KnoholEM

Knowledge-based energy management for public buildings through holistic information modeling and 3D visualization

FP7 – 285229 – Collaborative Project

Knowledge-based energy management for public buildings through holistic information modelling and 3D visualization

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Deliverable 2.1: Building Analysis

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SEVENTH FRAMEWORK PROGRAMME

1.1 Executive Summary

The delivery report DR2.1 “Building Analysis” describes the work performed in work package 2 and refers to the task “perform requirements gathering on demonstration objects to determine typical devices and user interaction paradigms within the demonstration objects. This work feeds into the development of the KnoHolEM taxonomy, functional models and generic ontologies set out in deliverable D1.1.

The report presents relevant data on the building objects with respect to energy consumption, thermal comfort and user behaviour. These include information on the different devices in the building, for example, heating, ventilation and air-conditioning (HVAC) systems, Plumbing facilities, Electricity Generation, Building Management Systems (BMS), sensors and actuators and other building specific devices. For the analysis of these a set of building specific use cases are developed for the application of the KnoHolEM solution.

Next information regarding the analysis of user behaviour and user interactions with the buildings is presented. This includes a state of the art overview of existing methods to capture use activities in buildings for the purpose of reducing energy consumption. From this a methodology is developed and applied to the four building demonstration objects. This methodology results in a set of Unified Modelling Language (UML) activity models which are also presented. From these a list of questionnaires for each building object has been developed to populate the presented activity models with data. Some initial findings from analysis of data gathered through this process are also presented.

From the previous two chapters, a general use case has been developed to be applied to all building objects. This involves the use of the KnoHolEM solution to identify and evaluate fault and energy wasting behaviours in buildings. This use case is presented using the Business Process Modelling Notation (BPMN) and described in detail, with reference to specific scenarios for its application. The report concludes with a summary of the findings from the building analysis and conclusion, and forms part of on-going research into the building usage and analysis as part of development towards the KnoHolEM taxonomy, functional model and ontology.

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2.1 Introduction

The deliverable DR.2.1 refers to the objectives of the milestone "Analysis of building use" and is the culmination of requirements gathering on demonstration objects to determine typical devices and user interaction paradigms within public buildings and spaces. From this, a set of use cases and scenarios are suggested for testing purposes.

Chapter 1 gives a description of the devices in each of the four building objects, B-Digital, the Forum Building, the Haagse Hogeschool (HHS) building and finally the BlueNet building. Each building is described in five parts. First, an overview of the building is given. This includes general information about the building and the occupants. Second, a description of the building facilities is given. This includes information on the different devices in the building, for example, heating, ventilation and air-conditioning (HVAC) systems, Plumbing facilities, Electricity Generation, Building Management Systems (BMS), sensors and actuators and other building specific devices. Third, these devices are analysed with respect to their energy consumption. Fourth, technical considerations which must be considered before any building specific solutions can be applied are considered, which results in the fifth and final section, the development of building specific use cases to manage and reduce energy consumption are presented. This chapter finalizes with a summary and conclusion.

Chapter 2 gives a description of user behaviour and interactions with the building objects. It begins with rationalisation for conducting this research and a review of the state of the art with respect to analysis of user behaviour for reducing building energy consumption. The methodology for analysing building user behaviour is given next, which includes descriptions of the initial building analysis and the first building visits conducted. Collectively, these resulted in the development of generic and building specific user activity models, presented using Unified Modelling Language (UML) Activity diagrams. From these a set of questionnaires were developed to aid in populating the activity models with information on user behaviour. Finally, initial findings using data gathered from these questionnaires are presented, along with a summary and conclusion for the chapter.

Chapter 3 gives a description of a general building use case developed for the building objects which is related to fault and energy wasting activity reporting. Business process modelling notation (BPMN) diagrams are used to capture these use cases. The use cases are related to building occupants and administrators (facility managers, system administrators) developing activity models for users to analyse energy wasting behaviours and to better understand the cause of faults. Some examples scenarios are also briefly explored. Finally, a summary and conclusion to the chapter is given.

Chapter 4 presents the final summary and conclusion to this report.

2.2 Building Descriptions and Devices

2.2.1 Introduction

This section gives a description of each of the four demonstration objects. Each section begins with an introduction and overview of the building. Next the different building facilities are detailed and described. Starting with the Media TIC (B-Digital).

2.2.2 Media TIC (B-Digital)

2.2.2.1 Overview and Occupancy

The Media-TIC building is promoted by the "Consorci de la Zona Franca" and the company 22@Barcelona. The building is located in the 22@Barcelona district at the Carrer Roc Boronat and Carrer Sancho de Ávila, near the Parc Barcelona Media. The building is designed to be a communications hub and meeting point for business and institutions in the world of information and communication technologies (ICTs), as well as for the media and audio-visual sectors. The main purpose of the Media-TIC building is business. To support the communication between institutions and to generate a business environment, the building includes different zones clearly separated (*Figure 1*). The following sections describe each area of the building, starting in the parking space in the basement.

2.2.2.1.1 Parking Space

The parking zone is located in the -1 and -2 floor. In the parking zone the main facilities sources that give services to the building (water facility, district heating, electrical source, etc) are also located. These devices are described in more detail in section 2.2.2.2.

2.2.2.1.2 ICT House and common spaces

This zone represents the first floor of the building (ground and attic). This space is dedicated to the general public and business. Furthermore, in this space different events can be held (launches, presentations, etc). Also, in the attic is located an open space owned by the Barcelona Digital Foundation called the Mezzanine. This space is equipped with ICT hardware and is used to do business and as a meeting point between different companies or project partners.

2.2.2.1.3 Spaces for Entrepreneurs

This building space offers infrastructure, development and financial services for business in the media sector (audio-visual, production and digital effects, etc). In this zone a number of companies are situated, such as:

1. *Admira Digital Networks (Admira DN) /TMB (MouTV section).* This company is focused on developing software solutions related with digital signage (advertisement located in the point of sales or narrow casting). The software offers functionalities and technical capacities to create, advertise, publish and produce (various formats like flash, HD and AVI), and circuit advertisement control. This company shares space with TMB (Barcelona public transport company) to offer the users of public transport advertisement and information related with transport (e.g. schedules, stops, etc). These companies are located on the **2nd floor** of the Media-TIC. Also, these companies are composed of **10-20 people** approximately.
2. *Barcelona Digital Centre Technologic (B-Digital).* This company is an advanced centre of technology specialised in the application of ICT in the fields of healthcare, security, mobility and energy, and food and environment. The mission of this company is to promote the growth of ICT sector and business transformation, to improve the competitiveness of the Catalan economy. B-Digital is located on the **5th floor** of the Media-TIC with **80-90 people** approximately.

2.2.2.1.4 Consorci Levels

The upper part in the building (6th, 7th and 8th floors) is used by the Internet Interdisciplinary Institute (IN3_UOC). The Internet Interdisciplinary Institute (IN3) is a research institute of the Universitat Oberta de Catalunya (UOC). IN3 is specialized in the research of the network society and the knowledge economy, as well as in the study of network technologies and specific areas of software.

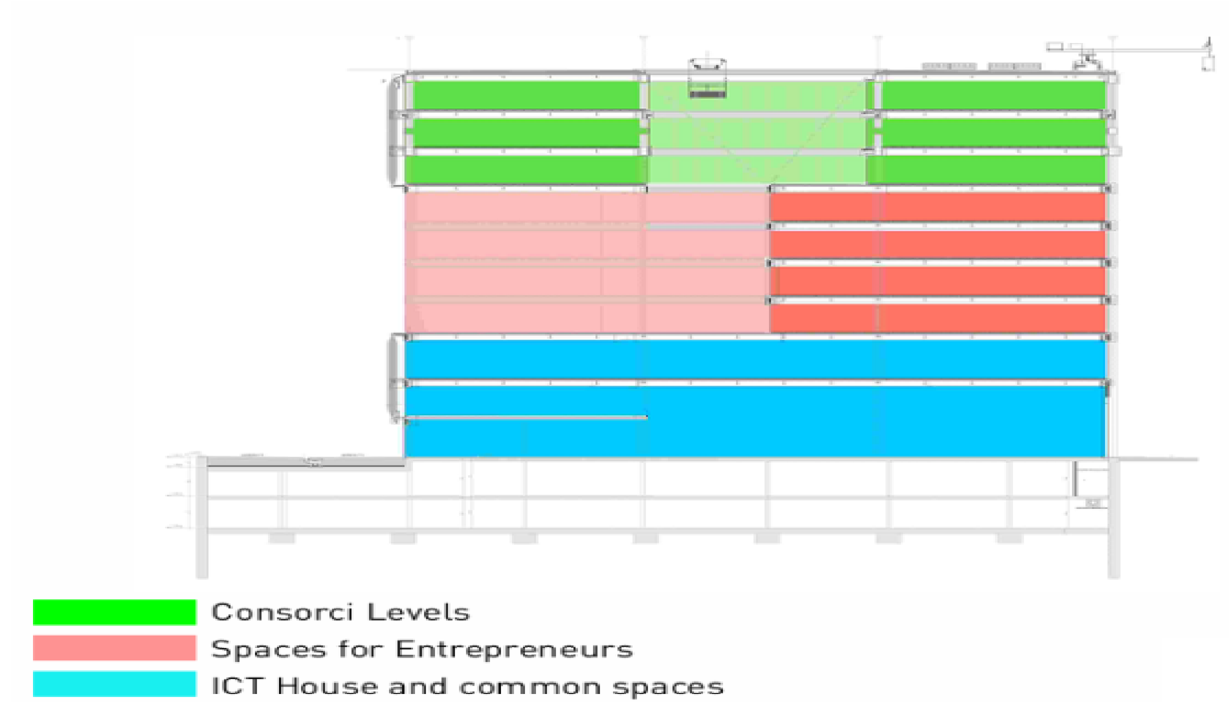


Figure 1: Media-TIC general overview

2.2.2.1.5 Summary of Building Overview and Occupancy

Currently, the entire building has an occupancy level of 65% of total office capacity. The 3rd and 4th floors are currently unoccupied. These un-occupied floors generate some anomalies in the building behaviour (ventilation and humidity system) which will be discussed in more detail in the following sections. The Media-TIC usage time table is between 7.30h to 21h. The maximum level of occupancy is reached at 10-13h when most of employers are at their workstations, and most of the usual occupants are in their respective meetings. The minimum level of occupancy is reached in the earlier hours in the morning (7.30h-10h), the breakfast hour (13.30h-15h) and last hours in the afternoon (19.30h-21h).

2.2.2.2 Building Facilities and Devices

The Media-TIC building is highly complex with respect to building facilities (*Figure 2*). The facilities installed in the building are technologically innovative with systems such as energy saving facilities (ETFE[1] systems), air renewal systems, water facility (efficient use of water) and thermal facility (heating and cooling system installed). Each of these are described in greater detail in the following sections.

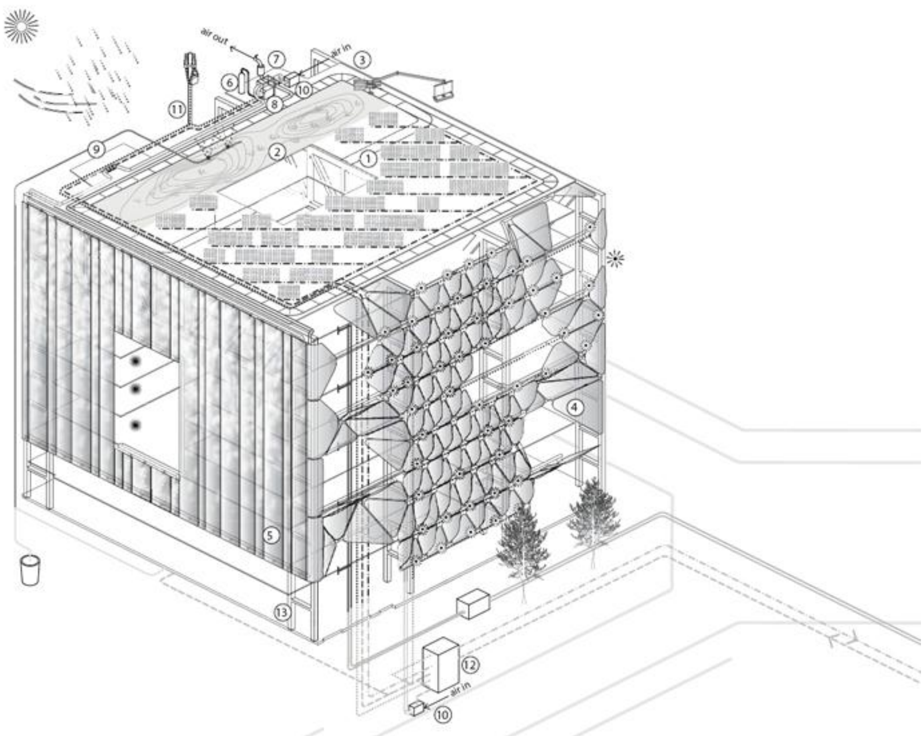


Figure 2: Media-TIC facilities installed

[1] Ethylene TetraFluoroEthylene

In the roof of the building, the systems installed are (see numbers in figure 2):

- *Photovoltaic Modules (Figure 2 - 1).* The photovoltaic modules are focused on generating electricity from the solar incidence in the building roof (solar energy transformation to electrical energy). The modules installed in the building are 140 units of 1.30m^2. These modules are “BP SOLAR mod. BP 3165S” of polycrystalline silicon type (SiN). The installation peak potential is 23.02 kWp (kilowatts-peak). Currently, the photovoltaic modules in the media-TIC building are not in use because the current legislation doesn’t permit self-sufficiency of the building (it is compulsory sell the energy generated to an electrical company that provides to the building the electricity needed).
- *Green Roof (Figure 2 - 2).* A green roof collects rainwater which is then stored in a tank and re-used for sanitation and landscaping.
- *Working platform (Figure 2 - 3)* This is used to clean the facades of the building.
- *Sensors (Figure 2 - 11).* In the roof of the building has been installed sensors to measure the temperature (temperature sensors) and solar radiation (solar radiation sensors). The solar radiation sensors are located in the cardinal cross form (east, north, south and west). The objective of this setup is to measure by each façade the solar radiation in a specific time.

Some of the building facades are provided by an ETFE system. The ETFE system is installed in the facades with high solar incidence throughout the year (taking also into account the season). The ETFE devices installed are two types:

- *ETFE cushions (Figure 2 - 4).* The ETFE cushions main objective is to generate shadows inside the building meanwhile maintain constant the internal temperature and luminosity. These devices use air to inflate or deflate the cushion depending on the solar incidence in the cushion. Each cushion is controlled by a black-box that measures the solar incidence and act depending on it. Furthermore, each cushion has a pneumatic system with three layers. The first layer is transparent, the second (middle) and third layers have a reverse pattern design which, when inflated and joined together, creates shade, or in other words a single opaque layer. When the second and third layers are joined, creating shade, the inflatable section only has one air chamber (Figure 3). Finally, each cushion is independent of the others. Also, the cushions are not connected with a centralized control system (building management system).

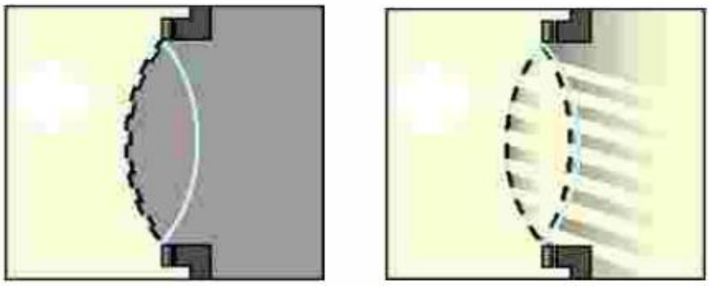


Figure 3: ETFE cushions performance

- *ETFE panel (Figure 2 - 5).* This element has a similar objective to that of the ETFE cushions devices. The difference resides on the process to reduce the solar incidence inside the building. In ETFE panel, when a solar radiation is above a pre-defined threshold, the circuit injects nitrogen inside the membranes generating a fog. In both cases (normal and fog activation) the ETFE is "inflated" (constant pressure) with air. The fog generation is created by specific fog machine (*Figure 2 -* 6). The fog machine sends the nitrogen around a specific circuit (located in the roof) (*Figure 2 -* 9). This device is connected to the building management system that controls the element (including the threshold definition). Currently, this device is not in use because building occupants do not like the impact of the fog on their view.

Following with the building description, each floor also has the following hardware:

- *Sensors.* The sensors installed on each typical floor are focused on measuring:
  - *Temperature (one temperature sensor by each two fan-coils)*. The temperature sensors measure the temperature in a specific floor zone. This sensor is connected with the thermostat located on the floor and is also connected with the building management system (temperature can be controlled by this software and displayed in the thermostat also).
  - *Motion Sensors*. The motion sensors measure the movements on the common zones. These sensors are connected with the luminance system and the building management system. The sensors are active when the pre-defined time tables for the luminance are out of schedule. In this period of time, when a movement is detected in the common zones, the light turn on (connect one/two rows of light each movement detected).
  - *Luminance sensors*. The luminance sensor measures the solar luminance close to the exterior walls. These sensors are located near the windows (in the facades which do not have the ETFE systems installed and solar incidence is an issue). The sensors are configured manually and individually by the facility manager (using pre-defined thresholds). This kind of hardware is connected with the luminance systems. That means, where the solar incidence near the window is beyond a pre-defined threshold, then the light in this zone is turned-off (the sensor controls lights in a distance less than 3m from the window). As they are located inside the building, the level of the blinds will affect the light levels reaching the sensor.
  - *Humidity sensors*. Humidity sensors also are installed in the building floor to measure (in average) the whole building humidity. These sensors are connected with the humidity station located in the facility manager office (ground floor).
  - *Fire sensors*. Also, in the building are installed fire detection sensors (smoke sensors, fire sensors) that measure the possibility of fire in a specific floor or zone.
- *Floor Facilities.* The most relevant facilities installed in each floor are:
  - *Thermal facility.* In each floor are installed fan-coils and ventilation elements to maintain an optimal temperature and also keep the ambient air in optimal conditions. The fan-coils are connected with a control unit (PLC-DG7000). This control unit also is connected with the temperature sensor and the thermostat (*Figure 4*). The control unit is in charge of

collecting the data generated by the sensors, thermostats and also the current fan-coil state. Based on this information, this hardware can change the state of the fan-coil (open/close cold/heat valves). Furthermore, each control unit is connected with the building management system and the facility manager can control and monitor the optimal conditions for every specific floor zone. The ventilation devices (extractors) are constantly collecting dirty air that is evaluated by the central ventilation device located in the -1 ground level. Also the ventilation fan-coils are constantly throwing up clear air (primary air).

- *Lighting Facility.* The lighting facility is focused on provided light for the floor. The light can be turned on or off depending on: 1/ Time Schedule defined by the facility manager; 2/ motion sensors (in case the schedule is out of range); and 3/ luminance sensors (for lights near windows).

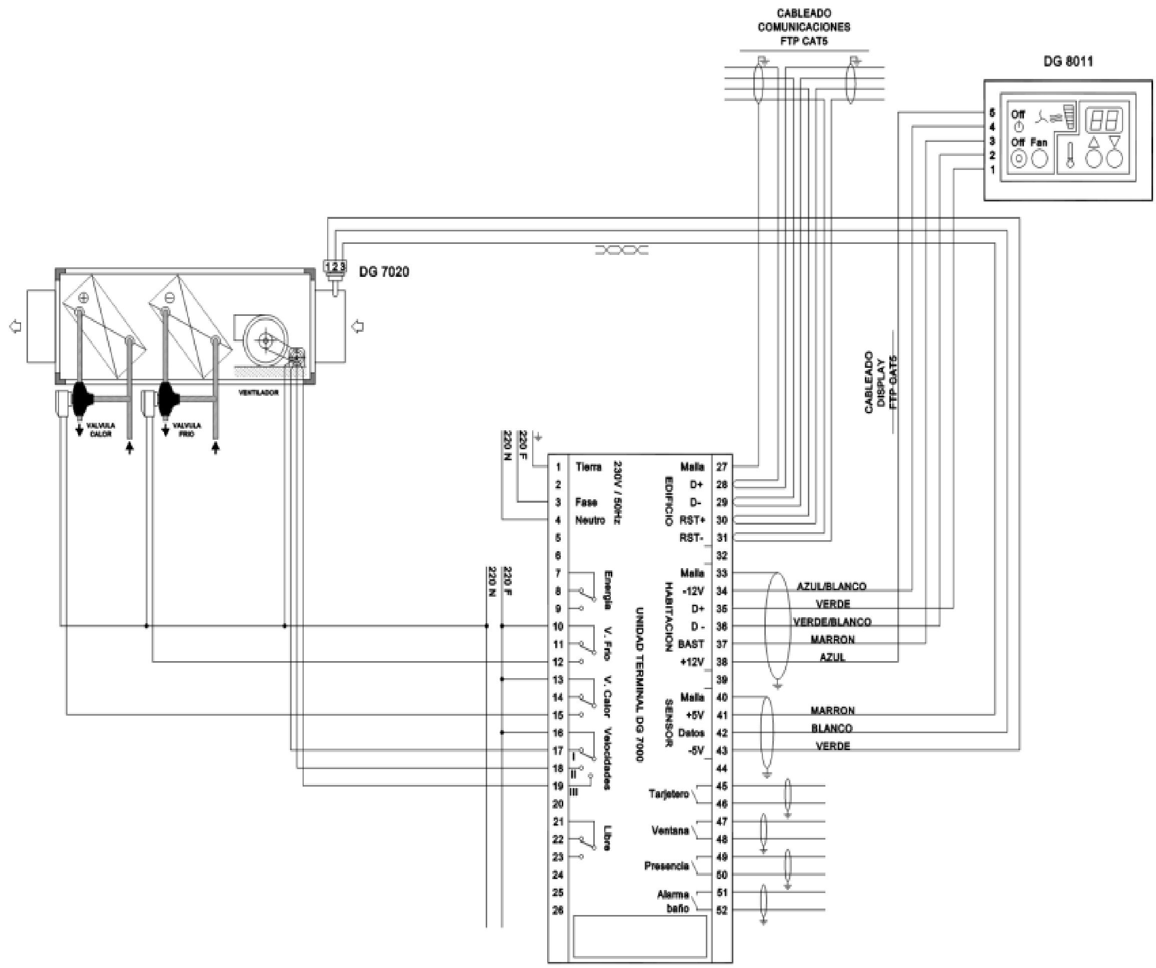


Figure 4: Thermal Floor control (each fan-coils)

In the case of the B-Digital offices, extra sensors and devices beyond those already discussed are also installed (for a list of these see section 0). In the B-Digital offices, sensors have been installed to measure the energy consumption (clean and dirty energy) and electrical pulses generated by B-Digital. Sensors have also been installed to measure humidity, temperature and occupancy (by detecting motion). The sensors installed are connected to a server that collects the information (*Figure 5*).

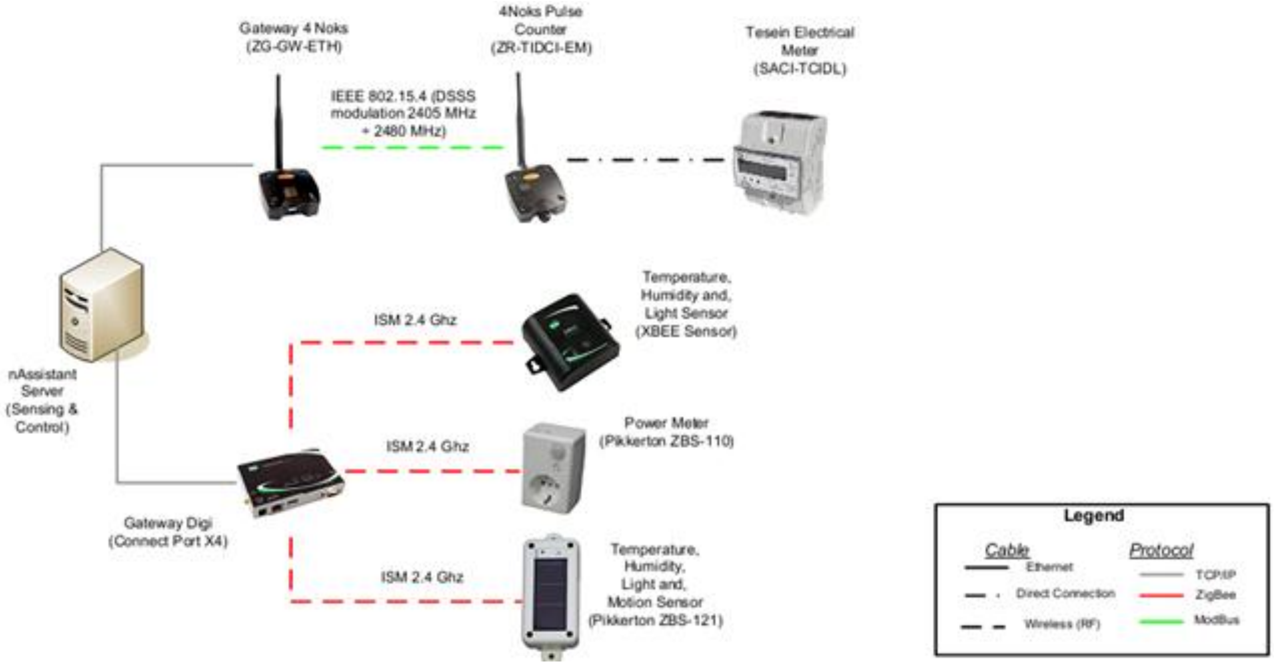


Figure 5: B-Digital sensor infrastructure

Electrical curtains have also been installed in the common room and are controlled by a remote control. To access the B-Digital offices, occupants should insert their thumb into a biometric device that controls whether they can enter or exit the office, although it is possible that occupants can tailgate and enter without inserting their thumb, so this is not a reliable method for tracking occupancy levels within B-Digital.

Continuing with the building description, in the ground floor is located the facility manager office. In this office are situated the systems that control the building performance:

- *Humidity Control System.* This system is focused on control the building humidity. The building humidity is measured by taking an average between all the humidity values provided for all the building floors. As a weakness, in the Media-TIC building exits some floors without occupants. Hence, the average in the building is not aligned with the real behaviour.

- *Building Management System (BMS).* The BMS is software which controls most of the building facilities (*Figure 24*). The software communicates with each facility (Ethernet protocol) to collect information and also control actuations. The facilities controlled by this software are:
    - *Thermal/Ventilation system*. Related with this facility, the system controls the fan-coils located in all the building floors, the district heating facility and the air renewal machine. It is possible to configure time tables and temperature thresholds (change also the thermostat display where the temperature is shown) for each fan-coil.
    - *Lighting/Electrical facility*. The lights which are controlled by the facility manager are related with the common zones and external façade lights. This system can also check the electrical generator state. The facility manager can define the time tables and select the light performance (manual or automatic). In case of automatic behaviour, the motion sensor turns on or off the light.
    - *ETFE facility*. Related to ETFE, the software only can manage the ETFE panel (air+nitrogen). The actions that can be done are to define a threshold and test ETFE performance.
    - *Water facility*. The system monitors pressure group in the landscaping, water circuit and fire extinction (BIES and sprinklers). Furthermore, this software monitors water tank pressure.
    - *Fire Detection facility*. The system also is connected with the fire detection system (NOTIFY system) to show alarms in the screen in case of fire or anomalies in the system.
    - *Sensors devices*. Related with sensor devices, the software also collects information about the external temperature and external solar radiation by façade.

In the lowest part of the Media-TIC building (-1 and -2 floor) the central machines for the facilities are installed. These facilities correspond with:

- *Plumbing Facility.* In the building, the plumbing facility is subdivided into two types of circuits: Sanitary Water Circuit and Waste Water Circuit. The ***Sanitary Water Circuit*** is focused on provide fresh water for the occupant use (e.g sinks). Fresh water is provided by the water companies and distributed through the building through pumps. Also, some fresh water provided is stored in tanks located on the -1 and -2 floor. This water is stored to provide self-sufficiency in the building, in case of emergency (or a cut off in general plumbing circuit). Furthermore, the sanitary water can be provided by filters located in the roof (rainwater). The rainwater is also stored in the tanks. Prior to use rainwater for the building use (e.g WC, landscaping, etc.), the plumbing system starts a water purification process. The purification process consists of chlorinated treatment. The process is done at the low activity building hours (at night) because the purification process needs several hours (4 hours approximately). Once the process has finished, the plumbing facility pushes the water through pumps. The purification process starts when the treatment control system (based on a thermostat) activates a chlorine pump. The chlorine pump generates a chlorine act on the rainwater stored. The tank water level is controlled by a pressure sensor that evaluates the level of water inside the tank. In case of low water level (rainwater or fresh water), the plumbing system activate a pump to provide the necessary fresh water to the water demanded by the building. Finally, to distribute the water throughout MediaTIC, is used a pump system to carry out water from lowest to highest building zones (similar installation as a plumbing house facility).

The ***waste water circuit*** is focused on collecting all the residual water from the building and evacuates it outside using the specific circuit to the waste water. The sewerage water is acquired from drains located in WC, kitchen, thermal devices, etc. The waste water installation is a specific circuit (similar to a house installation) that throws up the water to sewer circuit through gravity and using faecal pumps (ABS type).

- *Thermal Facility.* The temperature in the building is provided by a **district heating and cooling system**[2]. On one hand, the system heats and cools (most part of it) the water using the steam from the incineration of solid urban wastes (debris). As this energy source is not fossil fuel, it results in a reduction of CO2 emission to the atmosphere. The rest of the water cooling is done using energy efficient refrigerators that use sea water. The Media-TIC uses the hot and cool water to maintain thermal conditions in the building. In the building, the district heating installation is formed by two income pipes (heat/cool water) and other two outcome pipes (heat/cool water). The energy consumed by the building is calculated measuring the difference between the income energy (cool/heat water) and the outcome energy (cool/heat water). In winter the difference is between incoming heat water and outgoing cool water and the inverse in summer. Both energy (income and outcome), is measured in m^3 and kW. Once the energy demanded is received (heat/cool water), the building distributes it using the thermal installation (pipes) to send the water to each fan-coil located in the floors (as normal thermal installation).
- *Ventilation facility.* This system is focused on renewing the air of the building. First of all, the building has no windows which can be opened or close. For this reason, a ventilation system is needed. The ventilation facility monitors and controls the internal air quality. To control the air quality, the system collects the air used in the building (extractors) and measures its quality. If the quality is low (dirty air) the system tries to purify it. If the purified air hasn't reached an optimal quality then the ventilation system funnels the dirty air outside and collects new air, also from the outside. The purified (or externally collected) air is sent to the ventilation fan-coils to feed air into the building. As a weakness of the system, the air quality is measured using the whole air recollected in the building. This method is not optimal because some floors of the building are empty.
- *Electrical Generator.* The electrical generator is focused on provide electrical energy in case of emergency (or electrical cut off). The electrical generator is designed to maintain the common zones with energy (corridors, emergency lights, one elevator and fire system, etc). Furthermore, this device uses hardware (relay that is activated in case of energy) to activate the emergency electrical energy.

[2] DistriClima Network is a district heating network installed all over the city of Barcelona : http://www.redesurbanascaloryfrio.com/index.php?option=com_content&view=article&id=10&Itemid=28&lang=en

2.2.2.3 Analysis of Building Devices

The Media-TIC building manages energy efficiently. Before its construction, a number of energy tests were conducted. The tests that have been done in the building are detailed in Appendix 2.7. Summarizing this document, the tests done in the building are:

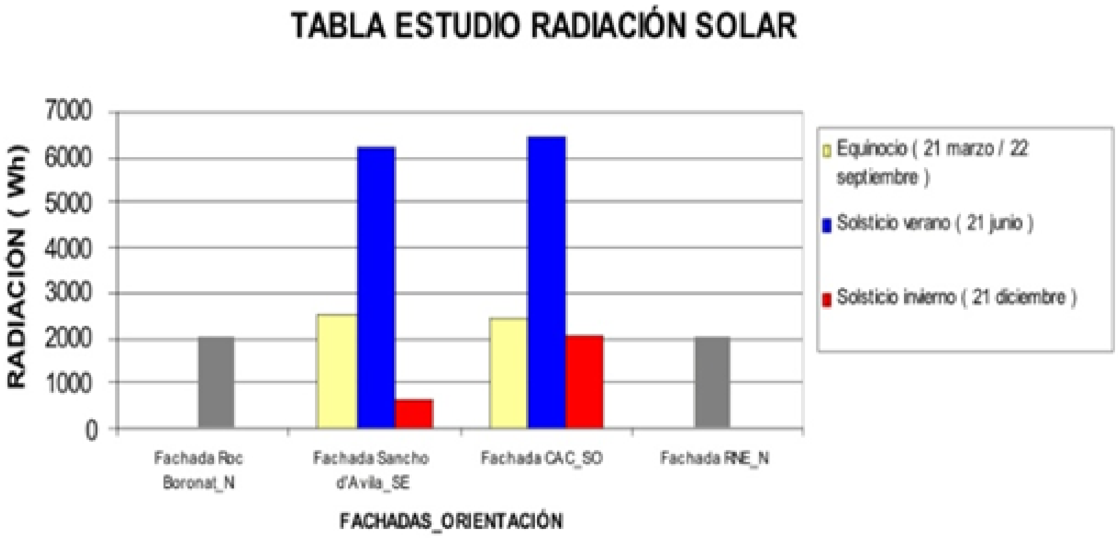


Figure 6: Shade Study conclusion

- *Shade Study.* This study allows the identification of the critical sun exposed facades, an analysis of the number of hours of sunlight on the various facades, with a shade study being made of the actual building and external buildings. The conclusion of this study (*Figure 6*) reveals that the facades with high sunlight exposure are "*Sancho d'Avila*" (SE[3]) and "*CAC*" (SW) in the winter (around *800-2000 Wh*[4]) and summer (around *6000 Wh*) seasons.
- *Energy use simulations.* An energy use simulation was carried out on the entire building (software DESIGN BUILDER 1.4), taken into account:
  - Basic Building. This refers to the evaluation of the building without considering the incorporation of ETFE on the SE and SW facades but by also complying with the building code; i.e., without taking the ETFE facades into account. As a consequence to the analysis and parallel to the architectural solution, passive protection elements are now incorporated (ETFE systems) to provide a solution to the excessive radiation on the SE and SW facades.
  - Heating demand calculation-dynamic method. These are calculated for all months of the year when the building requires heating, and with the calculations of hours per day (8.00 am – 6 pm). As a conclusion, the days of greatest demand coincide with the month of January. A closer inspection has also been taken to detect the week and specific day of

3 S= South; N= North; E=East; W=West
4 Watts per hour.

most unfavourable conditions. The most critical day has been identified as 18th of January in this case, which lead to a more detailed study of that day to determine power required.

- The greatest demand for cooling is due to radiation on the glass (43%). Yearly heating demand represents a low value with regard to total energy use. Yearly demand for cooling is much higher than for heating (*Figure 7*).

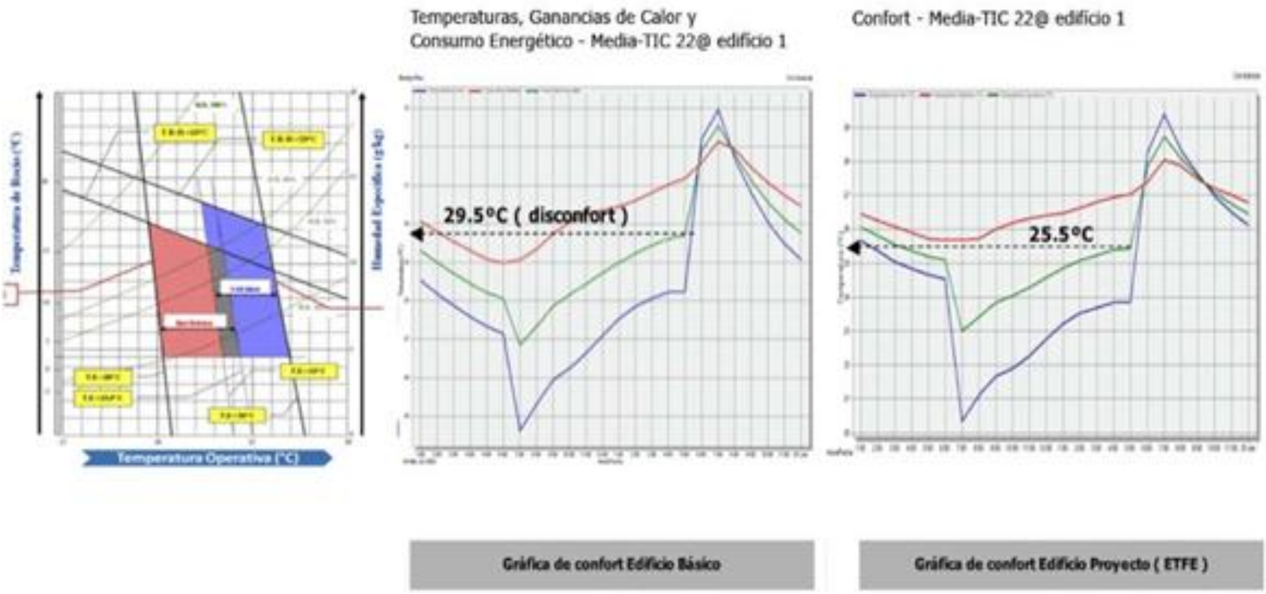
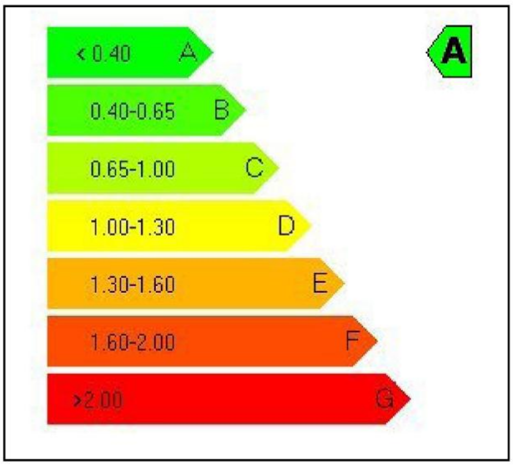


Figure 7: Cooling MediaTIC

- Building energy balance. This study compares the energy behaviour of the Media-TIC building, taking into consideration the inclusion or not of ETFE systems. This study reveals the necessity of ETFE in the most unfavourable facades. Also, the study reveals that the ETFE negatively affects the contribution of solar energy in winter as it increases the solar protection factor. Relating to the building heating and cooling, the incorporation of ETFE gives an irrelevant increase of energy demand in winter and potential benefit in a reduction of energy over the rest of the year. Furthermore, related with the energy used by the facilities over the year, the study reveals a good overall design (using the current systems installed).

- *Energy status (CALENER certification).* This certification probes that the building has a good energetic values and is catalogued as an energy efficient structure (A) (*Figure 8*).



Concepto	Edif. Obj.	Edif. Ref.
Energía Final (kWh/(m²año))	113.2	399.0
Emisiones (kg CO2/(m²año))	**66.1**	**167.0**

Figure 8: CALENER certification

Apart from these studies, the current building behaviour and the energy management can be improved solving the following facilities weakness:

- *Ventilation facility.* The air quality is measured taking into account the air collected in the entire building. This type of measurement is naive because some floors in the building are empty.
- *Humidity system.* Like the ventilation system, the humidity level is calculated collecting the information of humidity sensors of the entire building and calculating an average between it. This measurement process is not adequate to the reality because some floors in the building are empty.

2.2.2.4 Technical Considerations Moving Forward

The next steps in the KnoHolEM project are focused on finding a better way to solve the energy weakness discovered during the building analysis. In the KnoHolEM project data can be collected on the building to discover new efficient energy paths. However, the normal operation of the building cannot be affected and energy costs of the building cannot be increased. Due to the buildings low level of occupancy, the B-Digital offices are a valuable subset of the building. The action derived from the KnoHolEM project can be applied to the B-Digital office and then represent most part of building behaviour.

2.2.2.5 Building Specific Use Case

As showed in the facilities description, the B-Digital office has some new facilities installed. Also, B-Digital disposes a sensor network that measures the energy consumed on the floor. The actions to take into account in the KnoHolEM next steps are:

- *Analyse the improvement of the management policies implemented in MediaTIC* through the use of KnoHolEM recommendations in the B-Digital office through analysis of devices, sensors and building occupant behaviours. B-Digital office has the same weakness as the building has (ventilation and humidity system). For this reason, the improvements in B-Digital facilities will probably permit further improvements to the entire building.

- *Access to the MeditaTIC information.* Building information is needed to define building behaviour. Hence building behaviour supports the energy improvements generation. Furthermore, building information can be merged with the information collected in the B-Digital office (through the use of a developed sensor network) and then obtain new efficient energy paths.
- *Evaluate the possibility to measure parameters not controlled until now*. For example, B-Digital can try to measure CO2 levels because the building analysis revels that CO2 level in the building is high.

2.2.3 Forum Building (SmartHomes & WSZ)

2.2.3.1 Building Overview

The Forum building is a multifunctional building, with both residential and public zones. The main intended purpose of the building is to be an assisted living and retirement home. It has 22 apartments for assisted living on the second floor. It also has a closed area for special nursing cases on the first floor. While the main purpose of this building is to be a retirement home, it also has some facilities opened to the public giving its elderly inhabitants the opportunity to be in contact with people of all ages from outside. On the ground floor, there is restaurant with a kitchen, a large atrium, offices (administration), and bar with billiard room and a private space, all opened also to the public (Appendix 2.7.2.1). The ground floor also includes a physiotherapy section, a day care area and a hairdresser (for the inhabitants, as well as for people from outside). In the basement, there is also a garage.

