Measurement and Management of Energy Performance in Office Buildings

Guide for use by designers, operators and users of Positive Energy office buildings.

This is an English translation of a collaborative white paper written by the organisations involved in Bouygues Immobilier’s Positive Energy Consortium, in which Schneider Electric is an active participant.

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1.0 Introduction

1.1 Observations
Positive energy building* projects need, more than ever, to employ new processes that facilitate better control of the implementation system and a better understanding of the needs and behaviors of future users. The level of performance expected in these buildings requires the implementation of high technology systems to control energy usage and still provide a satisfactory level of comfort.

To date, construction projects have been driven by the traditional separate bidding and implementation of the various Building Services and Equipment (BSE) projects. Accordingly, it is often difficult to involve all of the stakeholders that are needed to achieve sustainable performance targets. The new regulations, which will come into effect shortly, encourage developers, investors, regulators and building occupants to work together to identify the ideal energy configuration.

1.2 The challenges
The Positive Energy Consortium, through the expertise and international reputation of its members, has the ability to leverage opportunities provided through new technologies and to capitalize on the pressure from emerging regulations to develop processes that reduce energy consumption in office buildings. The following issues are of paramount importance:

- To study and understand the main components of the overall energy balance of the building as it is currently being used.
- To analyze the existing roles and behavior of the various people involved with the building, so as to transform behavior to positively impact the energy and environment.
- To engage operational stakeholders in a virtuous cycle by providing them with simple and complete energy information that enables them to take positive actions appropriate to their role.

1.3 Levers and key factors
The working group has produced this white paper containing recommendations and suggestions for the most appropriate energy solutions, particularly in terms of the measurement and management of energy performance. The primary topics are:

- The definition of energy consumption optimization principles
- The mapping and architecture of the technical systems of the building, including devices for measuring consumption, fine-tuning and precision
- Project reorganization
- New missions within companies through the role of the Energy and Environment Manager
- Better control of performance through consumption benchmarks tailored to the new operating rules
- An approach to encourage occupants to engage in more positive environmental habits

This white paper addresses, as a priority, the stakeholders who are most directly involved in achieving the energy performance objectives for positive energy buildings.

Developers and designers

- A new design methodology that incorporates a technical engineering designer for energy and environmental performance. It also reinforces agreement of all stakeholders through all phases, beginning with building design, through the BSE packages and, finally, the optimization of settings in the operational phase.
- Recommendations on energy principles in anticipation of future energy regulation
- Incorporation of tools and procedures needed to achieve performance objectives

* Positive energy buildings consume less energy than they produce.
Users (site managers, occupants and energy managers):

• Raising awareness of energy performance.
• Developing stakeholder engagement (behavioral change, usage scenarios, etc.)
• Definition of the tools available to measure consumption, identify slippage and provide recommendations for action.

Service providers (operational):

• Essential involvement for the implementation of benchmarks which include contractual performance objectives
• Tools and control panels to aid management
• An administrative process required to achieve performance objectives

1.4 Use of this document

This white paper should be read as a design guide to develop positive energy buildings and as an operational guide for facilities, equipment and use. Incorporating new processes for a wider range of stakeholders, it complements the existing and future regulations, recommendations and labels, while providing perspective for innovative technological development.

There will be massive advancement of energy efficiency activity between 2010 and 2020. The advancement will include the implementation of solutions developed in positive energy buildings that are linked to a project management approach that is better suited to new build or refurbishment projects. Operating and service providers will be increasingly involved in attaining performance objectives, thanks to contractual benchmarks for energy consumption. Finally, the energy performance of buildings implies de facto management of renewable energy which contributes implicitly to a reduction in greenhouse gas emissions.
2.0 Needs analysis – design phase

2.1 Description of the approach

Stakeholders should include devices to measure and manage the energy performance of buildings as part of a comprehensive approach during the design phase of construction projects. This approach involves directly, or indirectly, a range of stakeholders and is based on:

- Operational programs
- Upstream structural design and technical solutions
- Management implementation
- Definition of the appropriate tools (Building and Energy Management Systems (BEMS), analysis software, instrumentation, etc.)
- Calculation of an energy performance evaluation baseline

The direct actors or stakeholders in the approach are:

- The building manager
- The building operator
- The building occupants

The actors involved in a preliminary approach are:

- The building contractors
- The project manager
- The local authority representatives

2.2 Energy and environmental performance consulting

Today, energy and environmental concerns are issues that cut across wide range of trades and specialty areas in the construction field.
Accordingly, it is necessary to identify a new design approach that we will call “energy and environment consulting”, whose focus will be:

**Project planning and outline phase**
- Define the objectives and overall project principles from the energy and environment perspective (notably energy, zoning, network and metering architecture).
- Define building occupation principles.
- Calculate provisional energy consumption for each use to provide a reference for the first year of operation.
- Produce the notes, documents and supporting information that is required for desired environmental certification.

**Design phase**
- Design the BEMS and coordinate the specifications of the other BSE packages to ensure consistency with the objectives.
- Define the implementation procedures so that they are under a process of continuous control.
- Define the procedure for acceptance of the work.

**Implementation phase**
- Acquire energy approval rating for the plans, technical specifications and modifications in order to validate compliance with energy balance.
- Provide ongoing monitoring of implementation and control procedures.

2.3 Legislative and regulatory context

Most developed countries have standards and regulations in place for energy consumption and greenhouse gas emissions. These are the result of two major factors:

1. The increase in the temperature of the surface of the earth, which is the result of emissions of greenhouse gases
2. The dwindling reserves of fossil fuels and the inevitable increase in energy prices

At the global level, the Kyoto Protocol set an objective of an 8% total reduction in greenhouse gases, as compared to 1990 levels, the years 2008 – 2012. An example of the implementation in France is shown.
Parallel to this, and in support of the Kyoto Protocol, many countries have developed an environmental certification scheme for the construction and management of buildings.

- **BREEAM®** (Building Research Establishment Environmental Assessment Method) has been in the United Kingdom since 1990. This approach is based on an analysis of the costs for environmental measures.

- **CASBEE®** (Comprehensive Assessment for Building Environmental Efficiency) was introduced in Japan in 2001. This benchmark is not limited to environmental requirements; it also covers energy, resources and materials.

- **LEED®** (Leadership in Energy and Environmental Design) was introduced in the United States in 1999. The most commonly used approach, LEED, enables building and renovation practices to be improved and is also an economic approach.

- **MINERGIE®**, introduced in Switzerland in 1998, identifies new and refurbished buildings that meet specific energy consumption levels.

All of these certifications are specifically directed at improving environmental quality.

In France, today, all new construction must, at a minimum, meet the requirements of **RT 2005** (French Thermal Regulations). RT 2005 sets minimum quality standards for all components and limits overall primary energy consumption per m²/year: CPE benchmark (CPE = Consumption in primary energy equivalence).

**RT 2012**, currently being drafted, will impose a CPE benchmark reduction of around 20% so that by 2020 the following standards are reached:

- **BBC**: low consumption building (Bâtiment Basse Consommation) with an objective of CPE benchmark = 50 kWhPE/m²/year in 2012.
- **BEPOS**: Positive energy building (Bâtiment à Energie POSitive), projected for 2020.
Current objectives are:

- For 2020, a reduction of 20% in energy consumption and greenhouse gas emissions
- For 2050: a reduction in greenhouse gas emissions by a factor of 4

**HQE® Association (High Quality Environment)**

This legal context for energy performance could also include the approach of the HQE® Association (High Quality Environment) which has devised benchmarks for the Environmental Management System. These benchmarks, combined with the explicit definition of Environmental Quality targets, guide building contractors in the implementation of an HQE approach, both operationally and descriptively, for environmental management. It also has the goal of facilitating the establishment of a certification system.

