thus controlled at the AHU level to meet the zone requirements. Flow valves are controlled by the use of dampers and by regulating fan speed by the use of variable speed drive attached to the fan motor. Air water systems correspondingly regulate the flow of refrigerant or chilled or hot water to the zone terminal units.

The supply side consists of three major components, chiller or boiler, distribution system (consisting of pumps) and a heat rejection device (condenser) in case of chiller. Chiller operation should meet the chilled water demand while operating at maximum efficiency. There are various techniques to achieve capacity control in chillers, so that they can work only to meet the demand and thus reducing excess load. This is done by a thermostatic expansion valve, inlet guide vane, hot gas bypass, variable speed driver or a slide valve depending on the kind of chiller and its compatibility with the control technology.

The most efficient and popular control technique is the variable speed drive, which is attached to the chiller and regulates its speed according to varying demand. In case multiple chillers or boilers are connected to each other, then sequential operating of chillers or boilers is very important for optimal efficiency. It has to be ensured that any given chiller is operated at its maximum coefficient of performance (COP) and every boiler at maximum efficiency most of the time.[36] Tab. 5 lists some of the key HVAC controls that save considerable energy.

Tab. 5: HVAC control strategies in BEM systems

| Control strategy | General description |
|---|---|
| **Adjustable thermostats** | By having individual room sensors and programmable thermostats (PT) it is possible to maintain different temperature in the different rooms. Programmable thermostats allow functions like cooling or heating the space just before occupancy and shifting the temperature to setback limits or turning off the system during standby or unoccupied periods. PT can be set for different modes as discussed in later section (AFMCS/start-up controllers) and can have a temporary override or hold function to manually control it when necessary. However, |

[36] Wang, (2010)

| | |
|---|---|
| | care needs to be taken that the user is in full control and fully aware of the functions of the programmable thermostats. Studies have shown that if the user is not aware of the control settings it is more likely to result in higher energy consumption than normal37. Iconography, ease of use and clarity are the important features that govern the appropriate use of a thermostat. Organizations like Building Controls Industry Association (BCIA) have studies on the psychology of the end user and studies on different kind of thermostat controls. Thereby they made recommendations on the appropriate iconography and checklists for building designers, manufacturers and suppliers and control installers so that the controls achieve the desired results in the form of energy savings and increased comfort.38 |
| **Demand controlled ventilation ($CO_2$ sensors)** | Minimum levels of ventilation are required in space for fresh air requirements both for breathing and to maintain optimum humidity levels. Various standards and guides like CIBSE Guide E, describe the minimum acceptable ventilation levels. Ventilation in the building can be optimized effectively through a strategy known as demand control. This strategy calculates the amount of required ventilation by sensing the amount of carbon dioxide ($CO_2$) and humidity in the space. $CO_2$ sensors and humidity sensors are placed either in the space or in the return air duct. They measure the amount of $CO_2$ and humidity present in the space and thereby adjust the ventilation rate accordingly. This enables reduction in the conditioned load of the fresh air by reducing the fresh air quantity and at the same time maintaining minimum fresh air levels. Studies show that by employing demand control ventilation energy savings of up to 40% can be obtained.[39] |
| **Cooling tower with fans enabled with Variable Speed Drive** | The main aim of the heat rejection device is to reduce the Entering Condensing Water Temperature of the chiller. The heat rejection device is generally either air-cooled or water-cooled and consists of a cooling tower with fans to dissipate heat to atmosphere. Cooling tower fans with variable speed technology achieves energy savings by optimizing the fan speed with varying load conditions. |
| **Chiller sequencing and optimisation** | It is usual that more than once chiller is required to meet the load of the entire building. Each chiller has different efficiencies in full load and part load conditions. As the load on the chillers increases it becomes necessary to operate more than one chiller to meet the demand. It is vital to sequence the operation of chillers based on the load so that they operate for most of the time at their peak efficiencies. For example, it could be efficient to run two chillers at their peak part load efficiency rather than to run one chiller at full capacity or three chillers at low capacities where their efficiency is decreased considerably. |
| **Water-side economizer control in water cooled condensers** | Water side economizer can help reduce load on the chiller by passing the chilled water from refrigerant and cool it directly by the condenser water from the cooling tower in seasons of low humidity and low temperature. Chiller load can be considerably reduced or completely bypassed during favorable ambient conditions. This can be achieved by using chilled water produced by evaporation or by heat exchanger between condenser water, which is cooled by evaporation, and chilled water. |
| **Pumps with variable speed drive** | Pumps drive the distribution system and it works in different configurations, constant primary only, constant primary and variable secondary, and variable primary only. Of late there have been arguments that constant speed pumps should be done away with totally and only variable pumps should be used in order to achieve actual energy efficiency both in order to reduce pumping energy and also to increasing chiller or boiler efficiency. In heating systems, up to 18 % of savings in pumping energy have been demonstrated through system optimization.40 |

[37] Meier, et al., (2014)
[38] Bordass, et al., (2007)
[39] Becker, et al., (2010)
[40]Adhikari, et al., (2012)

| | |
|---|---|
| **Airside economizer control** | Economizer on the supply side can significantly reduce the energy use by using a technique called free cooling. An economizer control added to an Air Handling Unit (AHU) enables the direct outdoor air to cool the space when the outdoor air temperature is lower than the return (mixed) air temperature and thus reduces or eliminates the cooling load on the system. ASHRAE 90.1 a standard on energy efficient buildings mandates the use of airside economizer in particular climate zones where it has significant energy savings. |
| **Energy recovery ventilation control** | Energy recovery ventilator (ERV) transfers heat and moisture from the exhaust air stream to the incoming air stream and thus precools or preheats intake air. However, ERVs consume energy to operate. In case the operational energy for ERV exceeds the cooling or heating energy saved the ERV function should be stalled. Controls are therefore required to operate ERVs only when there is considerable heating or cooling energy savings. |

### 4.4.2 Lighting controls

Lighting in buildings consumes approximately 20-50% in specialised retail buildings. The savings incurred by using efficient lighting (e.g. LEDs) can be further optimized by the use of different kinds of lighting controls available. Lighting control ensures the light is provided where and when it is needed in the right amount while maximizing the use of daylight and minimizing the lighting energy wastage. Lighting controls typically include occupancy sensors, daylight sensors, dimmers etc. and save approximately 20-50% of total lighting energy consumption. In typical office buildings the payback period for wireless lighting controls is approximately 2.3 years.[41] Lighting control systems consists of hardware such as sensors and, relay switches controllers which work using various communication protocols like DALI, enocean etc. DALI is an acronym for Digital Addressable Lighting Interface and is targeted to suit commercial architectural requirements. DALI is specifically developed for ballasts and relay switches. Lighting communication protocols can be used as a stand-alone lighting control system or integrated with other building automation systems using protocol translation with systems like BACnet, LonWorks etc. Tab. 6 lists some of the key lighting controls that save considerable energy.