By not being exclusively a retirement home, the building has a unique energy consumption pattern which is partly predictable, as it is based on a daily routine. Energy consumption in the apartments (gas and electricity) is individually metered and will not be considered within the scope of KnoHolEm, as this is a residential area and under the authority of the resident. The public area ends on the corridor in front of the entrance to these apartments. The closed area is for residents with highly specialised needs, like permanent ventilation, heating/cooling and illumination. Therefore, this area will not be taken into consideration either, as energy savings in such a highly complex use case requiring medical insights and so, is not an intended part of the project solution.

2.2.3.2 Building Facilities and Devices

The Forum has various facilities, such as heating, ventilation, and air conditioning (HVAC), sun shading devices and automatic windows (open/close). There exists a centralized Building Control System (BCS), called Priva[5] which manages the HVAC, however, no building bus system is installed. The communication with these devices takes place through the Priva-specific communication protocol; the devices are directly wired to the controlling devices.

2.2.3.2.1 Priva

The Priva BCS system is composed of two base modules (PLC type) connected to input/output extension modules, installed inside wall-panels in two different basement rooms. All base

[5] http://www.priva.ca/media/109974/640453gb_compri_hx_product_description.pdf

modules communicate with each other using serial Md P4 B RS485 interface (other specifications on the protocol used for this communication are still under investigation). A TCP/IP communication system is not implemented yet, but will be implemented in near future. A modem for public switched telephone network is not currently available. Extension modules are connected to sensors and actuators with single-cable one-to-one communication. The system control has two states (ON/OFF), so actuators which could control light dimming may not be possible.

2.2.3.2.2 Shading

The solar sunshades on the sides of the building (East, South and West), are automatically operated based on the data from a weather station. This measures wind and rain, as well as sun radiation on each of the mentioned sides of the building. At pre-set levels of solar radiation, the shades descend and respectively ascend. The position of the sun shadings can be adjusted manually from each room by overriding the position given by the steering system. Wind of a certain intensity and/or rain will override all manual settings and raise the sun shading, in order to protect these from being damaged or getting wet. The sunshades are controlled by a Somfy[6] central automation unit (wall mounted in one of the two basement rooms): this system is based on three weather stations (for east, south and west), each one composed by three sensors (wind, relative humidity, light) mounted on the building roof. The system communicates directly with all devices (including the weather station sensors). It also stores the weather station readings, as well as the performed action (lower/raise shades). Currently no information is available about protocols used for communications between sensors and central unit. The BCS and Somfy system are totally independent and do not exchange data or communications.

The possibility of bi-directionally connecting this system to the BCS will be examined, for reading and archiving the stored weather data, as well as for changing the system's settings or controlling the shades. For this, it also must be investigated if the state of each individual shade can be enquired by the system (due to the possibility of manual settings), and the solar shades can be accessed individually. There are considerations to add solar shading devices also on the roof of the atrium for extra shading during hot summer days. The shades would be connected to the existing coordination device. However, this measure cannot be financed through KnoHolEM.

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6 http://www.somfy.com/nordic/index.cfm?page=/nordic/home/products/interior_blinds/automation&language=EN-IS

2.2.3.2.3 Windows for Ventilation

Installed in the roof of the atrium these automatically open/close, depending on the readings of a second weather station (which measures wind and rain), and the readings of temperature sensors at the top of the atrium (in the interior). The value of the interior temperature is the threshold for opening or closing the windows, as soon as it reaches given thresholds; the windows are opened or closed. However, wind and rain override temperature and determine the automatic closure of all the windows or prevent the windows from opening (in case of strong wind or rain). Also the fire detection can overrule the setting from the windows.

The coordination is performed by another device in the cellar, to which the weather station, sensors and the windows actuators are directly connected. Weather station data is stored by the coordination system, too. The weather station is independent from the other one. It must be examined if it is possible to bidirectional connect this system to the BCS, for reading and archiving the stored weather data, as well as change the system’s settings or control the roof windows through the BCS.

2.2.3.2.4 HVAC Systems

The building has forced ventilation systems with cooling capacity that uses permanently 100% fresh air from outside. Heating is performed by gas boilers. Each system has a heat exchanger (Twin Coil, a coil in the extracted air absorbs the heat and transports the heat to a coil in the fresh air). The transport medium is water. The efficiency from this heat recovery system is 50%. No used air recycling is presently possible. Rooms are permanently ventilated, even if unoccupied. Fresh air is pumped in through injector nozzles, while consumed air is absorbed by extrusion dies. (Due to legal constraints (ref), permanent ventilation level is required). The ventilation systems levels are timer-controlled, according to a daily/weekly schedule. It is not possible to adjust the level of ventilation per room and per demand, this is possible only globally. There are two ventilation systems enhanced with gas boilers installed in the building, positioned in the cellar (on the same level with the garage) that perform the ventilation and cooling of the office space, the atrium, the restaurant and the corridors. Air inlet and outlet are positioned on the side wall of the building.

The closed area has a ventilation system that is connected to the offices and Atrium .The day-care centre, physiotherapy and the hair dresser have separate ventilation systems. With the exception of the closed area, these do not have a cooling capacity, nor do they have an extra boiler for heating (only exhaust air heat exchanger). The devices are also installed in the cellar and have air inlet and outlet also on the side wall. Gas boilers for heating are installed in the respective facilities (except the closed area). The housing area also has a forced individual ventilation systems with integrated forced cooling capacity (only with outside air). This forced ventilation system has a supplementary handicap in summertime, due to the air intake that is very close to the tar-covered roof (the inlet is supplementary coated with tar), that leads to absorbed air of temperature of up to 60° in hot days – accordingly, there is supplementary need for cooling. However, this part of the building is not to be taken into consideration by the KnoHolEM solution.

The ventilation and cooling systems are controlled by the BCS and each system is directly connected it. Through the BCS, the schedule, temperature and ventilation speed (2 stages) can be controlled. The gas boilers have a pre-set heating water temperature and operate demand-oriented. They are not connected to the BCS and must be switched of manually (in summer time). Heating is performed by radiators (hot-water circuit, based on the gas boilers). The day-care area has floor heating, controlled by a temperature sensors installed in the day-care area (This sensor is directly connected to the valve of the floor heating (the floor heating is separated in 2 circuits); it cannot be accessed or controlled by the BCS). The day-care area has separated gas boiler and an individual ventilation system that are controlled by the BCS (e.g., the heating level can be set hereby). Sunscreens can be manual overruled by the users.

The atrium area has extra floor heating, controlled by a temperature sensor installed in the atrium. This sensor is directly connected to the valve of the floor heating and cannot be accessed or controlled by the BCS. In winter, due to low temperature of the air pumped into the building and low heat exchange efficiency, radiator heating is permanently required. Each radiator is controlled by a manually settable thermostat, and the automatic building gas boilers are controlled by the BCS (e.g., the heating level can be set hereby).

The kitchen has supplementary ventilation systems, for the stoves and furnaces, as well as for dishwasher. This ventilation system does not have a heat/cold exchanger and extracts a lot of heated/cooled air from the building. The back door has to be opened during lunch time as a result of air current (from the ventilation system) disturbing some of the elderly guests of the restaurant (in front of the kitchen). This results in a higher heating demand in winter time. In summer the fresh air is very hot and must permanently be cooled (due to low cold air exchange rate) before being pumped into the facilities. Cooling capacity has proven itself to be insufficient for some of the facilities and as a result, the offices on the South side require extra cooling in summer. This is achieved through the use of additional air conditioning. The closed area also needs supplementary cooling and is provided by extra air conditioning devices.

The physiotherapy, the day care centre, and the hair dresser have extra air conditioning for summer time (as this is not provided by the installed ventilation devices). This is done by multi-split air conditioning devices, installed in the basement (the garage) of the building. These devices have temperature sensors on the inside (in the rooms where the splits are installed) and on the corresponding outside walls, the South side supplementary has humidity sensors installed in the rooms. The temperature can be adjusted in each room from a control panel, however, the air conditioning devices are not connected to the BCS (closed system) and must be switched on and off manually, accordingly. It must be mentioned that physiotherapy and the hairdresser requires very little heating and mainly cooling in the warm season.

Some windows (e.g. in the office area, the bar) and glass doors at the physiotherapy and the hairdresser can be opened, only manually. There are only housebreaker protections sensors installed that do not communicate with the building control system (and cannot be accessed due to security reasons). The bar/billiard, the hairdresser, the physiotherapy and the day care centre have their own gas boiler-based radiator heating with a thermostat with temperature sensor on the inside and the outside. Supplementary, the radiators have valves, to set up the temperature distribution in the premises.

The ventilation system as is could be improved by simple modification of the air duct (for the housing ventilation) and upgrading of the ventilation systems with an air recycling unit (with CO2-sensors). The same, the ventilation system of the kitchen could also be improved, e.g. by introducing a heat exchanger (for heat in winter time) and supplementary powerful air inlet nozzles inside the kitchen to balance the air absorption from the restaurant and atrium. However, these measures (that would improve the efficiency of HVAC substantially) cannot be financed by KnoHolEM. A simpler solution would be to automatically open the roof windows (when the weather conditions permit it) while the kitchen ventilation is on. A possible improvement can be made by having actuator-based radiator regulation, in connection e.g. with movement/presence sensors.

2.2.3.2.5 *Presence Sensors*

Currently the only presence sensors in the building are in the doorways. Where installed these control the opening and closing of doors. The control mechanism is connected to the building control system, as the doors can be operated only during a given time interval. These times are adjustable through the BCS. The state of the doors is also visible to the BCS and protocolled. The access doors to areas are opened by RFID[7] chips. This is also readable through the BCS (although the ID of the RFID chip is hidden to ensure privacy).

Lights are always on in the corridors, the atrium, the stair case and the toilets. This is a huge waste of energy. Movement and presence sensors, extended by light intensity meters connected with intelligent light switches can lead to an improvement on illumination energy consumption (the emergency lighting will however be permanently switched on). The threshold for switching on the lights can be increased, to adapt to the demands of elderly people. Inside the toilets, lights could be dimmed, but not entirely switched off. Although it must be verified if this is permitted by house policy, considering the elderly people who are using these facilities. These sensors can also be interlinked with the intelligent heating system described above.

2.2.3.2.6 *Parking Lot Devices*

The parking lot in the basement of the building has movement and CO2 sensors installed. Illumination is controlled by movement (except the emergency lighting that is permanently switched on due to legal constraints[8]). The parking lot has a forced ventilation exhaust system, partly controlled by the CO2 sensors (some ventilators must also be permanently switched on, again due to legal constraints[9]). Illumination and ventilation is connected to the building control system and the state is protocolled. This does not leave any space for improvement; however, the collected data can be relevant for a more detailed analysis of the building.

2.2.3.3 Analysis of Building Devices

There is great potential in the Forum building to improve its energy consumption. The analysis of the building has shown that the forced ventilation system leads to energy losses. The same, electricity is wasted through illumination that is permanently switched on. Several measures are possible, but these require building operations or renewing of building equipment. However, such measures cannot be part of KnoHolEM. The lack of a building bus is a supplementary

[7] http://en.wikipedia.org/wiki/Radio-frequency_identification
[8] Bouwbesluit 2003-BWBR0012727, NEN 1890, NEN 1891 (BB art 180)
[9] Bouwbesluit 2003-BWBR0012727, NEN 2443, NEN 1087

impediment; its installation would also cause costs that cannot be financed through KnoHolEM. Due to the lack of a wire-based building bus, a wireless solution is required, which must be compulsory connectable to the BCS. It is to be investigated which is the optimal solution for this. Still, there exists the possibility of intelligent energy management, with respect to heating and illumination.

While illumination savings can be solved with presence/movement sensors, the pre-heating (eventually also pre-cooling) of the facility must also be taken into consideration: heating/cooling of the facility the moment when presence is detected will lead only to discomfort, the room will be too cold/hot for a part of the duration of its utilization. Actuators are to be installed as remote controlled light switches and electro valves for the radiators. Also, several sensors are to be taken into consideration: movement/presence sensors combined with light intensity meters, room temperature meters as well as CO2-level meters. Electricity consumption of specific electric devices can also be supplementary measured with wireless power consumption measuring devices. A special case is the bar/billiard/private/day care room that has its own heating device. Hereby, the present thermostat must be replaced with a remote controllable switch, which shall permit remote regulation of room temperature.

The data from these newly installed sensors, as well as the data from the weather stations, the door sensors and from the state of the sun shading devices shall be collected over a longer period (different months of the year). Combining presence/movement sensors data with data from the CO2 meters and temperature variations can indicate the degree of occupancy of a room or facility. Collected over a longer period and analysed through data mining, it can give hints about the utilization of the room and accordingly determine different thresholds for temperature levels to be sustained during different times of day. This way, considerable savings can be achieved through optimised shading strategies (Wienold, Frontini et al. ; Wienold 2007; Ochoa, Aries et al. 2011).

In addition, the energy consumption data of different devices in the aforementioned rooms can give hints to the activity performed in that respective facility. For this, the evaluation of questionnaires about the performed activities of different user groups in that facility shall be combined with the data mining on the entirety of collected data (see Chapter 2). This will lead to a more precise prediction of the usage of the facilities and accordingly to a more accurate prediction of the required state of the facility. A supplementary possibility of saving cooling energy in summer time is to open the roof windows overnight (when the weather conditions permit it), in order to cool the building through natural ventilation.

2.2.3.4 Technical Considerations Moving Forward

A number of technical questions identified in this report must be solved. To begin, the establishment of an appropriate communication basis is required, e.g. a wireless building or bus system. These could be provided by either a system based on ZigBee or BACnet, which are described briefly next.

2.2.3.4.1 Zigbee

ZigBee provides for high data throughput in wireless applications where the duration of communication and amount of data can be low. This makes ZigBee ideal for home, business, and industrial automation where control devices and sensors are commonly used. Such devices operate at low power levels, and this, in conjunction with their low duty cycle (typically 0.1 percent or less), translates into long battery life. Applications well suited to ZigBee include heating, ventilation, air conditioning (HVAC), lighting systems, intrusion detection, fire sensing and the detection and notification of unusual occurrences. Due to its low duty cycle, ZigBee devices can sustain themselves on a small battery for many months, or even years, making them ideal for install-and-forget purposes, such as most small household systems. Predictions of ZigBee installation for the future, most based on the explosive use of ZigBee in automated household tasks in China, look to a near future when upwards of 60 ZigBee devices may be found in an average American home, all communicating with one another freely and regulating common tasks seamlessly. ZigBee is compatible with most topologies including peer-to-peer, star network, and mesh networks, and can handle up to 255 devices in a single wireless personal area network (WPAN).

2.2.3.4.2 BACnet

BACnet is a data communication protocol for Building Automation and Control Networks, developed to standardize communication between building automation devices and systems from different manufacturers. With BACnet it is possible to control products made by different manufacturers to be integrated into a single, uniform system. It is designed to allow HVAC/R, lighting, fire, access and security devices to interoperate. Owners can select the best technologies and services available, with the investment protection of being able to competitively expand current systems, without being “locked in” or having to replace them in the event that an original supplier loses favour. BACnet specifies six network types to accommodate different project and system requirements. These networks use widely accepted LAN standards, including Ethernet (IEEE 802.3/ISO 8802-3), ARCNET (ANSI/ATA 878.1), master slave/token passing (MS/TP, a twisted-pair RS-485 network created by BACnet), point-to-point (PTP, also created by BACnet) and LonTalk. The sixth option, BACnet/IP, was added later on to allow BACnet messages to be transported across the Internet and other IP-based wide area networks.

2.2.3.4.3 Extend Priva BCS

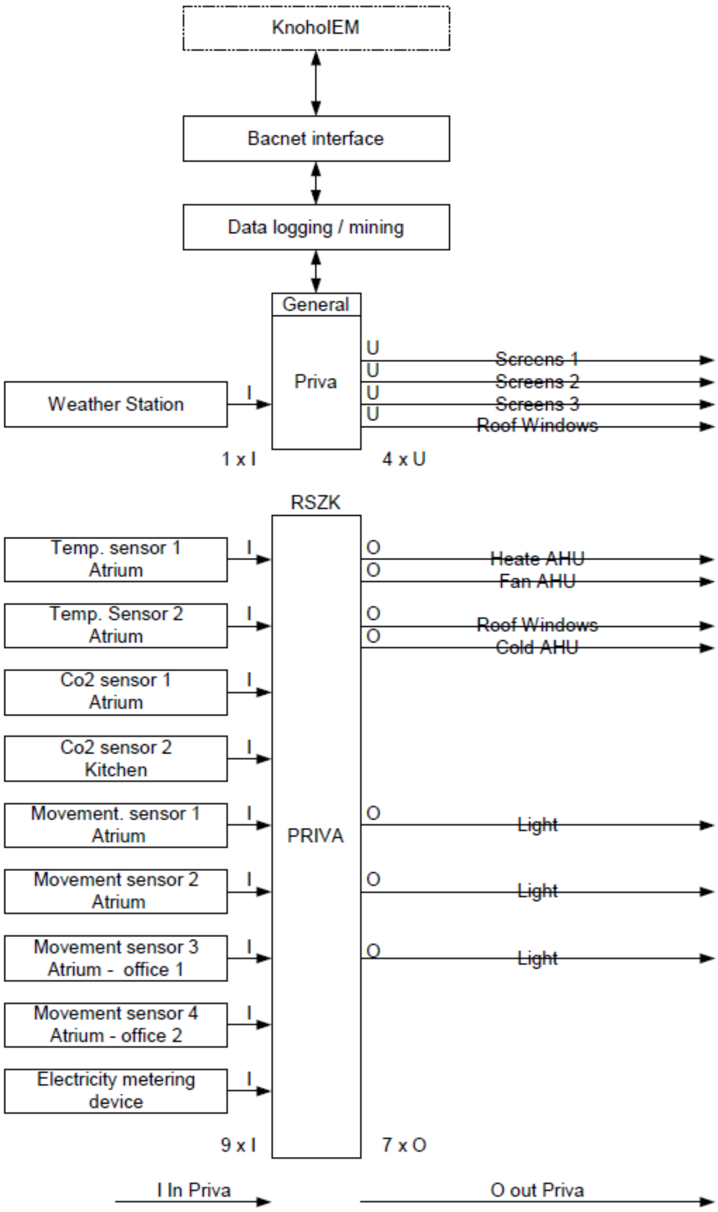


Figure 9 Extending Priva BCS to meet KnoHolEM requirements

The existing Priva BCS system will be extended with additional hardware and software to meet the requirements of the KnohoIEM project (Figure 9). A BACnet router and a History package will be installed to connect the BCS to the KnohoIEM solution. The History package is needed to store data from the building. Through the BACnet router, KnohoIEM can change settings from the Priva system. Also it is possible to get real-time / stored data from the connected sensors (movement, Co2, temperature, energy, weather).

2.2.3.4.4 Data Storage

Data storage is provided by Plugwise[10]. The Pluswise system (which uses Zigbee as their standard transmission protocol) will only be installed in one or two rooms due to the limitations of current available hardware. Exporting data from Plugwise is currently a manual process to convert the data into excel. This could be automated if required.

2.2.3.5 Building Specific Use Cases

Now that the technological considerations have been addressed, this section addresses the development of building specific use case. This begins by identifying some representative facilities: e.g., the atrium/kitchen and the day care ore bar/billiard/private room, the hair-dresser saloon and the physiotherapy facility. Next, it shall be determined what sensors/actuators and energy meters are required, and how they are to be installed. Sensors and meters are installed and connected to a control pc (with data storage facility). Then, data collection starts, combined with usage questionnaires for the different user groups that utilize these facilities, followed by data mining-based analysis. This will determine the optimal energy usage strategy for these facilities that will be later implemented in ontology rules.

2.2.3.5.1 Lunet Day care

A number of issues have been identified in the day-care centre. To begin, there is a heating problem due to close proximity with the boiler-room. The boiler heats up the day-care, making the temperature too high in some areas. By using the data from a range of types of sensors (presence, CO2, temperature, gas and electricity metering, the KnohoIEM system will analyse, predict, and adjust the settings from the Building Management System (BMS) to save energy. Sensors are to be installed in the day care centre to analyse the number of people going in and out to determine the relationship between occupancy and energy consumption. The solution will look at control groups of lights dependant on occupancy and also control blinds to control heating (although this requires the room to be empty so as to not disturb patients). Occupancy data will

[10] http://www.plugwise.com

also be used in conjunction with data from the weather station to control the heating and ventilation and the floor heating system.

Hardware to be installed - 4 movement sensors, 2 on the main door (in and out), and 1 on each side entrance (2 doors). 2 Co2 sensors. 3 temperature sensors. 1 energy sensor (gas). 1 energy sensor electricity (Figure 10).

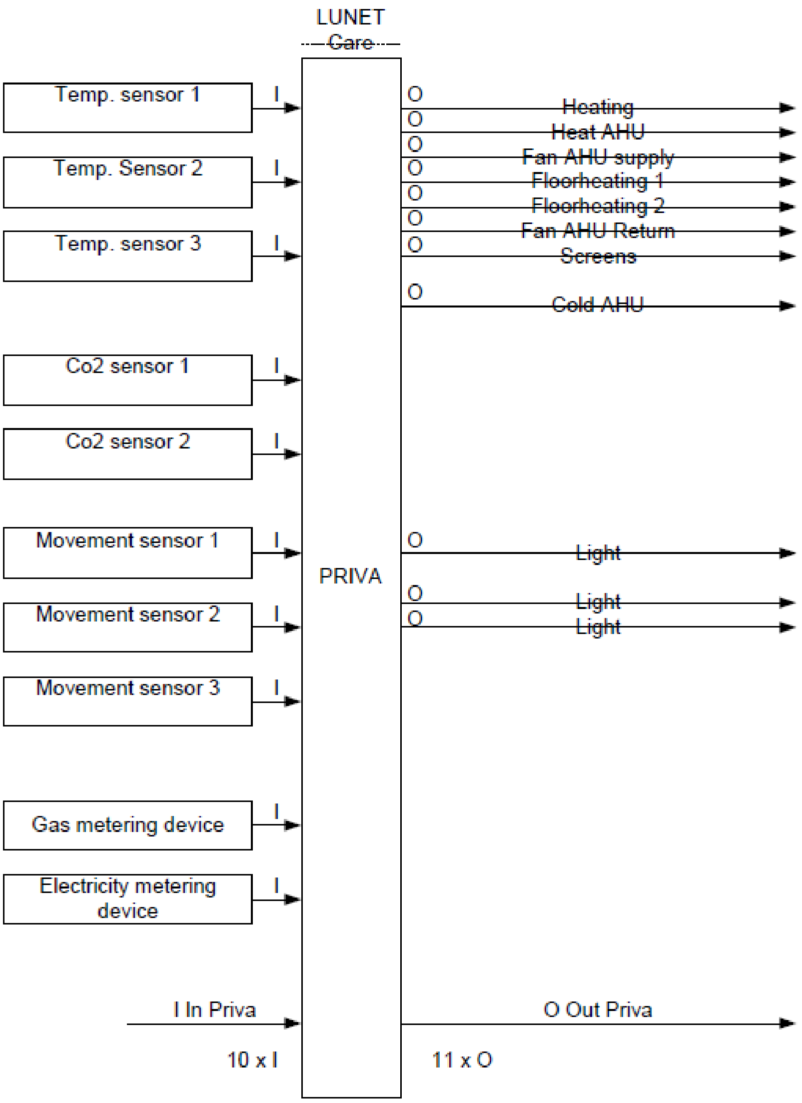


Figure 10 Overview: Priva and additional Sensors (Lubnet)

2.2.3.5.2 Atrium/kitchen

Due to the high temperature in the atrium in summer it is suggested to install sensors to enable use of the Air Handling Unit (AHU) from the kitchen to cool the atrium at night with outside air. This will be done in conjunction with the roof windows, which can be opened to let the hot air out.

This system requires the data provided by the weather station to determine if it is raining or the wind speed is too high for the windows to be open. CO2 sensors can measure the air quality and steer the AHU from the kitchen for more ventilation. Also, by using movement sensors it will be possible to analyse how many times people come in and out the Atrium. In combination with CO2 sensors, it can be determined whether there are people in the Atrium/kitchen, so that light groups could be switched off.

Hardware to be installed - 4 movement sensors, 2 on the main door (in and out), and 1 on each passage to the offices (2 doors). 2 Co2 sensors (kitchen and Atrium). 2 temperature sensors (High and low in the Atrium).

2.2.3.5.3 Offices

To begin, it should be noted that because the offices are connected to the HVAC system from the closed care area, no changes can be made on the system because this would directly influence the closed area. Nonetheless, as the offices have fewer occupants than the previous areas identified, more controlled measurements of occupancy and its relation to energy consumption will be possible. A wireless energy measurement system will be developed based on ZigBee and installed in each office. This system shall measure and store data from 9 different devices (Computers, printers, etc.), for a list of devices and lighting see Appendix 2.7.2.2. The data is collected on a pc by manually logging in to the system. The stored data will then be sent monthly and stored either in a database, or as excel files, using plugwise. A second measurement system (7 plugs) will be available within two or three months and could be used to measure the Hairdressers energy consumption.

2.2.4 The HHS-Building

2.2.4.1 Overview

The HHS-building is designed to accommodate more than 1000 students simultaneously in class rooms, computer pools, discussion rooms and workshops, as well as provide office space for several hundreds of scientists. It is also designed to be highly energy efficient and combine many building energy efficiency technologies and renewable energies technologies (in 2009, it was nominated most energy efficient building in the Netherlands). The building has 3 levels plus ground floor, a cellar with a bicycle parking space and several facilities like the heat pump, and a car parking lot with an external access ramp on the roof (Appendix 2.7.3.1). The center of the building consists of a large central atrium which is used as thermal equalizer as well as for collecting exhaust air from all areas. The building has forced ventilation; however room windows can be opened. The upper windows of the atrium are opened automatically during hot summer days, to permit hot air to be exhausted. All areas of the building, including the atrium, have floor heating/cooling, which can be supplemented by heated/cooled ceiling ventilation.

The building disposes over two building management systems, one to control the heat pump, roof ventilation and heat exchange devices, gas boilers, and one to supervise heating/cooling/ventilation and illumination in each room and area. It uses groundwater terrestrial heat through an 80 m deep well and a heat pump. It has photovoltaic and hot water solar panels on the roof and a heat exchanger between fresh air and stale air as an extension of the forced ventilation system. It also has a combination of presence and movement detectors, illumination intensity meters, humidity meters and CO_2 level meters in each area. Heating, cooling and ventilation are functionally combined and adjustable in each room, however, energy efficient usage of HVAC is considered for the entire building.

2.2.4.2 Building Facilities and Devices and Analysis

2.2.4.2.1 HVAC

The main source for heating and cooling of this building is terrestrial thermal energy provided by a deep groundwater well. Thermal energy is also partially reused through the heat exchangers of the ventilation system on the roof, where a heat/cold transfer between the incoming and outgoing airflows takes place. Accordingly, the only energy consumption for heating, cooling and ventilation originates from the heat pump (with thermal reservoir) and the ventilation machines, in form of electricity. There exist some gas-based backup boilers on the roof to be used in case of system failure or very low temperatures in extremely cold winter days to heat up the incoming fresh air.

Due to the very high efficiency of the renewable energy-based HVAC systems, the high performance glazing, the big number of heat producing electric devices (computers, printers, etc.) and the high density of building users (that are also natural heat sources), the building uses, on average per year, 10 times less gas for heating than its predecessor building did.

Heating and cooling is performed through in-floor heating. The pipes carry the pumped water from the heat exchanger of the heat pump beneath the floors. The heat pump (usually) can deliver simultaneously heated and cooled water, as some areas of the building require heating (in the cold season), while other areas (like computer pools, workshops with running machines or highly occupied class rooms) might require cooling. Valves regulate the water flow; however, 4 rooms are grouped to an area controlled by a group of valves. Accordingly, it is not possible to adjust the floor heating/cooling individually per room. It is therefore recommended to assign similar building use cases to a group of rooms, to avoid conflicting requirements in terms of heating and cooling demand in neighboring rooms controlled by the same valves. Ventilation ducts are placed beneath the ceiling, pumping fresh air into the rooms.

There exists the possibility to supplementary heat or cool a facility, as the ventilation system of each room has a heat exchanger (having its own valves) for the hot/cold water originating from the heat pump (the same pipes that are used to heat the floor above are providing the thermal factor for this heat exchange on that floor). In case more heating/cooling is required, air is absorbed through the ceiling and passes combined with fresh air to the heat exchanger. This system is however only intended to supplement heating or cooling, or in case floor heating/cooling is stopped due to no demand in the neighboring rooms from the floor heating/cooling group, to provide heating or cooling for that specific room. A “conflict” where the floor-based and the ceiling-based devices are antagonized in heating, respectively cooling (or vice versa) is not possible and prevented by the control system. The heating/cooling level is predefined by the facility manager through the control system. Depending on these presetting and readings of the temperature sensors in the rooms, the control systems regulates the temperature through the floor valves, and supplementary through the ceiling valves and the level of ventilation.

Temperature and ventilation could theoretically be influenced for each room by its occupants. However, this is not made possible, as this would negatively influence the energy efficient usage of the building. The same, unpredictable changes in one room can influence the neighboring areas. It must also be mentioned that through the heat exchange between exhaust air and fresh air, temperature is uniform and heat produced in some areas is equally distributed to the entire building.

The ventilation level is determined mainly by the CO_2-level in each room. Fresh air is pumped into the room from the ceiling. The walls to the inner corridors or to the atrium possess a very fine grid of orifices through which the air from the room is evacuated due to a slight overpressure. A fixed amount of fresh air is also introduced into the corridors and the atrium, as these have no CO_2 sensors. The stale air is absorbed at the roof level in the atrium to enter the heat exchanger before being exhausted. At this point, it must be mentioned that although a heat/cold exchange takes place, a part of the building's hot or cold air is exhausted unused. This could be prevented by mixing the stale air with the fresh incoming air, depending on the CO_2-level of the exhaust air. This feature has not been implemented, probably due to the expected high CO_2-level of the exhaust air – more than one thousand building users are expected a "peak" time.

The atrium has the possibility of natural ventilation: in case of very high temperatures in summer times. The hot air that is accumulated beneath the atrium's roof can be eliminated by automatically opening roof windows. This possibility of natural ventilation is however not used in other cases, like night time ventilation. Some windows of the rooms can be manually opened. Window frames sensors determine than the interruption of ventilation and heating/cooling. Although the building management system identifies an opened window, it cannot ensure its automatic closing, however can generate a malfunction report (this opened window influences the temperature also in the neighboring rooms due to the common floor heating/cooling). Hot water is provided in the building through gas boilers. Supplementary, solar thermal devices are used to heat-up the water.

The building has proved itself to be more energy efficient than expected. In winter days with moderate temperature, the heat pump and ventilation produce a surplus of heat that is released to the atmosphere. This heat could be used e.g. to supply neighboring buildings with heat. The building has also demonstrated that the HVAC system works perfectly. There are areas in the building with too high CO_2 level, as well as too hot or cold. It is however not a problem of malfunctioning or erroneously configured devices, but rather a very complex causal network that the present building management systems cannot identify. Accordingly, there exist improving potential for the functionality and efficiency of the HVAC system.

2.2.4.2.2 Illumination

Illumination in the office and classroom areas is controlled by presence and light intensity level sensors. Luminaires are installed on the ceiling in two rows, close to the windows front and close to the separating glass walls to the corridor/atrium, and are separately controlled, as it is possible that lighting level is sufficient close to the windows side, but not on the side of the wall. The presence sensors are able to detect human presence in the room even if no movement can be perceived (this increases the user comfort considerably). The information delivered by the presence and illumination sensors is however not correlated with the CO_2-level metering by the building management system. This could give insight e.g. on malfunctioning of one of the sensors.

There are no presence sensors on the corridors and in the atrium, light stays permanently switched on during daytime. The building management system switches the lights on and off, according to a given schedule. At night, only the emergency illumination stays switched on. Presence sensors for illumination could determine some electricity savings, as corridors are occupied mainly during breaks between lectures. The parking lot on the roof of the building illumination is steered by schedule and by presence and light intensity sensors. For security reasons, lights are switched on when presence is detected. However, these detectors are not functioning correctly. Lights are often switched on at night, probably triggered by birds.

2.2.4.2.3 Building Management Systems (BMS)

The HHS-building has two independent building management systems, Priva (see Forum building) and Octalix[11], which have different control tasks to perform. Priva controls the heat pump (and its thermal storage), the roof-based ventilation system and its heat exchanger, the backup gas boilers and the solar thermal devices, the solar panels and the entire HVAC system on the general functionality level. Octalix controls the HVAC on room and area level, in connection with the temperature, humidity and CO_2-sensors and windows sensors. Depending on these readings and on the facility manager's presetting, heating/cooling and ventilation is determined for each room and area of the building. There exists the theoretic possibility that a building user shall configure through Octalix the settings of his own room or area, however, this feature has not been

[11] http://www.octalix.com/

activated, mainly to maintain energy efficiency in the building.

Octalix controls the entire illumination system of the building: rooms and areas and roof parking lot with presence and light intensity sensors, corridors and atrium with fixed schedules from the facility manager. There exists also a weather station on the roof of the building connected to Octalix. Its readings are relevant to the temperature presetting in the entire building. Octalix also controls the atrium roof windows opening and closing, depending on the readings of an internal temperature meter, as well as on the weather conditions. All Octalix sensors are wireless and plug-and play, being automatically detected and included into the BMS. Due to the functional dependency between room/area HVAC control and the heat pump and roof ventilation/heat exchanger machinery control, there exists a connection between Priva and Octalix. Thus, the level of heat/cold extraction of the heat pump and the level of ventilation and air temperature exchange are strongly connected with the demand of the building (its occupancy and use cases), and with the weather station readings.

Both Priva and Octalix have web interfaces, as well as interfaces to connect other systems to it. This interface is used by statistical software also installed at HHS call Monavisa[12]. This software reads all sensor readings and settings from Octalix and uses a set of indicators whose reference values have been calculated over a longer period and compares it with recent or real-time data, such that exceptional situations in the building as well as malfunctioning could be identified. Monavisa also has a web interface to visualize statistics and momentary data, as well as long-time data storage possibilities through a database.

2.2.4.3 Technical considerations moving forward

The HHS building already has installed many of the necessary sensors and actuators. It would be problematic to supplement these, as this is considered by the building owners a closed and ready configured system. However, the system shows malfunctioning, as previously mentioned. The reason of these malfunctions is mostly unknown, due to the complexity of the building and the interconnection of the devices. The causes can be multiple and cross-linked. Functional modeling with fault and fault/malfunction propagation analysis, as described in DR1.1 can be the solution to this. Accordingly, functional models of the building devices, as well as of representative areas (corridor, office, class room, PC pool, workshop, etc.), including their devices, are being created.

[12] http://www.monavisa.info/

This shall give supplementary insight in the building's functionality as a total, as well as recommendations on how to solve such local malfunctions. The problem of this system is that its configuration is static, even if optimized. It cannot react on exceptional situations that are not foreseen in these static configurations and functionality rules. Functional modelling and ontology reasoning will add this flexibility to this highly optimized energy efficiency configuration and management of the HHS building.

2.2.4.4 Building Specific Use Cases

As described, the design of the HSS building currently achieves a high level of energy efficiency. Potential areas for consideration are the intelligent management of the HVAC system to maintain comfort and where possible to reduce energy consumption. A recent survey (Appendix 2.7.3.2) has shown that many building occupants are dissatisfied with the building air quality. The potential to integrate CO2 data from lecture rooms with data on usage schedules could be support intelligent management of air ventilation to improve comfort levels, as currently these rooms must wait for the CO2 level to rise above a certain threshold before it is switched on. This could be ameliorated by turning on the air conditioning in rooms before a lecture begins. This would improve comfort but may increase energy consumption.

2.2.5 Bluenet Building

2.2.5.1 Overview and Occupancy

The Advanced Technologies Building "BLUENET" is located in Seville, in the Technological Park Cartuja '93, Avenue Isaac Newton 3. It is an office building for companies of business and governmental administration, focused on General Information Technology (IT) and Energy. Out of the two governmental agencies, one is focused on Information Technology (IT) and the other on Farming, Fishing, Food and Organic Production. The building is a glass cubic prism which consists of a large central atrium. The layout of each floor has been designed to support maximum freedom and mobility, geared towards the central atrium. Every floor includes its own corridors and diaphanous windows, which are connected to the central atrium. The building is 19 meters high. Its walls are 40 meters wide on the sides facing the road and 48 meters wide on the adjoining parcels (structure). The building consists of two stories underground and five stories above ground. The upper floors surround the central atrium, which is crowned at the top level with a horizontal element for protection from weather and sun exposure. The two parts of the building are connected by vertical communication cores that run inside the courtyard, in the extreme north and south of it. The North core poses a high-capacity elevator to allow furniture and office supplies to be transported between floors. The other core, near the main entrance, contains two medium sized elevators for personnel. Given its location, these elevators give a panoramic view of the central courtyard. The Isotrol offices cover the entire third floor and typically have approx. 150 occupants, with a maximum of 186 and minimum of 2 (on weekends and holidays) (see Appendix 2.7.4.6).

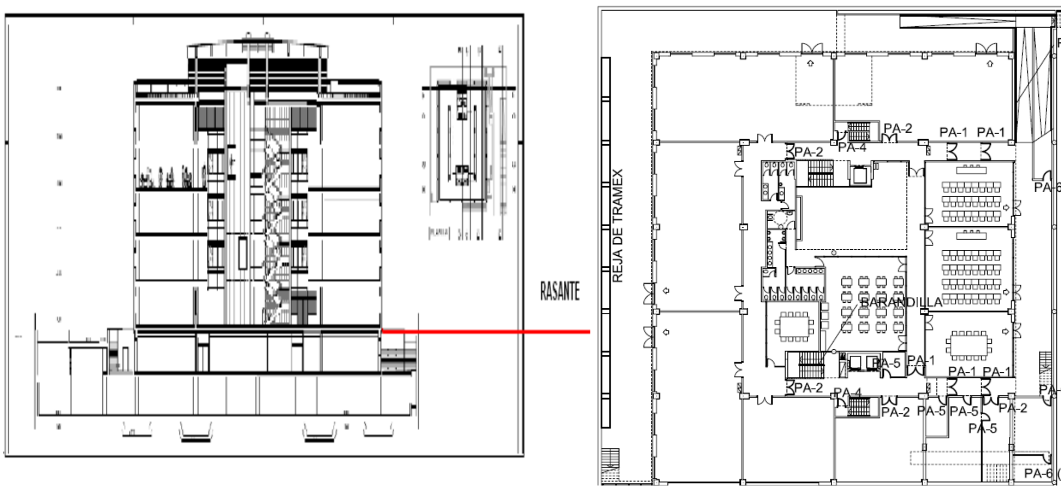


Figure 1: View the section of the building Bluenet.

2.2.5.2 Building Facilities and Devices

The building has been installed with a number of systems ensuring that it is sustainable, eco-efficient and functions with a high degree of independence. Each floor is divided into four independent modules of approximately 300 m2 each, with the possibility of individual adjustment of each of the systems. This results in greater flexibility in the use of offices and possible interior layout.

2.2.5.2.1 HVAV Equipment

The heating, ventilation, and air conditioning (HVAC system) is a Variable Refrigerant Flow (VRF) System[13]. Variable refrigerant flow (VRF) is an air-condition system configuration where there is one outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control, and simultaneous heating and cooling in different zones.

The term VRF refers to the ability of the system to control the amount of refrigerant flowing to each of the evaporators, enabling the use of many evaporators of differing capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and heat recovery from one zone to another. VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems.

2.2.5.2.1.1 VRF Systems

VRV/VRF systems can be used for cooling, heat pumping and heat recovery. With respect to heat pump models there are two basic types of VRF system: heat pump systems and energy-recovery. Variable refrigerant flow systems with heat recovery (VRF-HR) capability can operate simultaneously in heating and/or cooling mode, enabling heat to be used rather than rejected as it would be in a traditional heat pump system. VRF-HR systems are equipped with enhanced features like inverter drives, pulse modulating electronic expansion valves and distributed controls that allow the system to operate in net heating or net cooling mode, as demanded by the space.

[13] http://www.cedengineering.com/

Each manufacturer has its own proprietary design (2-pipe or 3-pipe system), but most use a three-pipe system (liquid line, a hot gas line and a suction line) with a special valve arrangement. Each indoor unit is branched off from the 3 pipes, using solenoid valves. An indoor unit requiring cooling will open its liquid line and suction line valves and will act as an evaporator. An indoor unit requiring heating, will open its hot gas and liquid line valves and will act as a condenser. Typically, extra heat exchangers in distribution boxes are used to transfer some reject heat from the superheated refrigerant exiting in the cooled area to the refrigerant going to the heated zone. This balancing act has the potential to produce significant energy savings. The terminal units are in all direct expansion, installed in false ceilings of the premises. The air-conditioning throughout the building is DAIKIN VRV model, and has the following power consumption characteristics:

TYPE	UNITARY POWER (W)
VRV FXSQ40 M	4.500
VRV FXSQ50 M	5.600
VRV FXSQ63 M	7.100
VRV FXSQ80 M	9.000
VRV FXSQ125M	14.000

TYPENº/FLOORPOWER UNIT (W)Table 1: Powers Unitary HVAC pumps.

The HVAC system also has a recovery plate located on the semi-basement floor. The temperature control inside the offices is done by manual thermostats located in various areas of the offices.