This approach includes 14 targets for QEB (Environmental Quality of Buildings):

**Eco-construction targets**

- Target 1 – A harmonious relationship between the building and its immediate environment
- Target 2 – Integrated choice of construction products, systems and processes
- Target 3 – Low noise site

**Eco-management targets**

- Target 4 – Energy management
- Target 5 – Water management
- Target 6 – Waste management
- Target 7 – Servicing and maintenance management

**Comfort targets**

- Target 8 – Hygrothermal comfort
- Target 9 – Acoustic comfort
- Target 10 – Visual comfort
- Target 11 – Olfactory comfort

**Health targets**

- Target 12 – Healthy spaces
- Target 13 – Healthy air quality
- Target 14 – Healthy water quality

<table>
<thead>
<tr>
<th>Environmental profile with 14 QEB targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high performance</td>
</tr>
<tr>
<td>High performance</td>
</tr>
<tr>
<td>Low performance</td>
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</tbody>
</table>

In all cases, n°4 “energy management” must be at high performance or very high performance levels to comply with current regulations. This target is the focus of this guide.

Within the framework of the current approach, the building must, at a minimum, qualify for BBC or BEPOS. Achieving this objective necessarily means choosing technical solutions and equipment that are linked to the building design in order to:

- Meet minimum quality standards for all components
- Guarantee overall consumption lower than the CPE benchmark (RT 2012)
3.0 Measurement and management system design

In order to measure and manage a building’s energy performance, it is necessary to implement a “Measurement and Management System” that goes beyond the traditional framework of Building Management System (BMS). Naturally, the system’s specifications, in line with its objectives, have an impact on the design of energy and fluid networks.

3.1 Goals

The goal of the measurement and management system is to provide the building stakeholders with the tools necessary to maintain and improve energy performance in office buildings. This requires us to address the complex problem of balancing the reduction of operating costs while ensuring continuity of services and the comfort of the building’s occupants, all at a minimum investment.

Our goal, then, is to describe an energy management solution that protects the interests of all involved. In order to meet this objective, the measurement and management system must have the following characteristics and functions:

- **Realistic**: to reflect the building’s actual energy performance
- **Durable**: to run smoothly, and without interruption, throughout the building’s useful life
- **Efficient**: to allow all parties to understand, take appropriate actions and share responsibilities
- **User-friendly**: to share knowledge effectively among all the stakeholders and to deliver only that information which is relevant to each person in a user-friendly format, exactly where and when it is needed.
- **Flexible**: to adapt to changing uses (i.e., changing space allocation), including rented spaces and their occupants.
- **Affordable**: to reduce operating costs throughout the building’s useful life, while minimizing investment costs.
- **Reliable**: to measure and record actual consumption, and provide accurate data without errors or omissions.
- **Secure**: to protect data, control of access rights and access tracking management.
- **Open**: to be capable of importing (e.g., degree-days) and exporting (e.g., multi-site comparisons) data over the Internet and facilitate remote management and supervision.
- **Powerful**: to be capable of simulating the impact of a single modification of the operating parameters on the building’s energy performance as a whole.

3.2 Outline of European standard EN 15232

New regulations concerning the management of energy efficiency and environmental quality are in line with previous standards and represent a logical progression towards established targets. EN 15232 establishes the conventions and methods used to estimate the effect of control automation systems and BMS on a building’s energy needs and performance.

**Scope of application**

The current European standard includes:

- A structured listing of the control automation and BMS functions which impact a building’s energy performance
- A method for defining the minimum specifications applicable to buildings of varying complexity with regard to automation control and BMS functions
- A way of estimating energy-saving factors which can be used in conjunction with a building’s energy evaluation

**General information**

Effective building automation, control systems and equipment ensure proper regulation of devices for heating, ventilation, cooling, water heating and lighting. They also increase operational performance and energy efficiency. In order to avoid unnecessary energy consumption and CO2 emissions, various subroutines and complex, integrated functions can be configured based on a building’s actual usage and according to its users’ real needs.
The BMS functions provide useful information regarding operations, maintenance and building management. This information is particularly applicable to energy management, including functions for analyzing trends, activation warnings and unnecessary energy consumption diagnostics. Energy management is a requirement for regulating, monitoring, optimizing and determining a building’s energy performance.

**BMS effectiveness grades**

Functions that play a role in a building’s energy performance are divided into three groups:

- Auto-regulated functions
- Building automation functions
- The building’s technical management functions

These functions are divided into four different BMS effectiveness grades (A, B, C and D) for both residential and non-residential buildings.

- **Grade D** means that the building’s systems yield poor energy efficiency. Buildings equipped with systems of this type should be brought up to standard. New buildings must not be built to Grade D standard.
- **Grade C** means that a building’s BMS is in line with current standards.
- **Grade B** means that a building’s BMS is in line with standard and advanced systems.
- **Grade A** means that a building’s BMS yields a high level of energy performance.

As this standard is official, its contents are reliable and can be used as a reference. *(Refer to functionality definitions in Appendix 5.1)*

### 3.3 Outline of European standard EN 16001

Published in July 2009, as a supplement to EN 15232, this standard is based on the so-called Plan-Do-Check-Act (PDCA) methodology, briefly defined below.

- **Plan**: establish the goals and processes necessary to obtain the results required according to the organization’s energy policy.
- **Do**: implement these processes.
- **Check**: monitor and evaluate these processes in line with the organization’s energy policy, goals, targets, legal obligations and any other requirements, and report on the results.
- **Act**: improve the energy management system’s performance on an ongoing basis by undertaking the necessary actions.

The adoption of this methodology contributes to a process of continued improvement and results in more efficient energy consumption. It also encourages an organization to begin initiatives to monitor and analyze energy use. This methodology is intended to help any organization, irrespective of its size or industry, to develop a thorough energy management approach and increase its energy efficiency. This European standard is the inspiration for the future International standard ISO 50001 which goes into effect by the end of 2010.

Drawing upon the competencies of an Energy and Environment Manager (see paragraph 4.3), a program for the measurement and management of energy performance is to be developed based on an energy metering plan and the consumption benchmark.
3.4 Areas of implementation

The proposed technical solution makes it possible to manage:

- All energy: includes energy produced and energy consumed
- All energy usage: heating, ventilation, water heating, lighting, office appliances, etc.
- All of a building’s space (both common areas and rented space)
- Actions in the operational phase.
- All equipment that generates or consumes energy

3.5 The structure of the measurement and management system

The first stage in the design of the measurement and management system consists of breaking down the building into areas of similar use.

In order to ensure accurate measurement and management as well as to maintain flexibility for modifications, each office area is divided into modules, the width of which is a multiple of the facade’s modular grid (generally 1.35 m).

The second stage consists of:

- Defining the measurement and reporting functions (i.e., dashboard) as well as the users.
- Defining the management functions.
- Allocating these functions according to their scope of application within the building.

This approach allows us to specify the functional applications of an office building, effectively providing a framework within which we can:

- Allocate corresponding instructions regarding temperature and scheduled use to each individual space.
- Use Heating, Ventilation and Air Conditioning (HVAC) systems only when needed.
- Divide energy costs between tenants fairly.
- Define and monitor the energy performance plan for each individual tenant.

The third stage consists of defining the interfaces between the measurement and management system and other technical systems related to energy and environmental performance.

Internal equipment and appliances include:

- Hardware (telephones and IT) powered by Ethernet (Power Over Internet). For example,
location’s actual use

• Office equipment so we can compile data on energy consumption to effectively monitor the total consumption of an operating office
• Systems for the reservation of meeting rooms, or offices in the case of job-sharing, in order to link the use of HVAC systems to their actual hours of usage

Other functions which extend beyond a single building:

• Tools used to record total energy and environmental data for a larger complex. These tools are increasingly necessary as companies seek to manage CO₂ consumption and emissions.
• Remote operation software
• Asset management tools used by real estate management professionals
3.6 Measurement and metering systems

The measurement infrastructure is established by mapping a building’s energy consumption and usage. It enables analysis at the individual office level, as well as individual-rented space, by actual usage. Measurement is based on an energy consumption tree diagram compiled from the building’s energy breakdown. This mapping is carried out in two successive phases.

