CommONEnergy

DELIVERABLE 3.1

Virtual IDP library

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Executive Summary

The majority of European shopping centres are already built, but there is still huge potential for energy savings due to the practice of regular rehabilitation and redesign of shopping centres. This state of constant change offers regular opportunities to improve the technical systems, such as lighting, ventilation, and refrigeration systems, or the building envelope. Comprehensive actions on these aspects, considering both retail (related to customers' experience, and marketing) and efficiency (related to building energy and facility management) needs have the potential to achieve significant energy reductions and IEQ enhancements.

Three different types of energy retrofit drivers have been identified:

- **Direct drivers** addressing the energy bills reduction or a more effective use of the sales area. They can trigger deep energy renovation to optimise the costs/benefits ratio. Their influence is direct and they may be seen as actively influencing energy use reductions in shopping centres.
- **Indirect drivers** providing support or background for direct drivers. For example changing shopping habits and user behaviour influences the non-energy related retrofitting activity. These retrofitting actions may affect energy use in shopping centres and associating them with energy retrofits is an action to be included in an integrated design process.
- **Potential drivers** not actually causing a direct and immediate effect, but with the correct set of circumstances in place they have the potential to become direct drivers.

Every retrofitting involves a detailed analysis of the building and its context peculiarities. Indeed, the analysis of technology features and the functional layout supports the retrofit design: first step is an auditing of the basic information about the building, such as general data (location, year of construction, shopping centre typology, climate, area of intervention), building features (design, shape, orientation, parking location), building envelope (structure, materials, glazed and opaque surfaces, thermal transmittance), HVAC plants and equipment and internal gains (lighting and electric equipment power density). With such information set it is possible to develop retrofitting concepts, further investigate through accurate numerical models of the shopping centre, enabling to predict possible performance enhancements.

All the collected information, as well as present and potential performances coming from modelling and simulations are reported in a structured repository we called virtual IDP library.

The Virtual IDP library is conceived to provide designers, owners and managers with relevant information to start a retrofitting process of a shopping centre by analysing the functional layout and the technology features of a meaningful number of other cases. The library describes the main technology features that characterize the architectural archetype of shopping centres in different context and representative of different archetypes.

Building energy simulation models are used to identify the more suitable solution-sets for a shopping centre archetype retrofitting and to estimate the relative energy savings, in order to ensure an effective investment, while exploiting, for each case, local natural sources and infrastructures.

In the Integrative Modelling Environment developed within the CommONEnergy project, the whole building system is divided into base blocks, making more effective the support of the shopping malls retrofitting phases (auditing, design, construction, commissioning and operation).

Each retrofit solution set is evaluated according to the a set of **Key Performance Indicators (KPI)**, which are calculated by means of building energy simulations and are: primary energy savings, carbon emission savings, comfort level, investment cost, operational energy cost, payback time, Net Present Value, maintenance cost.