2.2.5.2.2 Geometry and Topology of HVAC

The ventilation air flow is chosen according to ITE.02.2.2 RITE (Gómez) and is provided in the UNE 100,011[14]. The average rate of ventilation is 12.5 liters per second per person (IDA-2)[15] (Appendix x). The entire premises are normally occupied by a forced system, which requires outside air for ventilation, maintaining the air pressure in the premises in slight excess, in order to prevent infiltration of unwanted outside air. The primary air required for ventilation in the occupied rooms of the premises is provided by two central ventilation units (one for the west side and another for the east). In both cases energy is recovered from the exhaust air through the heat exchanger cross-flow. The design includes ductwork and two ventilation units (one from the west

[14] http://es.wikipedia.org/wiki/Norma_UNE
[15] http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/NTP/Ficheros/701a750/ntp_742.pdf

side and another from the east) where its function is to give outdoor air to the air-conditioned rooms.

To make the contribution air returns from the unit terminal, it needs its corresponding damper, in order to ensure that each unit receives the set flow rate. This ensures that the entire premises occupied are provided by the air flow set in HS-3[16]. The terminal units are in every case installed in the false ceilings of the same premises or adjacent premises. This type of equipment has a high seasonal efficiency, particularly between summer and winter (or vice versa) where both effects (heating and cooling) happen simultaneously, thus performing a transfer of energy between the various locations of the building, reducing energy consumption.

2.2.5.2.3 Lighting Equipment

The office lighting on each floor is distributed through flexible tubes in the false ceiling. The tubes are of sufficient width to allow easy insertion of cables and allow any additional extensions. The lighting system adopted for the working areas of each floor consists of office-based general lighting luminaries (3 x 18 watts). The recessed ceiling has specular aluminium parabolic louvers to achieve a level of lighting environment in excess of 500 LUX (Appendix 2.7.4.3). The lighting inside the building consists of:

- Recessed compact fluorescent lamps 3x18 w: 525 units / floor.
- Energy saving lamps of 16 w: 114 units / floor.
- Halogen 7 w: 35 units / floor.

Every room faces the exterior of the building, so the natural light is utilized as much as possible.

2.2.5.2.4 Shutters

The building has both exterior and interior windows, each 1.5 x 1.5 meters. These are hinged on the external side of the window and have manual shutters. Double glazing has been used for every window. The white aluminium shutters locks are inside the doors and windows. The external sides of the windows are aluminium grey. The internal office doors are solid wood and, painted white. The external company doors are white aluminium with windows

2.2.5.2.5 Consumer Equipment and Energy Production

The power supply to the building is provided by Transformer (CT) owned by electricity Distribution Company. The central transformer is located outside of the building. It consists of two 630 kVA transformers and two Low Voltage distribution boards. The Outputs that are coming from the low voltage distribution boards of the central transformer are connected to the building and electrical

[16] (http://www.codigotecnico.org/web/recursos/documentos/dbhs/hs3

meter readings, which are located on the lower ground floor of the building. The individual electrical lines are coming from the electrical meter readings and connected to the office electric switchboards.

Regarding electrical level, each floor is divided into different areas which have panels to each of the plants. This gives greater flexibility in the use of electrical installations in the offices, which leads to a rationalization of the use and sizing of associated facilities. This will result in significant energy savings that are associated to different uses. For example, if in one area the employees are meeting, it is possible to switch the lights off. For a more complete list of the low voltage boxes located on each floor and their associate power consumption see Appendix 2.7.4.5.

2.2.5.2.6 Sensors and Actuators

On the fourth floor, in the offices of Isotrol, several sensors and actuators are distributed in each of the areas. Within the control elements are installed the lighting controls, which are provided by a proprietary system developed by Philips. These sensor nodes include light sensors, movement detectors and infrared receivers (Appendix 2.7.4.4). There are two areas of the fourth floor controlled by a Digital Addressable Lighting Interface (DALI) system (Appendix 2.7.4.4). These sensors support controlling both the on off function of the light as well as light levels. DALI will also be installed in other zones to control lighting and will give information about the installed system.

2.2.5.3 Analysis and Technical Considerations Moving Forward

BLUE NET building has good potential to improve its energy efficiency. A quick checking of the analyzers in the fourth floor showed that illumination is the largest cause of energy consumption because the illumination is permanently switched on. The Illumination savings could be solved with presence/movement sensors. The technology of electronic ballasts also allows regulation of the lamp intensity as a function of the presence of daylight picked up by sensors, which in turn allows adjusting the level of illumination to the needs of the occupation. Energy consumption of the HVAC systems is more difficult to analyse because the installation of air conditioning and ventilation systems (HVAC system) is centralized (with distribution of Variable Refrigerant Volume to different terminal units provided), and data on the energy consumption is still not available. Therefore the fourth floor analysers only show a part of energy consumption of air conditioning and ventilation systems (HVAC system).

2.2.5.4 Building Specific Use Case

The following uses cases have been identified which are specific to the BlueNet building. Firstly, develop a system to distribute the energy consumption coming from the central installation of air conditioning and ventilation systems (HVAC system), to any part of the fourth floor.

Secondly, build a system to analyse the energy consumption of air conditioning and ventilation systems (HVAC system) and use this to decide which investments could reduce energy consumption, evaluate economics investments and calculate the payback for each investment.

2.2.6 Summary of Demonstration Objects and Conclusion

This chapter presented descriptions of each of the four building demonstration objects, MediaTIC, the Forum building, HHS and the Bluenet building. For each building an overview of the building, with information about its geometry and occupancy was presented. Next, a description of the building devices and facilities was given. This is followed by analysis and technical considerations moving forward, which was followed by building specific use cases.

As can be seen from the descriptions of the building devices, each building is unique in design and use (i.e. occupancy) and as such, different building specific use cases have been developed for each. The levels of analysis also differ, as the availability of information from each building demonstration object has varied, so this work should be seen in the context of on-going work towards creating the building-specific behavioural models and the building-specific ontology rule sets for each of the demonstration objects. The next section will examine the analysis of the user behaviour and interactions with the building demonstration objects.

2.3 Analysis of User Behaviour and User Interactions in Buildings

This section gives a description of the processes and methods employed during the analysis of the user behaviour and interactions in the aforementioned buildings. It begins with a rationalisation for undergoing this research.

2.3.1 Introduction

User behaviour has a large impact on the energy consumption of a building during operation (Hoes, Hensen et al. 2009). User behaviour here is defined as user presence, user activities and user controls of building systems, where these affect the indoor environment (Tabak and De Vries 2010). To understand how user's behaviour influences the energy consumption of a building, a model is required that captures user movements, activities and interactions with it and its systems. These models are used as inputs into building performance simulation tools. Building performance here is related not only to energy consumption, but also user satisfaction and job performance, factors which must be taken into consideration when developing energy reducing strategies (Zimmerman 2007). Building performance simulation tools can then inform those responsible for building energy management about their decisions regarding new policies and building configurations.

To illustrate, consider the effect of enforcing a policy of unplugging electronic devices, or the effect of placing passive infrared sensors to automate lights in corridors. In the former case, it is hard to quantify these savings without proper measurement of the energy consumption at each power outlet. In the latter, it may be difficult to know where to best place the sensors without adequate knowledge of how users move through the building, leading to sensors placed in positions which are rarely traversed. Models of user's activities, how they move, and what devices they interact with can inform both of these scenarios. In this section we explore the development of user activity models for buildings, in particular, those which can be used as inputs into simulation of user behaviour in buildings.

2.3.2 State of the Art

A number of researchers have looked at developing user behaviour models for the purpose of performance simulation. These have ranged from activity models to predict lighting energy performance (Reinhart 2004), to user interactions with windows and its effect on thermal comfort and energy use (Rijal, Tuohy et al. 2007), to larger sets of interactions including (in addition to aforementioned windows and lights) heaters and fans (Nicol 2001) and additional activities like going to lunch, getting a drink and having a smoke (Tabak and De Vries 2010). These studies have mainly focussed on office spaces. This may be due to the large number of office buildings in use, the similarity between the activities of one office user to another (e.g. working at desk, going to meetings, etc.) and the predictability of work times for the majority of office users (e.g. a nine to five work day). These factors make the task of modelling activities more applicable and also more simple than modelling activities for buildings which are less numerous and also have less predictable use (e.g. a university campus) and it has been claimed that building predictable usage is a pre-requisite for accurate predictions in simulation (Degelman 1999). While this is the case for skeleton activities as defined by Tabak (Tabak and De Vries 2010), when modelling intermediate activities the type of building has less impact on the predictability of the activity. Intermediate activities include actions like “going to the toilet” or “having a drink”, while skeleton activities are directly linked to the role of the person like giving a lecture or cleaning the toilet. To have a complete picture of building use, both activities must be modelled and we begin by examining the different methods for developing these types of activity models.

2.3.3 Methodology

When developing activity models the general approach is to use empirical data gathered from specific building objects during operation. These models then define the number of occupants, occupant mobility, types of activities and device (windows, fans, etc.) interactions and algorithms which define how and when the occupants conduct certain activities. The methods for gathering empirical data range from conducting longitudinal and transverse studies (Rijal, Tuohy et al. 2007) to online questionnaires (Tabak and De Vries 2010) to using regularly (5 minutes) monitored data from sensors, for example weather stations and presence sensors (Mahdavi, Lambeva et al. 2007). Shen et al. have also examined integrating building information modelling into activity simulation pre-occupancy using Tabak’s activity modelling method (Shen, Shen et al. 2011). They have developed tool support for users to specify their activities, along with start times, end times, etc. as well as graphical tools for visualising those activities.

An amalgamation of the approaches taken by (Rijal, Tuohy et al. 2007), (Tabak and De Vries 2010) and (Shen, Shen et al. 2011) have been applied to the four building objects: The Forum building in Eersel, the Hages Hogheschool in Delft, the B-Digital building in Barcelona and the BlueNet building in Seville. Firstly, information was collected about the building objects in the form of existing CAD drawings and information on existing devices in the building. Secondly, site visits where conducted on each building, conducting interviews with the facility managers and building demonstrators. These interviews covered topics like the types of building users and the types of interactions they can conduct (e.g. can they open windows, adjust temperature, etc.). From these interviews and through the examination of the architectural CAD drawings activity models were developed which give high level descriptions of each buildings use by occupants. Finally, these models were used to develop a set of initial questionnaires for each building to determine how specific users use the building as part of a transverse study to be conducted for one operational year. We shall now break down our findings for the three aforementioned methods with respect to activity modelling.

2.3.4 Pre-visit data gathering

Before any building visits were conducted, it was intended to conduct analysis of the building and activities through examination of existing 2D and 3D CAD models. These were received for both HSS and the Forum building. In the case of the Forum building, the 3D google sketchUp model only provided visualisation of the exterior of the buildings and was of no use for initial exploration of the building use cases related to user activities. HSS provided a detailed 3D model of a demonstration area of the building assigned to our study. This model detailed position of lights, sensors, power outlets and positions of desks etc. This model was therefore useful for initial analysis of the demonstration area. Both Smart Homes and HSS also provided 2D CAD drawings of their entire buildings. These provided a layout of the buildings and so, it was possible to explore potential paths and movements through the building.

2.3.5 Initial Building Visits

For each building object a day long visit was conducted, which included a full tour of the building as well as interviews with the facility managers and building administrators regarding the activities of different building users. These interviews set out to determine the different types of users of the buildings, the different activities they conduct and how they interact with the building. Using the information gathered here Unified Modelling Language (UML) (Fowler 2003) activity models were developed which captured these activities. In the next sections we give examples and descriptions of the resulting models.

2.3.6 Initial Use Case Descriptions: General Building User

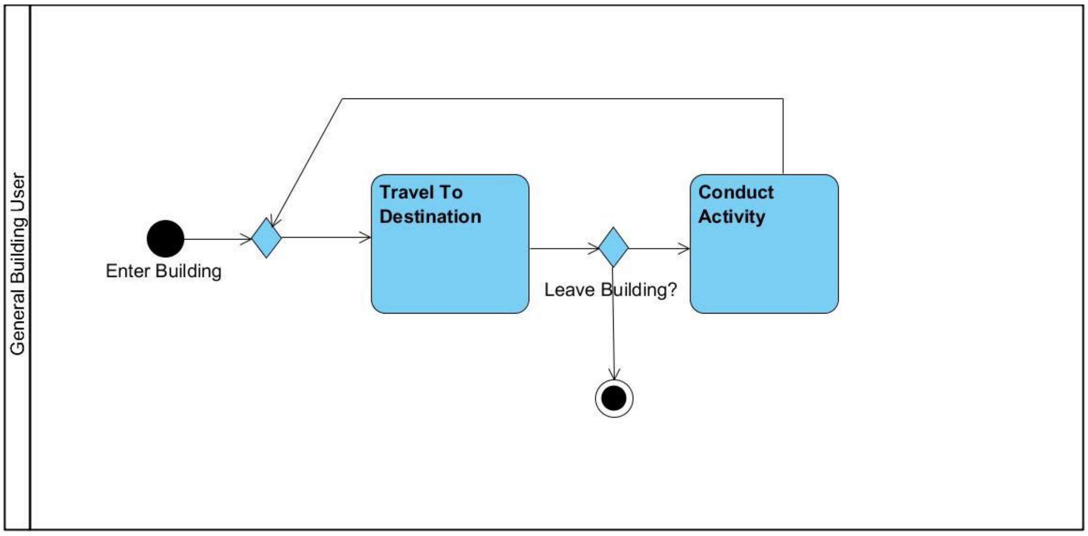


Figure 11 General Building User

Figure 11 breaks down how all building users interact with a building at a very high level. Upon entering a building all users of the building must begin by travelling to a destination. Once at a destination they can choose to conduct an activity. This activity may contain within it many sub activities at the same location or result in additional travel within the building. Any number of activities can be conducted within the building until the user travels to an exit and leaves, at which point they are considered to no longer have any impact on the consumption of energy in the building (in future there may be situations where users interact with the building from outside the building structure, but these are not covered here).This use case applies to all buildings.

In the next sections we shall look at use cases for a specific building, the forum building in Eersel, as this was the first building to undergo such a study. A similar set of models have been developed for B-Digital, HHS and Isotrol and these are included in Appendix 2.8. The below use cases may have slight differences from one building to the next, or sets of activities which only apply to one or more of the buildings.

2.3.7 Initial Use Case Descriptions the Forum Building

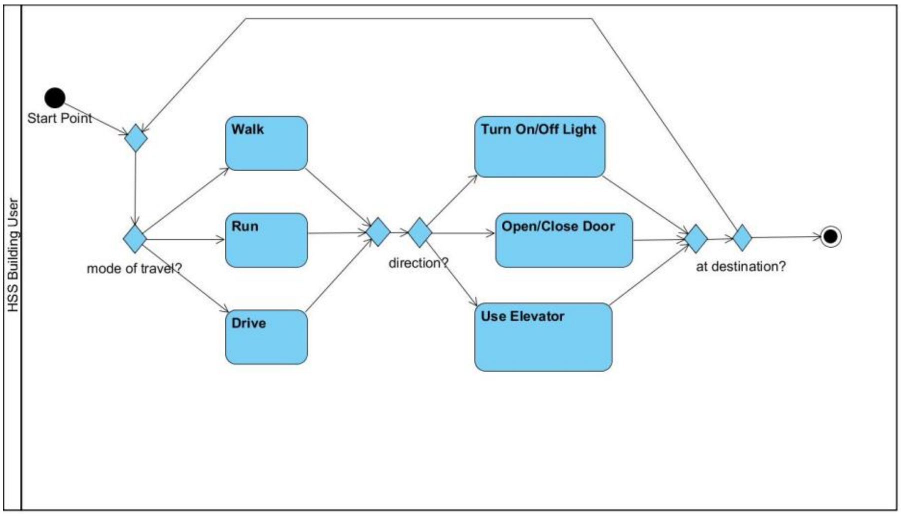


Figure 12 Building User (Forum Building): Travelling to Destination

Figure 12 captures the activities involved in travelling to a destination in the forum building. The activity begins with a decision about which mode of travel to take. Here we include only three, walk, run and drive (elderly inhabitants of the forum building can travel by buggy). The user may interact with doors, elevators and also lights as they travel to their destination. For example, in the forum building automated lights will be turned on and off if a certain path is taken. The travelling to destination can be modelled therefore as a start and end point, duration and a number of interactions with the aforementioned building entities. Changing the state of these may affect the air quality and temperature of zones (open/closing doors) and energy usage of the building (elevator use, light use) between those points.

Figure 13 captures the high level activities available to the different building user types. These types are: Office User, Bar Staff, and Kitchen Worker. Also captured here are activities available to specific rooms/zones which differ from the other rooms (the common room and toilet). This will be explained in more detail now. For each building user they begin by arriving at their destination, this is the beginning of this use case. They all then have a decision about whether they shall affect the environment or devices in the environment in some way. This includes changing the temperature, the lighting, the air quality or powering/interacting with devices. Once the user is happy with the state of the environment, they may conduct an activity (for example, working at their computer). The state of the environment at this point determines the energy consumption for this zone until an interrupt occurs. There are two types of interrupt, internal and external. An external interrupt here is associated with events which are external to the user. For example, a schedule may be used to determine at what time a break is taken (e.g. lunch) or at what time a meeting is to take place, or the work day ends. Unpredictable external interrupts may also occur, like an unscheduled meeting.

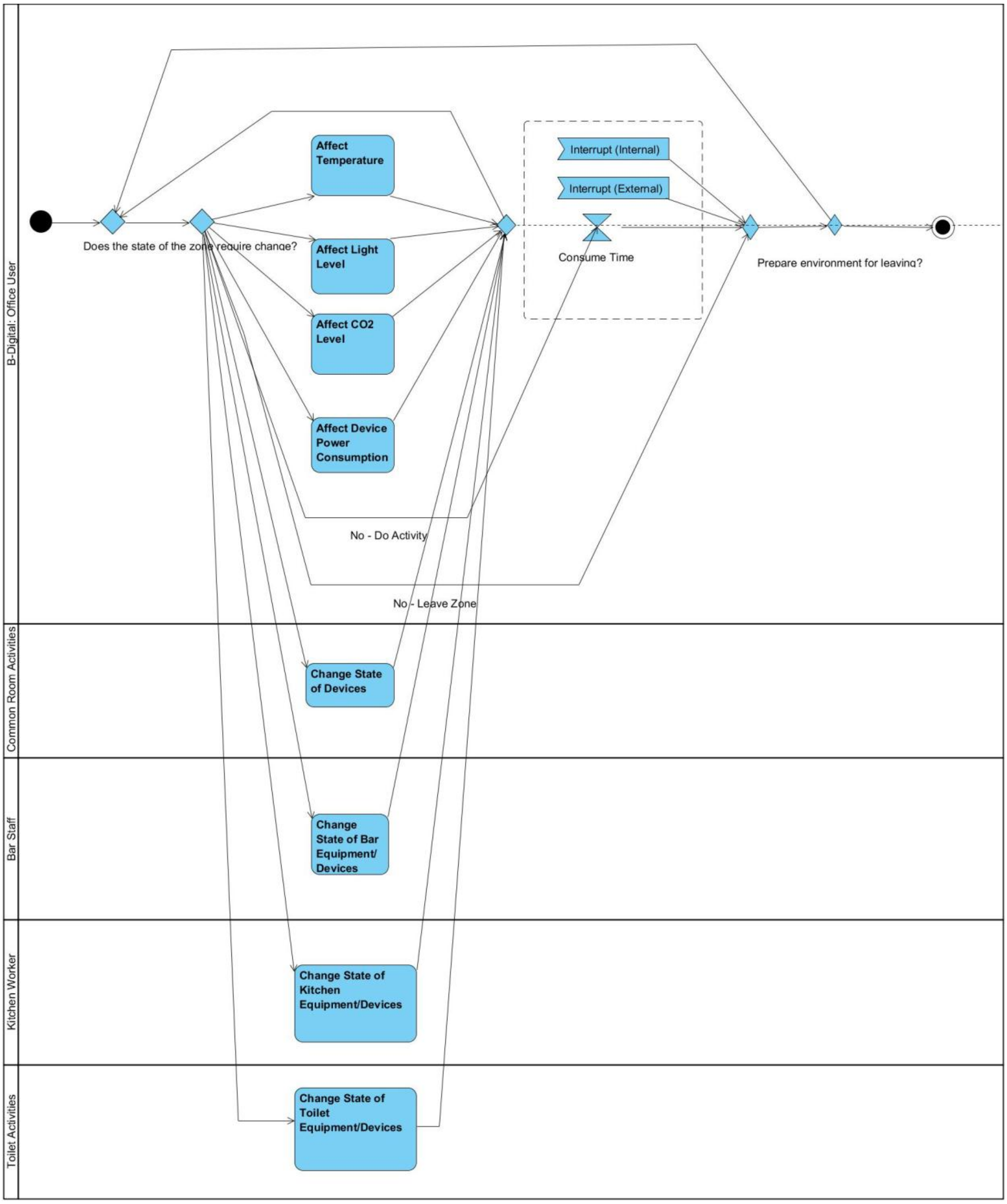


Figure 13 Building Activities (Forum Building)

The second type of interrupt is internal and is to do with the psychology of the user and their desire to maintain body comfort. These interrupts include toilet breaks, water/coffee breaks, snacks; unhappiness with the environment (requires change to temperature, air quality, and light levels). There is a relation therefore between internal interrupts and the external environment but are still classified as internal as they are mainly determined by the psychology of the users (social etiquette may also apply before making changes in rooms with more than one user) and are therefore less predictable than scheduled external interrupts. An unscheduled break initiated by a colleague would therefore also fall under this category. Once an interrupt occurs, the user will change the state of the environment and remain, change the state (for example, powering down) and leave, or simply leave without changing the environment in any way. Each of these has different consequences for the energy consumption of the zone.

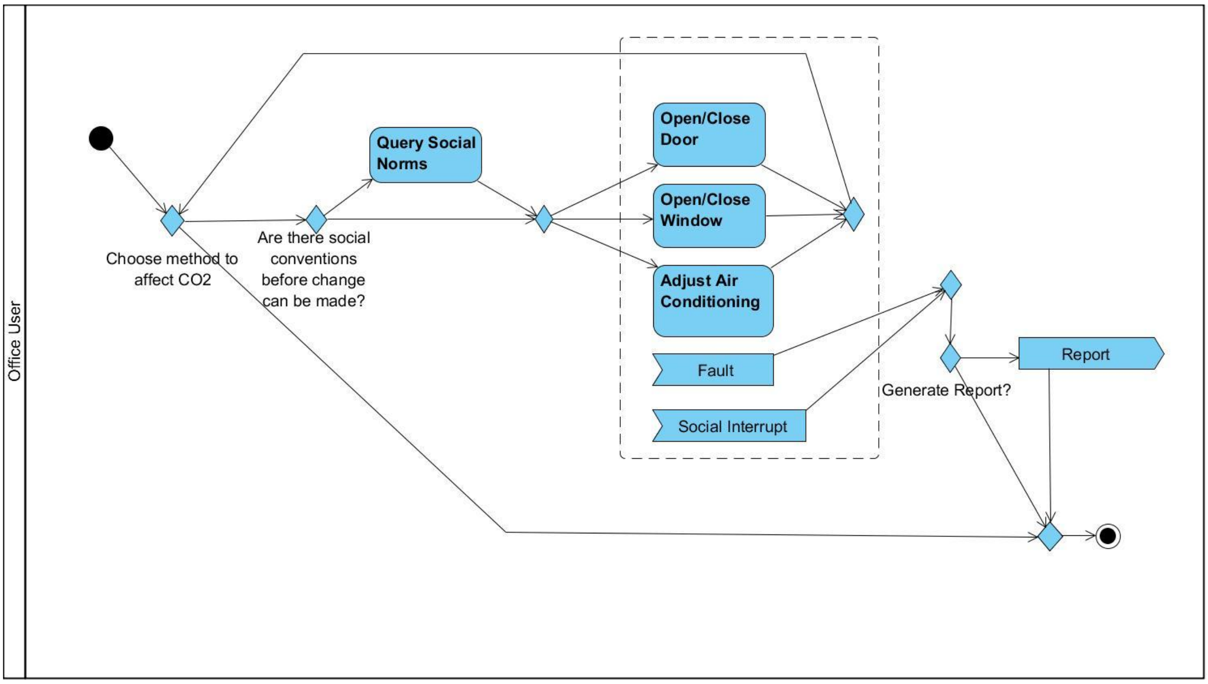


Figure 14 Affect CO2 Levels

Figure 14 gives on overview of a specific activity with relation to an office user. Here the office user wishes to affect the CO2 level in the room. It begins first with a decision regarding what method they wish to affect the CO2 level of the room. If there are additional occupants in the room, they may need to have some set of social conventions which influence their decision (again depending on the psychology of the user). Next the action is taken. In the forum building an office user may either open or close a door, open or close a window, or adjust the air conditioning and one or more of these may be done depending on the user and the circumstances.

At any point a scenario may occur which does not allow this action to be completed, for instance if the air conditioner is faulty. This may generate a report to the appropriate party (e.g. the facility manager). A social interrupt may also occur where more than one user is in the room and they disagree with the action taking place. This may also generate a report to the appropriate party (e.g. their manager). Once the action is complete the activity ends and they once again return to the previous activity diagram and do a check to see if the environment is now satisfactory, at which point additional actions may be taken or the user enters a time consuming activity.

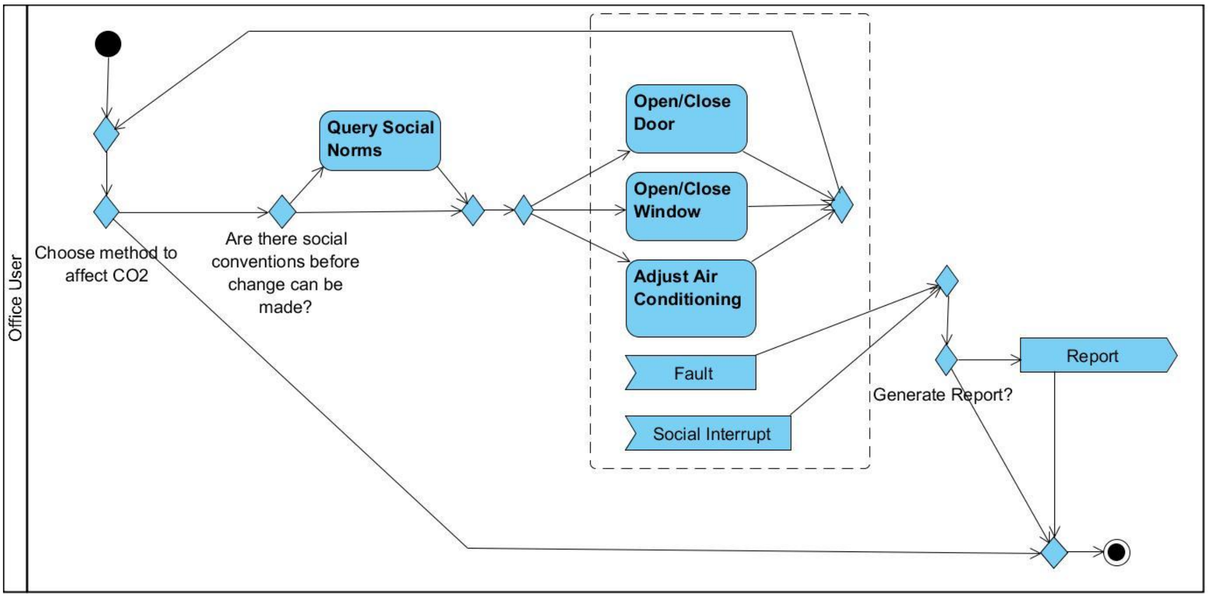


Figure 15 Office User Affect Light Levels

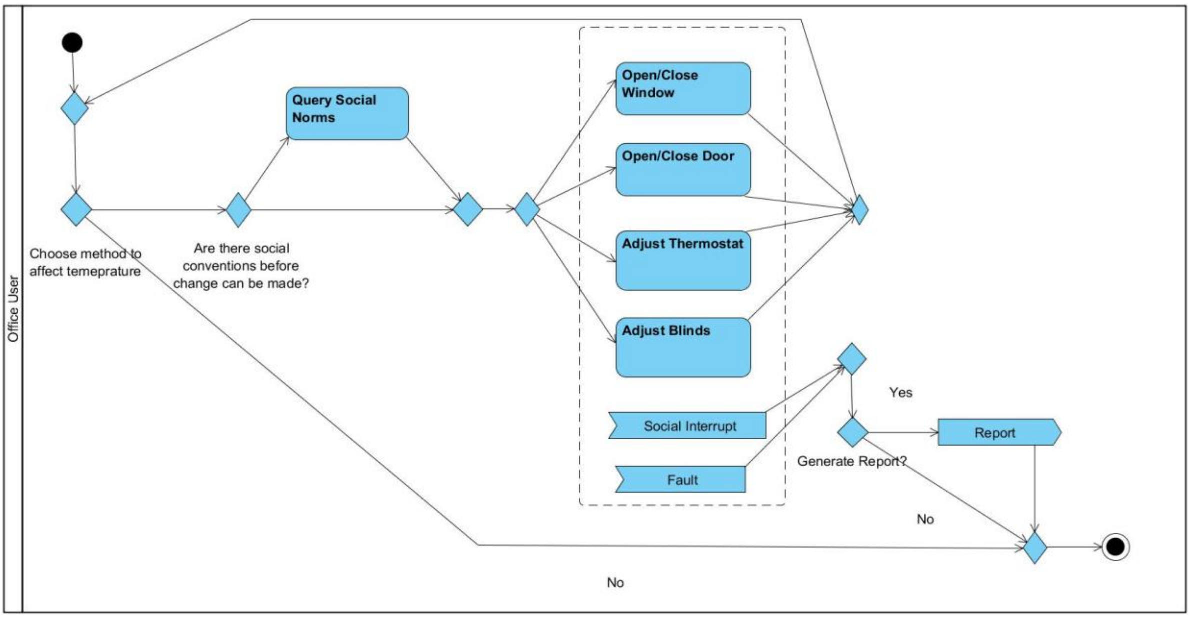


Figure 16 Affect Temperature

Figure 16 demonstrates how an office user in the forum building may affect temperature. Here the actions open/close window, open/close door and adjust the blinds can all affect the temperature.

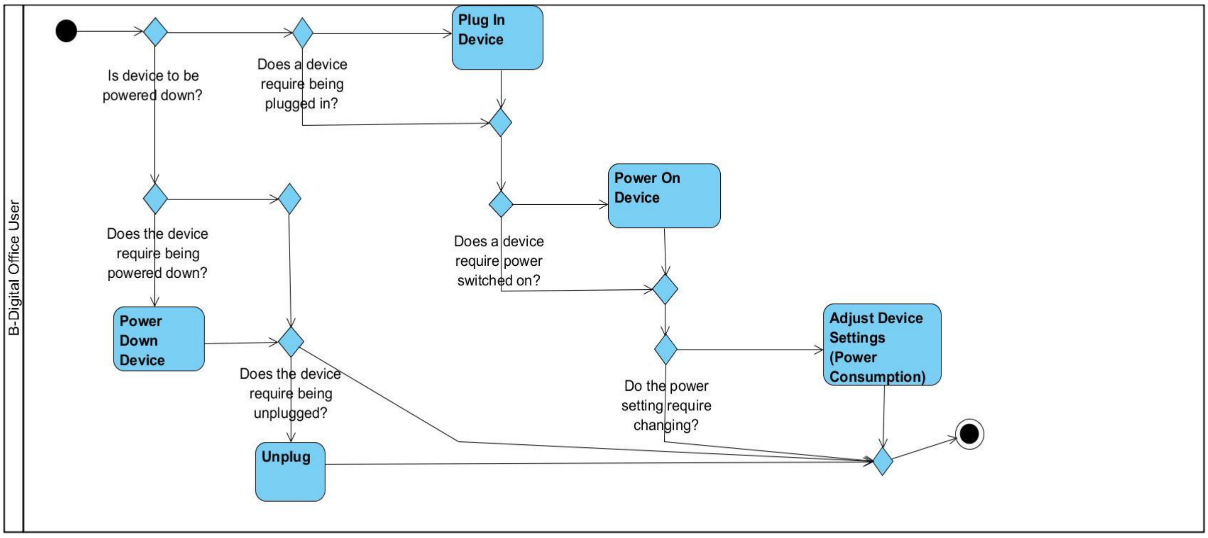


Figure 17 Affect Device Power Consumption

Figure 17 gives an over view of the activities involved in powering or powering down devices. It begins with a decision regarding whether the device needs to be powered down or not. If so, the device may first be switched off, and finally it may be unplugged. If the device requires power (to use, or to charge), first it may be plugged in, next it is switched on, finally the power setting may be adjusted (for example, the strength of a portable heater, or the energy saving mode of a personal computer).

Figure 18 gives activities for bar staff in the forum building. Here, additional activities, beyond those of affecting temperature, CO_2 and light levels as defined above, are modelled. The models here are quite simple and do not contain any order in actions, other than that contained in the decision nodes. The decision nodes therefore contain all the logic for when to trigger certain actions depending on the current state of the environment, for example, if all the glasses are dirty, it may be necessary to wash a glass before using the beer taps. How detailed this logic is depends on how much data can be gathered from the building object regarding how the bar staff interact with the bar and the requirements of the simulation itself. Fault reporting will be described in greater detail in Chapter 2.4, while social interrupts here may include things like cancelations of orders and are included here for completeness.

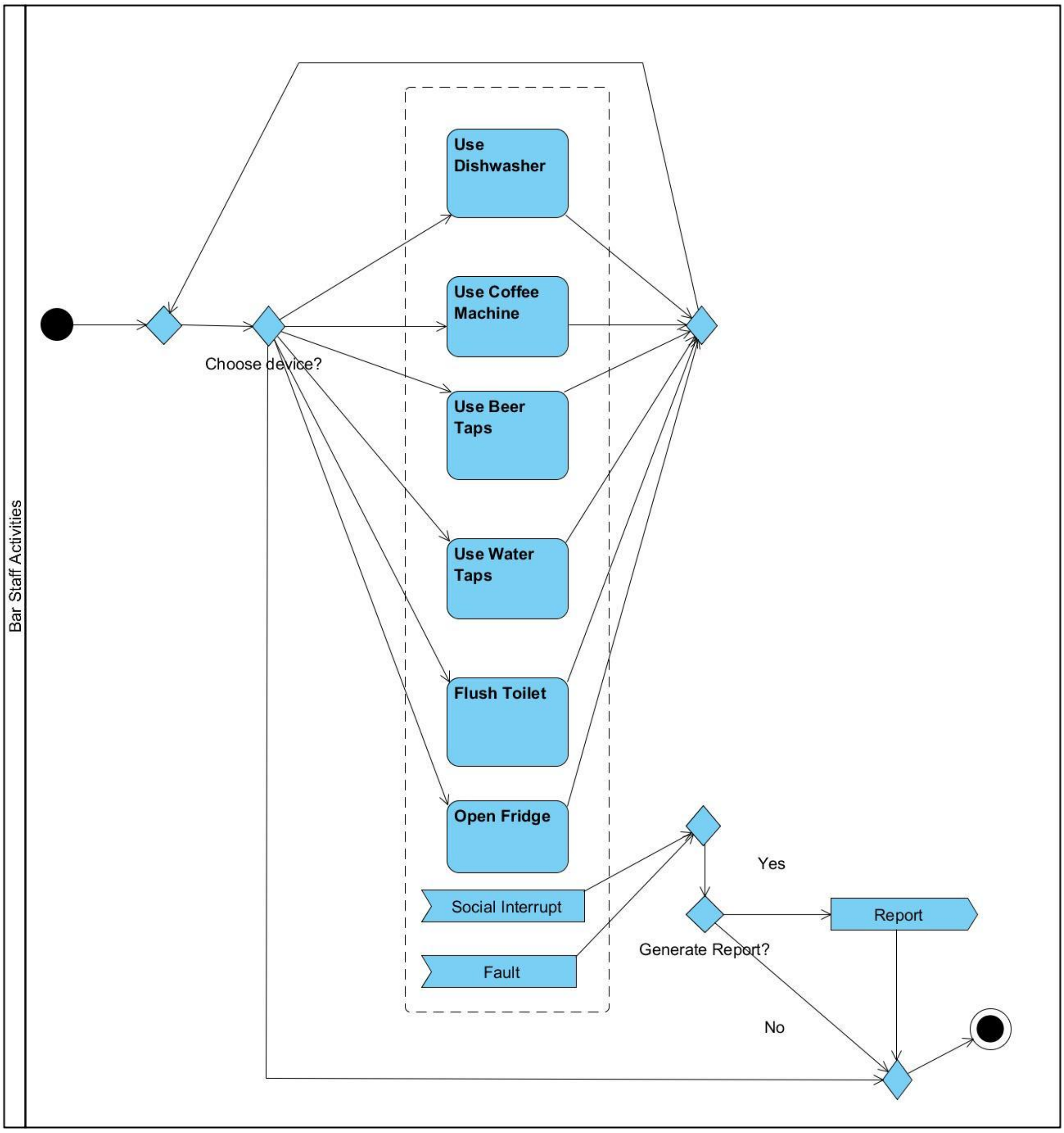


Figure 18 Bar Staff Activities

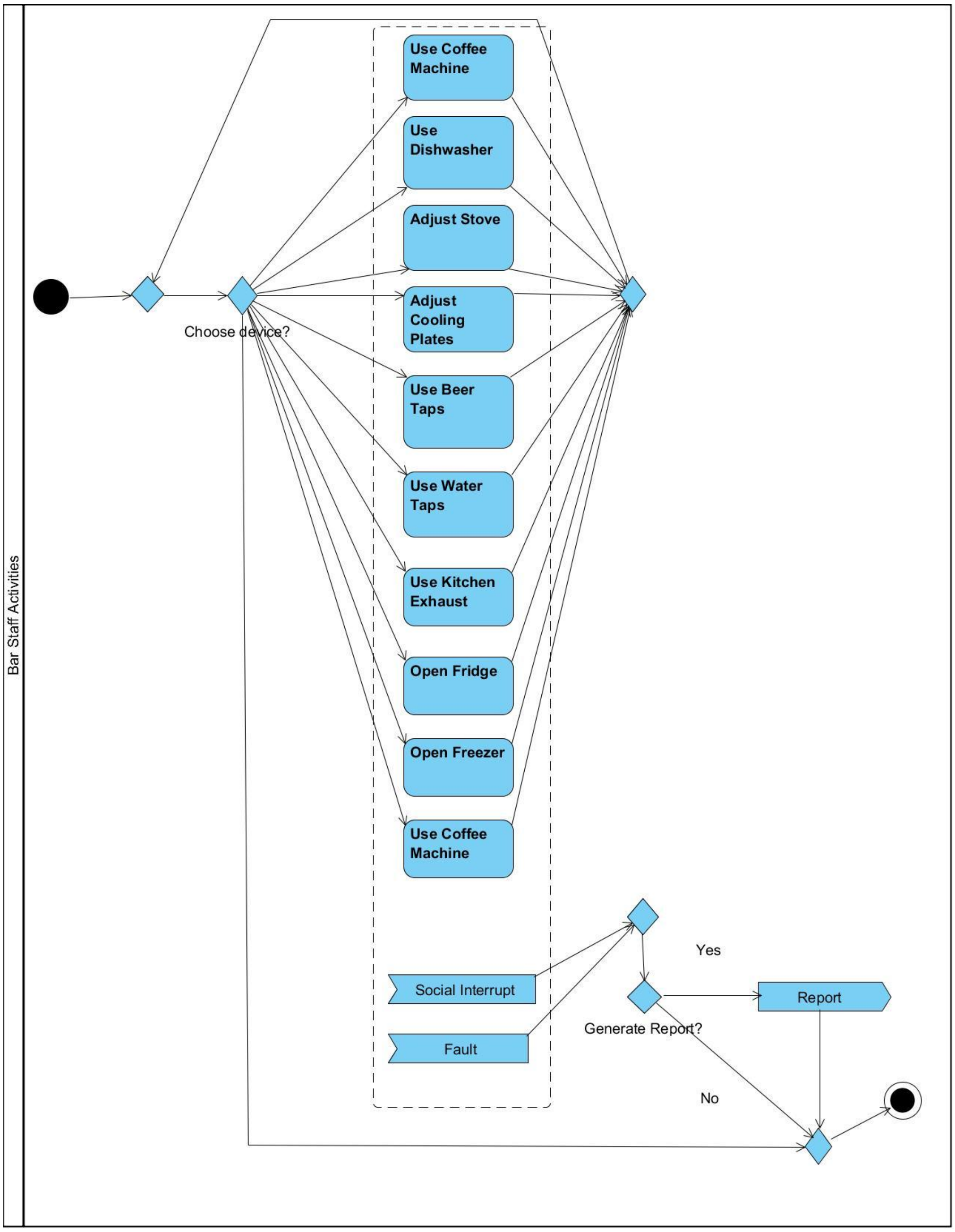


Figure 19 Kitchen Staff Activities

Figure 19 gives an overview of the activities available to kitchen staff. And the activities are comparable to those of the bar staff.