Tab. 6: Lighting control strategies in BEM systems

| Control strategy | General description |
|---|---|
| **Daylight sensors** | Buildings should be appropriately designed for effective distribution of daylight. Daylight sensors sense the amount of daylight illumination available in the space and accordingly reduce the artificial lighting either by turning off or reducing the intensity of lighting through the use of dimmers. Typical lighting sensors used nowadays are based on silicon photo diodes. Photodiodes are photo sensors that generate a current or voltage when the semiconductor is irradiated by light. Commercial sensors are made up of Photo ICs. They detect the varying levels of illumination in the space and relay a signal to a control section, which thereby controls the intensity of the lighting device. Daylight sensors are placed in the perimeter zone of a building till a point where the daylight penetration is possible. Care needs to be taken while placing the sensor. The effectiveness of the sensor depends on the task location, the algorithm that controls the daylight, the lighting system used and the sensor field of view.[42] |

[41] enocean alliance. (2011)
[42] LBNL, (2011)

| | |
|---|---|
| **Occupancy sensor** | Occupancy sensors detect the presence of people in the space and thereby turn on and off the lights accordingly. This increases occupant satisfaction by giving the occupant direct control on the environment while ensuring that the lights turn off automatically while there is no occupancy in the space, thereby minimizing lighting energy wastage due to negligence. Typical presence sensors available are passive infrared sensors known as PIR and active ultrasonic or microwave sensors. Occupancy sensors serve multipurpose functions by not only enabling lighting control, but also they can be integrated with HVAC and security systems. Care needs to be taken while choosing the type of sensor and also placing the sensors so that they maximise the detectable area while reducing the probability of false alarm. All these controls can be programmed to suit the user behaviour and can be overridden any time. Automatic window blind control devices can be used to allow desirable amount of light into the space and also avoid glare. |
| **Shading control devices** | Shading devices like fixed shades, internal and external blinds, louvers etc. are necessary in passive building design for controlling seasonal heat gain and amount of daylight in the space. Automatic window blinds/louver control devices can be used to allow desirable amount of light into the space and also avoid glare. They can be automatically regulated by fixed schedules depending on the Sun path of the place and prevailing ambient light conditions on the outside and can also be manually overridden. |
| **Switches** | A simple switch operates on the binary function on/off. A switch can be used to control the lighting using occupancy detectors. It also can be operated based on the schedules of building occupancy and connected to the central BMS system or can operate locally on the basis of manual on and auto off principle. Turning off the lights when not required is the most simple and effective way of conserving energy. |
| **Dimmers** | Dimmers control the brightness of the lamp by the use of dimmable ballasts. Unlike old dimmable ballasts that use resistance, reactor and transformer dimmers and loose energy as heat, modern dimmers are based on thyristors, transistors or silicon-controlled rectifiers (SCR).[43] The selection of control devices depends on the space layout and the availability of daylight. Energy savings and cost analysis has to be carried out before choosing a particular or a combination of technologies. It has to be noted that dimming is still expensive compared to switching technology and only suits a well day lit area. However, in abundant day lit areas dimming has an advantage as the occupants less perceive the changes caused in lighting levels used by dimmers and thus they are least disturbing.[44] |

### 4.4.3 Advanced Facility Monitoring and Control Systems (AFMCS)

In addition, to be able to optimize individual components the function of centralized control is important to regulate all the individual components of the system, i.e. supply side, demand side, distribution system and heat rejection device in conjunction to each other depending on the varying loads to reap all the benefits of energy efficiency.

Complex functions like night purge ventilation, pre-cooling and heating, load cycling, maximum demand control and monitoring can be sophisticatedly controlled by automated process.[45] Many energy saving measures typically used in advanced energy efficient buildings also tend to underperform because of the absence of corresponding control systems.[46]

[43] Wang, (2010)
[44] LBNL, (2011)
[45] Savage, (2009)
[46] New Buildings Institute, (2009)

Tab. 7: AFM control systems in BEM systems

| Control strategy | General description |
|---|---|
| **Optimum start up controllers** | Commercial buildings typically have a fixed occupancy pattern. However, a challenging aspect is that the HVAC system schedules are not only a function of the occupancy but are also dependent on outside ambient temperature, system operation sequences, thermal inertial of the building and their efficiencies while meeting the zone set points. Optimum start-up controllers, through intelligent algorithms, ensure the building reaches the desired indoor temperature by the time it is occupied by turning on the HVAC systems at an appropriate time depending on the external weather conditions (or seasons). This eliminates the unnecessary energy waste that is occurred otherwise by starting up the systems too early or cause discomfort by starting them too late. System start-up timings and night setback temperatures can be optimized for different seasons or as per the external weather conditions to save considerable energy. |
| **Scheduling** | Scheduling of HVAC, lighting and other systems depending on the regular occupancy patterns of various zones ensures that they are only operated when and where required. This minimises the possibility of the systems running during unoccupied hours in particular zones, for example, restaurants in hotel buildings have fixed timings, similarly, each retail shop, food courts, restaurants etc. in a big shopping mall have fixed timings in which they operate. |
| **Demand side management (DSM) and load shifting** | Various DSM measures can be adopted in order to avoid peak utility charges. For example, set points can be relaxed within permissible limits; non-critical equipment and non-emergency lighting can be turned off. The facility manager however, has to communicate with the building occupants of various DSMs in advance to avoid any inconvenience. |
| **Energy storage/Distributed energy resources** | Energy management systems enable sequencing of various energy resources available within the building when the building has more than one energy source. Energy from renewable sources such as solar or wind has to be used while producing in the absence of storage medium, although most of the modern renewable systems come with energy storage devices. It is also important to switch between different energy sources; for example, most of the renewable energy could be used at particular intervals in order to avoid peak utility charges. Similarly, switching between chillers and thermal energy storage systems such as chilled water or ice storage for cooling purposes, waste heat management for service hot water or space heating etc. can be sequenced using energy management systems. |

## 4.5 Analysis and Optimization

### 4.5.1 Data analysis and management

The energy consumption output data that are available from central monitoring and measurement unit can be analysed periodically for optimizing various processes. The analysis typically takes into account external weather data, occupancy schedules, automation schedules, user behaviour data and system performance.

The wealth of data obtained using BEMS can be analysed using various statistical procedures such as regression analysis/sensitivity analysis etc. For example, for cooling, the chiller energy use can be mapped against most likely candidates for its energy consumption such as weather data (e.g., cooling degree days), occupancy, peak demand and utility prices etc. among others. The ranking and magnitude of various candidates can be established which further helps in prioritizing the corrective actions accordingly. Most often the BEMS software is customised to conduct the analysis and produce the facility managers with the results of interest often in the form of graphs and tables, based on which a target action can be taken.