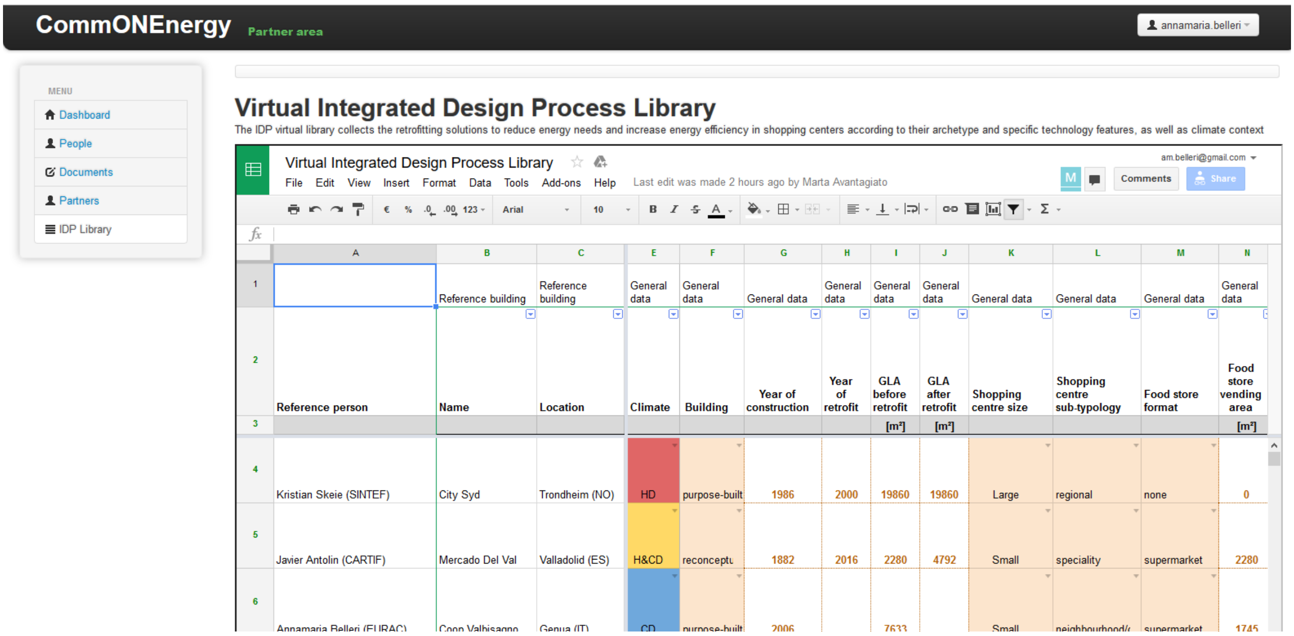
The intervention strategy in a retrofitting is hardly configurable with quantity indicators, so it can be based at a first stage on a *qualitative level* that can identify the applicable potential for each solution items of passive and active efficient proposals. **Qualitative indicators**, identifiable and marked as possible candidates for efficiency KPIs for a retrofitting, assess the quality of the action according to certain standards; they are divided into four categories:

- energy, or how the action affects the energy efficiency and energy savings;
- innovation, compared to current practices in use;
- accessibility, in sense of the integration possibilities, as due to the building codes restrictions, historical characteristics, etc.;
- costs, the economic investment level compared to market costs.

For each indicator, performance levels are expressed with three values: high, medium and low potential.

The IDP library will be publicly distributed on the CommONEnergy web-site (http://www.commonenergyproject.eu/integrated_library.html) as a free excel-based online repository available to help shopping centres owners and managers in planning malls retrofitting, providing a quick overview of the best solution-sets matching the building features and context. The structure of the excel sheet allows (i) easy filtering and user friendly visualization of the collected information, (ii) to add further reference building and solution-sets based on those buildings (iii) to extract information in automatic way (iv), and further informatics developing, moving the information in automatic way.

The mid-term vision, by a further informatic optimisation, is that the repository could be populated by external users and become a reference point for shopping centres retrofitting design.



The Virtual IDP library.

Thanks to its simple structure and ease of use, **energy audit** templates for information collection can be easily created from the virtual IDP library and used as walk-through survey by auditors during their inspection. On the other hand the energy audit can be also initial input information to start the comparison with similar cases, and to propose the energy efficient solutions potential to be adopted in retrofitting or potential certification process.

The data collected and the **benchmarking** with similar archetypes allow the auditors to easily identify potential cost-effective measures for improving energy efficiency. The solution-sets developed for the reference buildings and analysed by building energy simulation are an important source of inspiration for retrofit interventions in similar buildings. In fact, the IDP library provides a quick overview of the best solution-sets matching the building features and context.

While the role of IDP library during the **commissioning** phase is twofold:

- The IDP library contains predicted energy performance of reference buildings which can be used as benchmark during the commissioning phase;
- The commissioning can feed the IDP library by providing actual energy performance which can be useful to other users.

Thanks to an Integrated Design process the retrofit design can benefit from **added value due to the integration of different functions**, beyond the energy performance and the thermal comfort aspects. Identified co-benefits regard: security and safety, health, acoustic protection and environment quality, natural light and smoke ventilation.

1 Introduction

The concept for a library to support the "Integrated Design Process" of shopping centres is based on two main principles, the increase of an energy savings [%] on one side, and the increase of the indoor environment quality on the other.