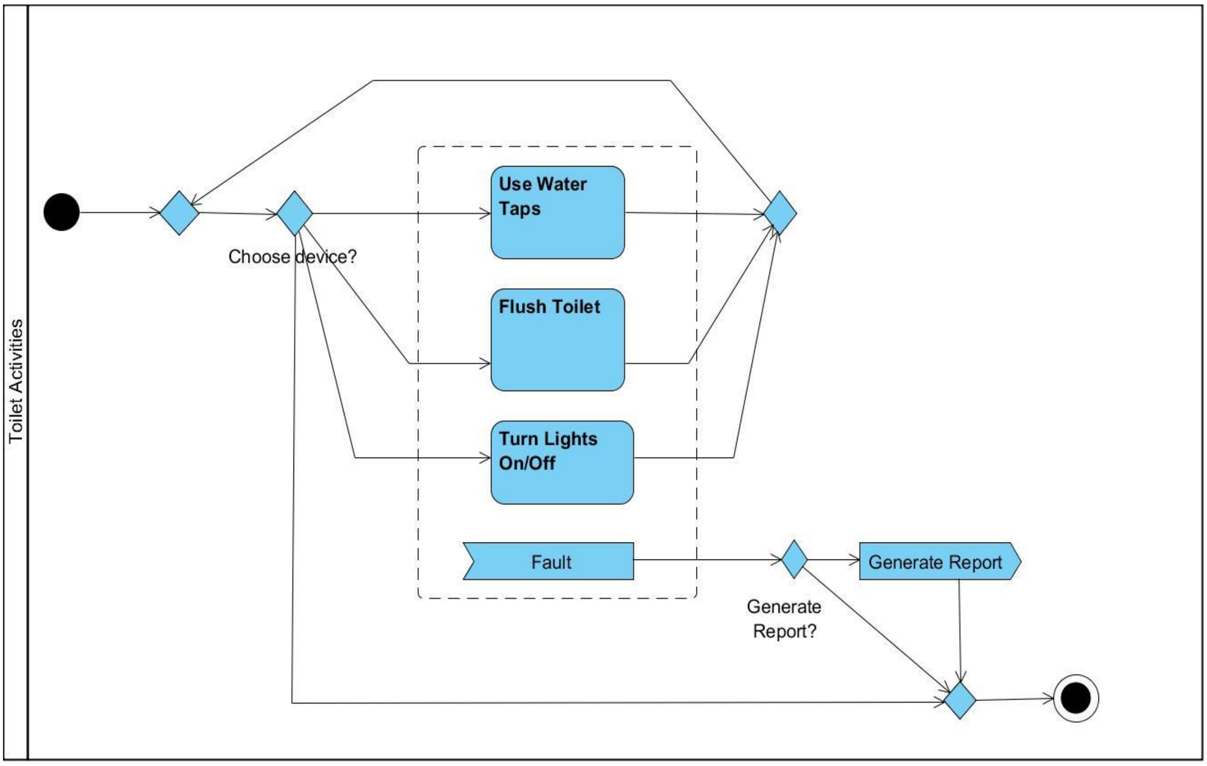


Figure 20 Toilet Activities

Figure 20 gives an overview of activities available to users in the toilets in the forum building.

2.3.8 Transverse Study Questionnaires and Findings

Using the activity models as a basis, an initial set of questionnaires has been developed to gather data on the actual use of the building. These questionnaires set out to determine things like the times user start and finish their day, when they start and finish their lunch breaks, how often they take toilet, coffee, smoking breaks and whether they take different routes when going to and from their desk, to and from the lavatory and to and from their lunch breaks etc.

Questions are categorised under specific areas, for example, in the B-Digital building office users were question under the following areas: “Movement to and from the Office”, “Information about the Office”, “Breaks and Movements”, “Devices and Interactions”, “HVAC and Interactions”, “Light and Interactions” and finally “Common Room Interactions”. In the next section we will give our initial findings from the questionnaires in the B-Digital offices.

2.3.9 Initial Findings B-Digital

See Appendix 2.9.4 for examples of initial findings from B-Digital office user survey. These results are currently being collated and require alignment with building sensor data and building geometry before they can be considered complete. For each office worker two tables are constructed which captures their activities (start times, duration and location) and routes (start point, end point, mid points traversed and duration). A route may result in interactions with doors, lights and elevators, but no specific activity takes place within a route. It is assumed that any time the user is not conducting another activity, they are at their desk. For certain activities the duration will be calculated on an average basis (e.g. toilet breaks) as it was felt that asking users about the length of their toilet breaks was not appropriate. The duration for routes will be calculated by computing the distance between each point traversed. Elevator durations will also be taken into consideration, although this may be highly dependent on their usage. This data will then be collated with any monitored data that is available (presence events, door events, etc.). Table 1 gives averages for the B-Digital building of 26 users who have answered the on-line questionnaires. A table will be developed for each user which records the specific activities they are involved in, start times, durations, locations etc. This is part of on-going work with the four building objects.

Table 1 User Activities

Activity	Avg. Start Time	Avg. Duration	Location (occupant numbers)	Frequency (Avg. Number per Week)
Work Day	9:00:00	9:30 mins	Fifth Floor Office (10), 5ª planta (2), JMAs (1), Lab (1), Mezzanine (1), Altell (1)	
Lunch	14:30	60 mins	Common Room (11), Outside Building (7), Outside and Common Room (6), Desk(1),	
Meeting	n/a	60 mins	Offices, Meeting	

			Rooms 1, 2, 3	
Smoke Breaks, Toilet Breaks Etc. (To be collated)				

Table 2 User Travel User X

Start Point	End Point	Mid-point and Interactions	Duration
Entrance	Desk x	Door x, elevator x, door y	10 mins
Desk x	Common Room	none	15 mins
Desk x	Toilet	none	
Etc.			

2.3.10 Summary and Conclusion

This chapter presented the development of user activity and interaction models for the four building demonstration objects. It presented the rational for taking this approach with reference to the current state of the art. A methodology was presented for gathering data on user activities, and Unified Modelling Language (UML) activity diagrams were presented which capture user interactions and activities for each building object. Finally, some initial findings from questionnaires to building users of the Media-TIC building were presented.

In conclusion, the development of user activity models is challenging due to the non-deterministic nature of users. To develop accurate models, input is needed both from the users themselves and also from the analysis of the building systems. These approaches together will be employed within KnoHolEM to building up both building specific behavioural models and also to inform the resulting generic user behaviour models. The next stages of this work will be the continuation of the development of the activity models and collection of user data in conjunction with analysis of data which gives indication of occupancy and user interactions from building devices. The next chapter shall present a proposed solution within KnoHolEM for collecting data on user behaviour and interactions in conjunction with fault and energy wasting activity reporting.

2.4 General Building Use Case Example

2.4.1 Introduction

This section gives a description of a general use case for the KnoHolEM solution to be applied across the building objects. It is concerned with reporting building faults and energy wasting activities.

2.4.2 Fault and Energy Wasting Activity Reporting

As part of the data gathering over the four demonstration objects interviews were conducted with facility managers (FM) and building System Administrators. For a general template of these questionnaires see Appendix 2.9.5, although this template was often adapted on site depending on the circumstances, as the four building objects are different in their design and in the method by which they are maintained. A general use case for the KnoHolEM solution identified was the development of a method for reporting and analysing faults and energy wasting activities in buildings. Figure 21 gives a high level overview of this use case described using the Information Delivery Manual (Espedokken 2008). IDM has been chosen within the KnoHolEM project as the method for communicating use cases and data exchange requirements for implementing those use cases. IDM supports the capture of use cases using the Business Process Modelling Language developed by the Object Management Group (OMG)(White 2004; OMG 2009). Business Process Modelling Notation (BPMN) is a standard for graphically capturing business process modelling and which aims to be understood by all business stakeholders (White 2004). BPMN supports association of activities with data objects, which is an important aspect when considering data exchange requirements to complete a use case. By taking a standard approach, IDM also enables communication of developed use cases within the broader BIM community, who can review, re-use and recommend changes to improve the overall quality (Eastman, Jeong et al. 2010).

Figure 21 presents a BPMN for conducting evaluation of reports of faults and energy wasting behaviours. Faults include equipment failures, e.g. a broken light bulb or malfunctioning air conditioning unit. Faults also include perceived faults or problem behaviours, for example, sensors to detect occupancy may be indicating that a room is full, and therefore less heating is required. But users may have opened a window for fresh air, thus causing the temperature to drop. The automation system is behaving correctly, but the users have created a situation in which there is an apparent “fault”, the room is too cold. Energy wasting behaviours are functions of the building which are resulting in energy wastage. These can be as simple as lights being left on, or also due to the proper functioning of automation systems, for example air conditioning turning on due to CO2 levels, even when occupants have already opened windows and doors to improve air quality. The latter energy wasting behaviour and problem behaviours are harder to detect and need more careful consideration of the activities of building occupants in relation to the building automation systems.

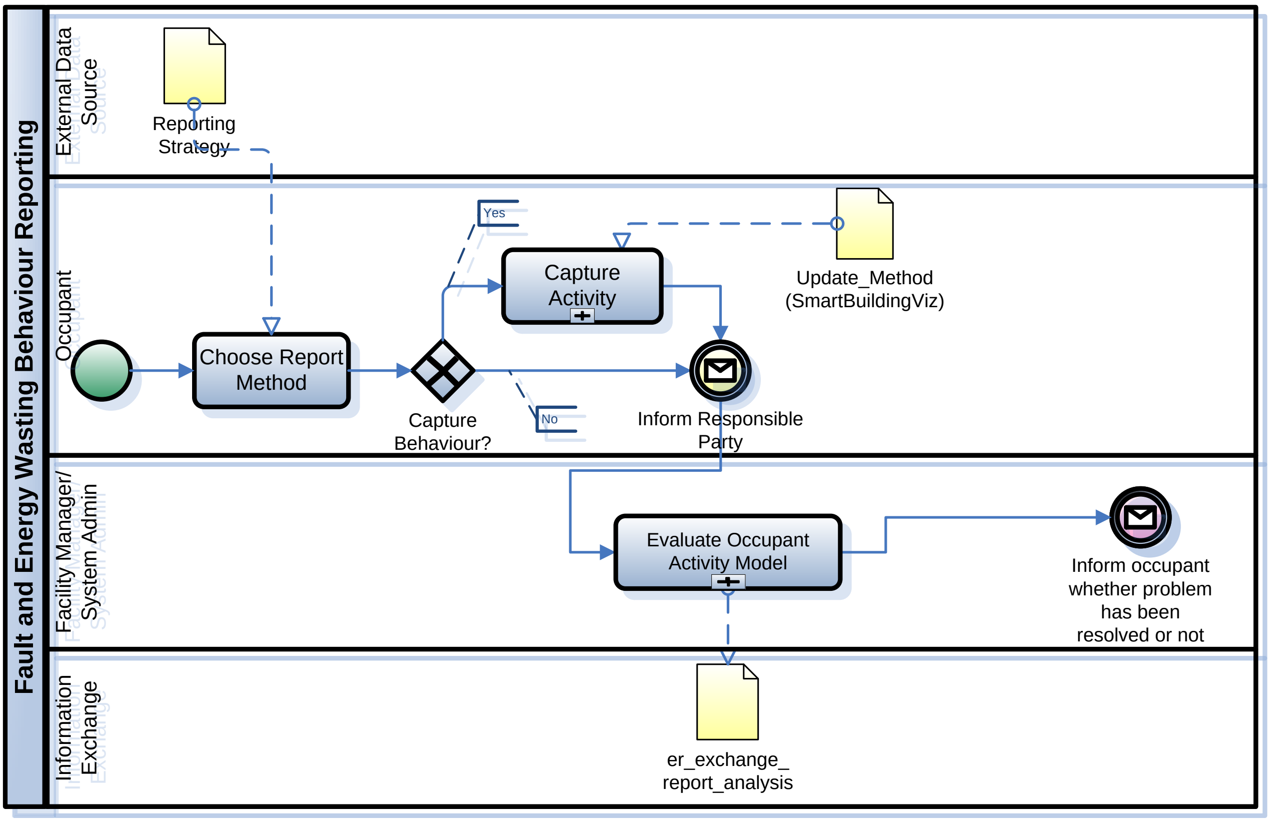


Figure 21 Fault Reporting

Figure 21 begins with a building occupant choosing a reporting method. Reporting strategies include traditional reporting methods like e-mail, via building reception or through direct contact. It also includes a proposed KnoHolEM developed solution which involves a web based graphical interface (SmartBuildingViz) for capturing the occupant’s activity when the fault or energy wasting activity took place to support better analysis of the report. SmartBuildingViz requires a geometric model of the building to exist, and this then supports the capture of activities when the fault or problem behaviour occurred. For example, the occupants place in the building or their movement through the building. The occupant also lists any building devices which were involved in the activity, for example lights, heating, etc. The activity model is not yet complete at this point, as it must first be sent to the appropriate person, e.g. the FM, System Admin, or whatever party is responsible (from now on referred to simply as FM). They must then evaluate it to determine its accuracy (as occupants may submit incorrect activities). The KnoHolEM solution then requires the FM to either evaluate the report and resulting activity (through the SmartBuildingViz tool) or to themselves create a model of their activity when the fault took place. This activity is described in greater detail in Figure 22. This final activity results in an analysis report, which is then be used if similar fault or energy wasting behaviour reports are created in future for comparison and adds to a knowledgebase regarding this types of activities and behaviours. When the use case is finished, the occupant who reported the issue is informed that it has been resolved.

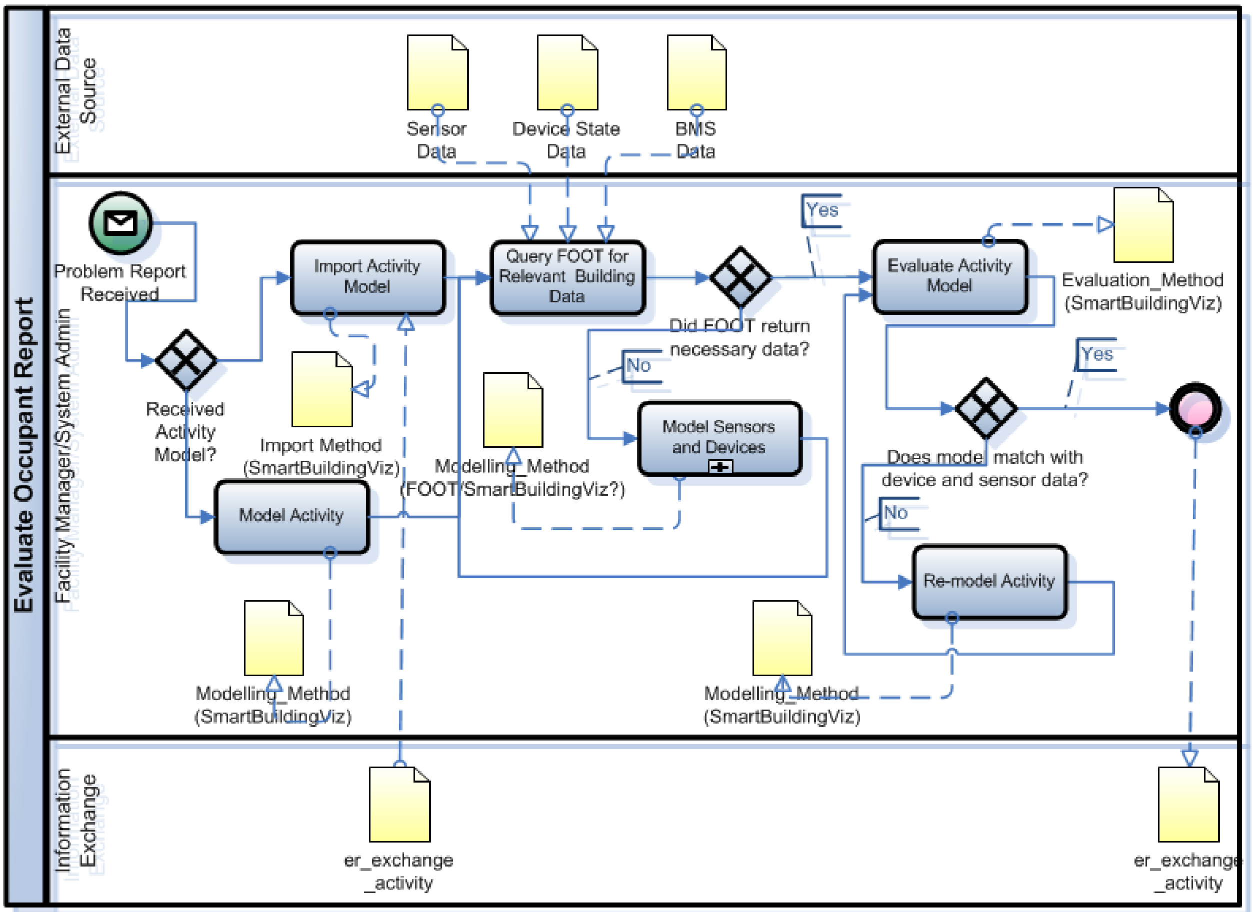


Figure 22 BPMN Evaluate/Create User Modelled Activity

Figure 22 shows the “evaluate occupant activity report”. Here the FM receives a report and evaluates it. If they have not received an activity model with the report, they must create it themselves. Otherwise they import the model sent to them. Now they evaluate the activity with data from the building itself. For example, consider a simple illustrative example of a system of passive infrared sensors (PIR) for turning on and off a light in a corridor. An occupant reports that the light did not turn on and they record the time and the path they took. There are two possible reasons why the light did not turn on. Firstly, the light bulb may be faulty; secondly a PIR sensor may be faulty. If the FM is provided with the exact path the user took, they can quickly check the PIR A sensor in that path to see if it is returning any data. Otherwise, they must check each PIR sensor which the occupant could potentially have triggered, and also the bulb.

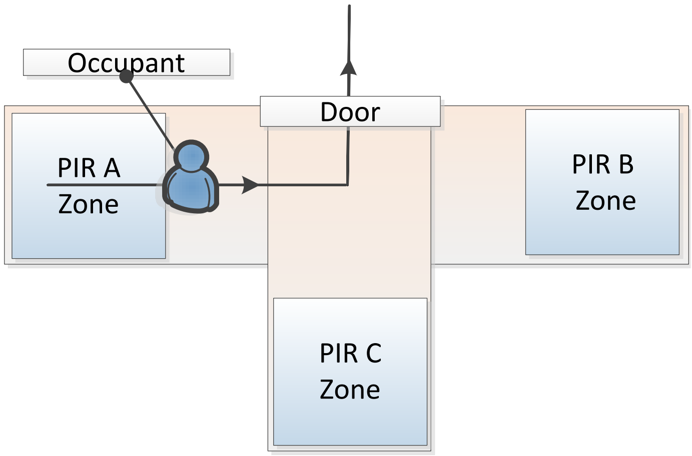


Figure 23 Fault Reporting Example

Figure 23 illustrates this. In this situation, it was the left PIR sensor which was faulty. Similarly, a conscientious occupant may notice that they are the only person in the building each night and that the corridor beyond PIR B leads to meeting rooms which are never occupied at night and which triggering any PIR in the corridor will turn on. They could recommend that the lights beyond PIR B no longer be turned on by triggering PIR A. Where there are more complex interactions of sensors and actuators and building systems (heating, air-conditioning), this type of information can become an invaluable part of determining the causes of faults in the building automation and also lead to more context specific energy efficient behaviours.

In order to evaluate such reports the FM or System Admin also requires access any available data from sensors, devices and Building Management Systems (BMS). The Function Oriented Ontology (FOOT) tool described in D1.1 provides a link between the SmartBuildingViz interface to support access to data on the state of sensor and devices. When a query is made by SmartBuildingViz for access to data on a sensor in a corridor for example, it passes this to FOOT. If no such model of the sensor yet exists, this can also be created through the SmartBuildingViz, supporting defining id, type and placement, as well as other relevant characteristics, for example, the measurement rate. This data then adds to the knowledge base for the building and results in a more complete building information model (BIM).

It should be noted that an occupant may incorrectly model an activity. Incorrect activity modelling can be evaluated also by comparing the activities with data from sensors and devices. The FM or System admin then either remodels the activity, or rejects it completely. The resulting activity model is added to the knowledge base for the building.

2.4.3 Summary and Conclusion

This chapter presented an example of a generic building use case, developed using the Information delivery Manual (IDM). It described the use of the SmartBuildingViz tool to model activities related to both faults of building devices and also energy wasting behaviours. It gave a breakdown of how these activities are carried out and then evaluated by a facility manager, or building administrator. It also described some illustrative examples where this solution may be applied. This approach forms part of the KnoHolEm solution for reducing energy consumption in buildings.

2.5 Conclusion

This deliverable D2.1 has summarized the last ten months' work performed as part of work package 2 on "Building Analysis" and refers to the task "perform requirements gathering on demonstration objects to determine typical devices and user interaction paradigms within the demonstration objects. This work feeds into the development of the KnoHolEM taxonomy, functional models and generic ontologies set out in deliverable D1.1.

The four demonstration objects present a considerable challenge for analysis due to their complex and differing designs, and usage. As a result it has not been possible to present all the data which has been accumulated, but only that data which has been considered relevant to the development of the building specific and also generic use cases presented here. The deliverable forms part of the continuing work on the demonstration object analysis and will be built upon as new and relevant data becomes available. Use cases will also evolve as more data on the behaviour of devices, sensors and users is gathered. This work should therefore be seen in the context of an on-going process of creating the building-specific behavioural models and the building-specific ontology rule sets for each of the demonstration objects, to meet the requirements of the KnoHolEM solution.

2.6 References

Degelman, L. O. (1999). A model for simulation of daylighting and occupancy sensors as an energy control strategy for office buildings.

Espedokken, K. (2008, Jan 11, 2008). "Information Delivery Manual - Confluence." Retrieved 28/05/2012, from http://idm.buildingsmart.no/confluence/display/IDM/Home.

Fowler, M. (2003). UML distilled: a brief guide to the standard object modeling language, Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA.

Gómez, C. C. "ARQUITECTURA TÉCNICA (PLAN 1999) INSTALACIONES DE CLIMATIZACIÓN (7322)."

Hoes, P., J. L. M. Hensen, et al. (2009). "User behavior in whole building simulation." Energy and Buildings **41**(3): 295-302.

Mahdavi, A., L. Lambeva, et al. (2007). "Two case studies on user interactions with buildings' environmental systems." Bauphysik **29**(1): 72-75.

Nicol, J. F. (2001). Characterising occupant behaviour in buildings: towards a stochastic model of occupant use of windows, lights, blinds, heaters and fans.

Ochoa, C. E., M. B. C. Aries, et al. (2011). "State of the art in lighting simulation for building science: a literature review."

OMG, O. m. G. (2009). Business Process Model and Notation (BPMN). Standard document URL: http://www.omg.org/spec/BPMN/1.2. **Version 1.2**.

Reinhart, C. F. (2004). "Lightswitch-2002: a model for manual and automated control of electric lighting and blinds." Solar Energy **77**(1): 15-28.

Rijal, H., P. Tuohy, et al. (2007). "Using results from field surveys to predict the effect of open windows on thermal comfort and energy use in buildings." Energy and Buildings **39**(7): 823-836.

Shen, W., Q. Shen, et al. (2011). "Building Information Modeling-based user activity simulation and evaluation method for improving designer-user communications." Automation in Construction.

Tabak, V. and B. De Vries (2010). "Methods for the prediction of intermediate activities by office occupants." Building and Environment **45**(6): 1366-1372.

White, S. A. (2004). "Introduction to BPMN." IBM Cooperation: 2008–2029.

Wienold, J. (2007). Dynamic simulation of blind control strategies for visual comfort and energy balance analysis.

Wienold, J., F. Frontini, et al. "CLIMATE BASED SIMULATION OF DIFFERENT SHADING DEVICE SYSTEMS FOR COMFORT AND ENERGY DEMAND."

Zimmerman, G. (2007). Modeling and simulation of individual user behavior for building performance predictions. Proceedings of the 2007 summer computer simulation conference. San Diego, California, Society for Computer Simulation International: 913-920.

2.7 APPENDIX A (Additional Building Information)

2.7.1 MediaTIC (B-Digital)

2.7.1.1 Energy Information

2.7.1.1.1 Introduction

In this document is explained a part of the energetic information study that have been done for the Media-TIC building. In the energetic domain, in the building have been done a variety of energetic calculus to measure and study how effective and efficient the Media-TIC building can be. The studies that have been done can be categorized in:

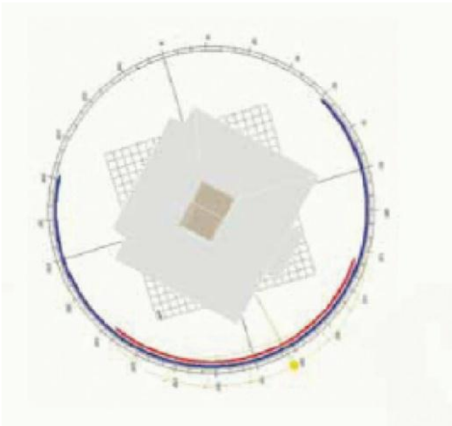
- Energy Balance.
- Shade Study
- Energy use simulation.
- Energy used
- Energy status.

The studies have been done for the PGI solutions company. The information have been translate and copied for its report to better Media-TIC understanding.

2.7.1.1.2 Studies

2.7.1.1.2.1 Shade Study

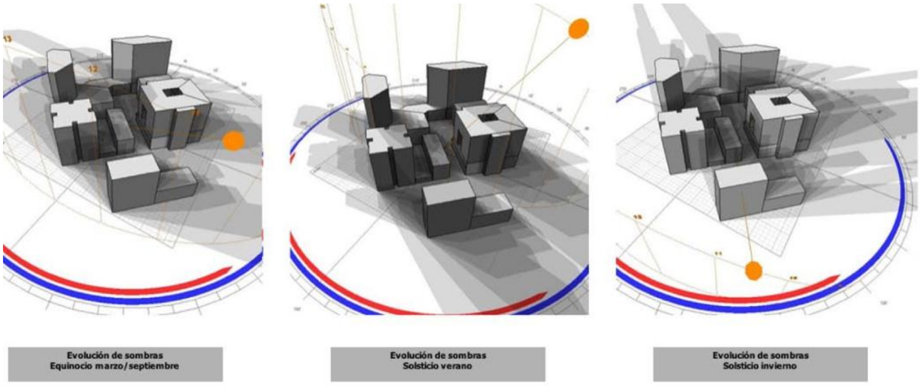
A study of shade and sun exposure was carried out that allowed the identification of the critically exposed facades, an analysis of the number of hours of sunlight on the various facades, with a shade study being made of the actual building and external buildings (Figure X).



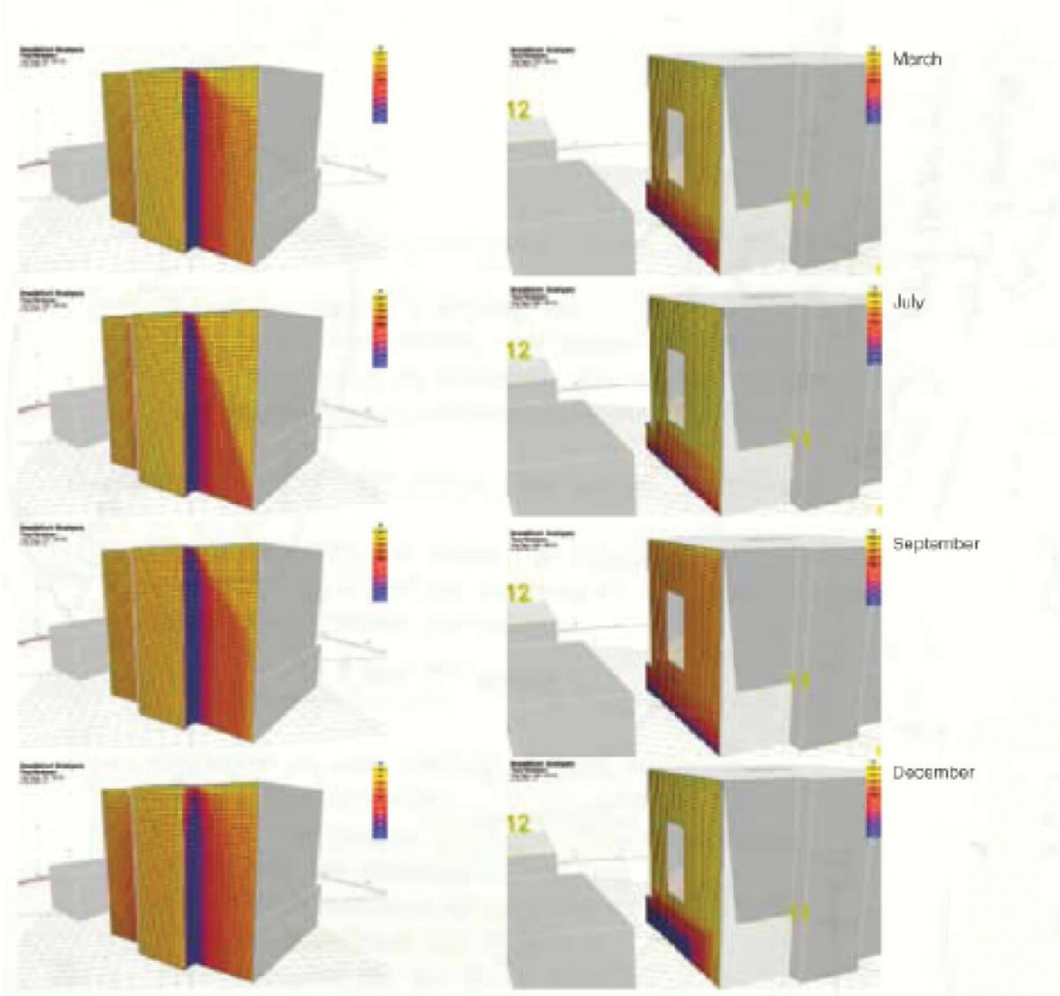
The blue line shows the sun's maximum movement coinciding with summer solstice and the red line indicates the sun's minimum movement coinciding with the winter solstice.

SEVENTH FRAMEWORK PROGRAMME

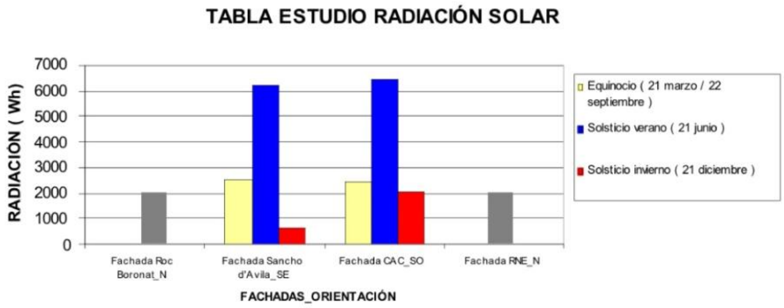
The radiation graphs (Figure X) show specific values for summer months of approximately 580 W/m2, which makes passive protection necessary for this facade.



The radiation graphs show specific values for summer months of approximately 580W/m2, which makes passive protection necessary for this façade.



As a conclusion, the preceding radiation study is summarized in the following representative table (Figure X) based on façade orientation and time of the year.

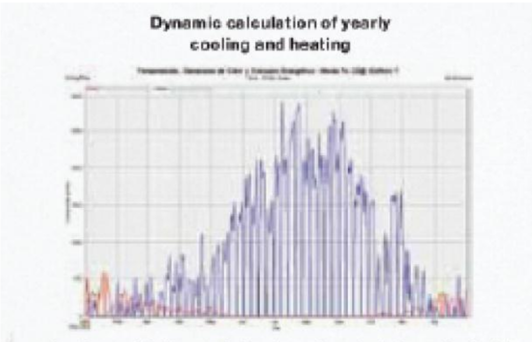


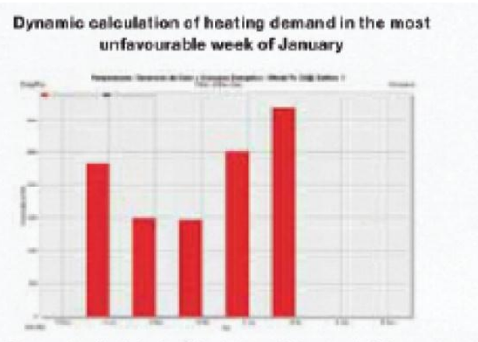
2.7.1.1.2.2 Energy use simulation

An energy use simulation was carried out on the entire building (software DESIGN BUILDER 1.4), with the following procedure being taken into account:

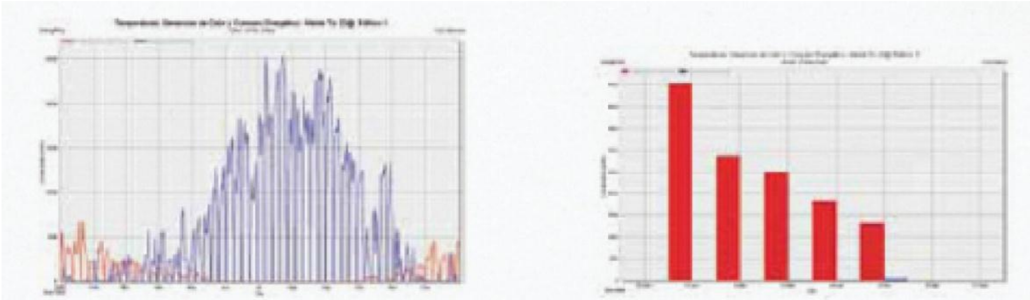
Basic Building. This refers to the building studied in the preceding sections without considering the incorporation of ETFE on the SE and SW facades, i.e. complying with the building code but with no other additional measures; in other words, without taking the ETFE facades into account. Consequent to the analysis performed previously and parallel to the architectural solution, passive protection elements are incorporated to provide a solution to the excessive radiation on the SE and SW facades, as mentioned.

Heating demand calculation-dynamic method. Calculated for all months of the year when the building requires heating, and with the calculations of hours per day (8.00 am – 6 pm). As observed in the firsts graphs (Figure X), the days of greatest demand coincide with the month of January. A close is taken to detect the week and specific day of most unfavorable conditions. Furthermore, the most critical day is detected on 18th of January in this case, leading to a more detailed study of that day to determine the power required to be produced.

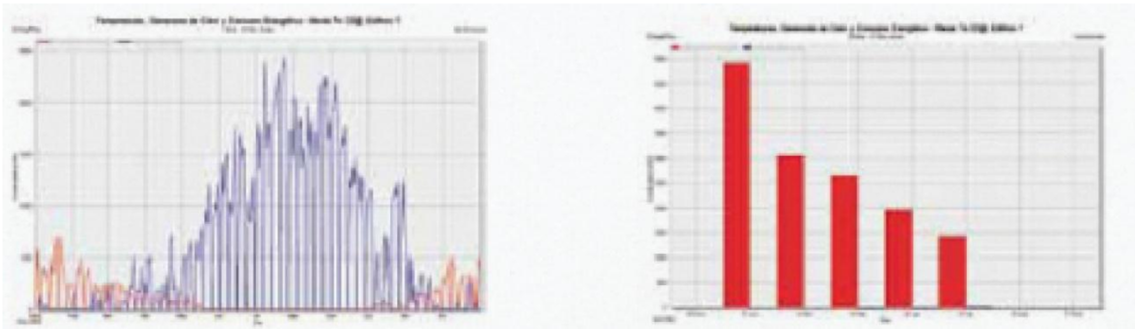




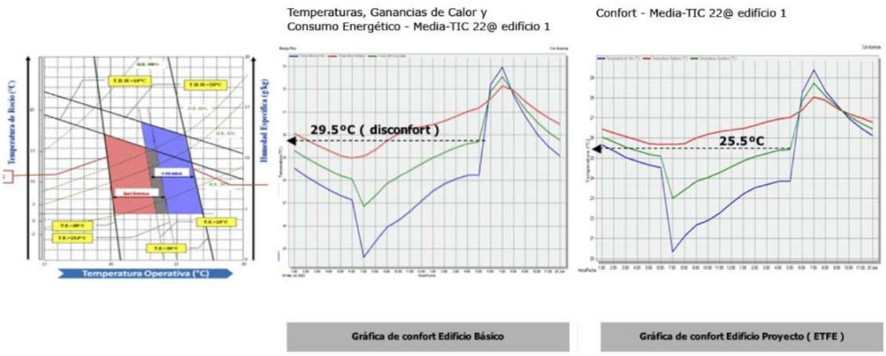
In the second graph (Figure X), the days of greatest demand coincide with the month of January. A close up is taken to detect the week and specific day of most unfavorable conditions. Furthermore, the most critical day is detected as 21th of January in this case, leading to a more detailed study of that day to determine the power required to be produced.

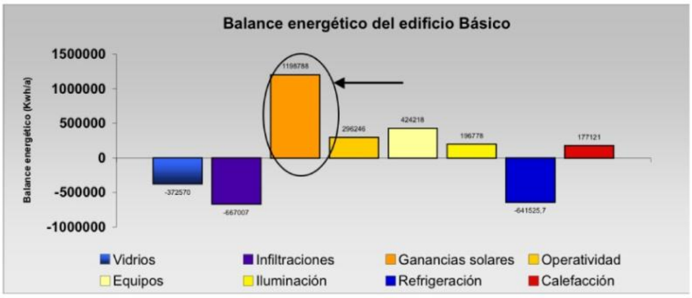


In the third graph (Figure X), the days of greatest demand coincide with the month of January. A close up is taken to detect the week and specific day of most unfavorable conditions. Moreover, the most critical day is detected as 21th of January. In this case, leading to a more detailed study of that day to determine the power required to be produced.



The greatest demand for cooling is due to radiation on the glass (43%). Yearly heating demand represents a low value with regard to total energy use. Yearly demand for cooling is much higher than for heating (Figure X).





Basic building energy balance (Figure X). This refers to the building studied in preceding sections without considering the incorporation of ETFE and according to regulation values (new building code). Project building (ETFE and ETFE open) refers to the project building with the architectural solution with ETFE. Project building (ETFE closed and ETFE with fog) refers to the project building with the architectural solution and modifying the properties of the ETFE when there is solar incidence on the facades and cooling in operation. The ETFE under different working conditions provides an air chamber and powerful sun protection factor that enhances the thermal behavior of the building. Starting hypothesis:

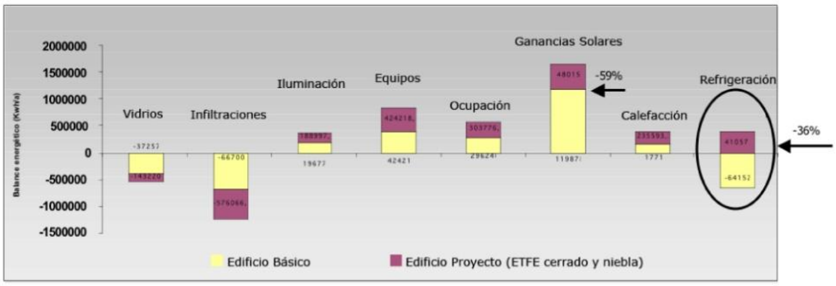
- Lighting ratio: 15 W/m2.
- Occupation ratio: 1 per/10m2.
- Sancho d'avila glass façade: 6/12/55 + ETFE open/closed U=2.8 W/m2.K; FSm=0.35/0.25.
- CAC glass: 6/12/66 + ETFE/fog U=2.8W/m2.K; FSm=0.45/0.10.
- Operating temp: 24ºC
- Lighting control at < 3m from the façade.

Balance energético edificio etfe y etfe abierto.

Edificio Proyecto (ETFE abierto)

Balance energético edificio etfe y etfe niebla.

Balance Energético del Edificio Proyecto (ETFE cerrado y niebla)



In agreement with all the studied variants and with the project solution, a summary is made of the results and a number of conclusions are given:

Energy use simulation summary. The following table (Table X) shows the calculations made by means of simulation software, in which the static calculations are presented, and the dynamic calculations are added in order to simulate the entire building.

Project Considerations	**Heating Power**			**Cooling Power**		
	Static Method (Kw)	*Dynamic method (kW)*	*Simultaneo usness (%)*	*Static Method (Kw)*	*Dynamic method (kW)*	*Simultaneousnes s (%)*
Basci building	944	336	36	1854	1128	61
Project building (ETFE and ETFE open)	863	412	48	1562	903	58
Project building (ETFE closed and ETFE smoked)	863	412	48	1519	887	58

2.7.1.1.2.3 Conclusions

With regarded to the difference between the basic building option and the project building option that incorporates ETFE on the most unfavorable facades (in accordance with the construction

solution proposed by the architects and validated by the first part of this report), it is observed that: The difference with regard to heating between the differences options considered is minor given that, as the double skin with ETFE is an open space, it does not provide the same benefits in winter as it does in summer. The result obtained is slightly contrary, owing to the ETFE penalizing the contribution of solar energy in winter as it increases the solar protection factor.
Nevertheless, heating requirements (kWh) over the entire year makes up 14% of energy use compared to the 86% demand for cooling, meaning that this slight increase in heating demand when ETFE is incorporated is irrelevant.