Periodical (typically monthly, weekly, hourly or seasonal) breakdown of some of the important data obtained from BEMs systems is recommended as follows:

Tab. 8: Data analysis and corrective measures using BEM systems

| Data | Example | Analysis and target action |
|---|---|---|
| **Break down of energy consumption by end use** | Equipment, lighting, HVAC, hot water, refrigeration etc. | Identifying pockets for saving energy by comparing the data to best practice consumption level targets. For example, compare the facility's lighting usage with best practices available and identify the remedies that can be applied to save lighting energy. Similarly process could be followed for other end uses such as HVAC, hot water etc.<br>The target action for optimization can be taken at both the supply side and demand side. On the supply side it can be done through measures such as adjusting the scheduling and automation process periodically. On the demand side identify the areas where there is energy wastage plug the deficiencies. |
| **Break down of energy consumption by space function** | Food court, retail spaces, common spaces such as atria etc. | Identifying pockets for saving energy by comparing the data to best practice consumption level targets. For example, compare the food court's energy usage with best practices available and identify the remedies that can be applied to save energy. Similarly process could be followed for other end areas such as retail spaces, common areas etc.<br>The target action for optimization can be taken at both the supply side and demand side. On the supply side it can be done through measures such as adjusting the scheduling and automation process periodically. On the demand side identify the areas where there is energy wastage plug the deficiencies. |
| **Break down of energy consumption by plant and mechanical systems** | Fans, pumps, cooling tower, chiller, boiler, steam generation, refrigeration etc. | Matching demand and schedules to optimize energy consumption. Scope for retrofitting and upgrading equipment can be identified. System can be further regulated by following an optimized start up and shut down patterns. |
| **Break down of energy consumption by fuel** | Electricity, Oil, Gas, Renewables etc. | Case should be taken to shift to more efficient fuels wherever and whenever possible. |
| **Break down of utility cost by fuel** | Cost of Electricity, Oil, Gas, Renewables etc. | Demand management and load shifting procedures should be applied to optimize the use of fuel during the times of peak cost. Also, care should be taken to shift to more cost effective fuels wherever and whenever possible. |
| **Break down of energy consumption by time** | Occupancy and non-occupancy hours, day-time and night-time, seasonal etc. | Revise scheduling and automation and adapt plant operation and user behaviour to achieve energy consumption targets. Demand management and load shifting procedures should be applied to optimize the use of fuel during the times of peak cost. |
| **Load or demand pro-** | Equipment, lighting, | Arrive at optimum load management patterns through load shift- |

| | | |
|---|---|---|
| **files of various end uses** | HVAC, hot water, refrigeration etc. | ing and minimizing peak demand. This helps in the efficient operation of systems such as chillers and boilers, which then operate at their maximum efficiency as well as to avoid peak utility charges. |
| **Load or demand profiles of various plant and mechanical systems** | Fans, pumps, cooling tower, chiller, boiler, steam generation, refrigeration etc. | Arrive at optimum load management patterns through load shifting and minimizing peak demand. This helps in the efficient operation of systems such as chillers and boilers, which then operate at their maximum efficiency as well as to avoid peak utility charges. |

### 4.5.2 Target action and optimization

Based on this data a schematic step-by-step approach is followed in order to optimize one or all of the above described parameters in isolation or in conjunction. In some cases the systems can be optimized by just recalibrating and adjusting the controls to suit updated user behaviour patterns. The energy usage data for various end uses can be compared to various parameters like weather conditions, user behaviour, occupancy patterns etc. The potential pockets of energy wastage can be identified and rectified accordingly. Based on the performance indicators from the data obtained tangible energy saving targets can be set periodically.

In commercial buildings with large and complex systems IPMVP provides guidelines on how to optimize energy consumption based on the monitored data. Energy conservation measures (ECMs), covered in the IPMVP, include fuel saving measures, water efficiency measures, load shifting and energy reductions through installation or retrofit of equipment, and/or modification of operating procedures.

The collected data is presented with a graphic user interface on TVs, computers and smartphones and can be remotely controlled using multipurpose remote controls or using Internet through laptops and smart devices. This makes it a cost effective and easy to use approach for saving energy for both new and existing buildings. The output data from the BEMS is both in the form of readable graphical format as well as text and CSV format depending on the system employed.

The following selection of key target actions based on best practice examples can be revised periodically based on the data available from BEMS. Most of the control strategies are segregated into two broad categories: Scheduling and automation, and load management and system rectification, although most often the corrective measures overlap between these two.

Tab. 9: Optimization strategies using BEM systems

| Corrective measure | Description |
|---|---|
| **Scheduling and automation**<br>**Override control and tenant billing**<br>**Night Setup/Setback**<br>**Optimum start and shutdown**<br>**Lockout settings** | The controls need to be scheduled and automated to ensure comfort while reducing energy wastage. Systems can be completely automated or a manual override can be provided to best suit the occupancy schedules and usage patterns of the inmates. Building Controls Industry Association (BCIA) suggests a manual on and auto-off approach while programming so that only services that people need, can be turned on at a time and turned off automatically when unoccupied. Optimizing system start-up timings and night setback temperatures can be optimized for different seasons or as per the external weather conditions to save considerable energy. |
| **Load management and system rectification**<br>**Chiller sequencing and chiller load management**<br>**Temperature, water flow and pressure resets**<br>**Demand limiting or load shedding** | Load shifting and other better load management techniques can optimize peak load or demand of various mechanical systems or end uses. This can help in efficient usage of mechanical systems both in terms of operational efficiency and reducing corresponding wear and tear, as well as results in the reduction of the utility tariffs by responding to demand charges efficiently |

### 4.5.3 Advanced optimization using Building Information Modelling (BIM) integration into BEMS

Building Information Modelling (BIM) presents a wide range of possibilities with the information stored within the model. The applications of BIM include three dimensional visualisation, facilitating fabrication/shop drawings used for construction, adherence to code reviews, cost estimation, construction management, conflict resolution, offers easy interoperability between various consultants in a project such as architect, structural engineer, mechanical engineer etc., forensic analysis and in facility management (including building energy management).

Of interest in this context are applications of BIM in smart building environments[47] and building energy management systems.[48] There is more than a single way to integrate and use BIM applications in BEMS. It can be applied for representational purposes where in BIM model contains all the information of BEMS components such as sensors, actuators, meters etc. and BIM model can produce a real-time graphical representation of various aspects such as energy consumption, lighting levels,

[47] Zhang, et al., (2015)
[48] Gerrish, et al., (2017)

temperature in a zone etc.[49] On the other hand, building energy optimization algorithms are also based on building energy simulations directly generated by BIM or in support with other energy simulation software for use as model guide for comparison (MGFC) that use machine learning techniques to optimize energy based on simulation model, past data and make model predictions for future. A sample framework on how this operated is shown in Fig. 6.