**Physical areas:** Areas corresponding to distinct, homogeneous activities which consume a significant amount of energy. For example:

- The exterior
- Parking areas
- Staff canteen
- Common areas
- Rented spaces
- Specific, shared services (child care center, copy center, etc.)

Every area should be taken into account during design so that energy can be measured across the entire rentable area. If a given area is greater than 400 m², a further, more detailed, breakdown may be needed (e.g. by floor, individual space, etc.).

**Functional usage:** as consumed by major systems and divided according to physical areas. For example:

- Heating
- Cooling
- Ventilation
- Hot water heating
- Lighting
- Office automation

You should define the measuring points necessary for the management of the building throughout its useful life from the outset. The number of measuring points determines the management system’s performance. Corresponding devices may be installed either when the building is placed into service or later. It is important to take installation and connection into consideration during the design of the BSE packages in order to minimize installation costs and inconveniences.

All metering equipment is integrated into the building’s technical installations from the outset, in order to eliminate the need for temporary installations. Manual readings are kept to a strict minimum; therefore data is collected from measuring points automatically.

The optimal technology to be used at each metering point is decided on a case-by-case basis, taking into account the amount of energy in question, technical feasibility, initial installation costs and ongoing operating costs.

![Energy Metering Architecture](image-url)
The following table provides a summary of the four different methods for measuring and metering energy consumption, based on the precision desired, the initial installation costs and ongoing operating costs.

To ensure accurate energy consumption readings within a specific rented space, direct metering is preferred, as this guarantees the reliability of the data obtained.

It is also possible to calculate the data for an area based on the sum of measurement point readings distributed over the area, provided it is adequately equipped.

**Electricity**
- Readings at the building’s point of delivery and for usage at each sub-distribution board in each area
- Readings, or a minimum estimate based on operating time and forecast load, for usage in each office or functional area

**Energy used by heating and cooling systems – calories and frigories**
- Readings at the building’s point of delivery and at each area’s point of exit
- Reading of calories produced (calculation of yield)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter</td>
<td>Direct measurement at the building’s point of delivery. Highly accurate.</td>
</tr>
<tr>
<td>Operating time (constant charge)</td>
<td>Very good. Usually more convenient than direct measurement.</td>
</tr>
<tr>
<td>Using calculations</td>
<td>Good. Calculating energy consumption based on operating time and forecast.</td>
</tr>
<tr>
<td>By difference</td>
<td>Acceptable. Suitable for estimating energy consumption based on calculations.</td>
</tr>
<tr>
<td>Estimate</td>
<td>Last resort. Only used as a last resort option when other methods are not feasible.</td>
</tr>
</tbody>
</table>

**Illustration of Measuring Point Techniques**

**By Calculation**

Energy consumption = \( \text{met} \times \text{(Temp (\text{in}) - Temp (\text{out})) \times 4.185} \)

\( \text{boiler efficiency} \times 3,000 \)

\( = 844.976 \times \frac{(65-10) \times 4.185}{0.75 \times 3,000} = 72,000 \text{ kVhr/yr} \)
**Water**

Install meters at water delivery points and at inputs to sanitary hot water tanks. If the hot water tanks are individually powered by electricity from the rented spaces, a pulse-based metering technology is used (specific outgoings in the sub-distribution board).

**Energy produced**

Meters are placed downstream from the generators.

**Temperatures**

- Sensors within the offices (One sensor for every two sections and common areas)
- Weather Center (i.e., outside $T^\circ$, hours of sunshine, wind speed, rain, etc.)

*(See algorithms in Appendix 5.2)*

### 3.7 BMS architecture

The BMS is divided into three different levels based on function and performance. Each level should be modular and independent, thus ensuring optimum performance in terms of operation, troubleshooting, fault tolerance and expansion.

The most appropriate technology to satisfy these specifications is chosen in accordance with building industry standards. In order to achieve maximum flexibility, necessary functions are always assigned to the most suitable system level, as described below.

**Field level**

The system must allow field-level installations to connect via a dedicated controller that allows for the management of terminal equipment.

The exchange of data between field-level equipment and automation-level controllers is carried out by means of buses that support standard, open and optimized communication protocols (e.g., Modbus®, LonWorks® and IP).

**Automation level**

Controllers constitute the second system level and are linked directly with, and placed in immediate proximity to, the facilities that they control. These controllers are current models of standard devices and are able to perform all necessary functions.
The exchange and transmission of data between controllers and from the controllers to the management level, is carried out by means of a bus that uses a standard, open and optimized communication protocol that specifically supports:

- TCP/IP Ethernet network or equivalent
- Bus compatibility with other controllers without disrupting the system
- OPC (Ole for Process Control) communications

**Management level**

The minimum configuration includes the following features:

- A structured database.
- Client and Server OPC to allow inter-application data exchange compliant with the COM/DCOM or .NET programming methods.
- Native integration of legacy market protocols over Ethernet TCP/IP
- Active X Container (insertion of external software components) and VBA compatible
- Ability to manage redundancy functions (e.g., server, Ethernet network, controllers, etc.)
- An integrated utility allowing for automatic synchronization of the controllers’ internal clocks

In order to exchange data with other, external systems, the supervisor provides:

- A development environment that allows the user to integrate a specific protocol (i.e., Ethernet TCP/IP)
- Web Service functions that allow other systems (e.g., Web Server, Intranet, etc.) to access supervisor data via a Web Server

The supervisor allows event notifications to be routed to various destinations (pagers, printers, e-mail addresses, etc.).

**Database**

All data readings are captured and stored automatically. Time-stamping of saved data is carried out in the LPU or the data capture controller. To prevent information loss due to a breakdown of the data transmission chain, the LPU is able to save recorded data and send it as packets to the BMS, either at regular intervals or at the request of an operator. The collection, data storage and processing infrastructure is unique for each of the BSE packages of the building (i.e., electricity, HVAC, and BMS) in order to reduce investment and operating costs.

The monitoring solution allows for system history data to be output in a format suitable for processing by external software. The following tasks are available:

- Sorting and outputting of history data by date.
- Display of history data in table form, sorted in ascending or descending order.
- Statistical analysis of certain trends in the historical data (e.g., number of records, minimum, maximum and average values).
- Creation of incident reports for various states and warnings.
- Regular reports generated directly in Microsoft Excel®.

**3.8 Software functions**

The Measurement and Management System must include a range of software applications.

**Energy monitoring program**

This module provides an overview of all of the building’s energy consumption and includes the following functions:

- Monitoring of energy supplier’s data
- Energy usage analysis
- Distribution of energy costs
- Sub-billing of energy
- Regulation compliance report
- Consumption profile editing
- What-if modeling of the energy impact of modifying parameters
Energy management program

This module manages a building’s energy flows with the following functions:

- Customization of heating and cooling as well as area-by-area demands
- Control of the building’s energy-storage capacity and management of resulting usage (e.g., management of nocturnal cooling)
- Management of the energy supplier’s data (e.g., rates, timeframes, interruption of supply)
- Allowance for external weather data

This module contains tools to help optimize energy consumption and facilitate energy performance evaluation and management. It also offers tracking software functions which ensure data capture, storage, dissemination and graphical usage of historical data obtained from technical facilities and generated by the BMS. It provides specific and timely solutions in the following areas:

- Technical monitoring of an installation’s status, (e.g., functional control of sensors, various measurement probes and energy meters.
- Demand-side management (DSM) by comparative analysis.
  - Energy consumption expressed as heating-degree days or other relevant parameters.
  - Ambient temperatures in relation to heating degree days or a given site’s occupation.

The full software suite allows for the analysis of fluid consumption status by providing:

- A summary of the total set of data managed by the software, by synchronizing and cross-referencing any and all desired parameters over a given period.
- A guide to evaluating future energy consumption.
- Control and reduction of energy consumption costs.
- A reduction of energy waste and optimization of settings.
- Increased responsiveness for accurate and timely identification of detected anomalies.
- Improved staff comfort through temperature control.