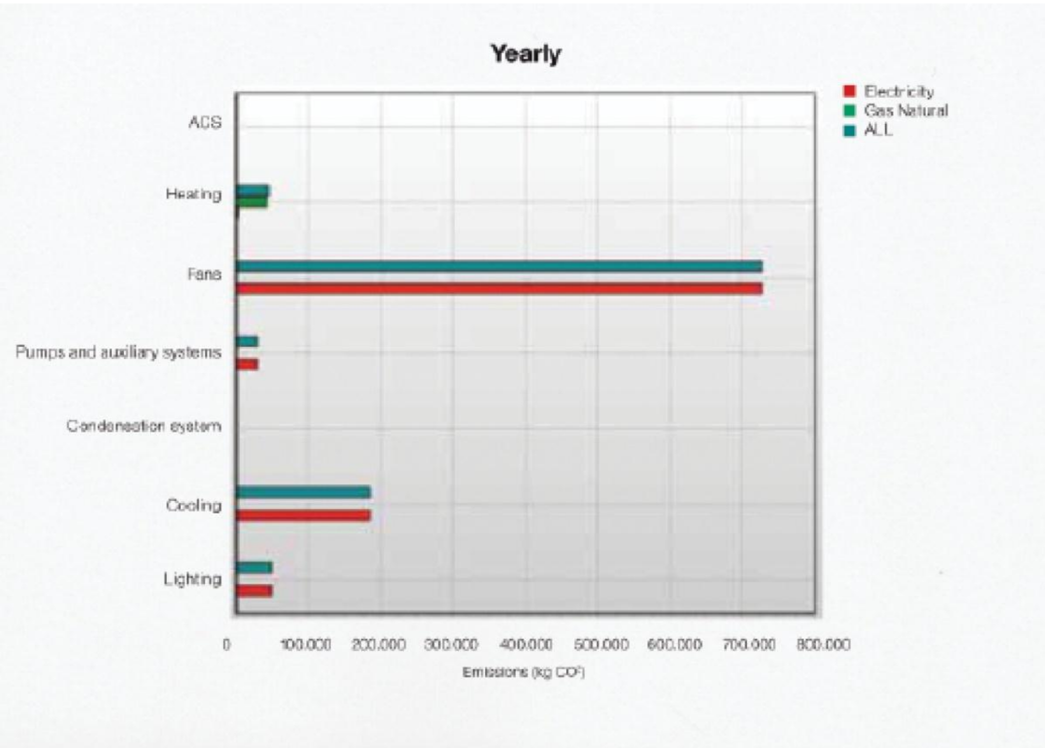
With regard to cooling, the difference between the basic building and the option of the project building incorporating ETFE and ETFE closed/fog is greater and therefore very beneficial in archiving a reduction in energy requirements over the entire year.

The power required is reduced from 1,854 kW to 1,519 kW, meaning a reduction of some 335 kW with the option incorporating ETFE closed/fog. This difference in installed kW power is in fact of great relevance given that the demand for cooling throughout the year makes up 86% of system operating hours. The following table (Table X) shows the difference in energy demand between the different options studied.

2.7.1.1.2.4 Energy use

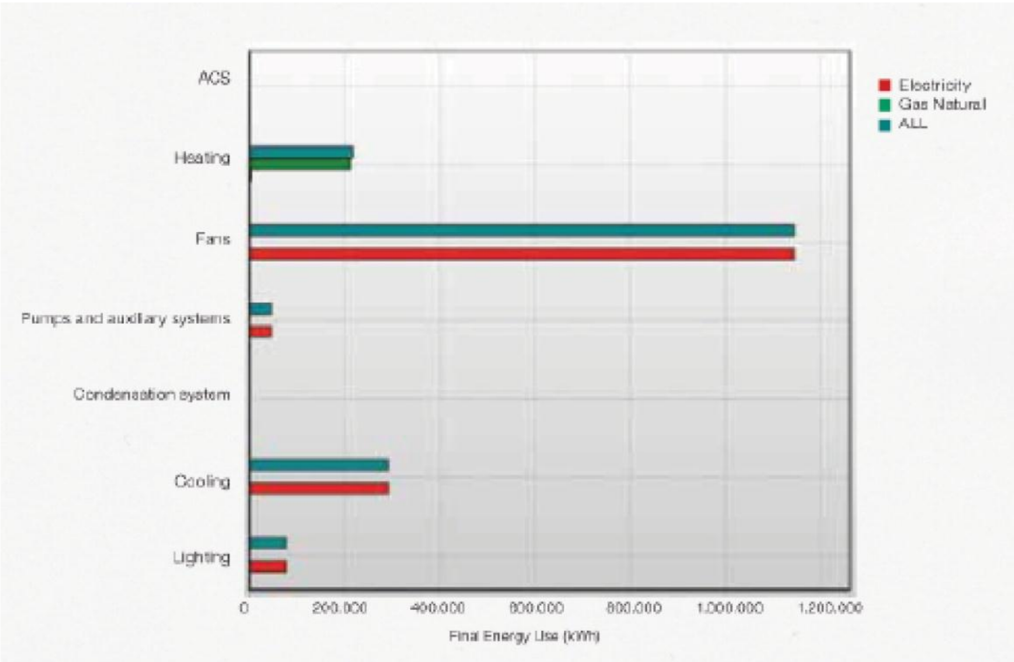
The building complies with regulations for new buildings. With regard to energy rating, we can conclude that we have a good overall design for lighting, pumps and auxiliary systems, heating and cooling.

	E	F	M	A	MY	JN	JL	AG	S	O	N	D	TOTAL
Lighting	*6403*	*4760,2*	*4043,2*	*2823,8*	*2943,2*	*2706*	*2876,9*	*2072,4*	*3078,7*	*4269,6*	*6491,6*	*6218,4*	*48687*
Cooling	*441,6*	*669,8*	*1878,4*	*2623,7*	*21079*	*26066,1*	*28460,5*	*28787,5*	*26800*	*21960,6*	*17024,2*	*12962,6*	*188753,7*
Pumps and Auxiliary	*1466,4*	*1484,8*	*1767,5*	*1917,2*	*3152,2*	*3217,6*	*3126,1*	*3116,3*	*3103,2*	*3282,2*	*2789,2*	*2359,2*	*30781,9*
Fans	*61939*	*55944,8*	*51939*	*59940,9*	*61939*	*59940,9*	*61939*	*61939*	*59941*	*61939*	*59940,9*	*61939*	*719281,4*
Heating	*170,8*	*105,9*	*89,5*	*52,3*	*304*	*247,1*	*232,4*	*230,8*	*237,6*	*287,4*	*314,9*	*382,8*	*2655,5*
TOTAL	*70420,8*	*62965,5*	*59717,6*	*67357,9*	*89417,4*	*92177,7*	*96634,9*	*96146*	*93160*	*91738,8*	*86560,8*	*83862*	*990159,5*



Once the building in project stage and construction stage receives an energy rating, a project energy rating needs to be obtained. This is an administrative procedure that verifies compliance with the project energy rating and leads to an energy efficiency certificate being issued for the project.

	E	F	M	A	MY	JN	JL	AG	S	O	N	D	TOTAL
Lighting	*10070,6*	*7499*	*6359,1*	*4441,2*	*4529*	*4256*	*4524,5*	*4675*	*4842,2*	*6715,3*	*10210*	*9760,4*	*77882,3*
Cooling	*694,5*	*1052,7*	*2954,4*	*4126,6*	*33153,1*	*39424,1*	*44747,1*	*45277,1*	*40678*	*34539,7*	*26775,8*	*20371,9*	*293794,8*
Pumps and Auxiliary	*2305,8*	*2336,2*	*2811,4*	*3015,4*	*4957,8*	*5060,6*	*4919,9*	*4901,3*	*4880,7*	*5162,3*	*4355,4*	*3710,5*	*48417,3*
Fans	*97417,9*	*97990,4*	*97417,9*	*94275,4*	*97417,9*	*94276,4*	*97417,9*	*97417,9*	*94275*	*97417,9*	*94275,4*	*97417,9*	*1157018,3*
Heating	*288,6*	*166,6*	*109,4*	*62,3*	*476,1*	*366,7*	*385,5*	*363*	*373,7*	*451,9*	*495,2*	*632,1*	*4171,1*
TOTAL	*110777,4*	*109044,9*	*109652*	*105921*	*140534*	*143383,8*	*151994,9*	*152634*	*145050*	*144287*	*136111,8*	*131893*	*1581283,8*

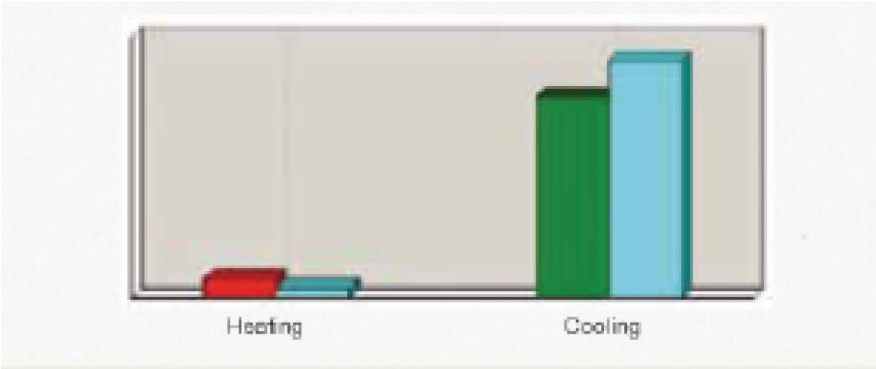


2.7.1.1.2.5 LIDER software results

The building describes in this report COMPLIES with the regulations established in the building code as describes in the basic document HE1(/Media-TIC_Building/Data/BuildingCalculus/….), Compliance with HE1 was performed with the new version of LIDER v1.0 (01/07/09) software. As the results received differ greatly respect to the previous version, pending consultations were made with the competent authorities in this regard ordered to obtain a response concerning the suitability of this new version and, therefore, the possible influence or lack thereof it might have on the building energy rating.

	Heating	**Cooling**
% of benchmark demand	*205.8*	*85.3*
Relative heating/cooling	*8.4*	*91.6*

proportion		

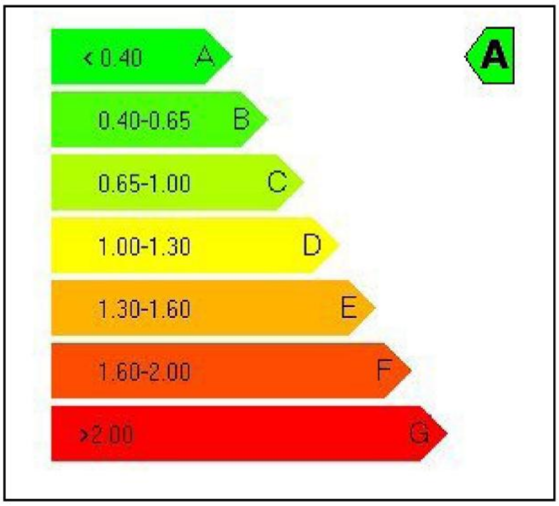


2.7.1.1.2.6 Results with CALENER

2. RESUMEN INDICADORES ENERGÉTICOS ANUALES

Indicador Energético	Edif. Objeto	Edif. Referencia	Índice	Calificación
Demanda Calef. (kW·h/m²)	58.3	10.1	5.79	G
Demanda Refri. (kW·h/m²)	79.1	180.6	0.44	B

Emisiones Climat. (kg CO2/m²)	62.9	140.6	0.45	B
Emisiones ACS (kg CO2/m²)	0.0	0.0	-1.00	-
Emisiones Ilum. (kg CO2/m²)	3.1	26.4	0.12	A
Emisiones Tot. (kg CO2/m²)	**66.1**	**167.0**	**0.40**	**A**



Concepto	Edif. Obj.	Edif. Ref.
Energía Final (kWh/(m²año))	113.2	399.0
Emisiones (kg CO2/(m²año))	**66.1**	**167.0**

2.7.1.2 B-Digital Sensor_ActuatorTable_v1.2

Device	**Kind of device (CO sensor, window motor, actuator, light sensor)**	**Description or Datasheet**	**Max. Num expected in floor (final number**	**Protocol version Supported**	**Output Power**
ZigBee Xbee Power outlet (Pikkerton)	Power control energy meter	http://www.pikkerton.com/mediafiles/43-ds_zbs-110_v1_10_en.pdf	20	ZigBee compatible with Digi Xbee	• 2 mW (+3 dBm) tp tu 50mW (+17dBm) TX power
ZigBee Xbee Presence/L/T/H (Pikkerton)	Integrated presence, ambient light, temperature, and humidity sensors	http://www.pikkerton.com/mediafiles/21-ds_zbs-x2x.pdf	2	ZigBee compatible with Digi Xbee	• 2 mW (+3 dBm) TX power
XBee /L/T/H Adapter (Digi)	Integrated ambient light, temperature, and humidity sensors	http://www.digi.com/products/wireless-modems-peripherals/wireless-range-extenders-peripherals/xbee-sensors#specs	10	ZigBee compatible with Digi Xbee Znet and EmberZNet	Transmit power output: 1.25 mW (+1 dBm) / 2 mW (+3 dBm) boost mode
X4 Gateway (Digi)	Gateway	http://www.digi.com/products/wireless-routers-gateways/routing-gateways/connectportx4#specs	1	UDP/TCP, DHCP, SNMPv1/v2 ZigBee compatible with Digi Xbee	Idle 1.5W, Max: 10.4 W (Power Consumption)

Data rate (data refreshing maximun/expected/allowed frequency)	**Kind of cable**	**Frequency range , bandwith, channel spacing**
RF data rate: 250,000 bps	NA	• ISM 2.4 GHz frequency • 2 mW (+3 dBm) TX power (up to 120 m range) • 50 mW (+17 dBm) TX power (up to 1.6 km range) with PRO option • Internal antenna • Approved for use in US, Canada,
RF data rate: 250,000 bps	NA	• ISM 2.4 GHz frequency • 2 mW (+3 dBm) TX power (up to 120 m range) • Internal antenna
RF data rate: 250,000 bps	RJ-45	Indoor/Urban range: 133 ft (40 m) • Outdoor RF line-of-sight range: 400 ft (120 m) • Transmit power output: 1.25 mW (+1 dBm) / 2 mW (+3 dBm) boost mode • RF data rate: 250,000 bps
RS 232: Up to 230 kbps Ethernet: 10/100 Mbps (auto-sensing)	RS 232 (Serial) USB RJ-45 (Ethernet)	Serial: 230 Kbps Ethernet: 10/100 Mbps RF: ZigBee(2.4 Ghz); DigiMesh(2.4 Ghz or 900 MHz)

Architecture/network topology, channel access mode, kind of routing	Kind of network (mesh, star,etc)
ZBS-110 devices are mains switches, controlled via the wireless ZigBee network (IEEE 802.15.4), acting as a router. The ZBS-110/M detects motion and transmits these events to the network coordinator. Both devices contain a high-precision	Mesh
	Mesh
XBee sensors offer the ability to provide real-time data from a variety of sensors (e.g., temperature, humidity, light) in a single solution for wireless communication across a ZigBee infrastructure.	Mesh
Modbus bridge enables Modbus serial to Modbus/TCP conversion; Integrated Python code allows gateway to act as Modbus client/master or Modbus server/slave; Functions like an Ethernet to serial bridge, but uses ZigBee to transport serial data; Handles unique timing issues per Modbus protocol rules Uses Modbus Unit ID to look up IP or mesh MAC address	Mesh

2.7.1.3 B-Digital Building Management System

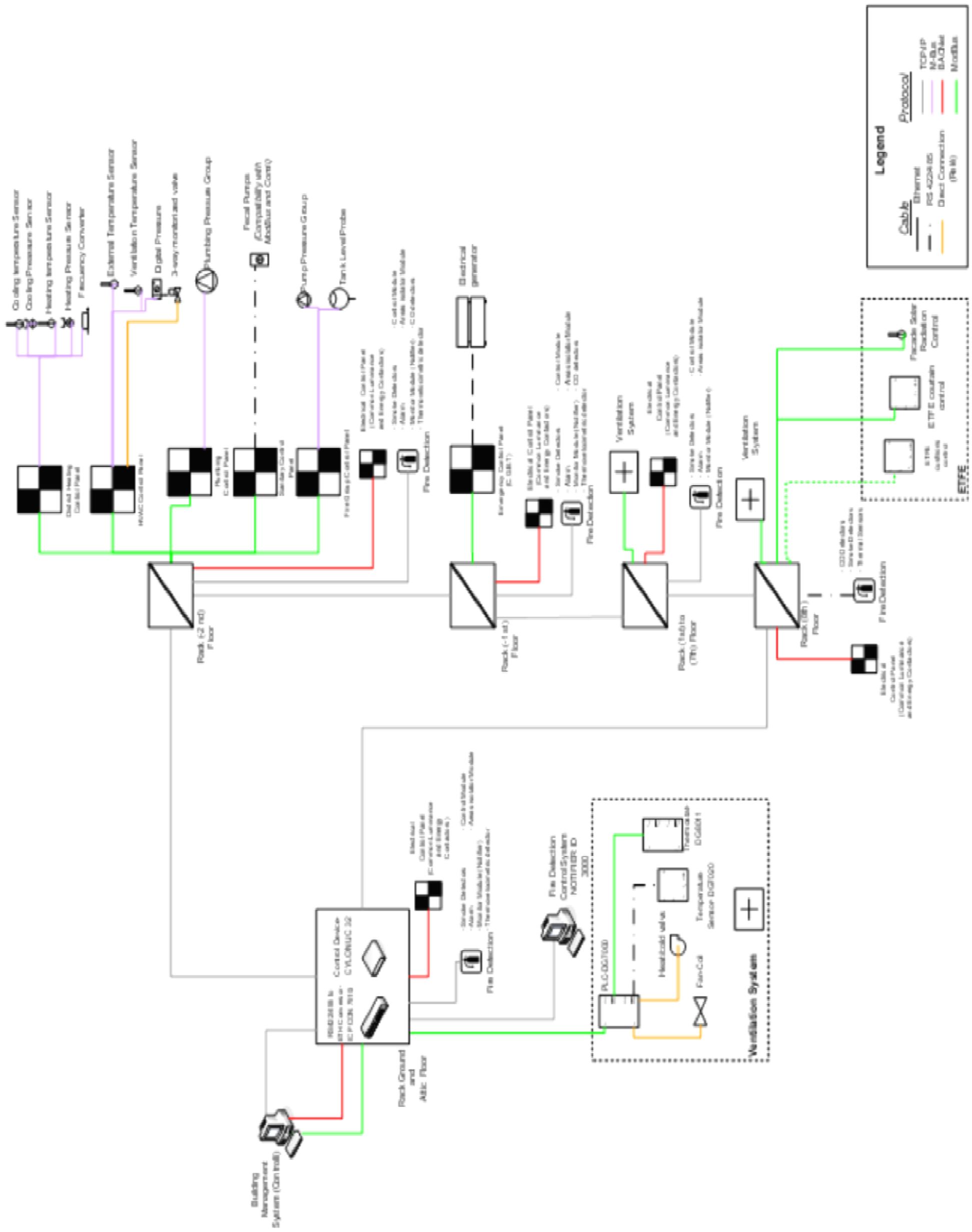


Figure 24: Building Management System infrastructure

SEVENTH FRAMEWORK PROGRAMME

2.7.2 Forum Building

2.7.2.1 Building Geometry 2D Models

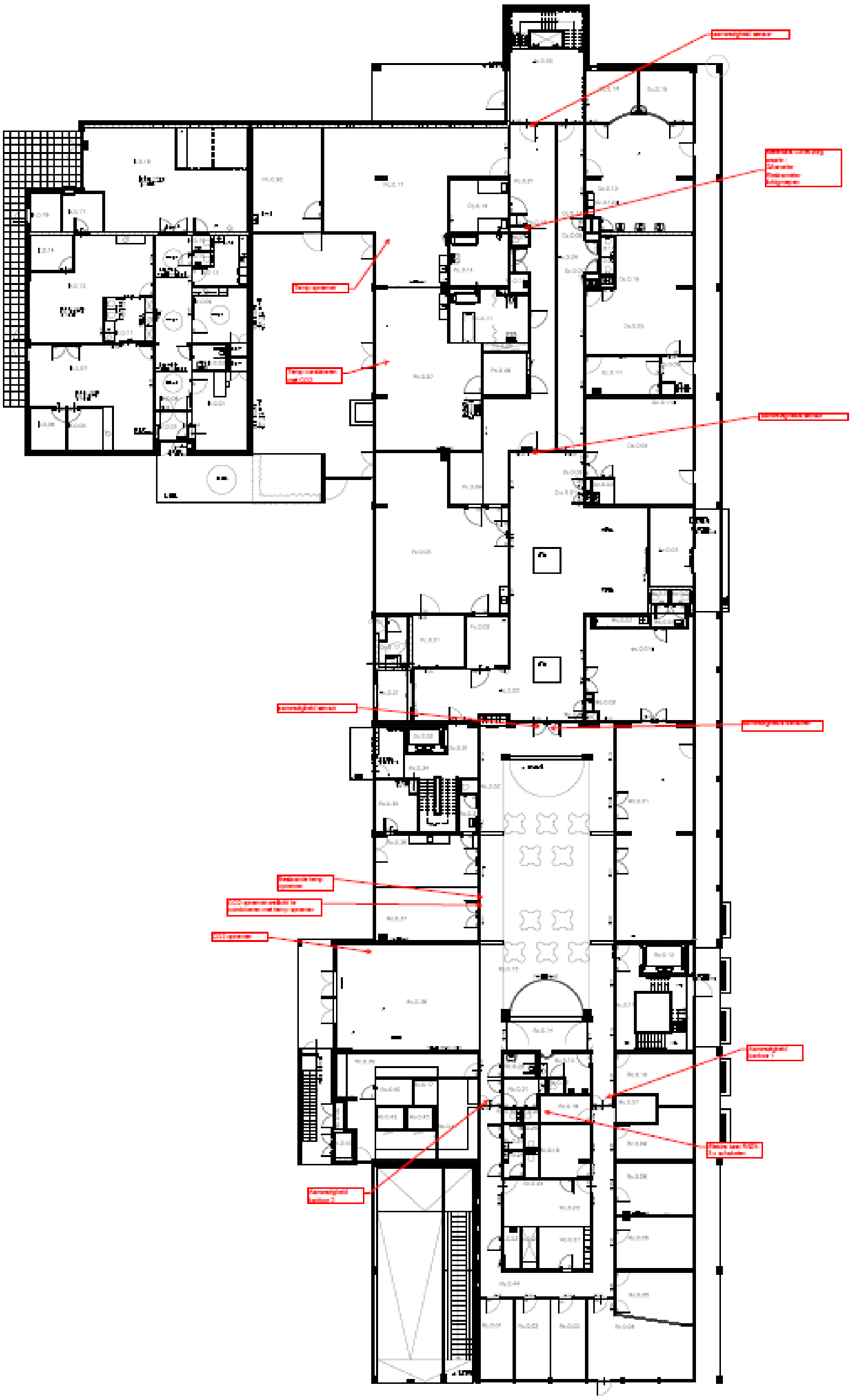


Figure 25 Forum Ground Floor

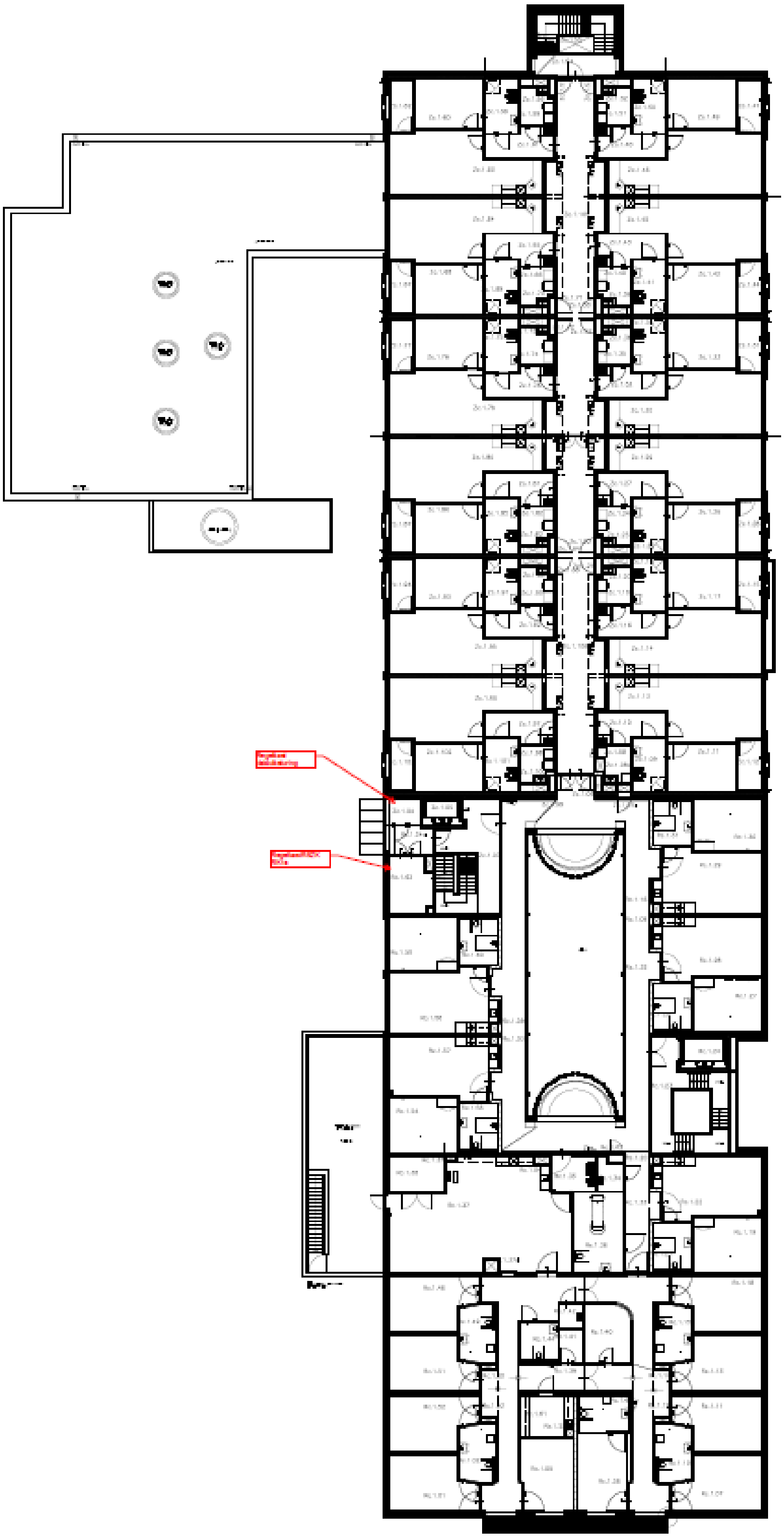


Figure 26 Forum 1st Floor

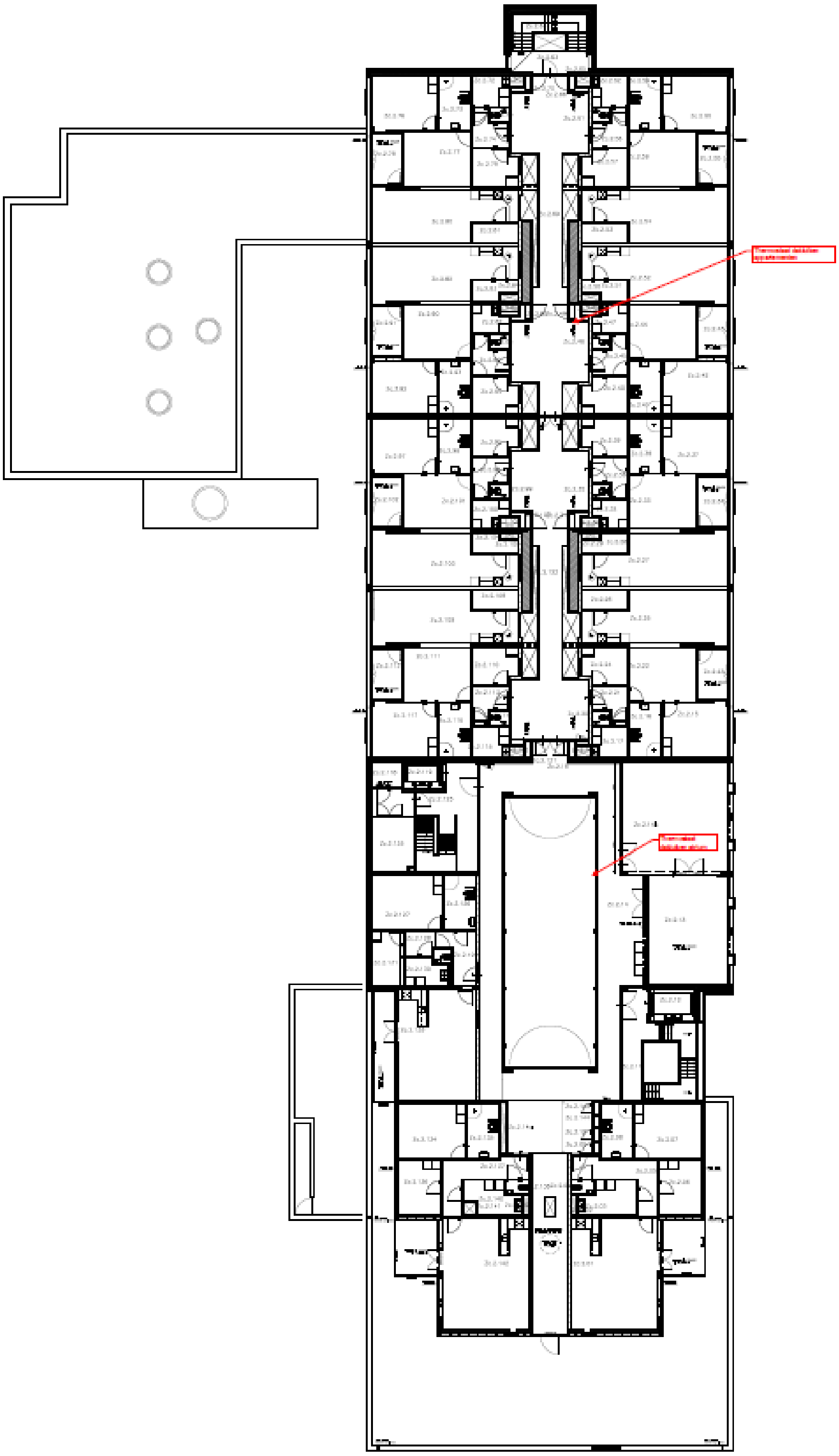


Figure 27 Forum 2nd Floor

2.7.2.2 Forum: Equipment in the Offices

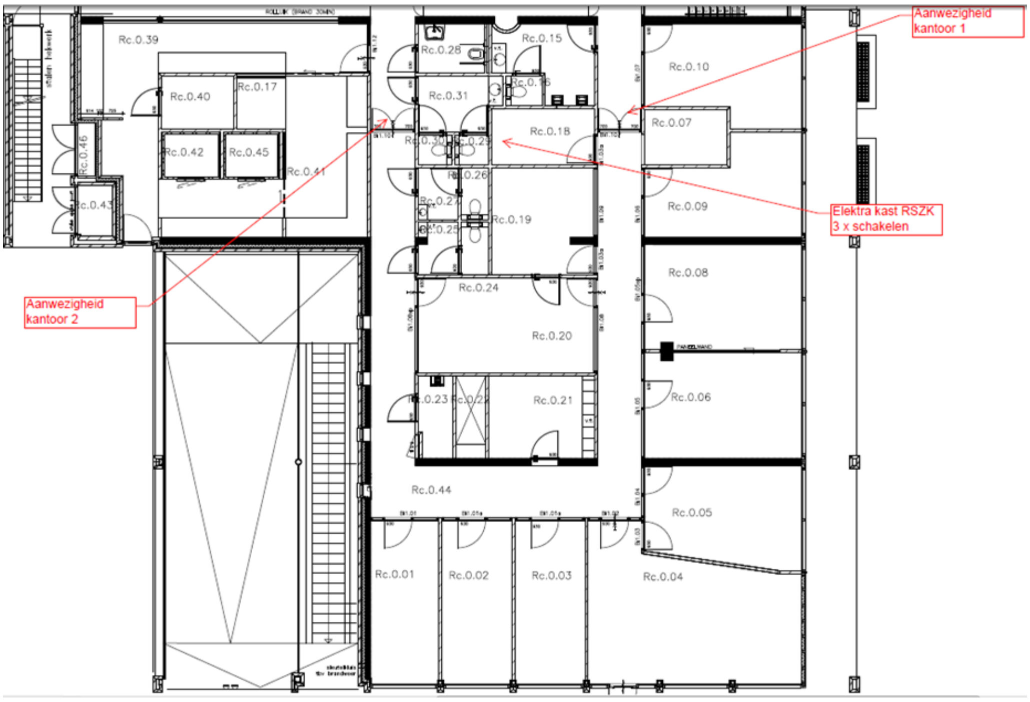


Figure 28 Office Equipment

Office Rc.0.01 3 x fluorescent Lighting 3 x PC	Office Rc.0.02 3 x fluorescent Lighting 1 x PC	Office Rc.0.03 3 x fluorescent Lighting 1 x PC
Office Rc.0.04 7 x fluorescent Lighting 2 x PC	Office Rc.0.05 3 x fluorescent Lighting 2 x PC 1 x Printer	Office Rc.0.06 4 x fluorescent Lighting 1 x Television
Office Rc.0.08 4 x fluorescent Lighting	Office Rc.0.0 9 3 x fluorescent Lighting 2 x PC	Office Rc.0.0 7 Printer Area 1 x fluorescent Lighting 1 x Printer 1 x Refrigerator
Office Rc.0.10 Reception 3 x fluorescent Lighting 1 x PC 1 x Paper shredder	Office Rc.0.19 Doctor 2 x fluorescent Lighting 2 x PC	

We have 11 plugs.
Example : To measure Office Rc. 0.07 you need 3 plugs.
To measure Office Rc. 0.10 you need 5 plugs

2.7.3 HSS

2.7.3.1 HSS Building Geometry (1st and 2nd Floor)

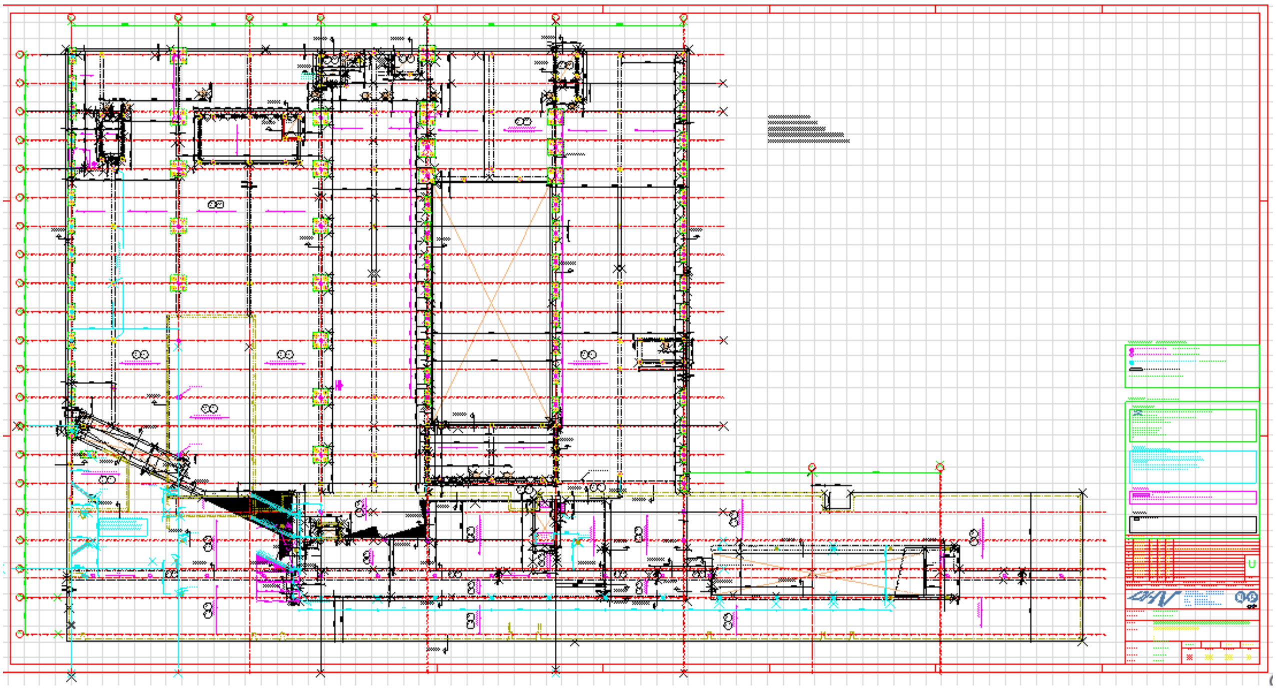


Figure 29 Ground Floor

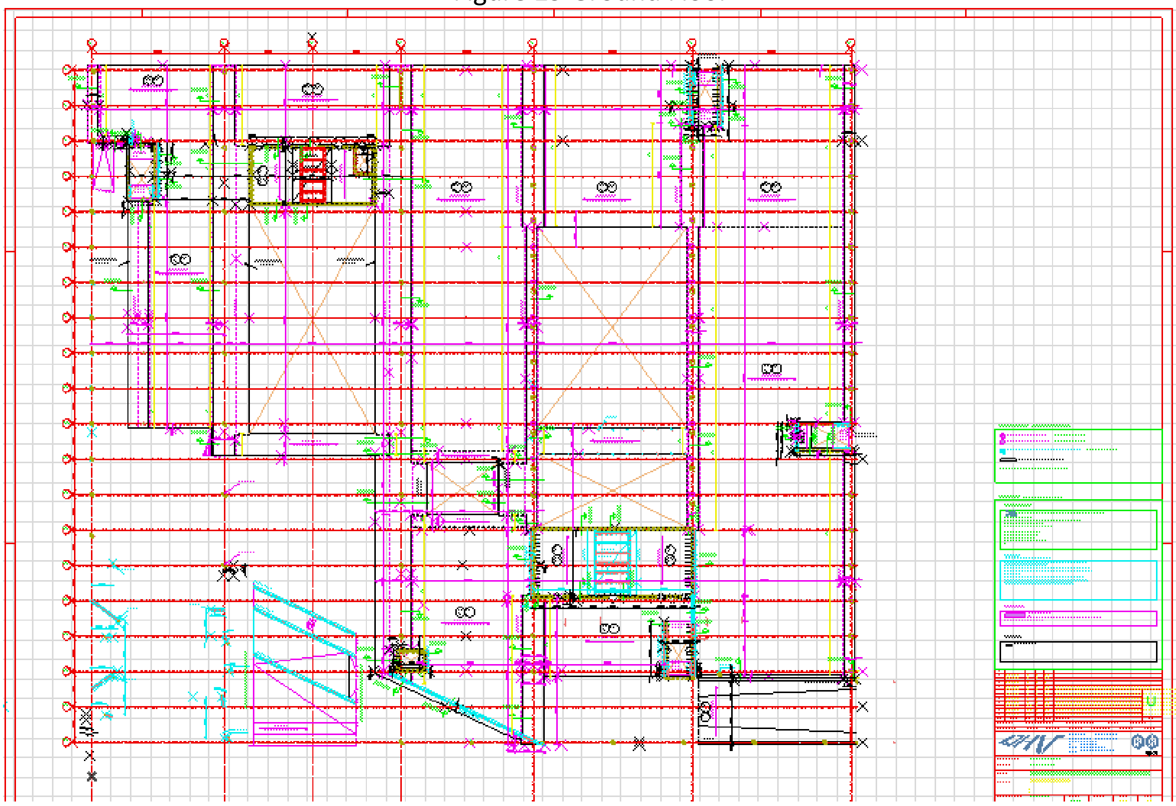


Figure 30 First Floor

2.7.3.2 *Survey user satisfaction indoor climate HHS (Delft)*

Two student groups in Facility Management have done research at the perception of the indoor climate in November 2010 in the Delft building of The Hague University.

2.7.3.2.1 *Introduction*

The new location in Delft (2009) is, compared to the old location in Rijswijk, a total change. It is has a demand-driven climate system and is the most energy efficient school building in the Netherlands. Some of the materials which have been used:

- Heat pumps
- Energy storage in the soil
- PV system
- Solar
- Roadway parking collector
- Improve insulation shell (extra insulation in the walls, improved draft proofing, application of HR + + glass)
- Concrete core activation / activated ceilings
- Energy efficient lighting
- Improved control of ventilation
- Innovative control: Ocatlix

Despite the many new materials and techniques that are designed and positioned it remains a new building with new systems. These systems are not optimally tuned. The criteria for these settings are often the legal standards. This doesn't mean that these standards are perfect for each building user. The data shows that generally responds positively to the new location in Delft.

Student Results Group 1

There are 82 surveys conducted in Delft. Because, unfortunately, is not representative of the results to measure the amount of men and women in Delft site, because only 9 women were walking around, we have chosen to only the general benchmark to use to be able to provide any advice. These general benchmark concerns: all factors of the indoor climate, such as temperature, light etc.

Total population: 82

Vragen	Ontevreden	Tevreden
Ervaring temperatuur	20,8 %	79,2 %
Geluidsniveau	19,5 %	80,5 %
Ervaring licht	11 %	88 %
Luchtvochtigheid	13,4 %	86,6 %
Ervaring luchtkwaliteit	24,4 %	75,6 %
Binnenklimaat totaal	15,9 %	84,1 %

The temperature, noise and air quality by approximately 20% experienced dissatisfaction. This is because location Delft climate has sent a question. The corridors are not used during school hours when no classes are the way as cold.The Delft offices there are many large areas to find, by the sound loudness leads to complaints from other building users. Many users are dissatisfied with the building air quality, this is remarkable because the amount of fresh air depending on the number of building users in that relevant area. A possible explanation is, as well as at the temperature, that spaces which are not widely used, is less of fresh air are provided.

Men

There are 73 men surveyed.