There are the architectural features and needs that might be common in shopping malls, the IDP treats them, and the main conclusions may be consulted in continuation of the document. Possible modifications of common retrofit practices, in order to improve the energy performance of building, will be proposed as well as the definition of an integrated approach for developing architectural solutions, including materials, components and systems conceived and realized within CommONEnergy project to effectively exploit local natural sources to their greatest potential. The three drivers for development are: to reduce energy consumption, to increase comfort level and functionality, to optimize building operation and maintenance costs.

To analyse and to propose the structure of the library, there have been analysed different aspects like:

- Main drivers for deep retrofitting and their role in decision making process;
- Architectural archetypes;
- Methods and tools to support IDP and to guarantee the high quality data.

The library collects the outputs of the analysis performed on shopping centres peculiarities like its functions, urban and social context interactions, architectural archetypes, technologies features and functional layout depending on different climate conditions and specific needs. Once concluded all those analysis, the repository file have been created, and friendly user guide proposed for its on-line exploitation by future users. The data available into the library is based on building energy simulations performed within the Integrated Modelling Environment developed within the project (Dipasquale C., 2016) and based on 11 reference buildings, which are meant to be representative of the whole European retail buildings stock.

2 Main drivers for deep retrofitting

2.1 Introduction

Retailing has undergone major changes in the last twenty or thirty years in both its commercial and economic organization as well as its geographical character. There have been major changes in ownership patterns leading to growth of large national and international corporate retailers at the expense of smaller more local operations. The way retailing is delivered to the public and self-service, spawning a variety of styles of selling, each requiring different types of location. The commercial success of different styles of selling depend increasingly upon the way we are able to create and offer comfortable, convenient and convivial environments to the consumer and decentralization in locations of consumer demand, away from inner city areas to the fringes of cities and beyond.

2.2 Objectives

The efficiencies and inefficiencies associated with the everyday management, operation and use of shopping centres were studied and aims to identify the drivers, barriers and potentials associated with the operation of shopping centres. These were used to define the specifications necessary to achieve effective energy investments within European shopping centres. The intention is to supply the shopping centre industry with tools and solutions which will transform them into lighthouses of energy efficient systems and architecture. The primary focus is energy use, but the fields of facilities, functions, management, ergonomics, safety and logistics are also studied, because sustainable shopping centres in addition to being energy efficient are commercially viable, accessible social arenas for all sections of society.

2.3 Methodology

This work was based on literature reviews, questionnaires and interviews. It required an analysis of the systemic inefficiencies associated with the fields of facilities, functions, management, ergonomics, economic models and logistics for European shopping centres. Data was therefore collected in a broad number of fields and over a wide geographic area. In order to achieve the broad base of information required for the study a number of different methods, including quantitative, qualitative and desk top approaches, was selected. A survey or questionnaire is used when a research question requires a quantitative or numeric description of trends, attitudes or opinions from a population sample. The intention has not been to test a hypothesis but to provide indicators with which to understand societal trends associated with energy efficiency and sustainability issues in shopping centres. The research project requires information about the current situation in Europe and a quantitative approach was chosen as the primary approach mainly due to a need for a quick and effective collection of data. Therefore, a web based questionnaire was developed and distributed to the relevant stakeholders with the aim of providing a statistical understanding of phenomena associated with energy efficiency and sustainability in shopping centres, and of the relationships between them.

Central aspects within this analysis are the definition of what a driver is, and describing the different kinds of drivers and their role in the decision making process. Drivers are primarily the factors which make things happen; in this case they may be expected to set in motion an action to reduce energy. Drivers are understood as influencing decision-making and energy use and may be divided into three different types: direct drivers, indirect drivers, and potential drivers.

Complex processes involving stakeholders that may lead to the selection of inappropriate and energy-consuming technical solutions, building and land design, and choices of operations and maintenance are studied. An in-depth analysis of the building envelope and technical systems is provided aiming to identify factors that influence the functional efficiency and energy consumption in shopping centres. The social environment, behavioural aspects are assessed and their influence on the decision-making process when implementing energy renovation measures considering six main fields: Facilities, Functions, Management, Ergonomics, Logistics, Economic models.