The Measurement and Management System complies, at minimum, with Grade A functionality (EN NF 15232).

3.9 Impact on network design

All BSE packages, circuits (e.g., wiring, tubing, ducting, etc.) are separated to allow for the measurement of energy and fluids (calories, frigories, kWh, m3), based on a breakdown by areas and usage (in the case of electricity) designated by the design team.
4.0 Needs analysis - operational phase

4.1 Approach to user behavior

Change management is critical to encourage future users of positive energy buildings to adopt lasting behaviors. Change management goes through a number of phases:

1. Provide information and explanation about the desired improvement objectives and challenges as early as possible in the building project.
2. Clarify the change effort and commitments required and related it to the expected benefits for individuals, teams, the business and the environment.
3. Encourage a desire for change through co-design approaches to develop buy-in.
4. Sustain new daily behaviors through continual information/correction/revision sessions focused on the experience of the change.

Change management includes communication on the overall approach to a building move. A move to a new site is the result of many decisions: financial, organizational, human, image, etc. For the future occupant, the move frequently provides an opportunity to re-think work patterns or change the culture of the business. Consequently, a lot of habits need to change. Examples include organization of work, travel, policies and procedures, spaces and the use of new office tools.

These changes are linked to specific changes in the workspace. A comprehensive change management project, including future users and designers of workspaces needs to be carried out early in the process. The project should make sure to address expectations related to Green Office® buildings. This will enable the occupants to understand their environment as a whole and provide psychological well-being.

Change management can use a range of different tools.

**During the project:**
- Information sessions on the challenges, objectives and solutions
- Internal communication tools during the main phases of project implementation, as appropriate to the business
- Co-design groups for the new practices
- A feedback group for addressing the most common forms of resistance
- Training in the new tools prior to the move.
- Promotions and motivational events (e.g., site visits, meetings/blogs with architects, project teams, etc.)
- Establishing targets for each department

**After the move:**
- Dissemination and explanation of the policies and procedures
• Explanation to users of the performance management tools
• Regular audit and feedback sessions
• A feedback group once the employees are settled in the new building to addresses the gains, benefits and commitments
• A system of rewards
• A protocol for integration of new employees

Issues to be addressed
The rules for the management and use of comfort parameters (e.g., air conditioning, heating, lighting and ergonomic modification of furniture) are defined in relation to usage modes in different types of spaces.

• Enclosed versus open spaces
• Allocated or shared offices
• Meeting room types (according to capacity)
• Staff canteen
• Other common informal spaces such as leisure spaces or a gym

Collaboration and communication tools
There are many appropriate options. Examples include:

• Terms of use, modes of operation of spaces and tools for video conferencing, telecommuting, etc.
• Displays with clear explanations of environmental and energy performance

Use of office tools and paper interfaces
• Rules for use, security and maintenance of PCs, laptops, telephones, etc.
• Location and terms of use of printing facilities.
• Classification, storage and archiving policy (digital and paper).

To guarantee buy-in, it is important to contextualize these behaviors along with other eco-practices advocated by the company, such as:

• Waste management and recycling policy
• Mobility, office presence, telecommuting and car-pooling policies
• Policies and procedures (respect for others in terms of noise, hygiene, food, dress etc.)
• Security, confidentiality and ID rules

Conditions of success
Change management is an integral part of the building project during the move and budget should allow for a dedicated manager, preferably from internal communications or HR. The management mission covers the whole range of expected changes at the user level and collaboration is indispensable with the Energy and Environmental Manager of the occupying business. All providers should supply information on their recommended criteria and behaviors.

4.2 Operating rules
The facility manager in charge of building operation is no longer the only stakeholder involved in energy performance. His mission is not limited to the operation and maintenance of equipment but now encompasses permanent optimization of consumption.

Therefore, the facility manager must:

• Adjust and fine tune regulations according to climactic conditions and the occupancy conditions of the sites
• Forecast likely functions
• Use free cooling
• Adjust the volume of fresh air to the correct hygienic requirements in a timely manner

The provider’s contract will include consumption targets by usage type (for those managed by the provider)

• Consumption target (calories), for heating according to DDU (Degree Days Unified), taking into account production and distribution yields (Good maintenance is required to maintain these yields.)
• Consumption targets (kWh) for ventilation
• Consumption targets (frigories) for air conditioning, if appropriate

Nature of the contract with the operator
The operator must propose an operating contract that requires the achievement of defined targets for optimization of energy and fluid consumption. This contract may take the form of an Energy Performance Contract (EPC). To evaluate the performance of the service provider, consumption
targets for heating are updated according to the average of Degree Days of each rented space, although the provider does not always have control of the comfort temperatures in each rented space.

4.3 Organizing principles

It is necessary to define the cooperation framework between property managers or owners, facility managers and occupants. For example, to define the lease conditions, the commitments and responsibilities (i.e., rights and obligations) of each party are identified.

- Frequency of data exchange
- Measurement frequency
- Frequency of summary reports – monthly at a minimum
- Rules for calculation of consumption and of consumption distribution
- Methods of evaluation of energy performance
- Organization of reporting to the occupants
- Specification of the interior layout (screening inside the building)
- Cooperation on strategies for reducing consumption
- Specifications of equipment added by the occupants
- Rules for the modification and replacement of equipment
- Rules for the maintenance of equipment

The owners keep an up-to-date building logbook and must make it available to the tenants. The logbook contains the energy performance certificate for the building, recommendations, consumption reduction targets, measurement data and energy consumption reports, environmental policies, water consumption data and the waste management strategy.

To facilitate all of these new processes, we propose the creation of a new post, the “Energy and Environment Manager.”

Definition of the role and purpose of the Energy and Environment Manager

The Energy and Environment Manager (EEM) converts into action the environmental commitments made by tenant companies of BBCs or BEPOS.

This role will:

- Set the energy policy and define energy training needs from environmental awareness-raising to action
- Set and monitor environmental targets for which the energy budget is implemented in the company and, or, the site in connection with the operator
- Prepare energy reports and send them to the CEO of the company
- Act as the interface between the occupants, building operators, the manager of the staff canteen and the building owner
- Monitor overconsumption by users and implement, with human resources and marketing departments, the most appropriate education and training for company personnel
- Identify areas of poor quality in operational activity, with the objective of guaranteeing the continuity and good governance of the service provided

The EEM must have:

- Access to energy data contained in the BEMS, via reports generated by the operator
- The ability to take action inside rented spaces to adjust the operating parameters of their usage patterns (e.g., turning off lights, general closing and opening of stores, reducing temperature settings, setting program schedules etc.)

The EEM prepares, and updates, the company’s environmental practice guide. He is responsible for developing a steering group to ensure that the building is managed properly. This steering group should consist of all the Energy and Environment Managers, the owner’s representative responsible for managing the company assets (i.e., Property Manager) and the building operator (i.e., Facility Manager). The EEM holds monthly meetings with the energy managers from the other entities occupying the building.
4.4 Dashboards

The measurement and management system publishes an energy dashboard for each user, which contains only the information relevant to the user and is in a format defined by the user. The software solution must be open and easy to use and offer customizable dashboards that are based on needs and user profiles. Customization options include what data is presented, custom graphics, access rights and available features. The users are:

- The property manager
- The building operator
- The occupant’s energy and environment manager

**Property manager dashboard**

The dashboard content features, for the entire building:

- Monthly total
- Annual total
- Consumption of all energy types, for all areas
- Ratio of consumption in kWh/m² year
- CO2 emissions
- Energy billing for tenants
- All comparative data in relation to the pre-defined benchmark

**Building operator dashboard**

The dashboard content for the building operator includes:

- Regular presentation of consumption data.
- Analysis of historical trends, charge curves, averages
- A -1 comparisons
- All comparative data in relation to the pre-defined benchmark
- Automatic display of usage anomalies.
- Automatic identification of alerts, recommendations
- Interventions

**Energy manager dashboard**

The energy manager’s dashboard includes, for the area occupied:

- Monthly total
- Annual total
- Consumption of all energy types for all areas
- Ratio of consumption in kWh/m² year
- CO2 emissions
- All comparative data in relation to the pre-defined benchmark

**Occupant dashboard**

The occupant dashboard content is specific to the area occupied and includes:

- Monthly total
- Annual total

**Direct access function on PCs**

- Energy Manager monthly report
4.5 Performance benchmarks

The original benchmark used for the first 12 months after the building becomes operational is the provisional energy performance that results from preliminary studies and simulations.