Vragen		Ontevreden	Tevreden	Onbekend
Ervaring temperatuur	experienced temperature	19,2 %	80,8 %	
Geluidsniveau	noise	21,9 %	78,1 %	
Ervaring licht	experienced light	11 %	89 %	
Luchtvochtigheid	humidity	12,4 %	87,6 %	
Ervaring luchtkwaliteit	experienced air quality	21,9 %	78,1 %	
Binnenklimaat totaal	total score indoor	15,1 %	84,9 %	

Women

There are 9 women surveyed

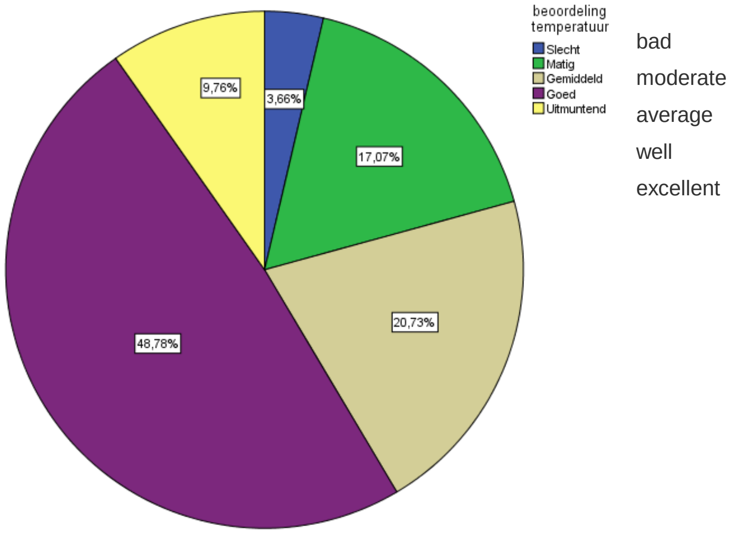
Vragen		Ontevreden	Tevreden	Onbekend
Ervaring temperatuur	experienced temperature	33,3 %	66,7 %	
Geluidsniveau	noise		100 %	
Ervaring licht	experienced light	11,1 %	88,9 %	
Luchtvochtigheid	humidity	33,3 %	66,7 %	
Ervaring luchtkwaliteit	experienced air quality	11,1 %	88,9 %	
Binnenklimaat totaal	total score indoor	22,2 %	77,8 %	

Women are more dissatisfied about the humidity and the temperature then the men,

Student Results Group 2

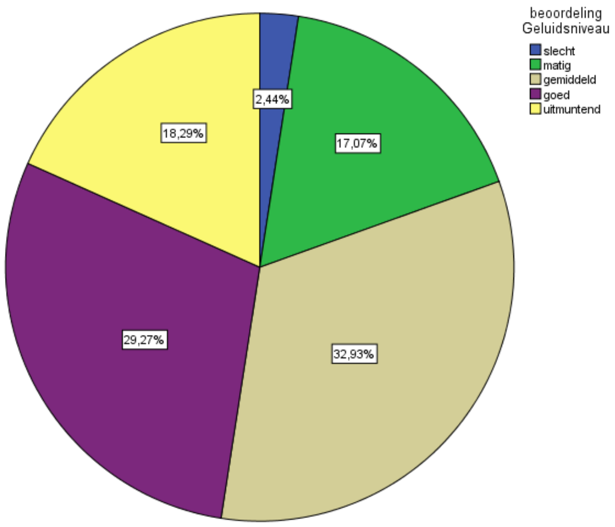
Temperature Rating:

Generally, the building users are satisfied with the temperature (48.78% experience this as well). This percentage seems to be high, concerning the energy efficiency of this building. However, there is a large group, of more than 20%, who do experience problems with the temperatures. The building control system controls the temperature on the basis of sensors that are developed according to agreed standards. This system allows to influence the temperature manually per classroom or workplace has four degrees up or down regulated. Nevertheless a large group has not been satisfied.



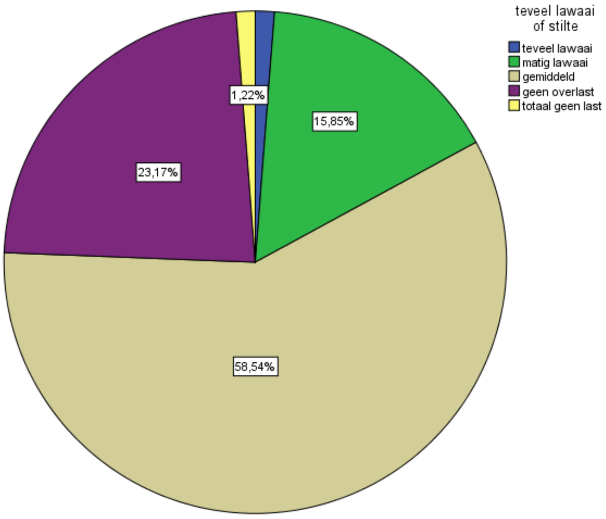
Noise level:

In general, there is responded well to noise level. Almost half of respondents found the sound good or excellent and have no complaints. This can be explained because students often works in groups on projects or assignments. In addition, the teachers often work in a work room. They are easy to find to consult. If multiple groups works at the same time this will make some noise. If this causes inconvenience to the users people will be looking to another quiet room.



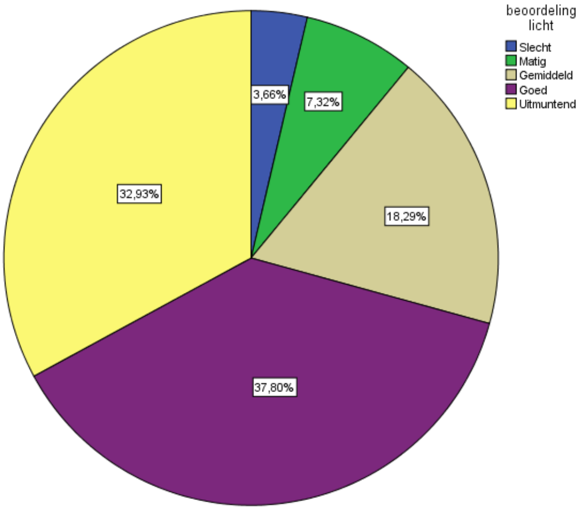
Too much noise or silence:

People experience the spaces not completely silent or noisy, moderately noisy when it might be, because people in a noisy environment at work. Average noise also corresponds to the previous question, which explanation is given.



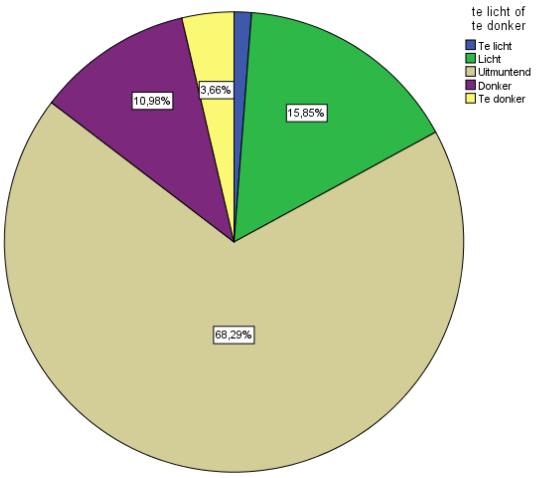
Assessment of light:

About light is very good to excellent response. This is attributable to the fact that the location in Delft is a new building where much glass is used. Because the light enters from different sides the building and then reflected on the walls and other surfaces. Spaces are well and equally lit. This automatically gives a pleasant light for building occupants. Due to the building manager indicates that there is relatively little artificial light is used in the building. This can be done because there are large amounts of light falling within the building.



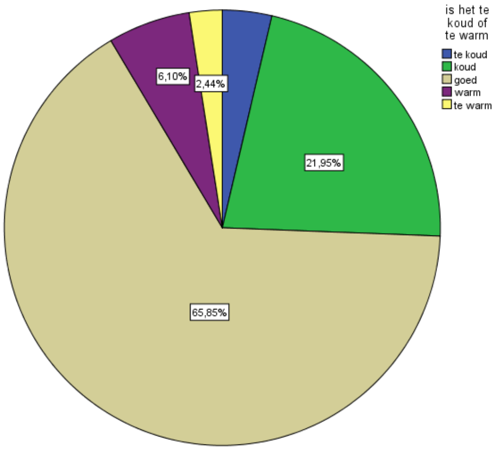
Too light or dark:

This is assessed as excellent (see text above).



Too cold or too hot:

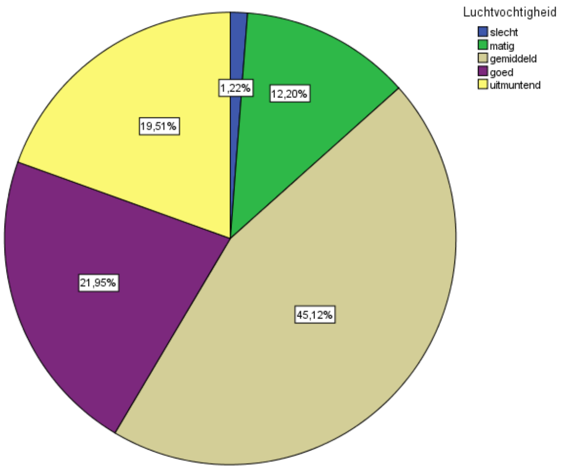
In general sense, the temperature is assessed as good. However, at certain locations in the building it is experienced too cold in winter and too hot in summer. The heat in the summer is explained by the light of the sun which is reinforced by the large amount of glass which is used in the building. The air inside the building is too low in summer and in winter too high. However, this can be set within the building management. In the winter, the temperature of the earth, even colder, so that the heat pumps, which are used to provide heat to the building, have to work harder to get the necessary heat to be generated. So it may take longer before the building becomes at the right temperature



Humidity:

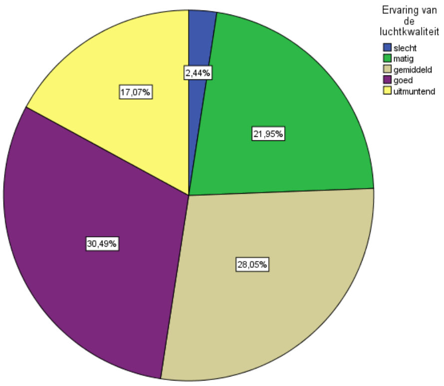
This factor is assessed very differently. There is much work with computers at the site Technology (ICT training) when regular prolonged use of PCs and printers some substances will be released that pollute the air. If not well ventilated rooms and no windows open may be a higher humidity caused some discomfort for the people.

In addition there is also a risk on the 'Computer Vision Syndrome (CVS). This is not the humidity, but can be a cause for dry eyes. Three-quarters of computer users suffer from this.



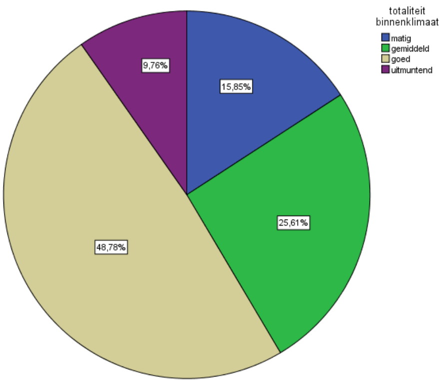
Air quality

The pie chart shows that opinions are divided on this survey question. There are several reasons to conclude. What is most striking is the 21.95% of respondents who found moderate air quality. This may be because the building has no windows open. When in a room air or an unpleasant odor hangs, a result that one unpleasant use of this space. This is especially true in the computer rooms.



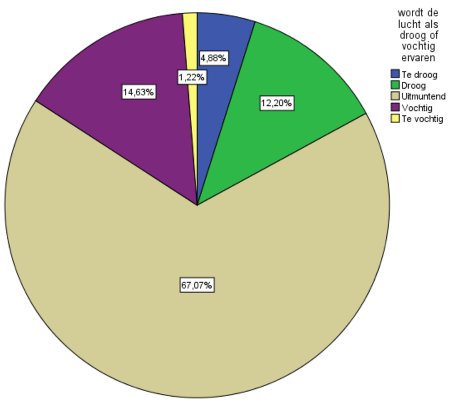
The indoor:

The indoor is generally well rated even with a selection of people who experience as excellent. The indoor climate is for 25.61% rated as average. These numbers are quite similar when you consider that there are always people dissatisfied. Here there is a majority of nearly 59% that the indoor experience as well.



Air quality:

67% were satisfied with the air quality. Yet there are people who do the air too dry at times and find this experience with dry irritated eyes



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2.7.4 BlueNet Building

2.7.4.1 BlueNet Devices

2.7.4.1.1 HVAC

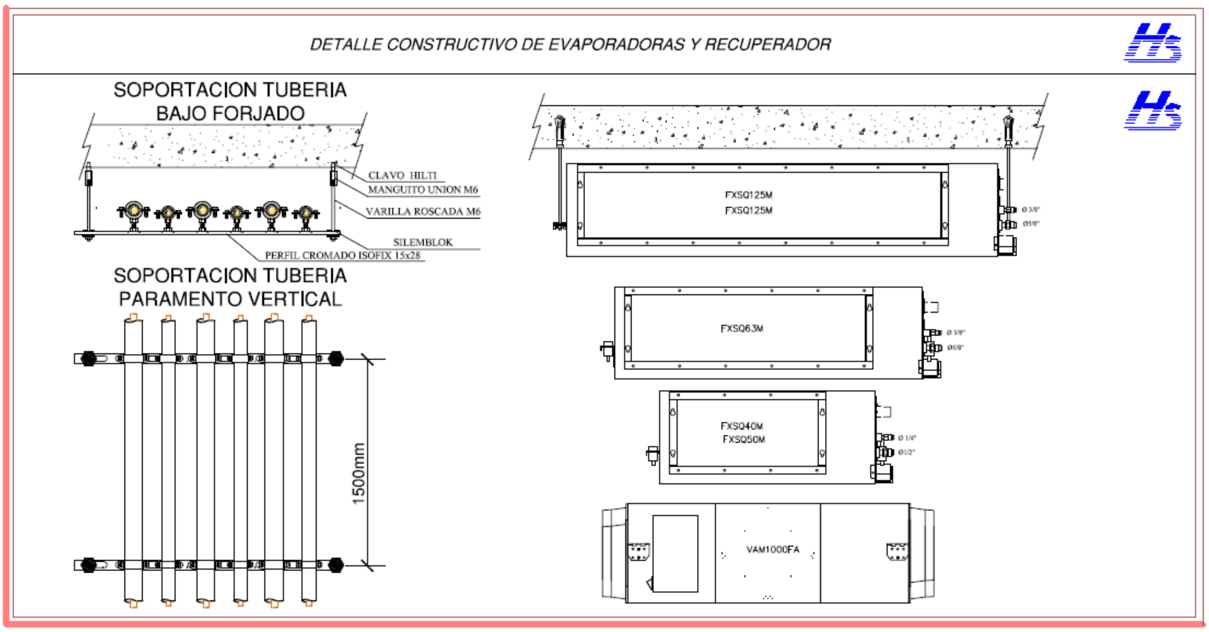


Figure 31 Details of Evaporators and Recovery

CUADRO CARACTERISTICAS EVAPORADORAS

REF.	MARCA	MODELO	POTENCIA FRIGORIFICA	CAUDAL AIRE ALTO m3/h	CONSUMO ELECTRICO	NIVEL SONORO (db) ALTO	FUENTE ALIMENTACION	CONEXION FRIGORIFICA LIQUIDO/GAS	PESO	DIMENSIONES ALTOxANCHOxLARGO
UI-1	DAIKIN	FXSQ40M	4.8 KW	150/192	0.9	29	- 220-240V 50Hz	1/4"-1/2"	30Kg	700*300*800
UI-2	DAIKIN	FXSQ50M	5.8 KW	183/250	0.9	31	- 220-240V 50Hz	1/4"-1/2"	31Kg	700*300*800
UI-3	DAIKIN	FXSQ63M	7.5 KW	258/350	1	35	- 220-240V 50Hz	3/8"-5/8"	41Kg	1000*300*800
UI-4	DAIKIN	FXSQ80M	9.3 KW	333/450	1.4	37	- 220-240V 50Hz	3/8"-5/8"	46Kg	1400*300*800
UI-5	DAIKIN	FXSQ125M	10.4 KW	467/633	2	40	- 220-240V 50Hz	3/8"-5/8"	52Kg	1400*300*800

Figure 32 Characteristics of Evaporators

2.7.4.2 Geometry of HVAC

Tabla 5
Tasas de aire exterior persona

CATEGORÍA	UNIDAD	TASA DE AIRE EXTERIOR POR PERSONA			
		Zona de no fumadores		Zona de fumadores	
		Intervalo típico	Valor por defecto	Intervalo típico	Valor por defecto
IDA 1	m^3/h/persona	> 54	72	> 108	144
	l/s/persona	> 15	20	> 30	40
IDA 2	m^3/h/persona	36 - 54	45	72 - 108	90
	l/s/persona	10 - 15	12,5	20 - 30	25
IDA 3	m^3/h/persona	22 - 36	29	43 - 72	58
	l/s/persona	6 - 10	8	12 - 20	16
IDA 4	m^3/h/persona	< 22	18	< 43	36
	l/s/persona	< 6	5	< 12	10

Nota
Las tasas dadas para la zona de no fumadores toman en consideración el metabolismo humano así como las emisiones típicas en edificios de baja contaminación.

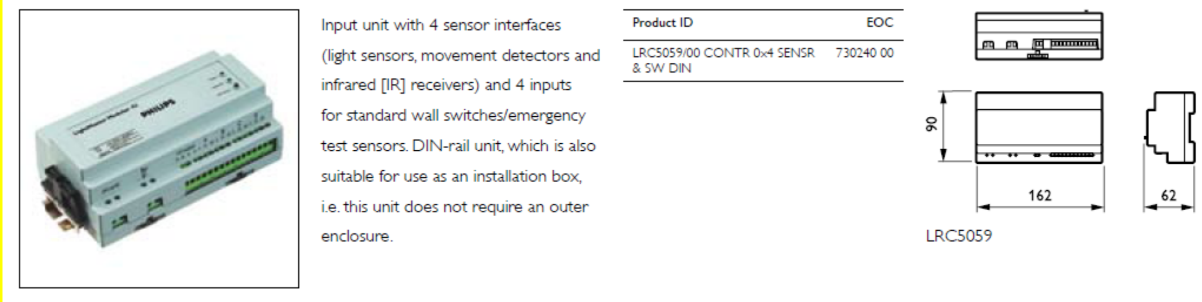
Figure 33 Outdoor Air Rates Per Person

2.7.4.3 Lighting

TECHNICAL CHARACTERISTICS	ADDITIONAL INFORMATION
Manufacturer	Osram
Product name	OSRAM L 18W/830
EOC / EAN Code	4008321923646
Wattage (W)	18W
Equivalent Inc. Lamp power (W)	N/A
Cap / Base	G13
Luminous Flux (Lm)	1350 Lm
Colour Temperature (K)	3000 K
Colour Rendering Index (Ra)	80...89
Length (mm)	590 mm
Dimensión Prod. Diámetro	26 mm

Figure 34 Technical Characteristic's: Lighting System

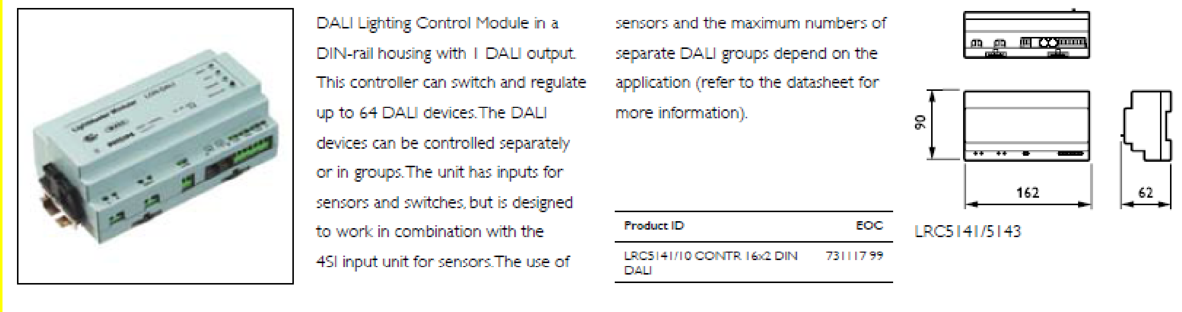
2.7.4.4 Sensors



Input unit with 4 sensor interfaces (light sensors, movement detectors and infrared [IR] receivers) and 4 inputs for standard wall switches/emergency test sensors. DIN-rail unit, which is also suitable for use as an installation box, i.e. this unit does not require an outer enclosure.

Product ID	EOC
LRC5059/00 CONTR 0x4 SENSR & SW DIN	730240 00

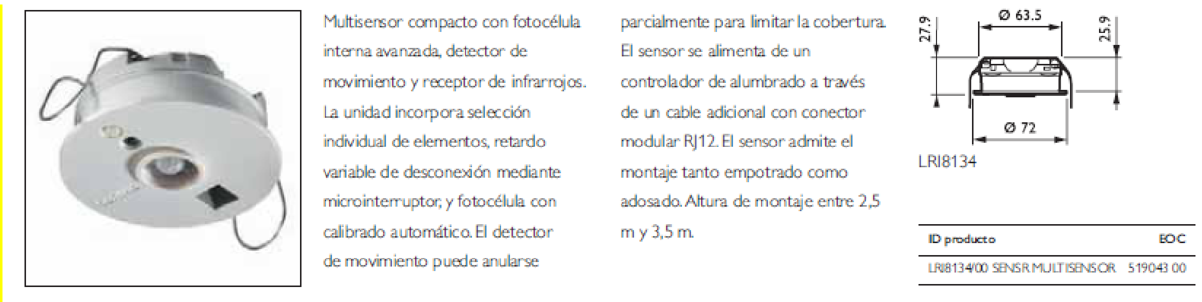
Figure 35 LMM driver of 4 inputs for DIN rail. (4SI)



DALI Lighting Control Module in a DIN-rail housing with 1 DALI output. This controller can switch and regulate up to 64 DALI devices. The DALI devices can be controlled separately or in groups. The unit has inputs for sensors and switches, but is designed to work in combination with the 4SI input unit for sensors. The use of sensors and the maximum numbers of separate DALI groups depend on the application (refer to the datasheet for more information).

Product ID	EOC
LRC5141/10 CONTR 16x2 DIN DALI	731117 99

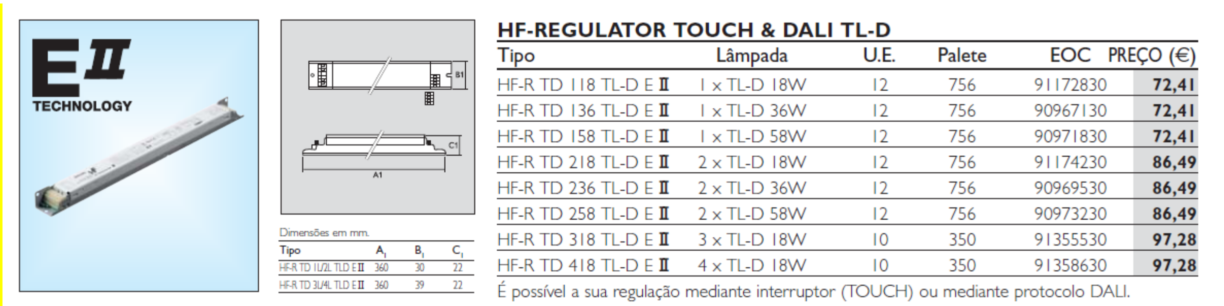
Figure 36 LON-DALI controller LMM DIN Rail. 64 DALI ballasts and 16 Groups



Multisensor compacto con fotocélula interna avanzada, detector de movimiento y receptor de infrarrojos. La unidad incorpora selección individual de elementos, retardo variable de desconexión mediante microinterruptor, y fotocélula con calibrado automático. El detector de movimiento puede anularse parcialmente para limitar la cobertura. El sensor se alimenta de un controlador de alumbrado a través de un cable adicional con conector modular RJ12. El sensor admite el montaje tanto empotrado como adosado. Altura de montaje entre 2,5 m y 3,5 m.

ID producto	EOC
LRI8134/00 SENSR MULTISENSOR	519043 00

Figure 37 Multi-sensor for Recessed Ceiling



Dimensões em mm.

Tipo	A1	B1	C1
HF-R TD 1L/2L TLD E II	360	30	22
HF-R TD 3L/4L TLD E II	360	39	22

HF-REGULATOR TOUCH & DALI TL-D

Tipo	Lâmpada	U.E.	Palete	EOC	PREÇO (€)
HF-R TD 118 TL-D E II	1 x TL-D 18W	12	756	91172830	**72,41**
HF-R TD 136 TL-D E II	1 x TL-D 36W	12	756	90967130	**72,41**
HF-R TD 158 TL-D E II	1 x TL-D 58W	12	756	90971830	**72,41**
HF-R TD 218 TL-D E II	2 x TL-D 18W	12	756	91174230	**86,49**
HF-R TD 236 TL-D E II	2 x TL-D 36W	12	756	90969530	**86,49**
HF-R TD 258 TL-D E II	2 x TL-D 58W	12	756	90973230	**86,49**
HF-R TD 318 TL-D E II	3 x TL-D 18W	10	350	91355530	**97,28**
HF-R TD 418 TL-D E II	4 x TL-D 18W	10	350	91358630	**97,28**

É possível a sua regulação mediante interruptor (TOUCH) ou mediante protocolo DALI.

Figure 38 DALI electronic ballast 3x18W screen: HF-R TD 318 TL-D

Datos técnicos	
Datos de entrada	
Tensión nominal de entrada	100 V AC ... 240 V AC
Margen de tensión de entrada AC	85 V AC ... 264 V AC (derating < 90 V AC: 2,5 % por Kelvin)
Tensión de entrada de corta duración	300 V AC
Gama de frecuencias AC	45 Hz ... 65 Hz
Absorción de corriente	0,95 A (120 V AC)
	0,5 A (230 V AC)
Extracorriente de cierre	< 15 A
Puenteo en fallo de red	> 20 ms (120 V AC)
	> 100 ms (230 V AC)
Fusible de entrada	2 A (lento, interno)
Fusible previo admitido	B6
	B10
	B16
Factor de potencia (cos phi)	0,72
Denominación de la protección	Protección contra sobretensiones transitorias
Circuito de protección/componente de protección	Varistor
Datos de salida	
Tensión nominal de salida	24 V DC ±1 %
Margen ajustable de tensión de salida	22,5 V DC ... 29,5 V DC (> 24 V potencia constante)
Corriente de salida	2,5 A (-25 °C... 55 °C)
Derating	55 °C ... 70 °C (2,5 %/K)
Posibilidad de conexión en paralelo	Sí, para redundancia y aumento de potencia
Posibilidad de conexión en serie	Sí
Carga capacitiva máxima	Ilimitado
Limitación de corriente	Aprox. 5 A (en caso de cortocircuito)
Desviación de regulación	< 1 % (cambio de carga estático 10 % ... 90 %)
	< 2 % (cambio de carga dinámico 10 % ... 90 %)
	< 0,1 % (cambio de tensión de entrada ±10 %)
Ondulación residual	< 30 mV$_{pp}$

Figure 39 Power supply 24-v. 2.5 a. Power Trio

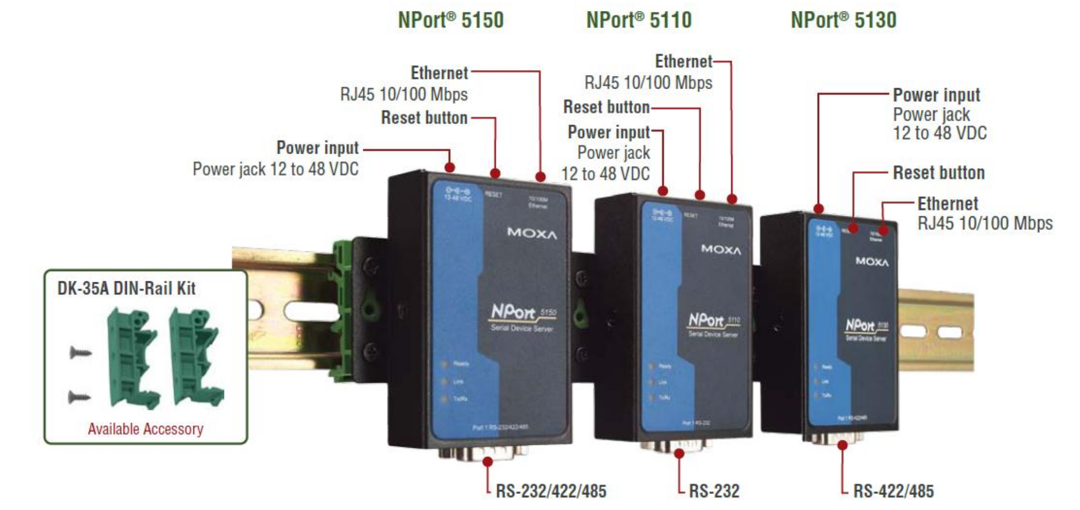


Figure 40 MOXA NPORT 5150, (conversor 485/ethernet)

Specifications

Ethernet Interface
Number of Ports: 1
Speed: 10/100 Mbps, auto MDI/MDIX
Connector: 8-pin RJ45
Magnetic Isolation Protection: 1.5 KV built-in

Serial Interface
Number of Ports: 1
Serial Standards:
NPort 5110: RS-232
NPort 5130: RS-422/485
NPort 5150: RS-232/422/485
Connector: DB9 male
Serial Line Protection: 15 KV ESD protection for all signals
RS-485 Data Direction Control: ADDC® (automatic data direction control)
Pull High/Low Resistor for RS-485: 1 KΩ, 150 KΩ

Serial Communication Parameters
Data Bits: 5, 6, 7, 8
Stop Bits: 1, 1.5, 2
Parity: None, Even, Odd, Space, Mark
Flow Control: RTS/CTS and DTR/DSR (RS-232 only), XON/XOFF
Baudrate:
NPort 5110: 110 bps to 230.4 Kbps
NPort 5130/5150: 50 bps to 921.6 Kbps

Serial Signals
RS-232: TxD, RxD, RTS, CTS, DTR, DSR, DCD, GND
RS-422: Tx+, Tx-, Rx+, Rx-, GND
RS-485-4w: Tx+, Tx-, Rx+, Rx-, GND
RS-485-2w: Data+, Data-, GND

Software
Network Protocols: ICMP, IP, TCP, UDP, DHCP, BOOTP, Telnet, DNS, SNMP V1, HTTP, SMTP
Configuration Options: Web Console, Serial Console (NPort 5110/5150 only), Telnet Console, Windows Utility
Windows Real COM Drivers: Windows 95/98/ME/NT/2000, Windows XP/2003/Vista/2008/7 x86/x64, Embedded CE 5.0/6.0, XP Embedded
Fixed TTY Drivers: SCO Unix, SCO OpenServer, UnixWare 7, UnixWare 2.1, SVR 4.2, QNX 4.25, QNX 6, Solaris 10, FreeBSD, AIX 5.x, HP-UX 11i
Linux Real TTY Drivers: Linux kernel 2.4.x, 2.6.x

Physical Characteristics
Housing: Metal
Weight: 340 g
Dimensions:
Without ears: 52 x 80 x 22 mm (2.05 x 3.15 x 0.87 in)
With ears: 75.2 x 80 x 22 mm (2.96 x 3.15 x 0.87 in)

Environmental Limits
Operating Temperature:
Standard Models: 0 to 55°C (32 to 131°F)
Wide Temp. Models: -40 to 75°C (-40 to 167°F)
Storage Temperature: -40 to 85°C (-40 to 185°F)
Ambient Relative Humidity: 5 to 95% (non-condensing)

Power Requirements
Input Voltage: 12 to 48 VDC
Power Consumption:
NPort 5110: 128.7 mA @ 12 V, 72 mA @ 24 V
NPort 5130/5150: 200 mA @ 12 V, 106 mA @ 24 V

Standards and Certifications
Safety: UL 60950-1, EN 60950-1
EMC: CE, FCC
EMI: EN 55022 Class A, FCC Part 15 Subpart B Class A
EMS: EN 55024

Reliability
Automatic Reboot Trigger: Built-in WDT (watchdog timer)
MTBF (mean time between failures):
NPort 5110: 279,122 hrs
NPort 5130: 246,505 hrs
NPort 5150: 246,034 hrs

Warranty
Warranty Period: 5 years
Details: See www.moxa.com/warranty

Figure 41 Communication Interfaces, Power Requirements and Physical Charecteristics.

2.7.4.5 Voltage boxes per floor, power consumption and autonomous power.

- ✓ **Basement floor.**
  - Parking spaces.
    - Chart CAF-S. Chart Facilities Basement.

      Lighting network.

      Road parking ramp, elevator lobbies and Storages 1 and 2 basement.

      Distributed emergency and signage along the road parking.
    - Force network.

      Outlets. Storage rooms 1 and 2 (Maintenance and Garage).

  - Machines. Pump rooms.

- Power Generator. (*See anexo X: Plano 4: Strength Basement).*
  - It is located in the basement.
  - If there is a power failure the building from the CT, would come to run the group, supplying power to the emergency services and special services.

- Lifts
  - CAF AS / 1.
    Lighting of the cabin. Elevators small (1 and 2).
    Lighting of the hole. Elevators small (1 and 2).
    Force machine room. Elevators small (1 and 2).
  - CAF AS / 2.
    Lighting of the cabin. Large elevator (1).
    Lighting of the hole. Large elevator (1).
    Force machine room. Large elevator (1).

- Pumping Sanitation. Evacuation Pump Room.
  - Chart CAF-BA.
    Pumps sanitation.
    Control of the pumps.

- Group water pressure.
  CAF-box GPAs
  Water pressure pumps.

✓ **Semi-basement floor.**

- It is divided into 5 sub-areas (Hall 1, 2, 3, 4 and 5) and areas (meeting rooms, dining rooms and hall). There is also the UPS.
- Zone 1: Offices 1.
  - chart CAF OF-SS/1.
    - Lighting network Location of luminaries and emergency services
      - Office Lighting.
      - emergency signs
    - Power supply network. Location of power points (sockets).
      - Power supply points

        - HAVC
        - UPS
- <u>Zone 2: Offices 2.</u>
    - Chart CAF OF-SS/2
        - Lighting network Location of luminaries and emergency services
            - Office Lighting
            - Emergency signs
        - Power supply network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS
- <u>Zone 3: Office 3.</u>
    - Chart CAF OF-SS/3.
        - Lighting network Location of luminaries and emergency services
            - Office Lighting
            - Emergency signs
        - Power supply network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS
- <u>Zone 4: Office 4.</u>
    - Chart CAF OF-SS/4.
        - Lighting network Location of luminaires and emergency services
            - Office Lighting
            - Emergency signs
        - Power supply network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS
- <u>Zone 5: Oficce 5.</u>
    - Chart CAF OF-SS/5.
        - Lighting network Location of luminaries and emergency services
            - Office Lighting

            - Emergency signs
        - Power supply network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS
- <u>Common Areas.</u>
    - General Bathrooms and dining room.
        - Chart CAF ASS.
            - Lighting network.
                - Lightning .
                - Emergency signs.
            - Power supply network.
                - Power supply points
                - Extractors.
                - Electric Boiler.
    - Rooms (polyvalent 1, 2 y 3, and meeting room), dining room, storage, files and equipment rooms
        - Chart CAF SS.
            - Lighting network.
                - Lightning.
                - Emergency signs.
            - Power supply network.
                - Power supply points.
                - HAVC.

- ✓ **<u>Ground Floor.</u>**
  - It is divided into 4 sub-offices and common areas (patio, bathrooms and hallways).

  The description by zones is:
  - <u>Zone 1: Offices 1.</u>
    - Chart CAF OF-0/1.
      - Lighting network: Location of luminaries and emergency services
        - Office Lighting
        - Emergency signs
      - Power supply network Location of power points (sockets).
        - Power supply points.
        - HAVC.
        - UPS.
  - <u>Zone 2: Offices 2.</u>
    - Chart CAF OF-0/2.
      - Lighting network: Location of luminaries and emergency services
        - Office Lighting
        - Emergency Signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points
        - HAVC
        - UPS
  - <u>Zone 3: Offices 3.</u>
    - Chart CAF OF-0/3.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting
        - Emergency Signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points
        - HAVC
        - UPS

- <u>Zone 4: Offices 4.</u>
    - Chart CAF OF-0/4.
        - Lighting network: Location of luminaries and emergency services
            - Office Lighting
            - Emergency Signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS

- <u>Other zones.</u>
    - <u>Ground floor toilets</u>
        - Chart CAF AS0.
            - Lighting network:
                - Lighting Ground Floor toilets.
                - Emergency signs on Ground Floor toilets.
            - Power supply network.
                - Power supply points.
                - Extractors.
                - Electric Boiler.
    - <u>Outdoor Areas. Periphery Building.</u>
        - Chart CAF EXT.
            - Lighting Outdoor areas.
    - <u>Common Areas on all floors.</u>
        - Chart CAF SG.
            - Lighting common areas.

✓ **First Floor.**

- It is divided into 4 sub-offices and common areas (bathrooms and hallways or distributors).

The description by zones is:

- Zone 1: Offices 1.
    - Chart CAF OF-1/1.
        - Lighting network: Location of luminaries and emergency services
            - Office Lighting.
            - Emergency signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points.
            - HAVC.
            - UPS.

- Zone 2: Offices 2.
    - Chart CAF OF-1/2.
        - Lighting network: Location of luminaries and emergency services
            - Office Lighting.
            - Emergency signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points.
            - HAVC.
            - UPS.
- Zone 3: Offices 3.
    - Chart CAF OF-1/3.
        - Lighting network: Location of luminaries and emergency services
            - Office Lighting.
            - Emergency signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points.
            - HAVC.
            - UPS.
- Zone 4: Offices 4.

- Chart CAF OF-1/4.
  - Lighting network: Location of luminaries and emergency services
    - Office Lighting.
    - Emergency signs
  - Power Supply Network. Location of power points (sockets).
    - Power supply points.
    - HAVC.
    - UPS.

- <u>Other Areas.</u>
  - <u>First floor toilets.</u>
    - Chart CAF AS1.
      - Lighting network
        - 1st & 2nd floor toilet lighting.
        - 1st & 2nd floor toilet emergency signs.
      - Power supply network.
        - Power supply points.
        - Extractors.
        - Electric Boiler.

- ✓ **Second and Third floor.**
  - These floors are identical, so are defined together. Like the previous floors are divided into 4 sub-office areas and common areas (bathrooms and hallways or distributors).
  - Zone 1: Offices 1.
    - Chart CAF OF-X/1. (X: indicate the floor located on the chart).
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points.
        - HAVC
        - UPS.
  - Zone 2: Offices 2.
    - Chart CAF OF-X/2.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points.
        - HAVC
        - UPS.
  - Zone 3: Offices 3.
    - Chart CAF OF-X/3.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points.
        - HAVC.
        - UPS.
  - Zone 4: Offices 4.
    - Chart CAF OF-X/4.
      - Lighting network: Location of luminaires and emergency services

            - Office Lighting.
            - Emergency signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points.
            - HAVC
            - UPS.

- <u>Other areas.</u>
    - <u>Toilets.</u>
        - Chart CAF ASX.
            - Lighting network.
                - 1st & 2nd floor toilet lighting.
                - 1st & 2nd floor toilet emergency signs.
            - Power supply network.
                - Power supply points.
                - Extractors.
                - Electric Boiler.

- ✓ **<u>Fourth Floor.</u>**
  - This floor is identical, so like the previous floors are divided into 4 sub-office areas and common areas (bathrooms and hallways or distributors).
  - <u>Zone 1: Offices 1.</u>
    - Chart CAF OF-4/1.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points
        - HAVC.
        - UPS.
  - <u>Zone 2: Offices 2.</u>
    - Chart CAF OF-4/2.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points
        - HAVC.
        - UPS.
  - <u>Zone 3: Offices 3.</u>
    - Chart CAF OF-4/3.
      - Lighting network: Location of luminaires and emergency services
        - Office Lighting.
        - Emergency signs
      - Power Supply Network. Location of power points (sockets).
        - Power supply points
        - HAVC.
        - UPS.
  - <u>Zone 4: Offices 4.</u>
    - Chart CAF OF-4/4.
      - Lighting network: Location of luminaires and emergency services

            - Office Lighting.
            - Emergency signs
        - Power Supply Network. Location of power points (sockets).
            - Power supply points
            - HAVC
            - UPS.
- <u>Other areas.</u>
    - <u>Toilets.</u>
        - Chart CAF AS4.
            - Lighting network:
                - 1st & 2nd floor toilet lighting.
                - 1st & 2nd floor toilet emergency signs.
            - Power supply network.
                - Power supply points.
                - Extractors.
                - Electric Boiler.