2.4 Results

The six fields have not been considered individually but as required in relation to four main sections: 1. User behaviour of primarily customers; 2. decision making structures associated with owners/managers and tenants; 3.The systemic inefficiencies associated with the function and use of a shopping centre building; 4.Economic models that are used to sell energy investment to tenants.

2.4.1 The influence of user behaviour on energy performance

The aspects which achieved the highest ratings in the three shopping centres are customer satisfaction, safety, logistics, the range of products, access to public transport and car parking. These qualities are important when customers are choosing where to shop. Customers are satisfied with the shopping centres where the surveys took place, but they are also keen to improve the energy efficiency of shopping centres in general and energy efficiency is one of the aspects where they saw the greatest possibility for improvement. There are three main aspects associated with user behaviour and energy performance:

- Customer knowledge or lack of knowledge is an important factor to be dealt with if shopping centres are to gain approval for actions associated with energy efficiency issues, or if customers are themselves going to demand energy efficient shopping centres.

- Energy efficiency does not influence customer choice of shopping centre. Location is the most importance factor influencing customer choice of shopping centre. This is closely associated with the importance customers place on car-parking.

- The physical framework provided by shopping centres does influence customer choice. However customers involved in the survey placed little importance on architecture and design when choosing where to shop. Owners and managers placed much more importance on physical structure and architectural quality ranked as highly as customer satisfaction and energy efficiency when suggesting the main reasons for a shopping centre upgrade. Tenants had customer satisfaction was their focus. The physical structure received less focus from tenants.

A shopping centre is more than what is directly perceivable to each customer and a fair judgement of i.e. recycling, energy efficiency or environmental friendliness in shopping centres requires more insight into the day-to-day operation of a centre and behind the scenes management. Importantly, the customer survey suggests that an environmentally friendly profile is not being communicated to customers.

2.4.2 Decision making structures for customers, tenants and owners/managers

Four stakeholder groups have been considered, customers, tenants and owners and managers and community. The main findings from the four stakeholder groups are as follows:

Customers: Shopping centres are not chosen because of their energy efficiency, although the appearance of an energy efficient shopping centre could encourage “green” thinking. Customers have low awareness of energy efficiency in shopping centres. Customers are interested in lower prices and a wide range of products and this is not directly associated with an energy efficient renovation.

Tenants: the energy efficiency of shopping centres is not of primary importance. It is important to improve the flow of information about energy efficiency among employees in shopping centres. Energy performance certificates could be used to strengthen awareness of how energy efficiency influences stores or retail units.

Owners and managers: equal the main decision making group and they are interested in energy efficiency. However they are reluctant to spend large amounts of resources on renovation. The value of the building is an important to this group and therefore energy investments may be expected. Common certifications for energy efficient buildings are not considered suitable for shopping centres by this group, but a certification specifically for shopping centres could be a step towards encouraging interest about energy efficiency amongst owners.

Community: the community has most influence over shopping centre energy use during planning and regulation when a new shopping centre or a major expansion is being planned. The municipality often negotiates with investment companies about issues such as size, location and grid access. However enthusiasm or protests from local residents can also influence the development and redevelopment of shopping centres. The development of a sustainable shopping centre, one which has low energy use and looks after green areas or established new ones, could potentially meet with less protest. The community does not have any direct impact on energy use. However, there are knowledge schemes which encourage demands for reduced energy use in shopping centres; building certification schemes could play a role here. Building codes could also cause demands for greater energy use reductions through the tightening of demands during the rehabilitation of shopping centres.

2.4.3 Systemic inefficiencies

This work considers four main areas which are a source of energy inefficiencies in shopping centres; lighting, HVAC measures, architecture and design which include ergonomics, safety and accessibility and building envelope.