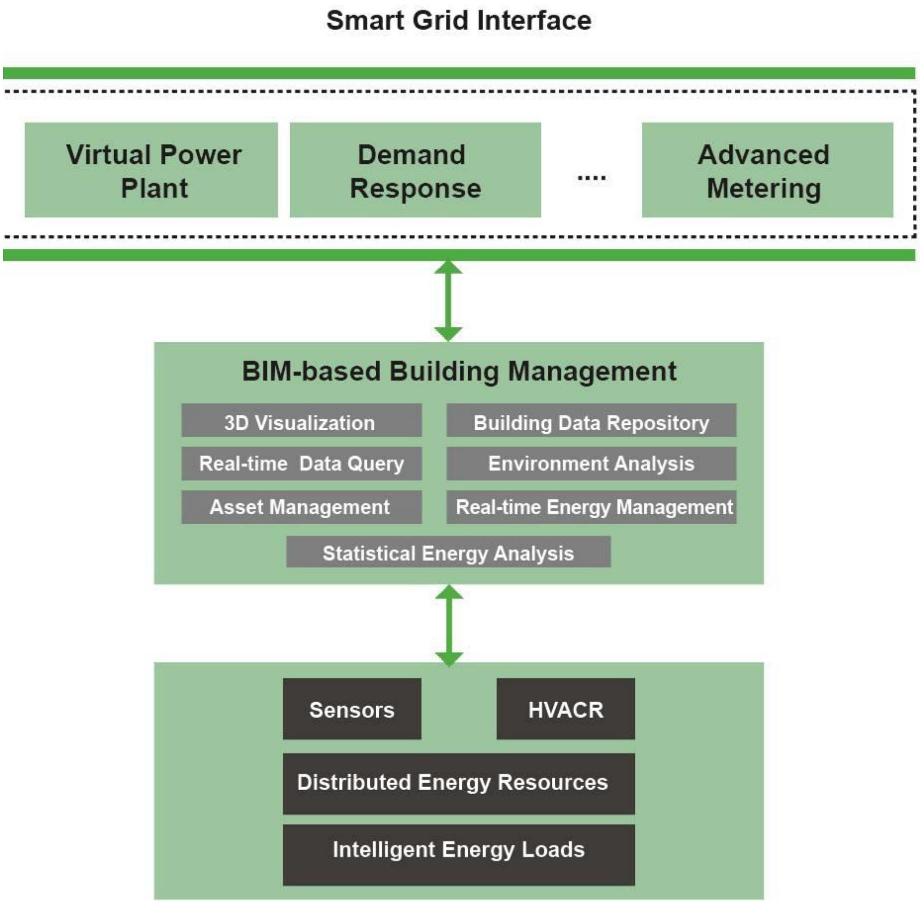


Fig. 6: Proposed BIM-based building management for a smart grid.

Source: adapted from Zhang et al. (2015)

### 4.5.4 Cost-effectiveness of BEMS

BEMS enables sophisticated monitoring and controlling of various building systems. However, its cost efficiency depends on the number of measures incorporated and savings incurred by them. The cost of installing a BEMS would highly depends on the hardware, software and installation. For example, considering building A and building B implement the following energy conservation measures (Tab. 10). Though building B has more measures compared to building A, the marginal cost of these extra BEMS measures for building B would only be around 1-3% compared to those for building A.

[49] Gerrish, et al., (2017)

Tab. 10: Overview on different ECM category buildings

| ECM category | Building A | Building B |
|---|---|---|
| **HVAC** | Variable Air Volume, Variable speed fans, $CO_2$ sensors | Variable Air Volume, Variable speed fans, $CO_2$ sensors, economizer control |
| **Lighting** | Occupancy sensors | Occupancy sensors, daylight sensors |

Economies of scale is key factor determining the cost effectiveness. Buildings consuming higher energy and with equipment of large capacity typically would have shorter payback periods for BEMS. Installation cost of sensors and incorporating them in BEMS would be outweighed by systems with higher capacity. For example, installing $CO_2$ sensors in a small space would lead to lesser savings compared to installing the same in larger spaces with high consumption. However, the cost of installing in larger spaces would be the same and only very marginal compared to the very high energy savings incurred in larger spaces. Typical payback period for installing BEMS (not the individual ECMs, but the cost of BEM hardware and software) is approximately 2-5 years.

## 4.6 Recommendations for small- and medium- sized buildings

### 4.6.1 Guidelines of energy management for small- and medium-sized buildings

Small- and medium-sized buildings, such as medium-sized hotels, often do not have the resources for deploying a full-fledged centralized BEMS within the facility. In such instances the feasible option is typically to identify the high energy end use (HVAC and lighting) and target at them by using local controllers. For example, programmable thermostats based on set point temperature control could be used for rooftop HVAC units. The central control should have the ability to communicate with various thermostats and other controllers in the building. The control unit could be analogue or digital, with interactive display or could be controlled via web/internet interface via Internet Protocol communication or via cloud based technologies (see next chapter). The configurations are in the form of global control catering to local actions and requirements in a master/slave configuration.

Energy sub-metering per area per end use, for example, guest room HVAC, hot water, lighting etc., for different areas and all important end uses provide valuable insights into energy consumption patterns of the whole facility. The data from various sub-meters can be analysed in regular intervals to find inefficient energy usage which can then be rectified.

The following guidelines can help small- and medium-sized building to enable BEMS while still cutting costs:

- Choosing the controls that specifically suit the needs for small and medium scale buildings. Control function such as occupancy scheduling, holiday scheduling, occupancy sensors, dimming, and economizer are generally recommended. Security and password authorization to the controls should be taken care of.
- Opting for plug and play type controllers, which work on open standards where available.
- Using control devices with local model predictive control or demand response capabilities or use

cloud-based technologies for such functions (see 4.6.2).

- Using individual control networks for different end uses such as HVAC, lighting, equipment, boilers etc.
- Local controls could also be manual controls such as on/off switch, window blind/share controls, local temperature regulation etc.
- Where automatic controls are not economically feasible, investing in staff training and incentivizing staff to adapt various control strategies such as regulating lighting after hours in corridors, lobbies etc. Measures encouraging behavioural changes and training can be nearly as effective as more sophisticated systems.
- Ensuring regular maintenance of various technical and mechanical systems for smooth operation and fault detection.

### 4.6.2 Cloud technologies for BEMS

Small- and medium-sized buildings do not often need to have a full-fledged BEMS monitoring and control system with full-time monitoring personnel. Cloud-Enabled BEMS (CE-BEMS) technologies could help to cut down on infrastructure and personnel cost by shifting the operations and controls to a remote server. CE-BEMS typically uses model predictive strategies based on machine learning optimization algorithms to achieve the established objectives. Still, a certain extent of physical infrastructure for BEMS is still needed in the facility such as the sensors, loggers for data recording, BUS systems to convey signals and actuator to take the necessary control action.

The key stakeholders in this area are BEMS technology supply companies, cloud-based energy management software suppliers, web-based energy management software suppliers, load control and demand response software companies and ESCO service suppliers. These different product and service groups are often intermixed and supplied by either one or two companies. For example, a single company (ESCO) can provide all the services or an ESCO can use technical supplies or software from other companies to manage its services etc.

Remote systems manager servers monitor the data from the facility and provide real-time and future predictions for various energy end uses such as HVAC systems, lighting etc. by controlling aspects such as temperature, humidity, air flow rate, lighting levels, and overall usage of different energy end uses. Most of the BEMS technology providers such as Siemens, Johnson controls, WAGO Honeywell offers cloud-based platform to back up their service-based energy services contracting (ESCO) work. These platforms either have proprietary software from BEMS that enables services such as demand response and performance optimization using building data analytics or use third party optimization applications that do this service based on the available could data.[50] This offers possibility to manage many building and facilities remotely via cloud-based technologies.

## 4.7 Good practice examples

This section includes a set of good practice examples of energy management systems in shopping malls and hotels.