2.7.4.6 Isotrol Occupancy Data

	AVERAGE			
FECHA	Time In	Time Out	Time inside	Nº Employees
3-ene-11	8.77	16.94	8.17	73
4-ene-11	8.76	16.34	7.58	81
5-ene-11	8.81	15.04	6.22	64
7-ene-11	8.51	14.49	5.98	43
10-ene-11	8.94	17.18	8.24	145
11-ene-11	9.00	17.19	8.19	157
12-ene-11	9.21	17.31	8.10	160
13-ene-11	8.90	17.19	8.29	147
14-ene-11	8.79	14.64	5.85	139
17-ene-11	8.94	17.35	8.41	143
18-ene-11	9.10	17.36	8.26	146
19-ene-11	8.90	17.34	8.44	146
20-ene-11	9.28	17.27	7.99	144
21-ene-11	8.63	14.90	6.26	136
22-ene-11	12.33	14.82	2.49	2
24-ene-11	9.28	17.37	8.09	155
25-ene-11	9.07	17.21	8.14	155
26-ene-11	9.05	17.35	8.30	159
27-ene-11	8.80	17.14	8.34	147
28-ene-11	8.49	14.94	6.45	143
29-ene-11	6.86	18.81	11.95	3
30-ene-11	8.87	16.83	7.97	3
31-ene-11	8.75	17.14	8.39	151
1-feb-11	8.82	17.15	8.33	153
2-feb-11	8.86	17.30	8.44	153
3-feb-11	8.99	16.89	7.90	151
4-feb-11	8.71	14.74	6.02	147
7-feb-11	8.77	17.08	8.31	157
8-feb-11	8.89	16.87	7.97	155
9-feb-11	8.82	17.18	8.36	156
10-feb-11	8.77	17.04	8.28	147
11-feb-11	8.49	14.63	6.14	145
12-feb-11	11.42	11.43	0.02	1
14-feb-11	8.57	16.89	8.33	147
15-feb-11	8.65	17.30	8.65	147
16-feb-11	9.14	17.14	8.00	158

17-feb-11	8.94	17.10	8.16	150
18-feb-11	8.77	14.76	5.99	146
20-feb-11	21.70	21.95	0.25	1
21-feb-11	8.80	17.05	8.24	159
22-feb-11	8.67	17.16	8.48	152
23-feb-11	8.77	17.43	8.66	149
24-feb-11	8.73	17.08	8.36	147
25-feb-11	8.55	14.62	6.07	139
26-feb-11	10.60	19.58	8.98	1
27-feb-11	10.43	23.75	13.32	1
28-feb-11	13.13	21.51	8.38	2
1-mar-11	8.73	17.08	8.36	150
2-mar-11	8.81	17.09	8.28	157
3-mar-11	8.80	17.26	8.46	158
4-mar-11	8.62	14.72	6.09	139
5-mar-11	10.16	13.68	3.53	2
7-mar-11	8.55	17.38	8.83	151
8-mar-11	9.17	17.09	7.93	159
9-mar-11	9.08	17.38	8.30	164
10-mar-11	8.92	17.42	8.50	158
11-mar-11	8.69	14.81	6.12	159
14-mar-11	8.74	17.32	8.58	151
15-mar-11	8.83	16.83	7.99	163
16-mar-11	8.90	17.55	8.65	147
17-mar-11	8.79	17.02	8.23	152
18-mar-11	8.60	14.69	6.09	150
21-mar-11	8.64	17.10	8.46	160
22-mar-11	8.89	17.00	8.11	155
23-mar-11	8.66	17.07	8.41	165
24-mar-11	8.85	17.12	8.28	160
25-mar-11	8.66	14.56	5.91	156
26-mar-11	12.83	20.68	7.85	1
27-mar-11	12.59	14.64	2.05	3
28-mar-11	8.50	16.08	7.58	176
29-mar-11	8.91	16.98	8.07	157
30-mar-11	8.92	17.19	8.27	159
31-mar-11	8.99	16.86	7.87	161
1-abr-11	8.62	14.74	6.11	159
2-abr-11	15.50	17.64	2.14	2
3-abr-11	13.90	19.13	5.23	1

4-abr-11	9.01	16.92	7.91	173
5-abr-11	8.80	16.90	8.10	170
6-abr-11	9.03	16.96	7.92	161
7-abr-11	9.27	17.01	7.74	167
8-abr-11	8.66	14.49	5.83	155
9-abr-11	13.48	15.87	2.38	1
10-abr-11	12.30	19.02	6.72	2
11-abr-11	8.77	16.94	8.17	167
12-abr-11	8.86	16.96	8.10	173
13-abr-11	8.78	16.97	8.19	161
14-abr-11	9.21	17.31	8.10	172
15-abr-11	8.72	13.96	5.25	152
18-abr-11	8.57	14.41	5.84	123
19-abr-11	8.63	14.36	5.73	125
20-abr-11	8.61	14.69	6.07	109
21-abr-11	11.20	12.52	1.32	1
25-abr-11	8.92	17.02	8.10	164
26-abr-11	9.32	17.00	7.68	173
27-abr-11	9.25	16.44	7.19	175
28-abr-11	8.85	16.21	7.37	160
29-abr-11	8.81	14.05	5.24	145
1-may-11	19.87	23.85	3.98	1
2-may-11	4.86	15.49	10.63	2
3-may-11	8.42	14.18	5.77	133
4-may-11	8.61	14.26	5.65	138
5-may-11	8.46	14.38	5.92	115
6-may-11	8.47	14.03	5.56	105
9-may-11	8.97	16.23	7.27	161
10-may-11	9.08	16.77	7.69	168
11-may-11	8.90	16.75	7.86	162
12-may-11	9.14	17.07	7.94	161
13-may-11	8.63	14.42	5.79	153
14-may-11	11.36	11.40	0.04	2
16-may-11	8.91	16.81	7.89	155
17-may-11	9.22	16.69	7.46	167
18-may-11	9.04	16.57	7.54	165
19-may-11	8.97	16.59	7.62	170
20-may-11	8.96	14.62	5.66	159
21-may-11	9.81	15.82	6.01	3
22-may-11	12.63	19.30	6.67	5

23-may-11	8.82	16.95	8.12	167
24-may-11	8.99	16.98	7.99	176
25-may-11	9.66	16.86	7.20	186
26-may-11	8.91	16.22	7.30	173
27-may-11	8.84	14.18	5.34	147
30-may-11	11.16	13.87	2.71	7
31-may-11	9.36	16.41	7.05	181
1-jun-11	9.00	16.99	7.99	175
2-jun-11	9.26	16.82	7.56	178
3-jun-11	8.76	14.76	6.00	155
4-jun-11	13.55	16.19	2.64	4
5-jun-11	21.97	21.97	0.00	1
6-jun-11	9.07	16.69	7.63	163
7-jun-11	9.15	16.50	7.36	171
8-jun-11	9.03	16.99	7.96	165
9-jun-11	8.92	16.75	7.84	163
10-jun-11	8.69	14.78	6.08	158
11-jun-11	9.08	13.38	4.30	5
13-jun-11	8.88	16.83	7.95	166
14-jun-11	9.27	16.71	7.44	158
15-jun-11	9.19	16.81	7.62	161
16-jun-11	9.18	16.23	7.05	154
17-jun-11	8.82	13.93	5.11	141
18-jun-11	13.43	16.65	3.22	2
20-jun-11	9.41	16.96	7.55	152
21-jun-11	9.20	17.08	7.88	153
22-jun-11	9.33	16.47	7.13	153
23-jun-11	8.32	8.32	0.00	1
24-jun-11	8.43	14.42	5.99	95
25-jun-11	19.62	19.72	0.10	1
27-jun-11	9.42	16.89	7.48	160
28-jun-11	9.02	17.18	8.16	155
29-jun-11	9.02	17.02	8.00	152
30-jun-11	9.26	17.14	7.88	153
1-jul-11	8.70	14.58	5.88	150
2-jul-11	11.17	21.61	10.44	5
3-jul-11	15.27	15.96	0.69	2
4-jul-11	8.57	14.81	6.24	149
5-jul-11	8.77	14.62	5.85	155
6-jul-11	8.72	14.61	5.89	154

7-jul-11	8.87	14.82	5.95	155
8-jul-11	8.67	14.60	5.94	147
10-jul-11	10.98	11.02	0.03	1
11-jul-11	8.71	15.05	6.34	149
12-jul-11	8.47	14.57	6.10	144
13-jul-11	8.55	14.67	6.12	150
14-jul-11	8.77	14.89	6.12	143
15-jul-11	8.61	14.28	5.67	133
18-jul-11	8.62	14.59	5.97	138
19-jul-11	8.83	14.41	5.59	144
20-jul-11	8.63	14.54	5.91	128
21-jul-11	8.81	14.72	5.91	130
22-jul-11	8.56	14.44	5.88	130
25-jul-11	8.61	14.92	6.30	129
26-jul-11	8.76	15.28	6.52	140
27-jul-11	8.86	14.83	5.96	131
28-jul-11	8.71	15.22	6.51	128
29-jul-11	8.53	14.27	5.74	120
30-jul-11	13.66	17.43	3.77	3
31-jul-11	11.80	18.02	6.22	1
1-ago-11	8.70	14.84	6.14	122
2-ago-11	8.70	14.73	6.03	118
3-ago-11	8.65	14.88	6.23	115
4-ago-11	8.60	14.78	6.17	108
5-ago-11	8.53	14.31	5.78	100
6-ago-11	9.97	13.02	3.05	1
8-ago-11	8.52	14.86	6.34	98
9-ago-11	8.57	14.86	6.28	94
10-ago-11	8.50	14.88	6.37	98
11-ago-11	8.50	14.69	6.19	97
12-ago-11	8.59	14.53	5.94	88
16-ago-11	8.39	14.76	6.37	96
17-ago-11	8.64	14.30	5.67	101
18-ago-11	8.51	14.91	6.40	95
19-ago-11	8.51	14.34	5.84	95
22-ago-11	8.47	14.52	6.05	124
23-ago-11	8.70	14.75	6.05	121
24-ago-11	8.50	14.59	6.09	121
25-ago-11	8.79	14.84	6.05	121
26-ago-11	8.63	14.41	5.78	118

27-ago-11	8.93	14.87	5.93	1
29-ago-11	8.54	14.75	6.21	132
30-ago-11	8.65	14.78	6.13	138
31-ago-11	8.51	15.09	6.58	141
1-sep-11	9.08	17.05	7.97	149
2-sep-11	8.63	14.51	5.87	138
5-sep-11	8.91	17.08	8.17	158
6-sep-11	8.84	17.22	8.38	153
7-sep-11	8.94	17.09	8.15	153
8-sep-11	8.78	17.12	8.33	147
9-sep-11	8.52	14.43	5.91	145
10-sep-11	9.83	13.03	3.20	3
11-sep-11	11.30	17.38	6.08	2
12-sep-11	8.92	17.17	8.26	150
13-sep-11	9.05	17.33	8.27	147
14-sep-11	9.10	17.37	8.28	152
15-sep-11	9.06	17.35	8.28	152
16-sep-11	8.58	14.48	5.90	144
17-sep-11	10.20	14.57	4.37	4
19-sep-11	8.84	17.39	8.55	154
20-sep-11	8.84	17.44	8.60	155
21-sep-11	9.02	17.07	8.05	152
22-sep-11	9.03	17.04	8.00	152
23-sep-11	8.73	14.79	6.05	139
26-sep-11	8.98	17.31	8.33	158
27-sep-11	8.90	17.32	8.41	155
28-sep-11	9.05	17.33	8.28	150
29-sep-11	9.13	17.59	8.46	154
30-sep-11	8.70	14.44	5.74	152
3-oct-11	8.98	16.88	7.90	160
4-oct-11	8.98	17.14	8.17	161
5-oct-11	8.91	17.24	8.33	155
6-oct-11	9.19	16.74	7.54	161
7-oct-11	8.64	14.36	5.71	145
8-oct-11	11.50	14.08	2.58	1
10-oct-11	8.95	17.02	8.07	143
11-oct-11	8.85	16.93	8.09	140
13-oct-11	9.20	17.05	7.85	144
14-oct-11	8.70	14.30	5.60	138
17-oct-11	8.78	17.22	8.44	146

18-oct-11	9.02	17.13	8.11	149
19-oct-11	8.75	16.65	7.90	149
20-oct-11	8.82	16.84	8.02	146
21-oct-11	8.51	14.50	5.99	140
24-oct-11	8.94	16.62	7.68	148
25-oct-11	8.97	17.09	8.11	152
26-oct-11	9.18	16.78	7.60	151
27-oct-11	8.86	17.13	8.27	151
28-oct-11	8.62	14.47	5.85	150
29-oct-11	11.33	11.35	0.02	1
30-oct-11	14.24	17.29	3.06	3
31-oct-11	8.89	16.54	7.66	105
2-nov-11	10.71	17.15	6.43	141
3-nov-11	8.98	17.08	8.10	150
4-nov-11	8.49	14.24	5.75	140
7-nov-11	8.77	17.11	8.34	146
8-nov-11	9.07	17.01	7.94	153
9-nov-11	8.81	16.73	7.92	154
10-nov-11	8.81	16.93	8.13	146
11-nov-11	8.65	14.77	6.12	147
12-nov-11	6.78	14.17	7.39	7
13-nov-11	10.31	21.56	11.25	7
14-nov-11	8.55	16.53	7.98	153
15-nov-11	8.97	16.85	7.88	148
16-nov-11	9.02	16.95	7.94	149
17-nov-11	9.12	16.71	7.59	152
18-nov-11	8.61	14.34	5.73	143
19-nov-11	8.58	16.09	7.51	4
21-nov-11	9.03	16.89	7.86	155
22-nov-11	9.19	17.15	7.96	153
23-nov-11	8.90	16.98	8.08	145
24-nov-11	9.15	16.81	7.67	143
25-nov-11	8.49	14.37	5.89	145
26-nov-11	8.97	17.18	8.21	8
27-nov-11	9.45	15.13	5.68	1
28-nov-11	8.97	16.77	7.79	146
29-nov-11	9.25	16.96	7.71	159
30-nov-11	9.06	16.62	7.56	149
1-dic-11	9.08	16.73	7.65	157
2-dic-11	8.75	14.49	5.73	150

3-dic-11	10.30	16.12	5.82	4
4-dic-11	13.03	17.23	4.21	2
5-dic-11	8.72	16.88	8.16	86
6-dic-11	8.91	16.67	7.76	42
7-dic-11	8.96	17.02	8.07	110
8-dic-11	8.96	16.79	7.83	37
9-dic-11	8.56	14.53	5.97	80
10-dic-11	8.82	14.85	6.03	1
12-dic-11	9.15	16.49	7.34	151
13-dic-11	9.12	17.11	7.99	153
14-dic-11	8.91	17.21	8.30	143
15-dic-11	9.20	17.06	7.85	147
16-dic-11	8.72	14.52	5.80	144
18-dic-11	11.70	11.77	0.07	1
19-dic-11	9.09	17.12	8.03	148
20-dic-11	8.93	17.03	8.10	157
21-dic-11	9.08	16.84	7.76	147
22-dic-11	8.89	16.84	7.95	143
23-dic-11	8.65	14.51	5.86	127
26-dic-11	8.82	17.25	8.43	5
27-dic-11	8.96	16.50	7.54	75
28-dic-11	8.88	16.22	7.34	74
29-dic-11	8.76	16.53	7.77	71
30-dic-11	8.80	14.11	5.31	63
2-ene-12	10.67	11.72	1.05	1
3-ene-12	8.58	16.31	7.73	66
4-ene-12	8.91	15.58	6.67	75
5-ene-12	9.00	14.27	5.27	59
9-ene-12	8.94	16.68	7.74	128
10-ene-12	8.82	16.99	8.16	136
11-ene-12	8.80	17.20	8.40	135
12-ene-12	9.20	16.59	7.38	144
13-ene-12	8.65	14.47	5.82	137
14-ene-12	5.09	22.22	17.13	2
15-ene-12	5.77	22.78	17.02	2
16-ene-12	9.20	16.89	7.69	135
17-ene-12	8.91	16.98	8.06	136
18-ene-12	8.81	16.95	8.13	137
19-ene-12	9.04	17.29	8.25	145
20-ene-12	8.78	14.83	6.05	132

21-ene-12	4.95	22.58	17.63	2
22-ene-12	9.90	22.02	12.12	2
23-ene-12	8.92	17.00	8.08	139
24-ene-12	9.13	16.72	7.59	139
25-ene-12	8.99	17.33	8.34	130
26-ene-12	9.13	16.93	7.80	134
27-ene-12	8.76	14.78	6.02	130
28-ene-12	10.19	16.44	6.25	6
29-ene-12	10.91	19.40	8.49	4
30-ene-12	8.93	17.01	8.08	142
31-ene-12	9.03	17.26	8.23	138
1-feb-12	9.11	17.32	8.21	138
2-feb-12	9.26	16.98	7.72	142
3-feb-12	8.70	14.58	5.88	140
4-feb-12	9.47	21.06	11.59	8
5-feb-12	9.98	20.51	10.54	9
6-feb-12	9.06	16.98	7.93	145
7-feb-12	8.99	16.91	7.91	147
8-feb-12	8.85	17.38	8.53	144
9-feb-12	8.77	17.45	8.68	146
10-feb-12	8.75	14.74	6.00	141
11-feb-12	7.08	21.98	14.90	2
12-feb-12	11.65	21.08	9.43	3
13-feb-12	9.44	17.05	7.61	154
14-feb-12	8.84	17.07	8.22	141
15-feb-12	9.04	17.26	8.22	142
16-feb-12	9.09	16.68	7.59	149
17-feb-12	8.84	14.53	5.69	148
18-feb-12	10.24	17.80	7.56	4
19-feb-12	5.14	21.88	16.74	2
20-feb-12	8.98	17.09	8.11	158
21-feb-12	8.86	16.66	7.79	154
22-feb-12	9.17	16.98	7.81	146
23-feb-12	9.01	17.02	8.01	151
24-feb-12	8.75	14.51	5.76	136
25-feb-12	9.63	17.44	7.81	3
26-feb-12	10.03	22.04	12.01	2
27-feb-12	8.93	16.75	7.81	105
28-feb-12	8.99	21.92	12.93	2
29-feb-12	8.81	16.96	8.15	138

1-mar-12	8.88	17.10	8.23	161
2-mar-12	8.66	14.84	6.19	148
3-mar-12	5.78	22.00	16.22	2
4-mar-12	9.97	20.59	10.63	3
5-mar-12	8.80	17.03	8.23	145
6-mar-12	9.01	17.37	8.36	146
7-mar-12	8.81	17.02	8.21	148
8-mar-12	8.90	17.12	8.22	149
9-mar-12	8.87	14.79	5.92	142
10-mar-12	10.75	20.90	10.15	3
11-mar-12	6.39	18.89	12.50	2
12-mar-12	8.80	17.51	8.71	150
13-mar-12	9.08	16.96	7.89	148
14-mar-12	9.10	17.11	8.01	145
15-mar-12	8.92	16.85	7.93	153
16-mar-12	8.62	14.61	5.99	142
17-mar-12	9.68	21.98	12.30	3
18-mar-12	9.66	22.90	13.24	2
19-mar-12	9.02	16.37	7.35	147
20-mar-12	9.86	17.54	7.68	142
21-mar-12	8.86	17.05	8.18	150
22-mar-12	8.91	17.24	8.33	154
23-mar-12	8.65	14.60	5.95	148
24-mar-12	9.48	19.65	10.17	4
25-mar-12	5.36	21.01	15.65	2
26-mar-12	8.40	16.83	8.43	155
27-mar-12	9.34	17.39	8.05	153
28-mar-12	9.01	17.10	8.09	150
29-mar-12	8.99	17.21	8.22	131
30-mar-12	8.77	15.03	6.25	139
31-mar-12	10.33	17.39	7.06	6
1-abr-12	9.88	21.92	12.04	2
2-abr-12	8.91	14.89	5.97	133
3-abr-12	8.66	14.87	6.21	122
4-abr-12	8.60	14.70	6.09	112
5-abr-12	11.07	20.61	9.54	3
6-abr-12	9.85	22.08	12.23	2
7-abr-12	9.97	21.99	12.03	2
8-abr-12	7.09	21.71	14.62	3
9-abr-12	8.97	16.44	7.48	146

10-abr-12	9.03	16.94	7.91	153
11-abr-12	9.11	17.31	8.21	152
12-abr-12	9.17	17.14	7.97	147
13-abr-12	8.94	14.68	5.75	141
14-abr-12	9.91	21.98	12.07	2
15-abr-12	11.61	19.95	8.34	3
16-abr-12	9.40	17.74	8.34	153
17-abr-12	8.97	17.43	8.47	151
18-abr-12	9.30	17.86	8.56	149
19-abr-12	9.28	17.49	8.21	150
20-abr-12	8.71	14.65	5.94	142
21-abr-12	10.06	22.08	12.02	2
22-abr-12	10.92	15.06	4.14	3
23-abr-12	8.93	16.92	7.99	144
24-abr-12	8.54	14.75	6.21	144
Total	8.90	16.26	7.37	46658