The measurement and management system provides stakeholders with all the elements necessary to define the operating performance benchmark during the first year of occupation. For subsequent years, it is preferable to establish the benchmark from energy use for the year N - 1 and to include corrections for variation in influential factors.

The aim of the benchmark is to control and verify performance, the achievement of targets, the allocation of responsibilities and the costs and benefits to the stakeholders. If the current benchmark is not adequate, an ad hoc benchmark can be defined on a case-by-case basis according to the International Performance Measurement and Verification Protocol (IPMVP) benchmark.

(See benchmark calculations in appendix, § 5.3)

4.6 Training

Energy performance also requires control of individual behavior in relation to use. Awareness training for the staff is helpful. Simple messages that lead to the adoption of good practices form the basis of the training. For example:

In winter, a 1°C increase in ambient temperature causes a 7% increase in energy consumption for heating.

Training courses should be offered regularly to embed good practice. In addition, ongoing training for the operations team enables them to maintain a level of expertise sufficient to meet, or exceed, their contractual performance targets. Introducing a system of rewards and sanctions may also motivate staff.
### 5.0 Appendix

#### 5.1 BMS features according to standard EN 15232

List of functions and assignment to efficiency classes

<table>
<thead>
<tr>
<th>Definition of grades</th>
<th>Residential</th>
<th>Non residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>C</td>
</tr>
</tbody>
</table>

#### Automatic Regulation

**Regulated Heating/Cooling**

**Regulated emissions**

- The control system is installed at the transmitter or room level. In example 1, the system can regulate several rooms.

<table>
<thead>
<tr>
<th>0</th>
<th>No automatic regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Central automatic regulation</td>
</tr>
<tr>
<td>2</td>
<td>Automatic regulation of separate rooms using thermostatically controlled valves or electronic regulators</td>
</tr>
<tr>
<td>3</td>
<td>Regulation of separate rooms with communication between regulators</td>
</tr>
<tr>
<td>4</td>
<td>Built in regulation for individual rooms with regulation based on need (occupation, air quality, etc.)</td>
</tr>
</tbody>
</table>

**Distribution network water temperature control (outlets or inlets).**

- A similar function can be used to regulate the direct electric heating network.

<table>
<thead>
<tr>
<th>0</th>
<th>No automatic regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regulated in accordance with outside temperature</td>
</tr>
<tr>
<td>2</td>
<td>Regulation of interior temperature</td>
</tr>
</tbody>
</table>

**Distribution pump control.**

- Regulated pumps can be installed at different levels of the network

<table>
<thead>
<tr>
<th>0</th>
<th>No regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Automatic stop/start control</td>
</tr>
<tr>
<td>2</td>
<td>Pump controls with varying speeds and constant Δp</td>
</tr>
<tr>
<td>3</td>
<td>Pump controls with varying speeds and proportional Δp</td>
</tr>
</tbody>
</table>

**Intermittence regulation for emission and/or distribution.**

- A regulator can control several rooms/areas with the same occupancy profile

<table>
<thead>
<tr>
<th>0</th>
<th>No automatic regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Automatic regulation with set program</td>
</tr>
<tr>
<td>2</td>
<td>Automatic regulation with optimized stop/start</td>
</tr>
</tbody>
</table>
List of functions and assignment to efficiency classes (monitoring)

<table>
<thead>
<tr>
<th>Generator controls</th>
<th>Definition of grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Constant temperature</td>
<td>Residential</td>
</tr>
<tr>
<td>1 Variable temperature in accordance with outside</td>
<td>Non residential</td>
</tr>
<tr>
<td>temperature</td>
<td>D</td>
</tr>
<tr>
<td>2 Temperature regulated according to load.</td>
<td></td>
</tr>
</tbody>
</table>

Sequencing of different generators.

<table>
<thead>
<tr>
<th>Priority based solely on loads</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Priority based on generator loads and capacity</td>
<td>Non residential</td>
</tr>
<tr>
<td>2 Priority based on generator efficiency (see other</td>
<td>D</td>
</tr>
<tr>
<td>standard)</td>
<td></td>
</tr>
</tbody>
</table>

COOLING REGULATION

Regulated emissions

The regulation system is installed at the transmitter or room level. In example 1, a system can regulate several rooms.

<table>
<thead>
<tr>
<th>Regulated emissions</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No automatic regulation</td>
<td>Non residential</td>
</tr>
<tr>
<td>1 Central automatic regulation</td>
<td>D</td>
</tr>
<tr>
<td>2 Automatic regulation by individual room using</td>
<td></td>
</tr>
<tr>
<td>thermostatically controlled valves or electronic</td>
<td></td>
</tr>
<tr>
<td>regulators</td>
<td></td>
</tr>
<tr>
<td>3 Regulation by individual room with communicating</td>
<td></td>
</tr>
<tr>
<td>regulators</td>
<td></td>
</tr>
<tr>
<td>4 Built in regulation by individual room including</td>
<td></td>
</tr>
<tr>
<td>regulation based on need (occupation, air quality,</td>
<td></td>
</tr>
<tr>
<td>etc.)</td>
<td></td>
</tr>
</tbody>
</table>

Water temperature control of the distribution network (outlet or inlets).

A similar function can be used to regulate the direct electric heating network.

<table>
<thead>
<tr>
<th>Water temperature control of the distribution network</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No automatic regulation</td>
<td>Non residential</td>
</tr>
<tr>
<td>1 Regulated according to outside temperature</td>
<td>D</td>
</tr>
<tr>
<td>2 Interior temperature control</td>
<td></td>
</tr>
</tbody>
</table>

Distribution pump control

The regulated pumps can be installed at different levels of the network.

<table>
<thead>
<tr>
<th>Distribution pump control</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No regulation</td>
<td>Non residential</td>
</tr>
<tr>
<td>1 Automatic stop/start control</td>
<td>D</td>
</tr>
<tr>
<td>2 Variable speed pumps with constant Δp</td>
<td></td>
</tr>
<tr>
<td>3 Variable speed pumps with proportional Δp</td>
<td></td>
</tr>
</tbody>
</table>
List of functions and assignment to efficiency classes (monitoring)

<table>
<thead>
<tr>
<th>Definition of grades</th>
<th>Residential</th>
<th>Non residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>C</td>
</tr>
</tbody>
</table>

**Intermittence regulation for emission and/or distribution**

- A regulator can control several rooms/areas with the same occupancy profile

| 0 | No automatic regulation |
| 1 | Automatic regulation with set program |
| 2 | Automatic regulation with optimized stop/start |

**Servo control system between the heating and cooling systems for emission and/or distribution**

| 0 | No control system |
| 1 | Partial servo control system (based on the HVAC system) |
| 2 | Total control system |

**Generator controls**

| 0 | Constant temperature |
| 1 | Variable temperature in accordance with outside temperature |
| 2 | Variable temperature based on load |

**Generators functioning in sequence**

| 0 | Priority based on the load |
| 1 | Priority based on the generator load and capacity |
| 2 | Priority based on generator efficiency (see other standard) |

**VENTILATION AND AIR CONDITIONING REGULATION**

**Air flow control in rooms**

| 0 | No regulation |
| 1 | Manual control |
| 2 | Programmed regulation |
| 3 | Regulation based on presence |
| 4 | Regulation based on needs |