[50] St. John, (2012)

### HUMA St. Augustin, Germany

| HUMA St. Augustin | | | |
|---|---|---|---|
|  | | | GFR m.b.H<br>GFR - Gesellschaft für Regelungstechnik<br>und Energieeinsparung mbH |
| **Building name** | HUMA St. Augustin | Floor area (sq mts) | 61,000 $m^2$ |
| **Location** | Rathausallee 16, 53757 Sankt Augustin, Germany | Number of floors | 4 |
| **Building use** | Shopping Centre | Built year | 2017 |
| **Short description of technologies and BEMS** | | | |
| **Cooling system** | 4 continuously variable screw compressor chillers with a total cooling capacity of 3 MW | | |
| **Heating system** | 2 condensing boilers with a total capacity of 3.3 MW heat output | | |
| **Ventilation system** | 17 RLT air handling units with a cumulative ventilation rate capacity of<br>1,340,000 $m^3/h$; 5 smoke extraction fans & 62 exhaust fans; 150 shops with flow control regulators for space cooling and heating | | |
| **Renewable energy system** | Geothermal heat pump | | |
| **BEMS** | Air conditioning, heating and ventilation | Occupancy schedules have been incorporated in the automation system.<br>Function selection between cooling and heating is determined by a temperature set-point control.<br>Air flow rate is controlled by a temperature set-point control<br>Ventilation system is capable of facilitating night cooling with appropriate controls | |

| | | |
|---|---|---|
| | | Room temperature can be adjusted through automatic individual room controls using thermostatic valves or electronic control devices. |
| | HVAC equipment and ancillary controls | Ventilation system is provided with air side economizer and heat recovery ventilation controls |
| | Total cost of all control strategies (EUR) | MSR – circa 2 Mio € |

**Longhu, China**

| **Longhu** | | | |
|---|---|---|---|
|  | | | Oventrop (China) HVAC Technology Co.,Ltd.<br><br>oventrop |
| **Building name** | Longhu | Floor area (sq mts) | 1.3 million $m^2$ |
| **Location** | Chongqing | Number of floors | 36 |
| **Building use** | Hotel, retail, office, residential | Built year | 2014 |
| **Short description of technologies and BEMS** | | | |
| **Cooling system** | Direct return chilled water system, centrifugal, primary fixed frequency pump, secondary variable-frequency, BA and DDC control, energy saving terminal with Oventrop balance valve | | |
| **Heating system** | Centralized hot water, centralized boiler, reverse return hot water circulation system | | |
| **Ventilation system** | Combined air handling units | | |
| **BEMS** | Lighting | On/off controls have been provided in all retail and office areas. Automatic lighting schedules have been incorporated in land- | |

| | | |
|---|---|---|
| | | scape lighting and common areas in office building. |
| | Solar shading | Louvre adjustment controls for glazing in shopping mall |
| | Air conditioning, heating and ventilation | Occupancy schedules have been incorporated in the automation system with optimum start-up function.<br>Function selection between cooling and heating is determined by a set-point control.<br>Ventilation is controlled by monitoring indoor air quality using $CO_2$ sensors.<br>Room temperature can be adjusted through automatic individual room controls using thermostatic values or electronic control devices.<br>Precision temperature control is enabled in server/equipment room. |
| | HVAC equipment and ancillary controls | Central cooling equipment (multiple chillers) has sequence control and load optimization features.<br>Chiller and pumps, cooling tower for all central chillers are enabled with variable speed control mechanism. |

**Boutiquehotel Stadthalle, Austria**

| Boutiquehotel Stadthalle | | | |
|---|---|---|---|
|  | | | Desigo by SIEMENS<br>SIEMENS<br>Ingenuity for life |
| **Building name** | Boutiquehotel Stadthalle | Floor area (sq mts) | 2,271 million $m^2$ |
| **Location** | Hackengasse 20<br>Vienna, Austria | Number of floors | 4 in main building and 5 in Passive House extension |
| **Building use** | Hotel | Built year (refurbished) | 2009 |
| **Short description of technologies and BEMS** | | | |
| **Cooling system** | Groundwater heat pump cooling system using a core activated slabs and auxiliary cool- | | |

| | | |
|---|---|---|
| | ing via pre-cooling the air through the ventilation system. | |
| **Heating system** | Groundwater heat pump cooling-system, using a core activated slabs/radiators and auxiliary heating via pre-heating the air through the ventilation system. | |
| **Ventilation system** | The ventilation air is via the garden, this aids cooling in summer due to the reduction of the warmer city climate through the plants. The ventilation system for the passive house extension had a heat recovery of up to 92% depending on the relative humidity. The solar thermal panel system also preheats the ventilation system. The ventilation system uses a minimum of EU 4 filters. In addition it has a microprocessor unit which balances air volume according to changing running conditions in the hotel. It also registers for example dirty filters etc. | |
| **Renewable energy system** | Geothermal heat pump/The heat pump is powered by a 13 kW peak PV System.<br>Hot water is provided by a 130m$^2$ solar thermal panel system. | |
| **BEMS** | Lighting | Lights are controlled by sensors in public spaces and in the guest rooms via the room key cards. |
| | Air conditioning, heating and ventilation | The building systems are managed by a 'Desigo' building automation and control system with<br>PXC controllers<br>Web operation<br>The BUS system is an Instabus EIB system which regulates, controls and monitors the concrete core activation, water heating, cooling, ventilation, the solar panel system, buffer management and the groundwater heat pump as well as the lighting and solar systems.<br>The bus system also automatically switches the cooling and heating of the building depending on needs and outdoor temperatures.<br>In addition, the system helps to maintain the right balance between guest comfort and energy savings by monitoring and enabling the regulation of heating and ventilation based on actual demand or pre-defined schedules. |
| | HVAC equipment and ancillary controls | The heating, ventilation and air-conditioning are programmed to match occupancy patterns and take into account room occupancy among other things via the guest key cards.<br>All data is visualised aiding the quick finding of deviation from estimates and well a for data recording. |
| | Total cost of all control strategies (EUR) | 2290 €/m$^2$ (Total refurbishment costs including BEMS system) |

## Chengdu Taiguli, China

| Chengdu Taiguli | | | |
|---|---|---|---|
|  | | | Oventrop (China) HVAC Technology Co.,Ltd. |
| | | | oventrop |
| **Building name** | Chengdu Taiguli | Floor area (sq mts) | 70,800 $m^2$ |
| **Location** | Chengdu | Number of floors | Shopping mall 4 floors, office 31 floors |
| **Building use** | Shopping mall, office building | Built year | 2014 |
| **Short description of technologies and BEMS** | | | |
| **Cooling system** | Direct return chilled water system, centrifugal, primary fixed frequency pump, secondary variable-frequency, BA and DDC control, energy saving terminal with Oventrop balance valve | | |
| **Heating system** | Centralized hot water, centralized boiler, reverse return hot water circulation system | | |
| **Ventilation system** | Combined air handling units | | |
| **BEMS** | Lighting | On/off controls have been provided in all retail and office areas. Automatic lighting schedules have been incorporated in landscape lighting and common areas in office building. | |
| | Solar shading | Louvre adjustment controls for glazing in shopping mall | |
| | Air conditioning, heating and ventilation | Occupancy schedules have been incorporated in the automation system with optimum start-up function. Function selection between cooling and heating is determined by a set-point control. Ventilation is controlled by monitoring indoor air quality using $CO_2$ sensors.<br>Room temperature can be adjusted through automatic individual room controls using thermostatic values or electronic control devices.<br>Precision temperature control is enabled in server/equipment room. | |

| | | |
|---|---|---|
| | HVAC equipment and ancillary controls | Central cooling equipment (multiple chillers) has sequence control and load optimization features.<br>Chiller and pumps serving the server/equipment rooms, cooling tower for all central chillers are enabled with variable speed control mechanism. |

# 5 Supportive Policies and Measures

While technologies play a key role in building energy management, its adoption depends on the incentives of different stakeholders, which are addressed by various policies and measures. That is why the implementation of a building energy management system cannot only focus on technical details but also on supportive policies and measures and the involvement of different stakeholders.