2.8 APPENDIX C User Interactions

2.8.1 B-Digital

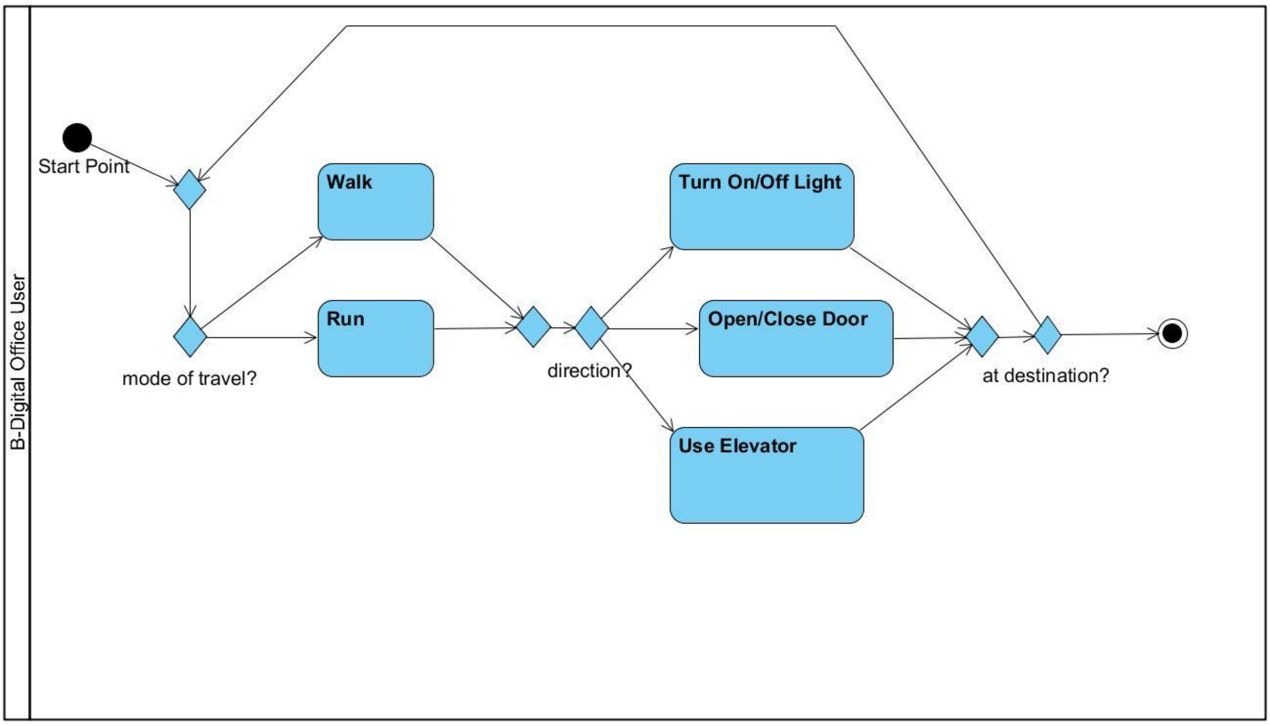


Figure 42 Travelling to Destination

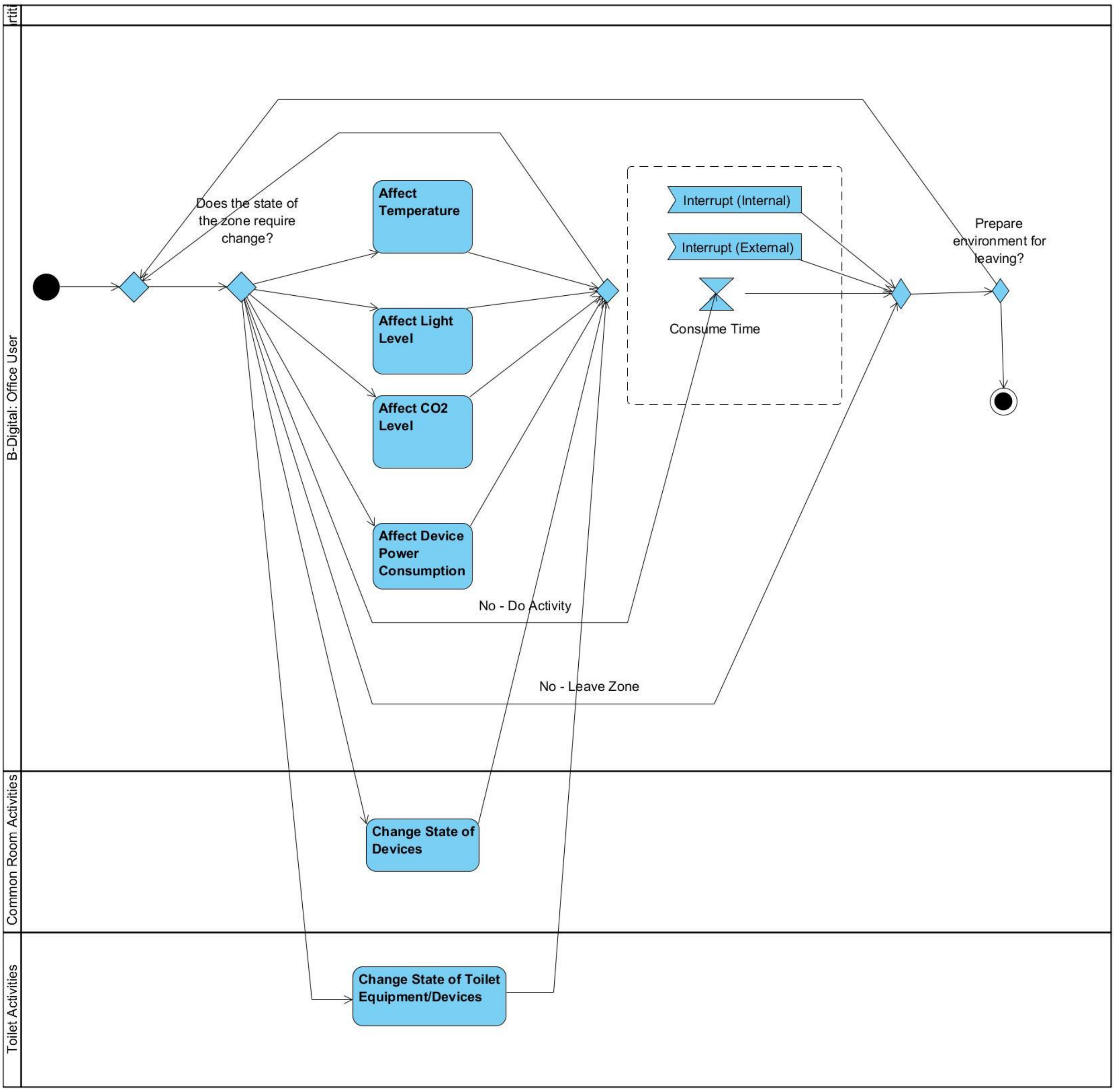


Figure 43 Building Activities

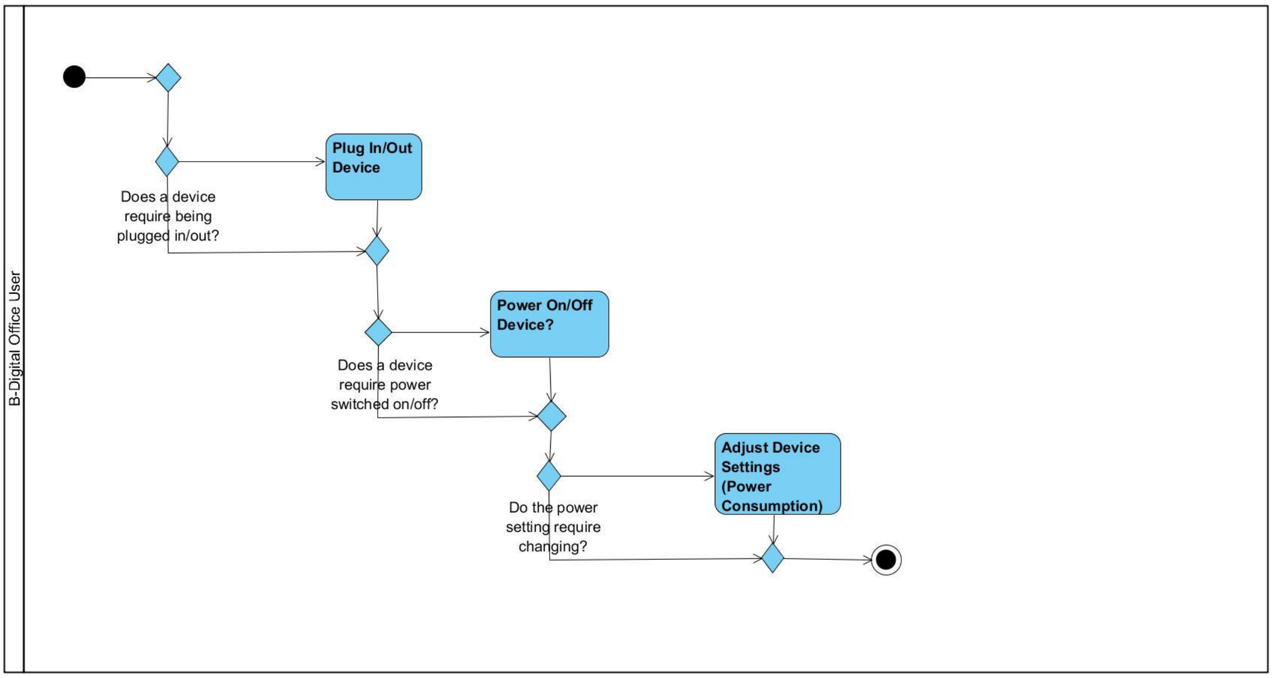


Figure 44 Use Devices

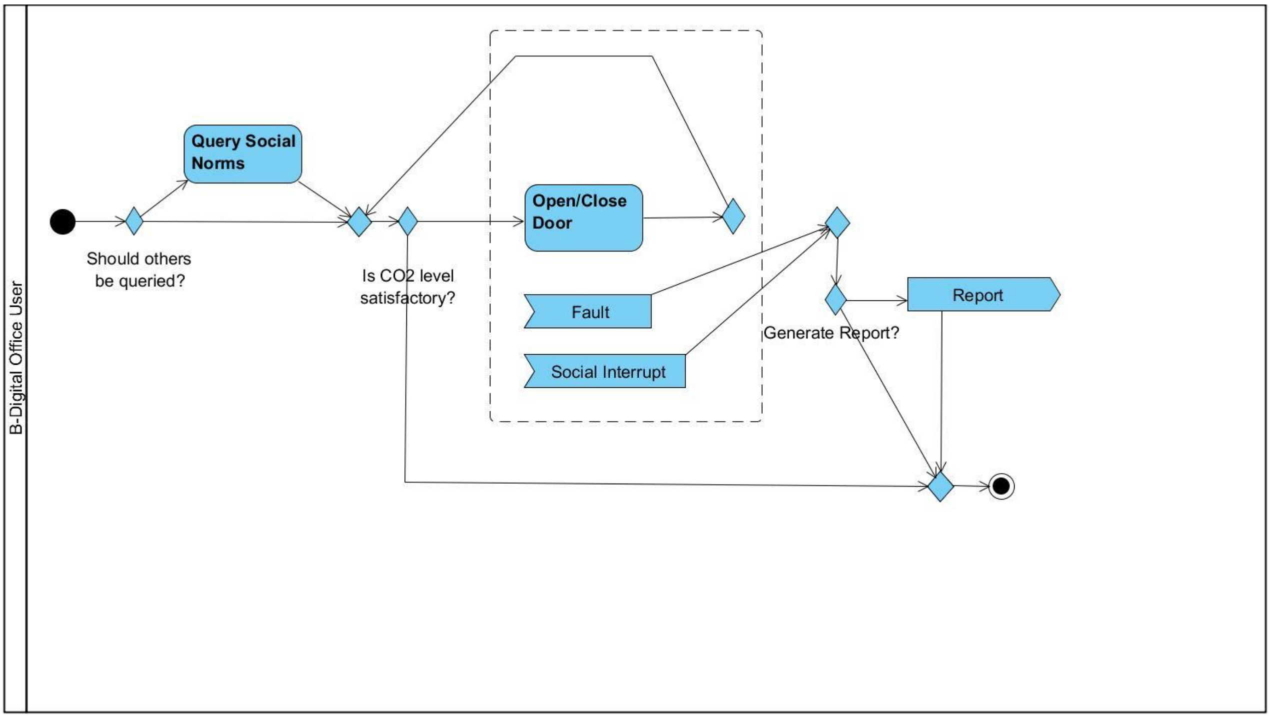


Figure 45 Affect CO2 Levels

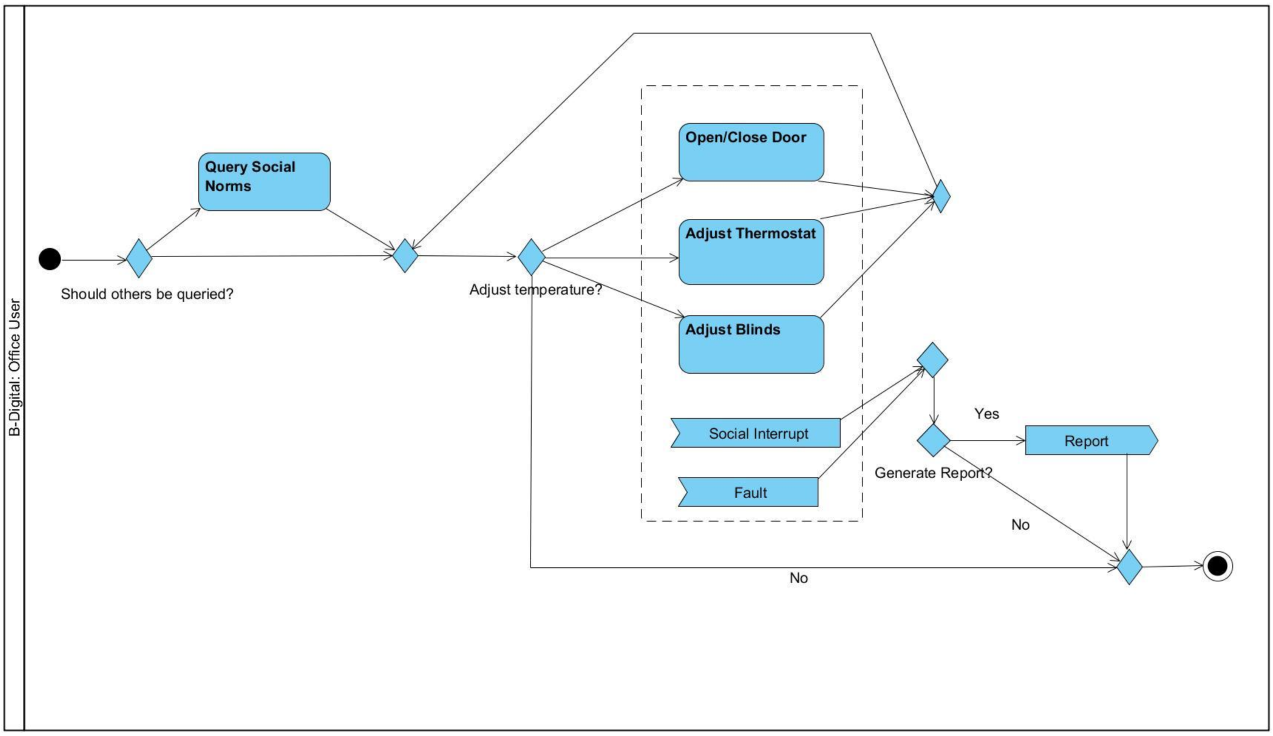


Figure 46 Affect Temperature Levels

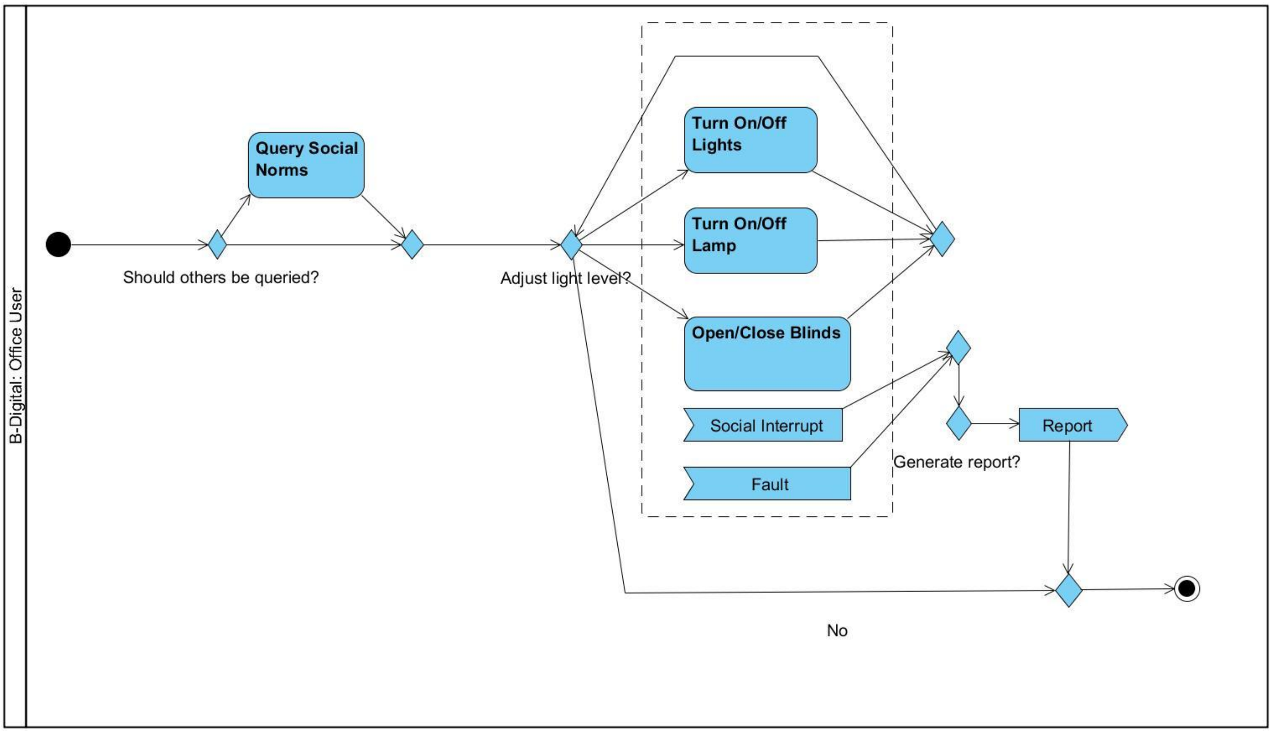


Figure 47 Affect Light Levels

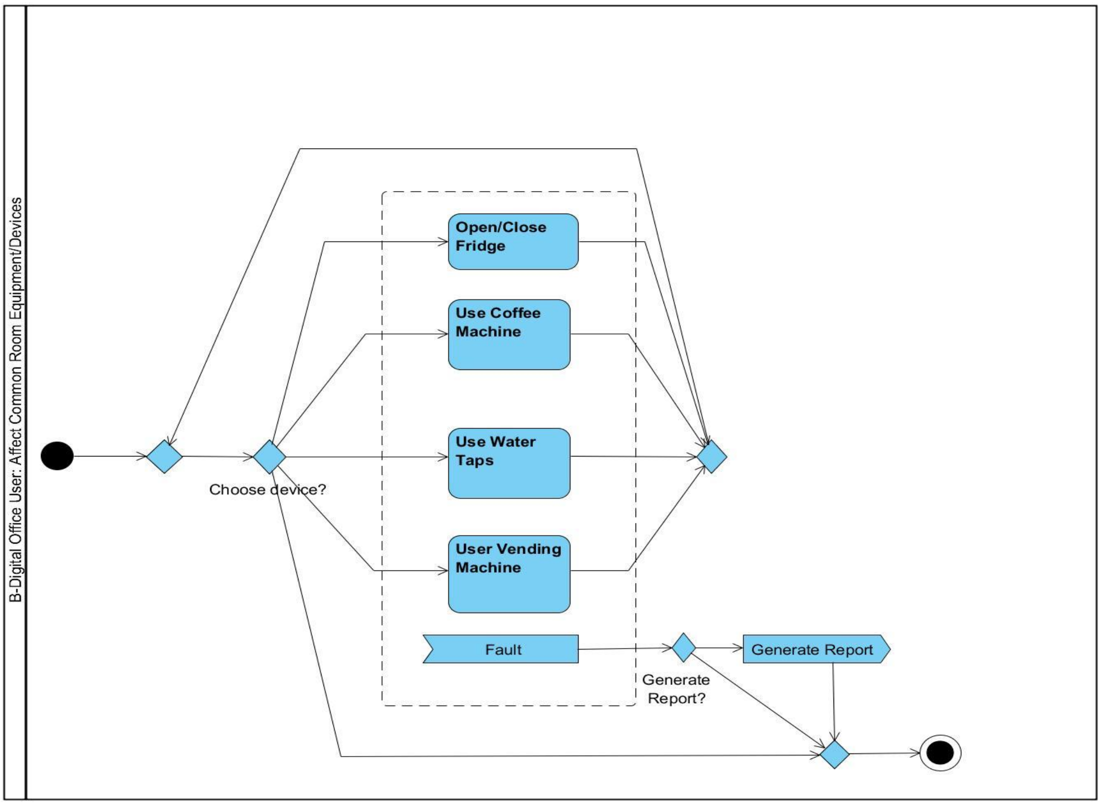


Figure 48 Common Room

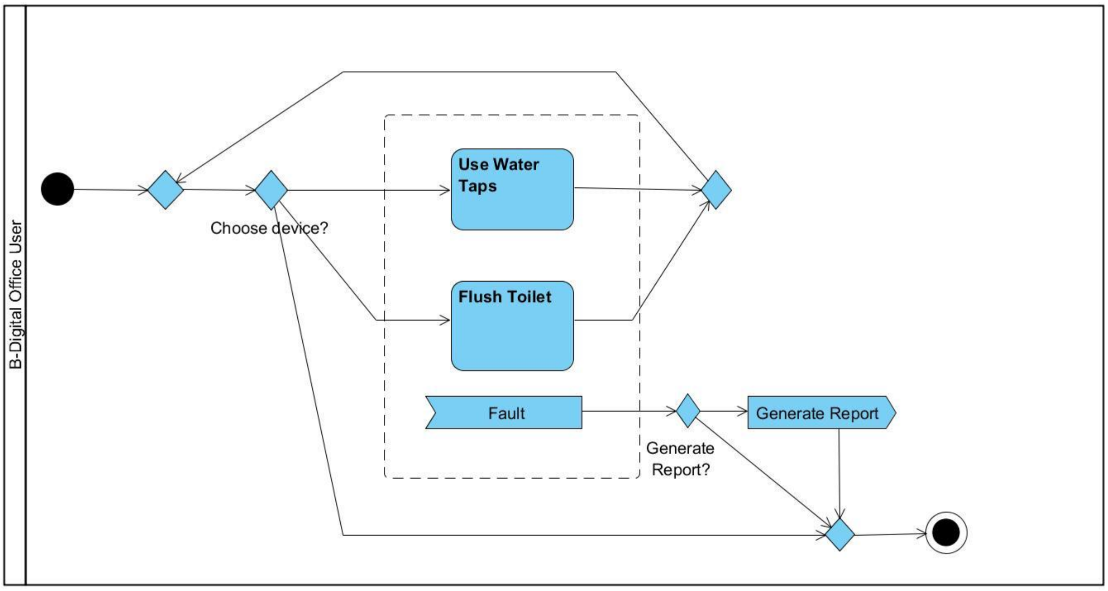


Figure 49 Toilets

2.8.2 HSS

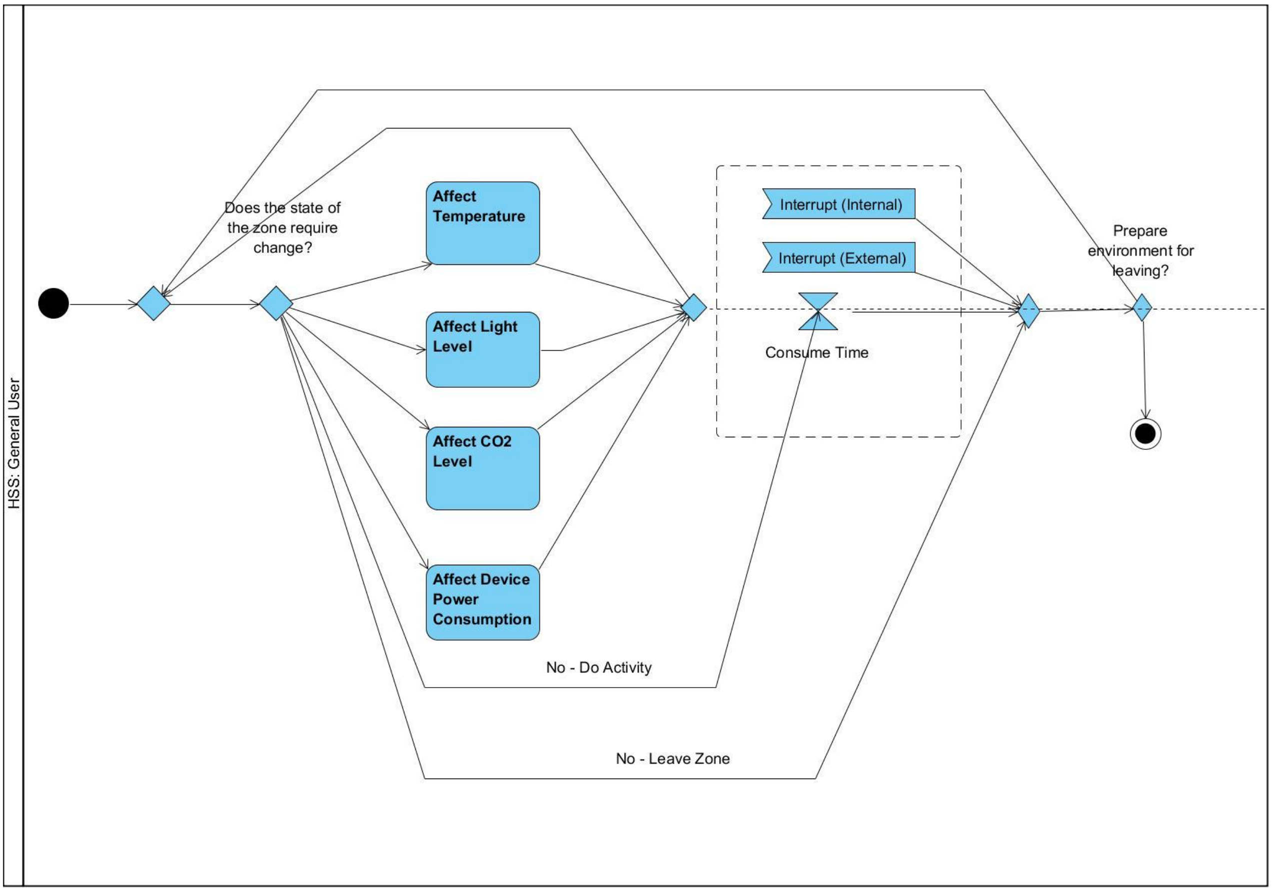


Figure 50 HSS: User Activities

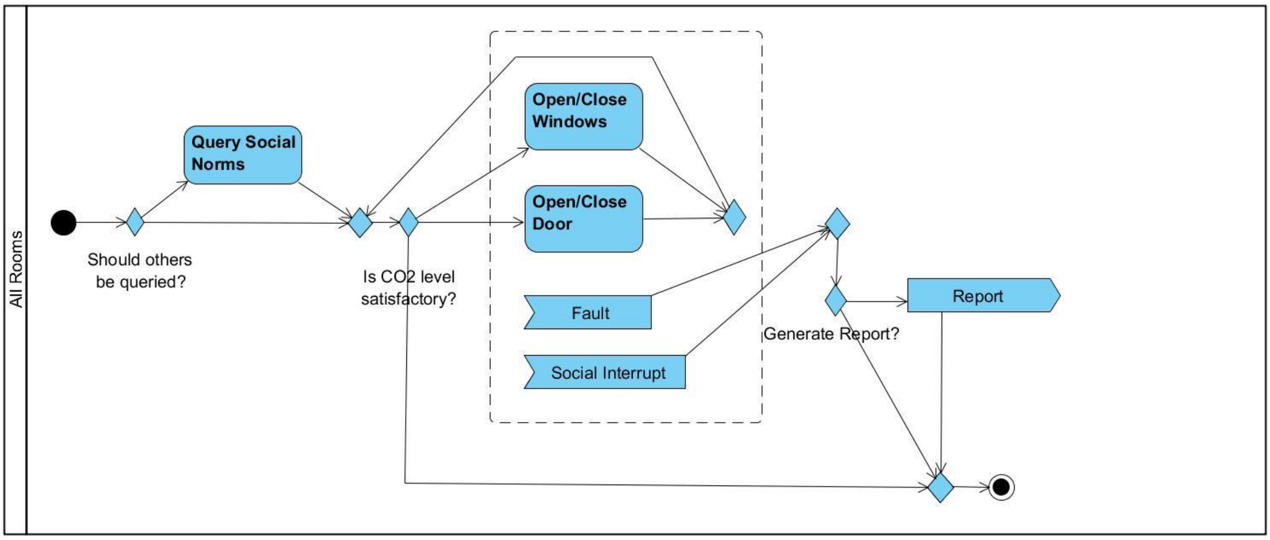


Figure 51 HSS: Generic Room Affect CO2

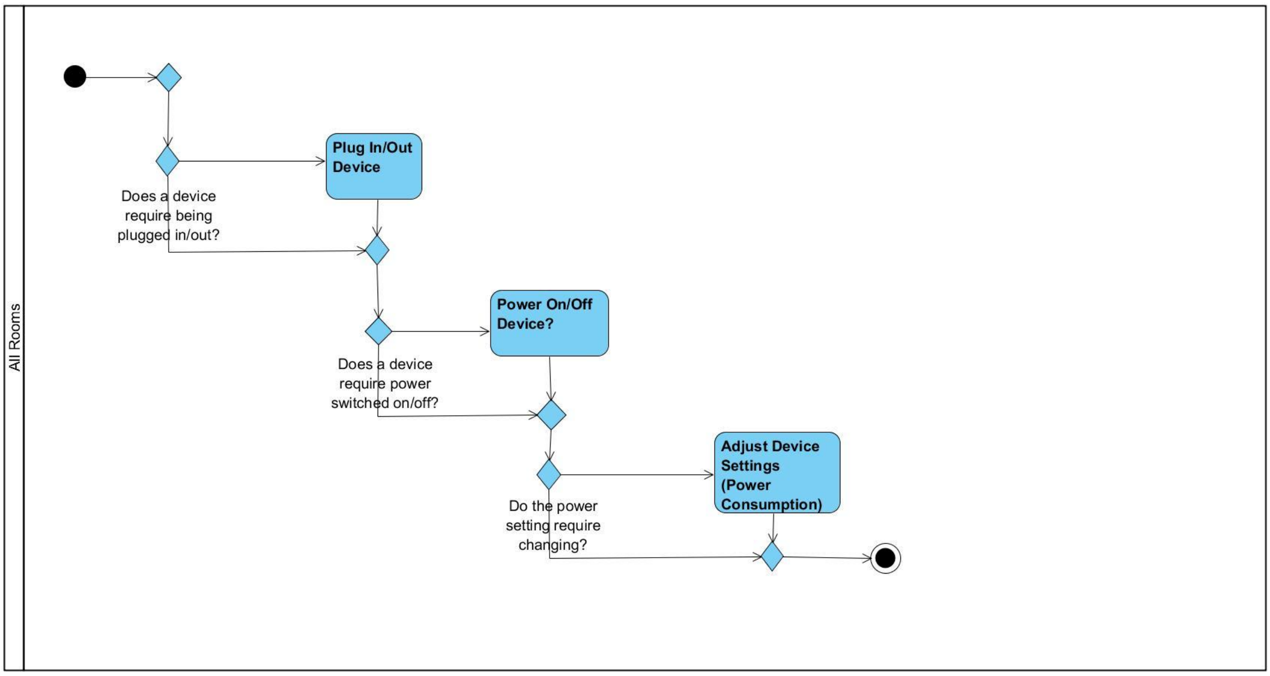


Figure 52 HSS: Affect Device Power

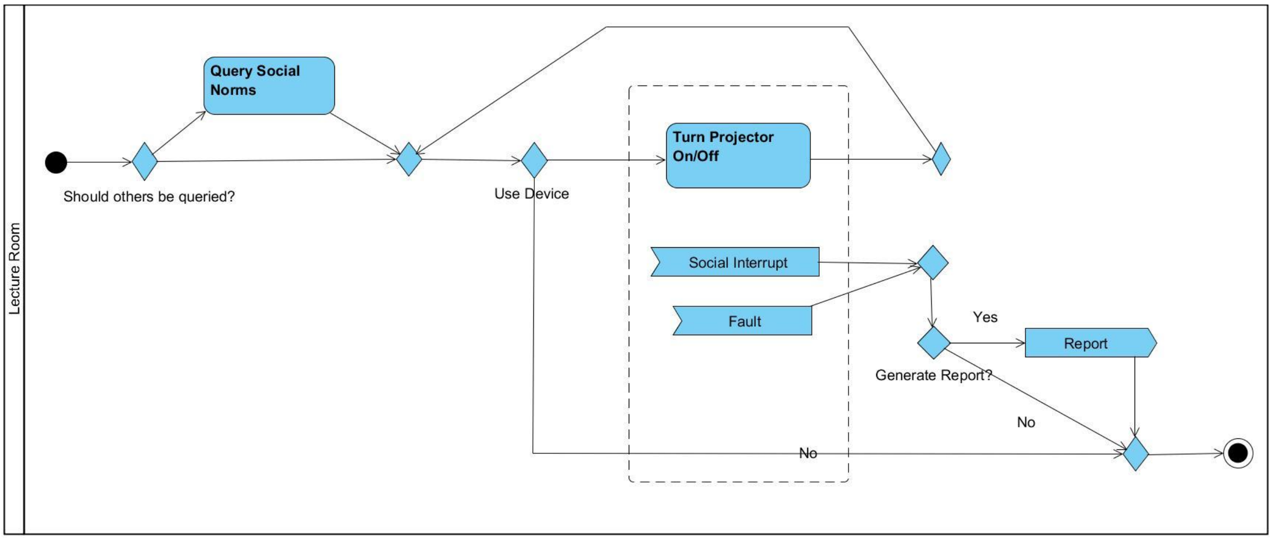


Figure 53 HSS: Lecture Room, Affect Equipment

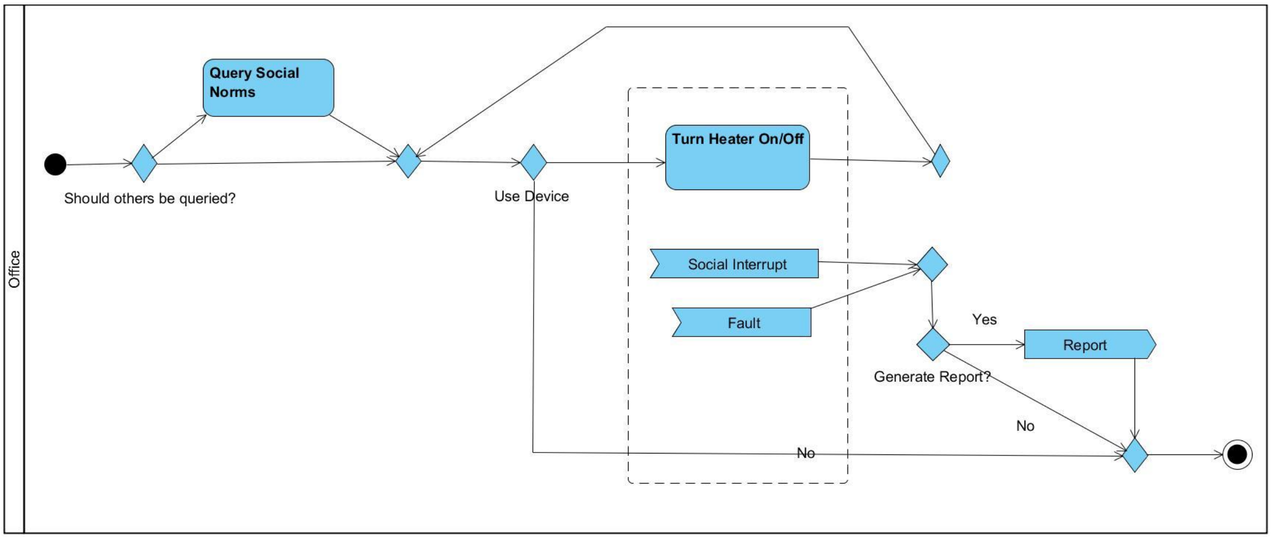


Figure 54 HSS: Office User, Affect Equipment

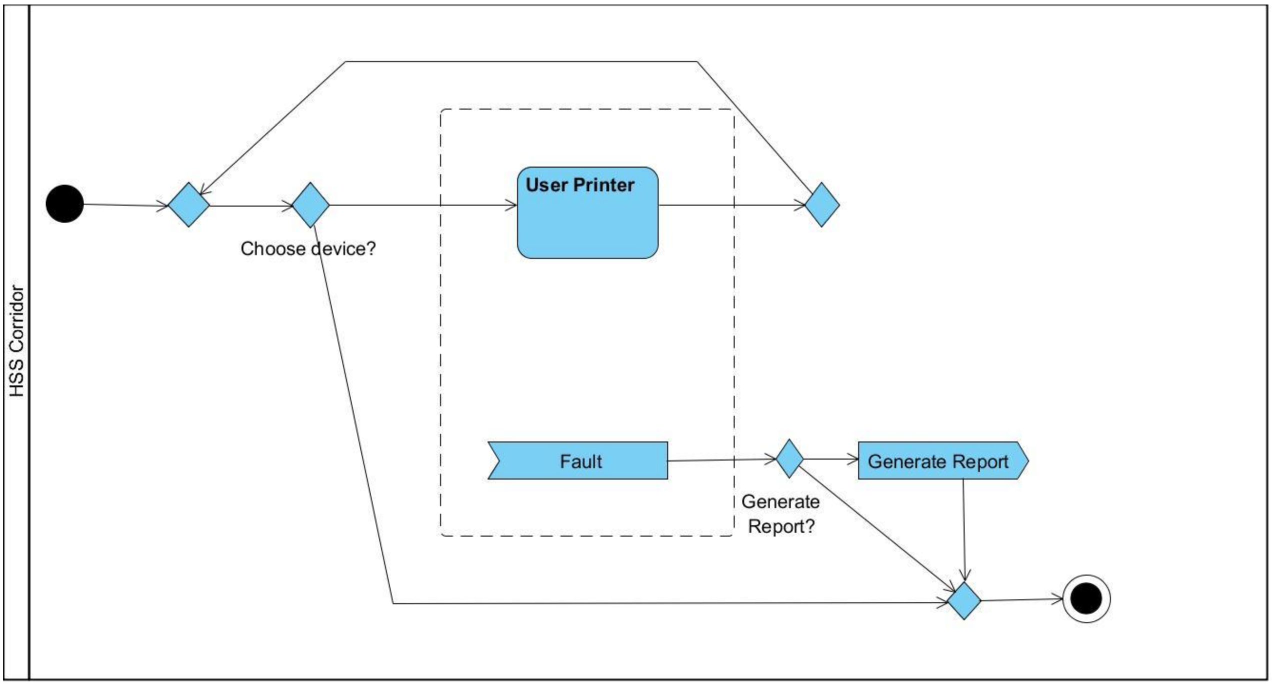


Figure 55 HSS: Corridor, Affect Equipment

2.9 APPENDIX B (Questionnaires)

2.9.1 Building Users

2.9.1.1 Office User: Movement to and from Office

What age are you?

Are you male or female?

- Male
- Female

What is your room number/name?

Where is your desk located? (E.g. near the door, centre of the room, by the window)

Do you share the office with other people?

- Yes
- No

Do you take the same route from the building entrance to your desk every day?

- Yes
- No

How many routes do you take to your desk? (If no to previous) From building entrance to desk.

- 2
- 3
- 4
- Other:

What are your reasons for taking alternative routes? (If no to previous)

- ☐ Go to common room.
- ☐ Go to toilet.
- ☐ Interact with other building users (at their desk for example)
- ☐ Other: [ ]

How many days do you spend on average per week in the building?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

How many hours do you spend on average per day in your office? Remember to subtract lunch breaks taken outside your office.

- ○ Less than 1
- ○ 1-2
- ○ 2-3
- ○ 3-4
- ○ 4-5
- ○ 5-6
- ○ 6-7
- ○ 7-8
- ○ 8-9
- ○ 9-10
- ○ 10-12
- ○ Over 12

Does your day start at the same time every day?

- Yes
- No

What time does it usually start? (If yes to previous)I.e. 9:00 a.m.

What window of time do you usually begin your day? (If no to previous)I.e. the window of time in which day usually begins (i.e. between 8:00 and 10:30)

Does your day end at the same time every day?

- Yes
- No

What time does it usually end? (If yes to previous)I.e. 17:00

What window of time does it usually end? (If no to previous)I.e. the window of time in which day usually ends (i.e. between 15:00 and 18:30)

2.9.1.2 Office User: Breaks and Movements

How long is your lunch break?

- ○ Less than 30 minutes.
- ○ 30-45
- ○ 46-60
- ○ 61-90
- ○ 91-120

Does your lunch break start at the same time every day?

- ○ Yes
- ○ No

What time does it usually start? (If yes to previous)I.e. 12:00 [ ]

What time window does it usually start? (If no to previous)I.e. the window of time in which lunch usually occurs (i.e. between 11:00 and 13:30) [ ]

Where do you have lunch?

- ☐ At your desk
- ☐ The common room
- ☐ Somewhere else in the building
- ☐ Outside the building
- ☐ Other: [ ]

On average, how many times per week do you leave your desk during your lunch break?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Other: [ ]

On average, how many times per week do you leave the building during your lunch break?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Other:

How long do you spend outside the building when you leave on average? (If previous answer is not 0)

- ○ Less than 15 mins
- ○ 15-30
- ○ 31-45
- ○ 46-60
- ○ 61-90
- ○ 91-120

Do you take the same route to get your lunch every day?

- ○ Yes
- ○ No
- ○ I don't move from my desk

How many alternative routes do you take?(If previous answer is no)

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ Other:

How many meetings do you attend every week on average?(Not at your desk)

- 0
- 1
- 2
- 3
- 4
- Other:

How many minutes do you attend each meeting on average?(Not at your desk)

- 1-30
- 31-45
- 46-60
- 61-90
- 91-120
- Other:

How many occur within the building?

- 0
- 1
- 2
- 3
- 4
- Other:

Can you name the locations they occur?(Room numbers)

How often on average each day do you leave your desk for refreshments?(I.e. to get water, coffee)

- ○ 0
- ○ 1
- ○ 2
- ○ 3-5
- ○ 6-10
- ○ Other: [ ]

Where do you usually go to get refreshments (i.e. water)? [ ]

How often on average each day do you leave your desk to visit the toilets?

- ○ 0
- ○ 1
- ○ 2
- ○ 3-5
- ○ 6-10
- ○ Other: [ ]

Where do you usually go to the bathroom?(Bathroom Location) [ ]

Do you smoke at work?

- ○ Yes
- ○ No

How often on average would you leave your desk to smoke in a day?

- ○ 0
- ● 1
- ○ 2
- ○ 3-5
- ○ 6-10
- ○ Other: [ ]

Where do you usually smoke? [ ]

2.9.1.3 Office User: Devices and Interactions

Do you have a PC at your desk? (If more than one put amount in other)

- Yes
- No
- Other:

Do you turn your PC off when not using it?

- Yes
- No
- Only at the end of the day
- Other:

What power plan is your PC set to? (In Windows 7 click "Start" and type "Power Plan" to determine your PC's power settings)

- Balanced
- Power Saver
- High Performance
- Other:

Do you bring a laptop into the building? (If more than one put amount in other))

- Yes
- No
- Other:

Do you use your laptop at your desk?

- Yes
- No

Do you use your laptop in other locations (e.g. meetings)?

- Yes
- No

Do you leave your laptop plugged in when you are not using it?

- Yes

- No
- Other:

What power plan is your Laptop set to?(In Windows Seven click "Start" and type "Power Plan" to determine your PC's power settings)

- Balanced
- Power Saver
- High Performance
- Other:

Do you have a lamp at your desk?

- Yes
- No
- Other:

Do you have any other devices you keep powered in your office?(e.g. mobile phone, portable heater, etc.)

2.9.1.4 Office User: Heating, Ventilation, Air Conditioning and Interactions

Do you have air conditioning in your office?

- Yes
- No

Can you adjust the air conditioning?

- Yes
- No

When are you likely to adjust the air conditioning?

- I never adjust the air conditioning
- When it is too hot
- When it is too cold
- When it is too stuffy
- Other:

Do you ever open any windows to affect ventilation?

- Yes
- No

What windows do you open? (for example, I open the window closest to me in my office).

Do you ever open any doors to affect ventilation?

- Yes
- No

What doors do you open? (for example, I open the door into my office or I open the door closest to me in my office).

Do you have heating in your office?

- Yes
- No

Can you adjust the heating?

- Yes
- No

When are you likely to adjust the heating?

- I never adjust the heating
- When it is too hot
- When it is too cold
- When it is too stuffy
- Other:

Do you ever open any windows to affect heat?

- Yes
- No

What windows do you open? (for example, I open the window closest to me in my office).

Do you ever open any doors to affect heat?

- Yes
- No

What doors do you open?(for example, I open the door into my office or I open the door closest to me in my office).

2.9.2 Users Light and Interactions

Do you have a light in your office you can turn on and off?

- Yes
- No

When do you turn the lights off? (If yes to previous question)

- Whenever I leave the office
- Only when everyone has left the office
- When it is bright outside
- Other:

Do you have blinds in your office?

- Yes
- No

Can you open and close the blinds?

- Yes
- No

When do you close the blinds?

- I never close the blinds
- When it is too bright
- When it is too hot
- When the sun is on my screen
- When the sun is in my eyes
- Other:

2.9.3 Office User: Common Room Interaction

How often do you use the vending machine on average in a week?

- 0
- 1
- 2
- 3
- 4
- 5
- Other:

How often do you use the coffee machine on average in a week?

- 0
- 1
- 2
- 3-5
- 6-10
- Other:

How often do you use the sink to wash dishes on average in a week?

- 0
- 1
- 2
- 3
- 4
- 5
- Other:

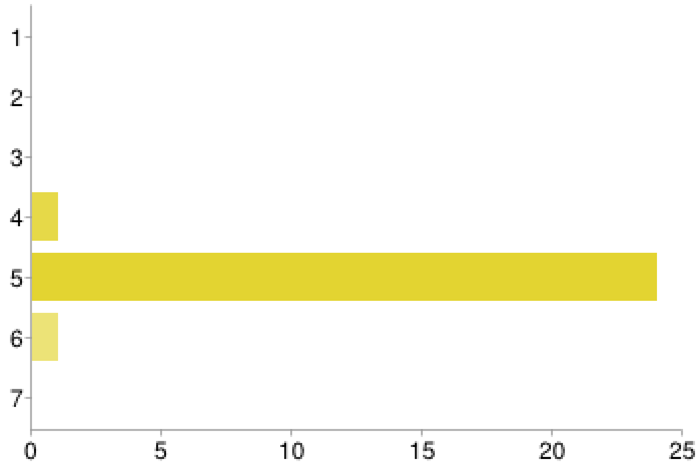
How often do you use the microwave on average in a week?

- 0
- 1
- 2
- 3

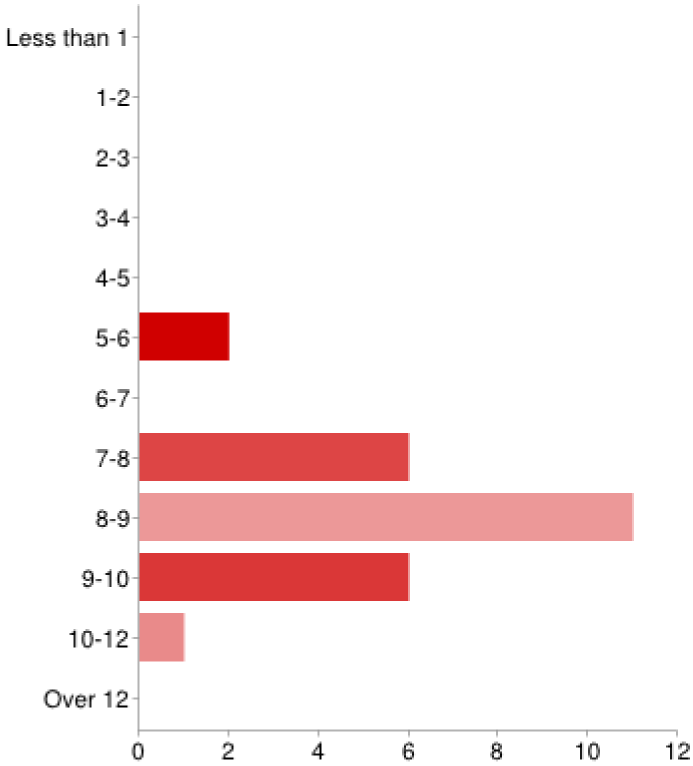
- ○ 4
- ○ 5
- ○ Other:

2.9.4 Example Response: B-Digital

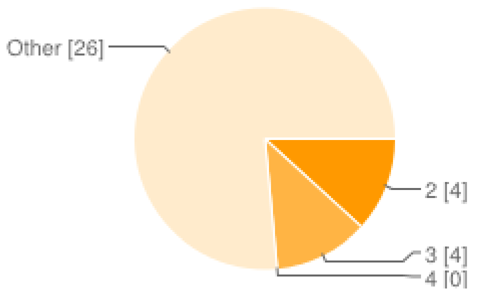
How many days do you spend on average per week in the building?



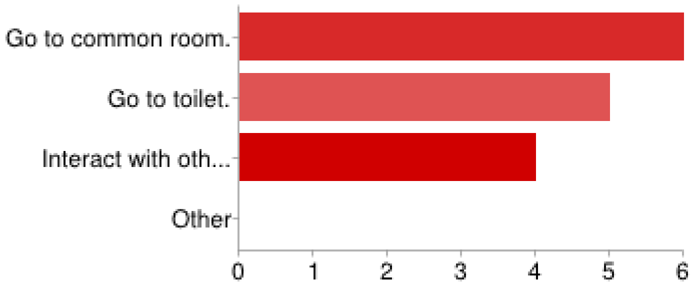
How many hours do you spend on average per day in your office?



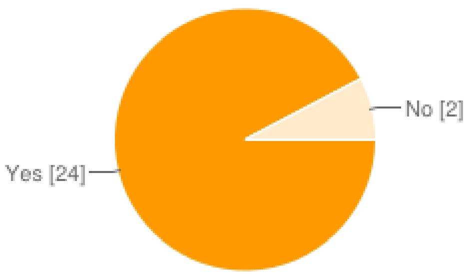
How many routes do you take to your desk?



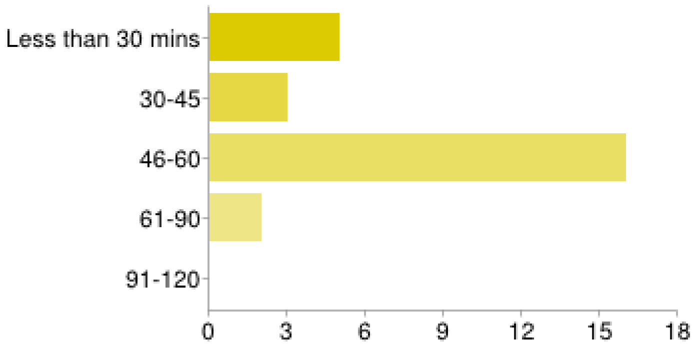
What are your reasons for taking alternative routes?



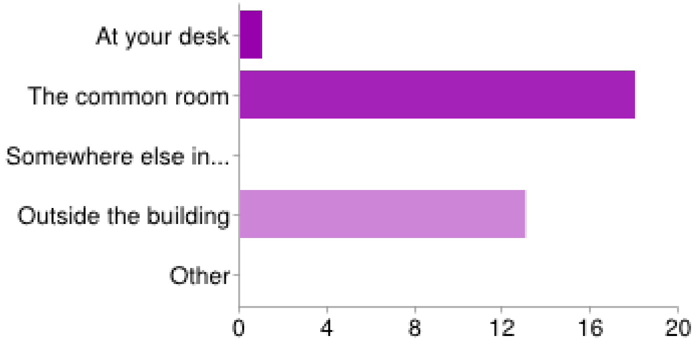
Do you share the office with other people?



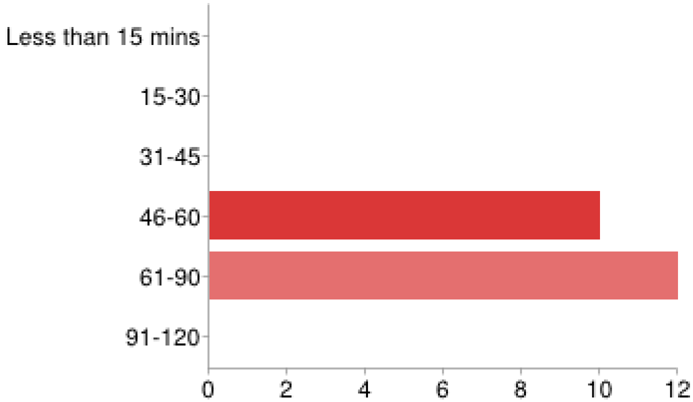
How long is your lunch break?



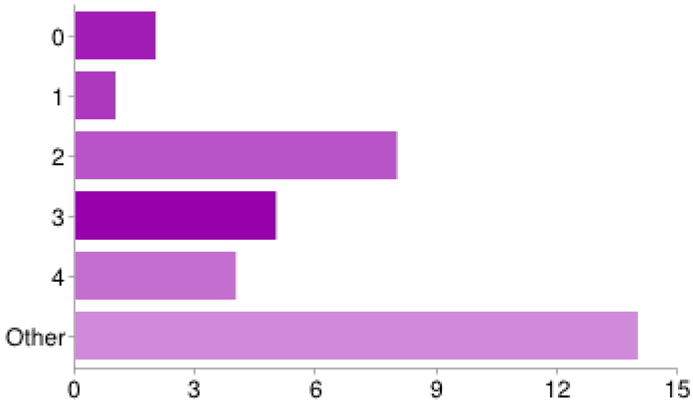
Where do you have lunch?



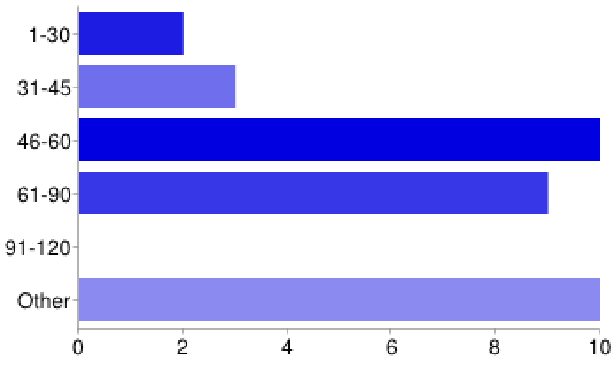
How long do you spend outside the building when you leave on average?



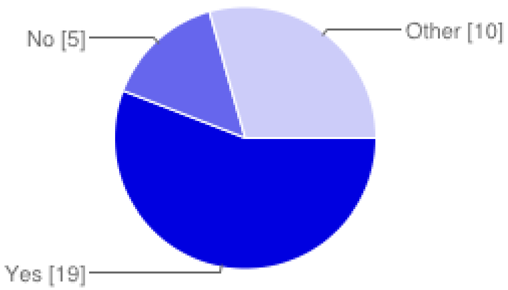
How many meetings do you attend every week on average?



How many minutes do you attend each meeting on average?

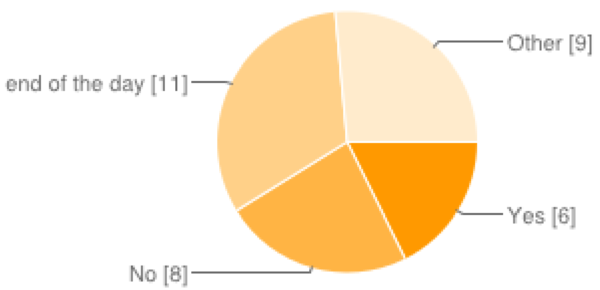


Do you have a PC at your desk?



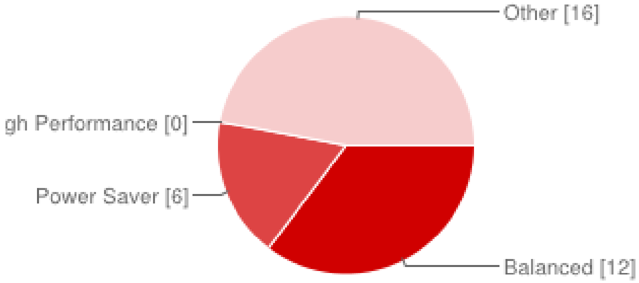
*

Do you turn your PC off when not using it?



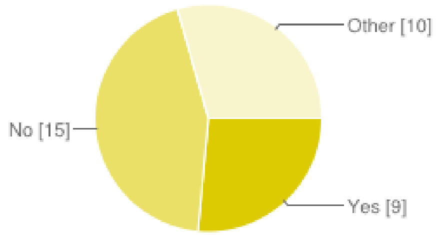
*

What power plan is your PC set to?



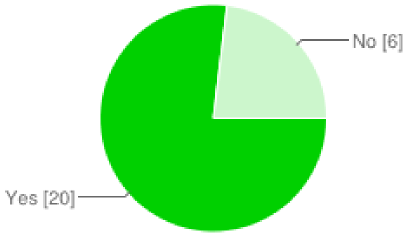
*

Do you bring a laptop into the building?



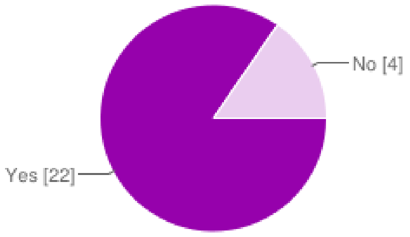
*

Do you use your laptop at your desk?



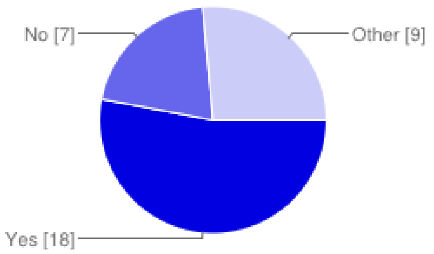
*

Do you use your laptop in other locations (e.g. meetings)?



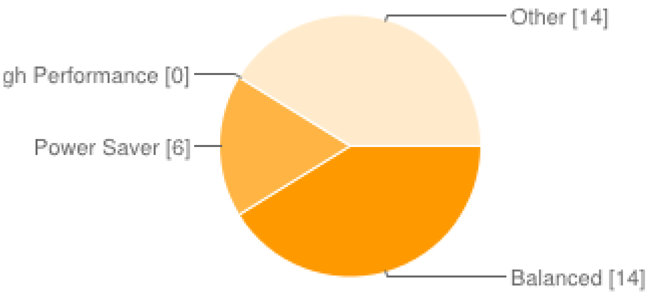
*

Do you leave your laptop plugged in when you are not using it?



*

What power plan is your laptop set to?



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2.9.5 Facility Managers: Generic Questionnaire

This questionnaire will determine some background information with respect to the facility managers of building x.

What is the name of your building(s)?

____

____

Does the building have a building automation system/building management system (BAS/BMS) in place? *(If more than one enters value in "other")

- ◯ Yes
- ◯ No

◯ Other: ________________________________

____

____

____

Are you responsible for the following with respect to the BAS? (If yes to the previous answer)

- ☐ Installation
- ☐ Upgrading
- ☐ Configuring
- ☐ Maintenance

◯ Other: ________________________________

____

-

How do you evaluate the effectiveness of the BAS? (If yes to the previous answer)

____

____

How do you detect faults in the building? *

- Inspection
- Reported by word
- Reported by phone
- Reported by e-mail

Once you are aware of a fault, how do you deal with it? *

- First come, first serve basis
- Prioritise

When a fault has been identified, how do you record it? *

- No record is kept.
- Records are kept and can be referenced if the same, similar or related behaviour occurs again.
- Other: __________

- How do you detect inappropriate behaviour in a building? *For example, lights being left on, heating on when a room is not in use, (or either turning on/off due to incorrect automation)

- Inspection
- Reported by word
- Reported by phone
- Reported by e-mail

Once you are aware of inappropriate behaviour in the building, how do you deal with it? *

- First come, first serve basis
- Prioritise

When evaluating a report of inappropriate behaviour, how do you analyse the cause? *For example, if someone is complaining the room is to hot, what investigation of their situation would you conduct to determine the cause?

- ☐ I simply take the persons word for it.
- ☐ I inspect the location where the inappropriate behaviour occurred to determine a cause.
- ☐ I examine a building model to determine a possible cause.
- ☐ I run simulations to determine a cause.
- ☐ Other

When an inappropriate behaviour has been identified, how do you record it? *

- ○ No record is kept.
- ○ Records are kept and can be referenced if the same, similar or related behaviour occurs again.

○ Other: ____

____

____

____

When you apply a solution to resolve an inappropriate behaviour, how do you evaluate its effectiveness? *

- ○ Query the person(s) who reported it.
- ○ Wait to see if another report is produced as a result of your solution.

○ Other: ____

____

Are you responsible for managing building energy consumption? *

- ○ Yes
- ○ No

Do you have an energy conservation strategy in place? (If yes to previous question)
*Explain (for example, turn off computers, heating, lights etc. when not in use)

____

____

How do you evaluate the effectiveness of the energy conservation strategy? (If yes to the previous answer)

____

Would it be useful if users could report energy saving strategies the same way they report faults? *

- Yes
- No

Do you have a model for user activities in the building? *

- Yes
- No

What kind of activities do you record? (If yes to previous answer) *For example, for spaces (meeting, office rooms) or for individuals (lunch breaks, routes through building, etc.)?

How do you store these models? (If yes to previous answer) *For example, excel sheets, word documents, etc.

Would it be useful if building users could create activity models to record their behaviour in the building? *(With respect to analysing faults, inappropriate behaviour and energy consumption).

- Yes
- No

Other: __________

Would it be useful if building users could record their activity when reporting faults or inappropriate behaviour? *

- Yes
- No

Other: __________

Would it be useful if building users could record report energy saving strategies directly to you? *

- Yes
- No
- Other: ______

Would it be useful if building users could record their activities when reporting inefficient energy consuming behaviour in the building *I.e. if they are doing an activity which they feel is resulting in wasteful energy.

- Yes
- No
- Other: ______