**Air flow control in central air treatment system**

| 0 | No regulation |
| 1 | Automatic stop/start timer |
| 2 | Automatic control of air flow and pressure with or without reinitialization of pressure |
### Benchmark BMS functions

<table>
<thead>
<tr>
<th>Definition of grades</th>
<th>Residential</th>
<th>Non residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>C</td>
</tr>
</tbody>
</table>

#### Frost-free function control on heat exchanger
- 0 No frost-free function
- 1 With frost-free function control

#### Overheating control on heat exchanger
- 0 No overheating control
- 1 With overheating control

#### Free mechanical comfort cooling
- 0 No regulation
- 1 Night comfort cooling
- 2 Free comfort cooling
- 3 Direct control h, x (enthalpy)

#### Temperature control of incoming air
- 0 No regulation
- 1 Constant set point
- 2 Variable set point with compensation for the outside temperature
- 3 Variable set point with load-based compensation

#### Humidity regulation
- 0 No regulation
- 1 Limitation of the humidity of incoming air
- 2 Regulate humidity of incoming air
- 3 Regulate humidity of air in the room or the extracted air

#### LIGHTING CONTROL

#### Control based on occupation
- 0 Manual stop/start switch
- 1 Manual stop/start switch + additional switch off signal
- 2 Detection, automatic switch on/dimmer switch
- 3 Detection, automatic switch on/off by automatic detection
## 5.2 Consumption calculation algorithms

<table>
<thead>
<tr>
<th>Usage</th>
<th>Area</th>
<th>Designation</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>Delivery</td>
<td>Final energy supply metering</td>
<td>Heating delivery meter ($C_1$)</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>$\Delta T \times$ output (permitting distribution efficiency calculation $R_P = C_L/C_P$)</td>
<td>Heating production meter ($C_P$)</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
<td>kWH metering for distribution pumps</td>
<td>Distribution pump electricity consumption meter ($C_d$)</td>
</tr>
<tr>
<td></td>
<td>Area</td>
<td>$\Delta T \times$ Output</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calculate distribution efficiency $R_P = 1 - C_L/(C_P + C_d)$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area energy use: $OC_P = C_P/(P_P \cdot R_P)$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$QC_n = OC_P \times % \cdot QC_b$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$% QC_b = DJmoys \times S_b / \sum(DJmoys \times S_b)$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td>Offices/area</td>
<td>Calculation broken down by surface area and ambient temperature</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>kWh metering for not water battery</td>
<td>Electricity use meter - ventilation ($V_{P1}$)</td>
</tr>
<tr>
<td></td>
<td>Area</td>
<td>$QV_P = V_{P1}/R_P + V_{P2}$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breakdown in proportion to surface area</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$QV_P = QV_P \times S_P/S_{T_P}$</td>
<td>Calculation</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Metering at supply terminal</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td>Lighting</td>
<td>Metering at the low voltage circuit breakers for box</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td>Area</td>
<td>Metering DP</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calculation based on hours of use and known charge</td>
<td>Meter or calculation</td>
</tr>
<tr>
<td></td>
<td>Hot water heating</td>
<td>Metering DP</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td>Other uses</td>
<td>Metering DP</td>
<td>Meter</td>
</tr>
<tr>
<td></td>
<td>Offices</td>
<td>Difference between total energy use for area and total energy use for lighting broken down, proportionally by surface area.</td>
<td>Compteur ou calcul</td>
</tr>
</tbody>
</table>

Where:

- $C_1$: Heating delivery meter
- $C_P$: Heating production meter
- $C_d$: Electrical consumption meter for distribution pumps
- $C_n$: Heating meter, area n
- $QC_n$: Heating consumption, area n
- $QC_b$: Heating consumption, office b
- $V_{P1}$: Calorie consumption meter, ventilation
- $V_{P2}$: Electrical consumption meter, ventilation
- $QV_P$: Total consumption, ventilation
- $QV_n$: Ventilation consumption, area n
5.3 Performance benchmarks

The following benchmarks will be used for comparative analysis of the first year of operation.

Note: For the first year of operation, given the important differences that may exist between different rented areas (exposure, level), where possible, the benchmark can be calculated directly by the calculation engine of the current regulations, instead of by pro rata calculation of the floor space.

Heating

Key factors:

- Degree days
- Comfortable temperature (behavior)
- Occupation schedules
- Renewal of fresh air

Benchmark energy rating for heating the building = \( \frac{C_{\text{BuildingRef}}}{S_{\text{Building}}} \).

Consumption for a rented space: \( C_{\text{PL,TH}} \) (kWh)

The parameters corresponding to each rented space should be considered each time.

\( C_{\text{BuildingRef}} \): Consumption for the entire building, following the calculations of the current RT
\( S_{\text{Building}} \): Floor space of the building
\( S_{\text{PL}} \): Floor space of the rented space
\( H_{\text{Ref}} \): Benchmark hours, occupation/week
\( H_{\text{Period}} \): Number of hours, occupation/week
\( T^\circ_{\text{Ref}} \): Benchmark comfortable temperature during period of occupation: 18°C
\( T^\circ_{\text{Period}} \): Actual comfortable temperature during the period under consideration
\( R^\circ_{\text{Ref}} \): Benchmark reduction in temperature during unoccupied periods (in °C)
\( R^\circ_{\text{Period}} \): Reduction in temperature during the benchmark period (in °C)
\( \text{DDU}_{\text{Ref}} \): Comfortable benchmark DD, used to calculate \( C_{\text{BuildingRef}} \) (baseline \( T^\circ_{\text{Ref}} = 18 \) °C)
\( \text{DDR}_{\text{Ref}} \): Benchmark reduction DD used to calculate \( C_{\text{BuildingRef}} \) (baseline \( T^\circ_{\text{Ref}} - R^\circ_{\text{Ref}} \))
\( \text{DD}_{\text{C,Period}} \): Comfortable DD temperature for the period under consideration (baseline \( T^\circ_{\text{C,Period}} \))
\( \text{DD}_{\text{R,Period}} \): Reduced DD for the period under consideration (baseline \( T^\circ_{\text{C,Period}} - R^\circ_{\text{Period}} \))
\( V_{\text{Ref}} \): Benchmark volume of renewal of fresh air
\( V_{\text{Period}} \): Volume of renewal of fresh air in the period

\( C_{\text{BuildingRef}} = K \times ([H_{\text{Ref}}/168] \times \text{DDU}_{\text{Ref}} + ([168 - H_{\text{Ref}}]/168) \times \text{DDR}_{\text{Ref}}). \)

Where

- \( K \) is a constant for the building = \((24 \times G \times V)\)
- \( G \) = Coefficient of volume loss
- \( V \) = Heated volume of heated building
- \( 24 = 24 \) hours

Benchmark energy rating for heating the building = \( \frac{C_{\text{BuildingRef}}}{S_{\text{Building}}} \).

\( C_{\text{PL,TH,Period}} = S_{\text{PL}}/S_{\text{Building}} \times (K \times ([H_{\text{Period}}/168] \times \text{DD}_{\text{C,Period}} + ([168 - H_{\text{Period}}]/168) \times \text{DD}_{\text{R,Period}}) + (0.34 \times H_{\text{Period}}/168) \times (V_{\text{Period}} - V_{\text{Ref}}) \times \text{DD}_{\text{J,Period}}) - \text{internal contributions} \)

Where “0.34” is the volumetric heat capacity of air.
Internal contributions = L\textsubscript{PL,TH/Period} + CP\textsubscript{PL,TH/Period} + \textit{Off}\textsubscript{PL,TH/Period}.