Lighting: There are large inefficiencies associated with lighting as a general concept and among different lighting systems. Managers of shopping centers may not have strict restrictions from owners, but they are generally responsible for lighting only in common areas and exteriors, and importantly for all direct energy costs and lighting represents a key area for savings. Lighting is often spread over a large area, and centrally controlled systems are crucial to overall lighting management. It is essential to extend the use of daylight to additional floor areas and this can be achieved by opening additional building surface areas or by redirecting light in the building depth. Common areas are often daylit but shops and other sales areas are seldom daylit. This leads to an additional inefficiency, the use of daylight to an unreasonable level, due to overlit areas often found in common areas. Display lighting is important for drawing attention to showcase items and enhancing aesthetic quality, but many retailers use inefficient spotlights. LED together with controlled beam lighting can save energy while maintaining excellent colour rendering. If windows also supply daylight, then integrated concepts for display lighting, daylighting (and inside exhibition of merchandise at shelves) must be developed. Sensitive adjustment of indoor luminance values generates the requested result. Often daylight levels are higher than necessary which needs to be compensated for by the use of more artificial light in shops and sales areas.

In order to establish sufficient light levels the use of efficient light sources and electronic gear concerning energy demand is important. The environmental impact and life-cycle performance (including maintenance efforts) needs to be considered when choosing the most appropriate luminaires. Finally, automatic control regulation is essential and occupancy sensors for less used areas (such as back-of-store areas, staff rest rooms, storage areas and office space) that do not require light 24 hours a day should be installed. Replacing fixtures with T5 or T8 compact fluorescents will save even more energy.

HVAC measures: Quality control of the complete energy system is necessary throughout the entire building if energy-efficient solutions are to be met. This requires adequate information about building systems and assessment tools. A second requirement is a commissioning procedure that enables follow-up of the building performance during the building lifetime, thereby helping to detect systemic inefficiencies. A third requirement is comparative analysis including a detailed monitoring system to track energy use and fault detection, with yearly and hourly energy consumption profiles analysed in a holistic manner.

Building envelope: Recommended levels of thermal insulation in the building envelope depend on the climate. Building energy use should be calculated and insulation levels optimized in relation to these variables. Single measures often do not yield cost-effectiveness but deep retrofitting (a number of measures implemented together) achieves high levels of energy savings. Ideally, this should be simulated using building performance simulation tools.

Architecture and design: Shopping centres are complex buildings with a complicated layout, with sophisticated utility plants and a very high concentration of customers and workers, the latter making repetitive material handling tasks. These factors, as well as the large amount of young workers, imply serious ergonomic issues and H&S hazards. There is a consistent set of regulations and guidelines related to ergonomics and H&S, but the options for their implementation are diverse and may have implications for energy efficiency.

Integrated design solutions are more effective than individual actions in improving the quality of the built space, both energy and design wise. Universal design is associated with ergonomics and accessibility, and has implications for the design of sustainable shopping environments. Accessibility and ergonomics are not drivers for energy use reductions, but combining these actions with those aimed at achieving energy use reductions will increase the energy impact. Owners, managers and tenants should therefore be encouraged to work with more than more than one action at once. It is suggested here that the aim to provide good shopping centre architecture has the potential to be a driver for achieving energy use reductions, because applying the available best solutions to support stakeholder needs, today also means applying the most energy efficient solutions.

2.4.4 Legal/economic issues between owners and tenants

Legal and economic issues affect how costs associated with the day to day running of the shopping centre, maintenance and upgrades are distributed among stakeholders, and they influence stakeholder actions with regards to energy retrofitting. It is suggested here that actions to achieve energy use reductions will be implemented if they are seen within the wider context of retail success and profits "successful retailers will be those who respond most positively to the changing patterns of shopping behaviour.

If communicated effectively to the different stakeholder groups and when combined with efforts to respond to changing patterns in shopping behaviour, legal and economic actions could become direct drivers for deep energy retrofitting. In addition the inclusion of non-technical clauses for example requiring energy use reductions or the meeting of energy targets in in tenant leases will support the more technical actions, potentially strengthening their impact. A number of legal and economic issues which influence stakeholder activity in shopping centres were identified about user behaviour. These are:

- Customers: price of goods, free parking
- Tenants: sales maximisation and profits, rental costs, billing systems, reduced costs, transparent billing systems, green leases, length of leasing period
- Owners and managers: sales maximisation and profits, rental costs, billing systems, reduced costs, high occupancy, building codes, property value
- Community: Building codes, jobs and revenue

Not all of the aforementioned aspects have implications for deep energy retrofitting. Free parking although it affects customer choice, is an example of this. Aspects such as sales maximization and profits do not at first glance appear to have anything to do with deep energy retrofitting, but they are important to owners, managers and tenants. The whole retrofitting process has implications for profits and the price of goods, because it can have implications for property value and the rental price. These can in turn affect occupancy levels and thereby the popularity of shopping centres among tenants and customers. In addition although tenants and managers are interested in sales maximization and profits, their attitudes towards how and why this is to be achieved vary. The goal of the owners is to increase property values while tenants aim to minimize rent and ancillary rental costs. It therefore considers billing systems, overheads/running costs, green leases and the length of the leasing period. These aspects affect the relationship between owners, managers and tenants.