The next chapter focuses on the regulatory framework (standards and certification) but also raises the question how to finance the energy management system. In addition, networking activities, trainings for energy managers / facility managers and staff members and the concept of green lease will be illustrated briefly.

## 5.1 A prototypical policy package

Policy makers are an important actor group in the development of energy efficiency improvements in hotels and shopping malls. Governmental policies and measures address a number of barriers, which were identified in chapter 2. Energy management programmes play an important role in showing that improving energy efficiency is not only compatible with – but also drive – profitable business development. In some countries, energy management programmes have existed for more than 20 years.[51]

Fig.8 illustrates some of the main elements of a prototypical policy package that addresses energy management issues. Not all elements of this package necessarily policy-driven. The measures listed

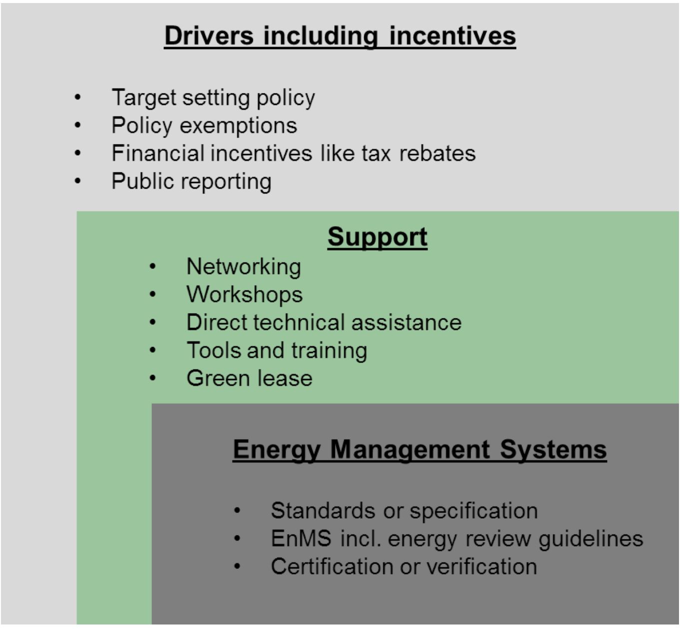


Fig. 7: Elements of building energy management programmes.

Source: adapted from IEA, (2012)

[51] IEA, (2012)

## 5.2 Specific elements of the policy package

### 5.2.1 Standards and Certification

Once targets are established by policy or by the building owner / manager, the next step is to institutionalise energy management in a wider culture for energy efficiency improvement. Energy management standards can provide a framework for the company to implement the building energy management system. It establishes the structure and discipline to implement technical and management strategies including the content, scope and methodology. The most common standard is the ISO 50001 standard, which can be adopted by different organisations. It is a proven framework for industrial facilities and organisations to implement technical and management strategies that significantly increase energy efficiency.

The ISO 50001 standard is based on the Plan-Do-Check-Act cycle, which can be described as follows:

- **Plan**: Establishing energy-saving targets, determining the strategy, identifying measures and responsibilities, providing the necessary resources, preparing the action plan
- **Do**: Establishing management structures for maintaining a continuous process, undertaking improvement measures
- **Check**: Reviewing the level of target achievement and the effectiveness of the BEMP, collecting new ideas via energy audits, if necessary, consulting an external expert
- **Act**: Strategic optimisation by consolidating the current energy data, audit results and new information, evaluating the progress with the help of current energy market data, deriving new objective[52]

Other standards are, for example, the ISO 14000 environmental management standard, which includes criteria for an environmental management system and the European Environmental Management Standard (EMAS). It was introduced in 1995 as a voluntary system that has been developed further to more than 14000 standard.

If a company fully introduces an Energy Management System (e.g. ISO 50001), it is possible to get certified by an external independent certifier. The certificates should be renewed regularly.[53] In September 2017, over 12,000 companies worldwide have achieved ISO 50001 certification.[54] Several other certificates and tools have also been developed to evaluate, rate, and certificate buildings. One example is the European Union's Eco-Management label. The benefit of these certificates is the communication of the environmental performance to relevant stakeholders and the society in general.[55]

*This instrument addresses the barriers "Different expectations from store owner and shopping mall owners", "Lacking information", "Lack of interest and motivation" and "Regulatory barriers".*

[52] Kahlenborn, et al., (2012)
[53] Kahlenborn, et al., (2012)
[54] U.S. Department of Energy. (n.a.)
[55] Woods, et al. (2015). CommONEnergy

### 5.2.2 Financial incentives

Especially for SMEs, the costs for an energy efficiency measures can be prohibitive. Money is needed for the institutional, technological, administrative, financial and personnel resources.[56] Especially the initial costs for the implementation of the energy management system can be high. This is a key barrier although the energy efficiency measures usually turn out to be profitable after a period of time. A relevant factor is the organisational structure of the enterprise. In hotels, the hotel owners or managers is directly responsible for the energy costs. They have a direct incentive to invest in energy efficiency measures as energy costs are reduced in the long term (depending on the pay-back periods of the energy efficiency measure). In shopping malls the structure is more complex. In some cases, the tenants of the individual shops do not pay the energy costs directly but pay a defined service charge to the shopping mall manager or owner. In this case, there is no financial incentive to invest in energy efficiency. It is therefore recommended to install individual metering systems and to let the tenants pay for their energy consumption. Then, the tenants would have an incentive to reduce their energy consumption and to invest in energy efficiency measures although the measure has initial high investment costs. The investment costs usually pay off in the long term.

If structure of the energy bill is not likely to change, the lack of financing can be addressed by financial incentives. Financial incentives from governmental institutions or a third party investor can make an important contribution to foster energy efficiency improvement either by reducing the costs or by increasing the benefits of energy efficiency investments. Examples of such instruments are: direct subsidies, tax incentives, or subsidised loans, all of which reduce the incremental costs of higher energy efficiency for the investors. The scale of investment available from the public sector is limited by available public budgets.[57] In additional to these financial incentives, the company can use own resources of third party financing. This is further illustrated in chapter 5.4.

*This instrument addresses the barriers "Uncertainty about Saving Potential", "Lacking financing", "Uncertain about how the investment will perform in terms of revenue and risk" and "The split incentive"*

### 5.2.3 Networking and Knowledge Sharing

To push all relevant actors to implement an Energy Management System, networks, workshops and technical assistance are needed to support the development. Networks can effectively pool the expertise and the resources and build up capacities, especially, for SMEs. Often, SMEs have a lack of resources, competences and commitment to implement a systematic energy saving initiative. In the European Union, several countries like Denmark, Germany and Ireland have implemented networks to learn from each other and to discuss barriers and opportunities.