Where

\begin{align*}
L\textsubscript{PL,TH/Period} &= \text{Contribution of Lighting (see the calculation mode for lighting benchmark)}.
CP\textsubscript{PL,TH/Period} &= \text{contribution of people present.}
\textit{Off}\textsubscript{PL,TH/Period} &= \text{contribution of office equipment operation (see the mode of calculation for benchmarked electrical).}
\end{align*}

\begin{align*}
L\textsubscript{PL,TH/Period} &= \text{Contribution of Lighting (see the calculation mode for lighting benchmark)}.
CP\textsubscript{PL,TH/Period} &= \text{contribution of people present.}
\begin{align*}
CP\textsubscript{PL,TH/Period} &= \text{contribution of people present.}
&= \text{NB}\textsubscript{PL} \times 0.070 \times H\textsubscript{Period}.
\end{align*}
\begin{align*}
\textit{Off}\textsubscript{PL,TH/Period} &= \text{contribution of office equipment operation (see the mode of calculation for benchmarked electrical).}
\end{align*}
\end{align*}

Energy rating for period for heating rented space = \frac{C\textsubscript{PL,TH/Period}}{S\textsubscript{PL}}.

For the control panels, it will be desirable for actual consumption to come close to the theoretical consumption level \((C\textsubscript{PL,TH/Period})\) for the same period and to perform the analysis for action and corrections if required.

Consumption for a zone within a rented space can be calculated by one of two means:

- Based on the calculation mode explained below
- Pro rata floor space

**Total building consumption:** \(C\textsubscript{Building,TH/Period} \text{ (kWh)}\)

To the extent that the rented spaces would not necessarily have the same operating conditions (comfort \(T^\circ\) and hours of occupancy), total theoretical building consumption will be equal to the sum of the theoretical consumption of the rented spaces plus consumption for the common areas and other specific parts (technical locations, staff canteen, etc.).

\begin{align*}
C\textsubscript{Building,TH/Period} &= \sum C\textsubscript{PL,TH/Period} + C\textsubscript{PC,TH/Period}
\end{align*}

Energy rating for the period, for heating the building = \frac{C\textsubscript{Building,TH/Period}}{S\textsubscript{Building}}.

It will be desirable for actual consumption to come close to the theoretical consumption level \((C\textsubscript{Building,TH/Period})\) for the same period and to perform the analysis for action and corrections if required.
**Lighting**

**Key factors:**
- Sunlight
- Occupation schedules
- Behavior of occupants

**Consumption for a rented space:** \( L_{PL\cdot TH} \) (kWh)

The parameters corresponding to each rented space should be considered, each time.

\[
L_{BuildingRef}\]: Consumption for the entire building, following the calculations of the current RT.

\( S_{Building} \): Floor space of the building.

\( S_{PL} \): Floor space of the rented space.

\( H_{Ref} \): Benchmark hours occupation/week.

\( H_{Period} \): Number of hours occupation/week.

\[
L_{BuildingRef} = P \times (H_{Ref} \times 52) \quad \text{(annual consumption)}
\]

Where:

\( P \): average power output during occupation times

Benchmark energy rating for lighting the building = \( L_{BuildingRef}/S_{Building} \)

\[
L_{PL\cdot TH/Period} = (S_{PL}/S_{Building}) \times P \times (H_{Period} \times \text{Num weeks in the period})
\]

Energy rating for lighting in the rented spaces = \( L_{PL\cdot TH/Period}/S_{PL} \)

It will be desirable for actual consumption extrapolated for a year to come close to the theoretical consumption level (\( L_{PL\cdot TH/Period} \)) for the same period and to perform the analysis for action and corrections if required.

**Total building consumption:** \( L_{Building\cdot TH/Period} \) (kWh)

\[
L_{Building\cdot TH/Period} = \sum L_{PL\cdot TH/Period} + C_{PC\cdot TH/Period}
\]

Benchmark energy rating for lighting the building = \( L_{BuildingRef}/S_{Building} \).
Production of hot water

Hot water consumption is an average of 5 l/day/occupant (at 50 °C), that is, around 0.22 kWh.

Key factors:
- Number of occupants
- Behavior of occupants

Consumption for a rented space: \( WH_{PL,TH} \) (kWh)

The parameters corresponding to each rented space should be considered, each time.

\[ WH_{BuildingRef} = 0.2 \times (NB_{Building} \times D_{Ref} \times 52) \]  

Where:
0.200 Wh is consumption/person/day for the production of hot water (about 5l/person/day).

Benchmark energy rating for hot water in the building = \( WH_{BuildingRef} / S_{Building} \).

\[ WH_{PL,TH/Period} = 0.20 \times (NB_{PL} \times D_{PL} \times Number\ of\ weeks\ in\ the\ period) \]

If \( NB_{PL} \) is unknown take \( NB_{PL} = S_{PL}/12 \) (one person per 12 m²)

Energy rating for hot water in the rented spaces = \( WH_{PL,TH/Period} / S_{PL} \).

It will be desirable for actual consumption extrapolated for a year to come close to the theoretical consumption level (\( WH_{PL,TH/Period} \)) for the same period and to perform the analysis for action and corrections if required.

Entire building consumption: \( WH_{Building,TH/Period} \) (kWh)

\[ WH_{Building,TH/Period} = \sum WH_{PL,TH/Period} + C_{PC,TH/Period} \]

Benchmark energy rating for hot water in the building = \( WH_{Building,TH/Period} / S_{Building} \).

Ventilation

Key factors:
- Degree days
- Comfortable temperature (behavior)
- Occupation schedules
- Renewal of fresh air

Consumption for a rented space: \( V_{PL,TH} \) (kWh)

The parameters corresponding to each rented space should be considered each time.

\[ V_{BuildingRef} = P \times (HR_{Ref} \times 52) \]  

Where:

- \( V_{BuildingRef} \) Consumption for ventilation of the building, following the calculations of the current RT.
- \( HR_{Ref} \): Benchmark hours ventilation/week.
- \( H_{Period} \): Number of hours ventilation/week.
- \( V_{BuildingRef} \) = \( P \times (HR_{Ref} \times 52) \) (annual consumption)
Where:
P: average power output of the ventilation equipment

Benchmark energy rating for ventilation = \( \frac{V_{\text{BuildingRef}}}{S_{\text{Building}}} \).

\[ V_{\text{PL.TH/Period}} = (\frac{S_{\text{PL}}}{S_{\text{Building}}}) \times P \times (H_{\text{Period}} \times \text{Num weeks in the period}) \]

Energy rating for ventilation = \( \frac{V_{\text{PL.TH/Period}}}{S_{\text{PL}}} \).

It will be desirable for actual consumption extrapolated for a year to come close to the theoretical consumption level (\( V_{\text{PL.TH/Period}} \)) for the same period and to perform the analysis for action and corrections if required.

**Total building consumption:** \( V_{\text{Building.TH/Period}} \) (kWh).

\[ V_{\text{Building.TH/Period}} = \sum V_{\text{PL.TH/Period}} + C_{\text{PC.TH/Period}} \]

Energy rating for the office equipment of the building = \( \frac{V_{\text{Building.TH/Period}}}{S_{\text{Building}}} \).

**Heating system equipment (Pumps, etc.)**

Key factors:

- Degree days
- Comfortable temperature (behavior)
- Occupation schedules

**Consumption for a rented space: \( PP_{\text{PL.TH}} \) (kWh)**

The parameters corresponding to each rented space should be considered each time.

\( PP_{\text{BuildingRef}} \): Consumption for the operation of the heating system equipment, following the calculations of the current regulation.

\( H_{\text{Ref}} \): Benchmark number of hours of operation of the heating equipment per week, in seasons when the heating is operational.

\( H_{\text{Period}} \): Number of hours of operation of the heating equipment per week, in seasons when the heating is operational.

\[ PP_{\text{BuildingRef}} = P \times (H_{\text{Ref}} \times 52) \text{ (annual consumption)} \]

Where:
P: power of the heating equipment.