2.5 Final considerations

The majority of European shopping centres are already built, but there is still huge potential for energy savings due to the practice of regular rehabilitation and redesign of shopping centres. This state of constant change offers regular opportunities to improve the technical systems, such as lighting and ventilation, or the building envelope and monitoring systems. Consideration of these aspects along with the other drivers has the potential to achieve significant energy reductions and IEQ improvement. Three different types of drivers have been identified: Direct, indirect, and potential. The direct drivers for energy use reductions in shopping centres should be seen in collaboration with potential and indirect drivers which may either support or hinder efforts to achieve the desired energy reductions, depending on the conditions or context provided. The potential and indirect drivers are specific for shopping centres and are driven primarily by retail and stakeholder requirements. Their influence provides background for direct drivers and means that actions taken are specific for shopping centres.
The three different types of driver, their challenges and effects are as follows.

Direct drivers for energy retrofits actually cause a phenomenon for example a deep energy retrofit to happen. Their influence is direct and they may be seen as actively influencing energy use reductions in shopping centres today. However there is more than one side to direct drivers, and they may not always have a positive effect on energy. This because if the consequences are not correctly understood they may in some cases function as barriers to energy use reductions, this may for example be clearly seen in the cases of knowledge and costs. In the following some examples of direct drivers:

- The need to reduce energy use in shopping centres is in itself a driver based on the needs to reduce operational costs and overhead costs.

- The improvement of thermal and visual comfort issues could be drivers to improve lighting and thermal aspects related mainly to the envelope, HVAC system and lighting devices.

- The need for systems which are easier to control and maintain is a driver, especially regarding the overall management, functional and energy flexibility that could lead to economic benefits, including taking advantage of building-grid interaction aspects.

- Lack of knowledge among stakeholders is a barrier to energy use reductions. Increasing knowledge will potentially function as a driver for implementing actions to achieve energy use reductions. On the other hand, increasing knowledge about energy use in shopping centres on all stakeholder levels is a potential driver for energy efficient upgrades. User awareness and motivation must be seen as a driver for energy use reductions. Increasing user awareness might for example be achieved through use of building certification systems. It is important that certification systems are measuring improvements and especially account for the changes during rehabilitation which occur much more frequently in shopping centres than in other building types.

- Costs associated with retrofitting may be seen both as drivers and barriers.

Indirect drivers provide support or background for direct drivers. For example changing shopping habits and user behaviour influences the non-energy related retrofitting activity. These retrofitting actions may affect energy use in shopping centres and associating them with energy retrofits is an action to be included in an integrated design process.

Potential drivers are drivers which are not actually causing an effect at the moment, but with the correct set of circumstances in place they have the potential to become direct drivers. It is not always easy to separate indirect drivers and potential drivers from each other, because they could both affect energy actions. The difference between them is that indirect drivers are already in place, and they are having an effect on the physical structure in shopping centres, for example user behaviour, but they are not the main reason for actions to reduce energy use. Potential drivers are not at the moment in place, but if they were in place they could have a great impact on the amount of energy used in shopping centres. An example of a potential driver is tenant knowledge that can address their potential engagement.

Sustainable solutions require the inclusion of socio-cultural actions. Owners and managers are interested in reducing energy use, but both customers and tenants have limited knowledge about energy use in shopping centres. Customer needs and interests are at the centre of attention in shopping centres, and because customers are not interested there is a danger that other stakeholders will not focus on energy use reductions. Tenants are responsible for a large part of energy use in shopping centres, and this disinterested energy use implies an acute need to work on changing attitudes and aspirations in the everyday activities in shopping centres.