*This instrument addresses the barriers "Lack of information", "Uncertain about the saving potential" and "Lack of interest and motivation"*

### 5.2.4 Training

The energy management team and all other relevant actors should have sufficient knowledge to

[56] IEA, 2012
[57] Fawkes, et al., (2016)

implement an building energy management system and to increase the energy efficiency of the company. This is a prerequisite for a successful implementation. The provision of information can be made through several channels, like information campaigns and newsletter. Another important measure are trainings. All relevant actors should have the required competences to conduct their tasks in the field of energy management. Trainings can be differentiated between specialist training on the one hand and meetings and demonstrations for non-technical staff.

Training-specific topics are for instance:

- The advantages of energy efficiency for the environment and for the company
- The importance of compliance with the energy policy
- The requirements of the BEMS
- The consequences of non-compliance with the specifications of the BEMS
- The potential impacts of their own individual activities on energy consumption and achieving the energy objectives and targets
- Their tasks, responsibilities and competences in implementing the energy management (e.g. according to ISO 150001)[58]

Training programmes should be developed as early as possible. Most of the time, these trainings are conducted by governments, certification bodies and third parties.

*This instrument addresses the barriers "Lack of information", "Uncertain about the saving potential", "Different expectations from store owner and shopping mall owner" and "Lack of interest and motivation"*

### 5.2.5 Green Lease

In the shopping mall sector, the tenant of individual shops often lack motivation to invest in energy efficiency improvement measures. Green lease is a lease, which describes how building is to be occupied, operated and managed in a sustainable way by the landlord and the tenant. Green lease align the financial and energy incentives of building owners and tenants so they can work together to save money, conserve resources and ensure the efficient operation of the building. It is thus a framework to overcome the split incentives between landlord and tenant. Retail stores and other commercial buildings in the UK already make use of the green lease model.[59]

There is no uniform model green lease that is appropriate for all kind of enterprises but in theory, a Green Lease consists of five main elements[60]:

- **An agreed target rating including annual assessments**: The landlord and tenant agree on a binding target. This enables the owner to improve the energy performance and to reduce the energy costs. An annual assessment guarantees the monitoring of the energy performance.
- **Separate digital metering**: Digital meters should be implemented. In shopping malls, all tenants (shop owners) should be equipped with individual meters. The common areas should also

[58] Kahlenborn, et al., (2012)
[59] Better Building Partnership (2013)
[60] Ogier, (2010)

be separately metered.

- **Building Management Committee**: The Committee should consist of the Landlord's Energy Representative (this could be the energy manager or the facility manager) and the Tenant's Energy Representative.
- **Energy Management Plan**: The management plan is a document setting out technical requirements for on-going sustainable building management and operation.
- **A dispute resolution process**: This enables the parties to manage the risk and avoid possible lease termination or other onerous consequences of a breach of the Green Lease.

Benefits for property owners:

- The building is maintained in accordance with the energy saving and sustainability targets
- The building achieves maximum rental returns and occupancy rates
- The costs for the owner of maintaining the asset are minimized
- The owner benefits from an improved public image and related marketing position

Benefits for tenants:

- A safe, productive and green work environment
- Lower operating costs through reduced energy and water consumption rates (if the tenant pays the energy costs directly)
- The tenant benefits from an improved public image and related marketing position

*This instrument addresses the barriers "Lack of interest and motivation", "Regulatory barriers", "Different expectations from store owner and shopping mall owners" and "The split incentive"*

## 5.3 Financing energy management

The high upfront costs of energy efficient renovation including a building energy management programme are perceived to be a major barrier hindering the adoption of energy efficiency measures. This can be addressed by Energy Performance Contract (EPC), in which the energy service providers develops, implements, and sometimes finances an energy saving project or a full range of measures. These measures include a wide range of activities:

- energy audits and economic analysis
- energy management
- measurement and verification of energy and cost savings
- facility management
- energy supply
- provision of services

In general, the energy service company (ESCO) starts with the development of a study, which includes an energy efficiency diagnose, energy saving potentials and the costs and benefits of these measures. Then, a set of recommendations is developed to increase energy efficiency. This includes investments in energy efficiency and energy efficiency improvements but also management activities and inspections. Fig. 8 illustrates the basic concept of EPC.


Fig. 8: Energy Performance Contracting Basis concept.

Source: adapted from World Bank (2007)

The shared savings model is typically used, when the ESCO finances the project, either by its own funds or by third party financing (usually bank loans). The ESCO and the client share the cost savings based on a predetermined percentage for a certain time frame. The percentage division is based on the project costs, the length of the contract and the project risk. As the ESCO is financing the project, it assumes the credit and technological risk. For this reason, the share of project savings is usually higher for the ESCO than in guaranteed savings contracts.[61] The shared savings model is mainly used, when the customer does not have own funds or borrowing capacity.[62] The shared savings model is the most widely used contracting model in the Chinese ESCO market.[63] One important reason for this dominance in China is that only shared savings contracts are currently eligible for favourable tax treatment of ESCOs and the financial incentives available in China.[64] In shared savings contracts, access to third-party finance represents however often an important barrier for smaller ESCOs (particularly for MSMEs) without a large balance sheet.

[61] JRC.( 2014)
[62] Ellis, J. (2010)
[63] Agster, R., Eisinger, F., & Cochu, A. (2016)
[64] Crossley, D., Xuan, W. (2013)

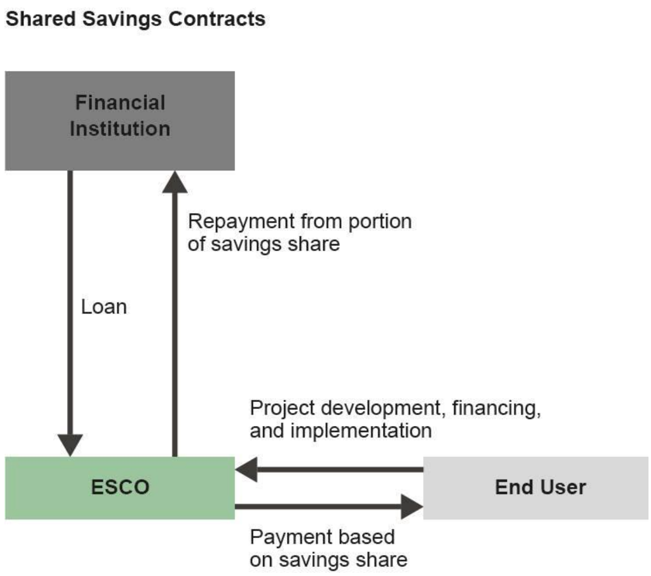


Fig. 9: Shared Savings contract model.