Benchmark energy rating for heating equipment = \( \frac{PP_{\text{BuildingRef}}}{S_{\text{Building}}} \).

\[ PP_{\text{PL.TH/Period}} = (\frac{S_{\text{PL}}}{S_{\text{Building}}}) \times P \times (H_{\text{Period}} \times \text{Num weeks in the period}) \]

Energy rating for heating equipment = \( \frac{PP_{\text{PL.TH/Period}}}{S_{\text{PL}}} \).

It will be desirable for actual consumption extrapolated for a year to come close to the theoretical consumption level (\( PP_{\text{PL.TH/Period}} \)) for the same period and to perform the analysis for action and corrections if required.

**Total building consumption:** \( WH_{\text{Building.TH/Period}} \) (kWh).

\[ WH_{\text{Building.TH/Period}} = \sum WH_{\text{PL.TH/Period}} + WH_{\text{PC.TH/Period}} \]

Benchmark energy rating for hot water in the building = \( \frac{WH_{\text{Building.TH/Period}}}{S_{\text{Building}}} \).
Office automation

Key factors:

- Occupation schedules
- Number of occupants
- Behavior of occupants

Consumption for a rented space: \( \text{Off}_{\text{PL,TH}} \) (kWh)

The parameters corresponding to each rented space should be considered each time.

- \( \text{NB}_{\text{Building}} \): Number of occupants in the building.
- \( \text{NB}_{\text{PL}} \): Number of occupants in rented space.
- \( H_{\text{Ref}} \): Benchmark hours occupation/week.
- \( H_{\text{Period}} \): Number of hours occupation/week.

\[
\text{Off}_{\text{Building,Ref}} = 0.10 \times (\text{NB}_{\text{Building}} \times H_{\text{Ref}} \times 52) \quad \text{(annual consumption)}
\]

Where: 0.10 is the average power output by office equipment per person.

Benchmark energy rating for office equipment in the building = \( \text{Off}_{\text{Building,Ref}}/S_{\text{Building}} \).

\[
\text{Off}_{\text{PL,TH,Period}} = 0.10 \times (\text{NB}_{\text{PL}} \times H_{\text{Period}} \times \text{Number of weeks in the period})
\]

If \( \text{NB}_{\text{PL}} \) is unknown take \( \text{NB}_{\text{PL}} = S_{\text{PL}}/12 \) (one person per 12 m²)

Energy rating for office equipment in rented space = \( \text{Off}_{\text{PL,TH,Period}}/S_{\text{PL}} \).

It will be desirable for actual consumption extrapolated for a year to come close to the theoretical consumption level (\( \text{Off}_{\text{PL,TH,Period}} \)) for the same period and to perform the analysis for action and corrections if required.

Total building consumption: \( \text{Off}_{\text{Building,TH,Period}} \) (kWh)

\[
\text{Off}_{\text{Building,TH,Period}} = \sum \text{Off}_{\text{PL,TH,Period}}
\]

Energy rating for the office equipment of the building = \( \text{Off}_{\text{Building,TH,Period}}/S_{\text{Building}} \).

Air conditioning

Key factors:

- DD air conditioning
- Comfortable temperature (behavior)
- Occupation schedules
- Renewal of fresh air

Consumption for a rented space: \( \text{AC}_{\text{PL,TH}} \) (kWh)

The parameters corresponding to each rented space should be considered each time.

\( \text{AC}_{\text{Building,Ref}} \): Consumption for the entire building, following the calculations of the current regulation.

If consumption is not calculated as part of the current regulation, environmental and energy consultant must impose it.

- \( S_{\text{Building}} \): Floor space of the building
- \( S_{\text{PL}} \): Floor space of the rented space
- \( H_{\text{Ref}} \): Benchmark hours occupation/week
- \( H_{\text{Period}} \): Number of hours occupation/week
- \( T^\circ_{\text{Ref}} \): Benchmark comfortable temperature during period of occupation: 24 °C
- \( T^\circ_{\text{Period}} \): Actual comfortable temperature during the period under consideration
- \( R^\circ_{\text{Ref}} \): Benchmark reduction in temperature during unoccupied periods (in °C)
- \( R^\circ_{\text{Period}} \): Reduction in temperature during the benchmark period (in °C)
- \( \text{AC}_{\text{Ref}} \): Benchmark comfortable DD, used to calculate \( \text{AC}_{\text{Building,Ref}} \) (baseline \( T^\circ_{\text{Ref}} = 18 ^\circ \)).
The DDAC_{Ref} will be calculated from the average daily outdoor temperature known for the last 3 years and the period of cooling (June, July, August and September).

DDAC_{Ref}: Benchmark reduction DD used to calculate AC_{BuildingRef} (baseline T°_{Ref} + R°_{Ref}).  
AC_{CPeriod}: Comfortable DD temperature for the period under consideration (baseline T°_{CPeriod}).

AC_{RPeriod}: Reduced DD for the period under consideration (baseline T°_{CPeriod} + R°_{RPeriod}).

V_{Ref}: Benchmark volume of renewal of fresh air.

V_{Period}: Volume of renewal of fresh air in the period.

AC_{BuildingRef} = K x [(H_{Ref}/168) x DDAC_{CRef} + ((168 - H_{Ref})/168) x DDAC_{RRef}] + internal contributions.  

Where:
- K is a constant for the building = (24 x G x V)
- G = Coefficient of volume loss
- V = Volume of heated building
- 24 = 24 hours

Benchmark energy rating for heating the building = C_{BuildingRef}/S_{Building}

AC_{PL.TH/Period} = S_{PL}/S_{Building} x [K x [(H_{Period}/168) x DDAC_{CPeriod} + ((168 - H_{Period})/168) x DDAC_{RPeriod}] + (0.34 x H_{Period}/168) x (V_{Period} - V_{Ref}) x DDAC_{CPeriod}] + internal contributions

Where: “0.34” is the volumetric heat capacity of air.

The contribution of sunlight should be mentioned in the initial calculations.

Internal contributions = L_{PL.TH/Period} + CP_{PL.TH/Period} + Off_{PL.TH/Period}.

Where:
- L_{PL.TH/Period} = contribution of lighting (see the calculation mode for lighting benchmark)
- CP_{PL.TH/Period} = contribution of people present = NB_{PL} x 0.070 x H_{Period}

Where:
- NB_{PL}: Number of occupants in rented space.
- 0.070 = Power dissipated by a person in an office (kW)
- If NB_{PL} is unknown take NB_{PL} = S_{PL}/12 (one person per 12 m²)
- Off_{PL.TH/Period} = contribution of office equipment operation (See the mode of calculation for benchmarked aids.)

Energy rating for period for heating rented space = AC_{PL.TH/Period}/S_{PL}

It will be desirable for actual consumption to come close to the theoretical consumption level (AC_{PL.TH/Period}) for the same period and to perform the analysis for action and corrections if required.

Consumption for a zone within a rented space can be calculated by one of two means:
- According to the mode of calculation explained below
- Pro rata floor space

Total building consumption: Off_{Building.TH/Period} (kWh)

To the extent that the rented spaces would not necessarily have the same operating conditions (i.e., comfort T° and hours of occupancy), total theoretical building consumption will be equal to the sum of the theoretical consumption of the rented spaces plus consumption for the common areas and other specific parts (e.g., technical locations, staff canteen, etc.).

AC_{Building.TH/Period} = \sum AC_{PL.TH/Period} + AC_{PC.TH/Period} + ...

Energy rating for the period, for heating the building = AC_{Building.TH/Period}/S_{Building}.

It will be desirable for actual consumption to come close to the theoretical consumption level (AC_{PL.TH/Period}) for the same period and to perform the analysis for action and corrections if required.
Common areas

Using the same calculation methods, a benchmark can be provided for consumption for common areas, which includes

- Lighting of common areas, corridors and parking areas
- External lighting
- Operation of elevators
- Ventilation of parking areas

Note: Calculations should ensure uniformity of kWh units and the conversion of final energy values to primary energy values (EF to EP)

For the analysis, actual consumption, derived from measurements which have been reformatted using the calculation algorithms, should be compared with theoretical consumptions derived from the benchmarks.