We cannot expect shopping centres to disappear and take their energy use problems with them, the number of shopping centres continues to grow and the GLA in existing shopping centres are growing. Customers will continue to focus on commodities and location if they are not encouraged by those who own and run shopping centres and stores to shop more sustainably. Shopping centres have a responsibility to encourage sustainable customer satisfaction. If owners, managers and tenants provide shoppers with sustainable retail environments it may be assumed that shoppers will, to an increasing degree, demand that all shopping centres are sustainable, which will have implications for the design of shopping centres. The retail market needs to change how it presents itself to customers, through for example shopping centre design and it requires greater focus on customer awareness with regard to energy use.

3 Identification of architectural archetypes

A shopping centre is a building, or a complex of buildings, designed and built to contain many activities: shops, neighbourhood services and other discretionary goods stores; restaurants and cafes; common areas and courts for selling activities and events; outdoor parking area or few car parks levels. These areas are interconnected with walkways enabling visitors to walk from unit to unit, from entrance and parking lots to common areas and shops. Sometimes, outdoor spaces host resting area and/or temporary retail units or kiosks for markets and events and green or play areas or forecourts.

Besides to public spaces, there are areas related to work spaces, with different usage and location and according to the type of the centre: staff rooms, restrooms, storage and warehouses, service entrances and unloading services. They have different hours and entrances than the shopping centre.

Today, in addition to the mere commercial function, a shopping centre responds to customer needs: it exhibit recreational attractions and modern amenities for shoppers, commonly visited for shoppers' security and eating-out motives than buying daily needs. The retail tenant mix and atmosphere had the highest relative importance (Teller, 2008), with also convenience, refreshments and location.

Every retrofitting involves a careful analysis of the building peculiarities. The analysis of technology features and the functional layout supports the retrofit design: first of all, the basic information about the building, such as general data (location, year of construction, shopping centre typology, climate, area of intervention), building features (design, shape, orientation, parking location), building envelope (structure, materials, glazed and opaque surfaces, thermal transmittance), HVAC plants and equipment and internal gains (lighting and electric equipment power density).

For example, in case of old and/or masonry building, the retrofitting intervention needs to focus on the building envelope. The use of building energy simulations can help to evaluate the balance between gains and losses and the energy uses and to test design option and solution sets: i.e. external wall insulation combined with natural ventilation; daylighting and lighting controls etc. Moreover masonry work for plants adaptation usually reveals significant. A plan adaptation to a new specific layout is also hard, due to the masonry walls.

When the outer surfaces majority are made of steel and glass, most consistent part of intervention involves the systems efficiency: glass surfaces are subject to significant solar gains and thermal losses therefore involve high energy consumption. The proper design of cooling/heating systems linked to an effective control system (BMS), delivers excellent efficiency results. The inclusion of any adjustable shields/shielding or protections to counteract effects of glare or irradiation or otherwise window opening for natural ventilation can be valuable supports.

This chapter describes the main technology features that characterize the architectural archetype of a shopping centre. The virtual IDP library structure has the same layout (see chapter 7).

3.1 General data

Every mall is characterized by special functions according to the potential customers and tenants and to the place where they are built[1], i.e. general data on urban context, shopping centre size and food store format.

Thus, we can identify different types of shopping centre and a first schematic overview of the peculiar architectural features:

Neighbourhood centre

The neighbourhood centre, the smallest type, is a convenience centre, whose tenants provide a narrow mix of goods and personal services to a very limited common area. These shopping centre usually appears as a small closed building (enclosed structure), with single level in which the architectural connotation is slightly marked as an area mainly destined to the purchase: the main goal is functionality. Daylighting is poor, often obtained with skylights on the gallery roof. Sometimes there is not a close and conditioned gallery, but only a covered passage to connect the shops.

Community centre

The community centre offers a wider range of apparel and other soft goods offerings than neighbourhood centres. The community centre area expands and becomes more 'collective' than the neighbourhood centre: not only a site for the purchase but also a meeting place. The common area hosts bars, cafés and other services. Usually the parking area is along the building. The building is extended in size and floors, as well as services offered. The interior design is more accurate as well as the internal lighting.