Source: adapted from Agster et al. (2016)

*This chapter addresses the barriers "Uncertainty about Saving Potential", "Lacking financing", "Uncertain about how the investment will perform in terms of revenue and risk".*

## 5.4 Good Practice Examples

### 5.4.1 Networks: The Large Industry Energy Network, Ireland

| Name of the Policy | Large Industry Energy Network (LIEN) |
|---|---|
| **Country** | Ireland |
| **Type of Policy** | The LIEN belongs to the policy type "Voluntary Agreements". However, the aim of the programme is not only to define energy saving targets for large industries but also to provide information and advice to the participants and to establish an energy management system. |
| **Duration** | The LIEN was established in 1995 and is on-going. An end date is not envisaged |
| **Overall targets and/or achievements** | According to the Irish Article 7 notification of the Energy Efficiency Directive, which was published in 2014, projections for the years 2014 – 2020 result in expected energy savings of 3,153 GWh in 2020. |
| **Barriers addressed** | Lacking information about energy efficiency systems and best practice on energy efficiency<br>Uncertain about saving potential<br>Lacking financing<br>Lacking information: Unskilled staff |

| | |
|---|---|
| **Actions targeted** | The LIEN was founded in 1995 and is operated by the Iris energy agency "Sustainable Energy Authority of Ireland (SEAI) for energy-intensive businesses. The membership is voluntary. Companies can participate if they have energy expenditure of more than EUR 1 million[65].<br><br>LIEN was established to support companies with the introduction and further development of an energy management system. Further tasks of the LIEN are the organisation of workshops and seminars, the special training for employees and the assistance in monitoring activities. Member of the LIEN ha have to introduce an energy management system, define individual targets, conduct annual energy audits and publish annual energy consumption reports. The online platform LIEN LINK promotes the communication among the members and presents the upcoming events.[66]<br><br>Around 170 companies are participants of the network. They are responsible for about 17% of the primary energy consumption of Ireland and about 50% of primary energy requirement in the industry sector. It is already planned to extend the network to 200 companies. More than 80 members of the LIEN are also participating in the Energy Agreement Programme, a sub-set of the LIEN. The requirements of the programme go beyond the standard commitments of the LIEN. The members agree to pursue a more ambitious schedule of energy efficiency improvements in their company. They commit themselves to implement and maintain an Energy Management System and to achieve ISO 50001 certification within 12 month (maximum 24 month). The companies receive technical and financial support for implementation. This includes funding for a gap analysis study to identify what is missing to receive the ISO certification, financial incentives for evaluation of energy efficiency projects, and project-specific technical expertise. If companies do not meet the targets to achieve ISO 50001 certification within 24 month, they are excluded from the Energy Agreement Programme.[67] |
| **Transferability to hotels and shopping malls** | Although this measure is introduced to address industrial companies, it can also support the development of energy management in hotels and shopping malls. The network organisation can invite hotels or shopping malls as members and provide them technical and financial advices and encourage mutual learning among them. It can be built within associations of hotel or shopping malls. |

### 5.4.2 Financing: Financial Incentive Scheme, Germany

| **Name of the Policy** | **Financial Incentives to increase Energy Management in German Companies** |
|---|---|
| **Country** | Germany |
| **Type of Policy** | Financial Incentive: Exemption from electricity tax |
| **Duration** | The exemption from electricity tax was established in 2007. All policies are on-going. |

[65] MURE II, (2015)
[66] SEAI, (2015)
[67] Cahill, et al., (2012)

| | |
|---|---|
| **Overall targets and/or achievements** | 3,000 companies were certified according to ISO 50001 to receive tax reduction. |
| **Barriers addressed** | • Lacking financing<br>• Regulatory barriers<br>• Uncertainty about how the investment will perform in terms of revenue and risks |
| **Actions targeted** | Since 2007, the electricity tax in Germany is very high and accounts for 20,5€ per MWh. However, exemptions are possible. Until 2009, exemptions were possible for firms paying more than 1000€ electricity tax per year. They could apply for 90% tax reduction. Changes were made in 2013 and additional requirements were introduced. Since that time, companies must prove that they have an energy management system implemented to receive the tax discount. Alternative systems for SMEs, like energy audits, are also possible for the tax discount. In Germany, about 25,000 firms are eligible for the tax reduction and 3,000 companies were certified according to ISO 50001 to receive the tax reduction.<br><br>Furthermore, since 2010, Germany uses the Feed-in-Tariff called "Renewable Energy Law (EEG)" to support electricity generation from renewable sources. These subsidies are passed on to electricity consumers who pay the so called EEG levy. This amounted to 5.3 Eurocents per kilowatt hour in 2014. In order to sustain international competitiveness of German enterprises, exemptions are possible, when companies have a certified Energy Management System (like an ISO 50001 certificate or an EMAS certificate).<br><br>Another policy from Germany is the Special Fund for Small and Medium Enterprises. It is an initiative of the Ministry of Economy and the KfW bank group for SMEs and promotes initial and detailed energy audits. Initial audits take 2 days. In this case, up to 80% of the costs are granted. A detailed audit takes 10 days and 60% of costs are granted. It is possible to combine both programmes. Advisors need to be certified as energy efficiency advisor (an online database is available). The programme is connected with the KfW soft loan programme for financial energy efficiency investments. |
| **Transferability to hotels and shopping malls** | This policy was not designed exclusively for hotels or shopping malls. Nevertheless, tax rebates are a common measure to incentivize companies to implement an energy management system. The example from Germany shows how successful such a policy is. For hotels and shopping malls, the conditions should be adapted. The third measure, the Special Fund for SMEs could be a good starting point. |

### 5.4.3 Training: BESS and EUREM, European Union

| Name of the Policy | BESS - Benchmarking and Energy Management Schemes in SMEs<br>EUREM – European Energy Manager |
|---|---|
| **Country** | European Union |
| **Type of Policy** | Training |
| **Duration** | The BESS project was finalized in 2007. The EUREM project is still on-going. |
| **Overall targets and/or** | Within the EUREM programme it was calculated that each Energy Manager develops measures with savings potentials of 750 MWh/a for his company. |

| | |
|---|---|
| **achievements** | Cost savings of more than 30,000 EUR/a and a $CO_2$ reduction of more than 200 t/a can be realised. |
| **Barriers addressed** | • Lacking information: Unskilled staff who are not properly trained to run existing facilities efficiently<br>• Lack of information about energy efficiency systems<br>• Uncertain about saving potential<br>• Technical barriers, e.g. poor design of the building |
| **Actions targeted** | The European Union finances several projects to train energy manager and other relevant actors. Two programmes (one terminated and one on-going) are EUREM and BESS:<br>**EUREM**[68]: European Energy Manager (EUREM) is a training programme comprising courses, self-learning and practical work. Target groups are energy representatives, facility manager, maintenance manager, consultants etc. The EUREM programme is offered in 30 countries. It is coupled with an alumni network for continued knowledge exchange. More than 4,000 alumni are part of the network. The content of the training are inter alia:<br>• Energy technical basics<br>• Economic calculation<br>• Energy management<br>• Building energy requirement<br>• Heating technology<br>• Process heat, steam, heat recovery<br>• Ventilation and air conditioning<br>• Refrigeration technology<br>• Lighting<br>• Green IT<br>**BESS**[69]: Often, SMEs do not have the personnel and financial resources and sufficient knowledge to implement a comprehensive energy management system. Within the EU project BESS, different tools were developed like an energy management implementation model and an e-learning system. Furthermore, an international benchmarking scheme for specific energy consumption was established, offering the possibility to compare specific energy consumption with a large number of other companies from the same sector. |
| **Transferability to hotels and shopping malls** | Local government or association can provide such a training programme to hotels and shopping malls. An e-learning tool provides an easy way to impart knowledge. Training courses support responsible persons, like facility managers and provide sufficient knowledge. A network of energy managers from e.g. the hotel industry could exchange experience and develop benchmarks. |

[68] EUREM, (2017)

[69] Intelligent Energy Europe, (2009)

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