Strip malls and precincts

Strip malls vary widely in architecture. Older strip malls tend to have plain architecture with the stores arranged in a straight row, though L-shaped configurations are rather common. Newer strip malls are often built with elaborate architecture to blend in with the neighbourhood.

Retail parks and factory outlets

The buildings that constitute the retail parky can have different sizes and be separated from each other: generally they look as a disharmonious architectural complex of various 'boxes', transformed into one large commercial area at the same unique level; which tries to impose itself on the surrounding context but it has no architectural identity. Originally they may have been built with industrial or otherwise use destinations, other than commercially function.

However, when the buildings were made specifically to accommodate a retail parks, the effect of a continuous space is searched and emphasized with architectural and decorative elements, with attention

[1] The selection of the store type, where to make purchases, depends in large extent also the breadth of the territorial context of residence: it is obvious, in fact, that in a small town with few people it has available an offer less varied respect to what occurs in large metropolitan centers. In addition, engraves the length of the journey to reach their destination.

to new connections and distribution of spaces, to create a strong character of uniformity and essentiality. Lights and systems usually are designed and managed independently by each managers/owners.

Regional or super-regional centres

The regional and super-regional centres include retailers usually selling fashion apparel, accessories and shoes, home furnishings, electronics and other discretionary goods but that also provide services in full depth and variety; they often include a food court with restaurants and cafes. Its main attraction is generally the combination of 2 or 3 anchors or department stores; the mall has various entrances and it could be multi-levelled. A regional mall could be located in downtown areas of major metropolitan markets. A Super-Regional Centre is the largest in size, and with a more extensive offering of anchors and retailers plus a larger food court and service uses; it may also offer a more comprehensive mix of entertainment activities and dining options (like theatres, gym, restaurants, ...). As with regional malls, the usual configuration is an enclosed centre, frequently with multiple-levels of sales and parking floors, connected by common areas and walkways. It is often situated on mass transit lines and along major highway corridors. The primary trade area is ten to thirty kilometres and encompasses an extensive population base.
Usually, these large shopping centres have a great architectural impact: architecture plays an important role for its recognisability and identification. The building facades consists mainly in closed or semi-open surfaces (with coatings, colours and decorations related to the identity of the place or the designer fantasy/creativeness) on which stand out, with great evidence, the entrance areas. Even the lighting is used to highlight them and to create a strong visual impact at night and evening. Similarly, the gallery and connections have a development strongly identified with large, fluid and dynamic spaces, often with different volumes and large skylights to report the various areas and levels: paths and squares, food court, relaxation areas, few parking floor. The materials used for the interiors are related to financial resources but also to the target to obtain a strong commercial attraction: this approach often leads to choose a modern language with the use of high quality materials for finishes, furniture and plant equipment.

Speciality centre

In this type of building, usually the place dedicated to the shopping centre was not born for a commercial function, but was later converted or is planned to be. Thus the importance of a good architectural design, because it makes the difference for the right balance between functionality and aesthetics. Especially for historic building, there is not always the opportunity to intervene with total freedom in aesthetic and plant engineering (for historic constraints and/or for the construction characteristics of the structure) and the redevelopment project must be carefully designed, it should not be too intrusive and blend with the environment. The historical character may influence a lot the retrofit design options. The traditional and historical buildings founds many restrictions from regulation point of view, and many of the innovative technologies have to be deeply analysed as not to destroy the traditional aesthetic character, many of them directly cannot be taken into account as due to the high visual impact.

All of the presented types differ in specific architectural features, affecting the archetype. Architectural features of a shopping centre also depend on functions, commercial objectives and location.
An energy retrofit needs to consider also climate conditions. According to the methodology developed by Cory et al. (Cory S., 2011), we identified three **climate conditions**:

- Heating dominated climate (HD)
- Cooling dominated climate (CD)
- Mixed dominated climate (HCD)

The dominating climate condition is defined as making up 70 percent or greater of the buildings space conditioning needs (i.e. heating dominated, or cooling dominated). If both, the heating and cooling needs are less than 70 percent, the climate is classified as mixed dominated (i.e. heating and cooling dominated). This classification is particularly useful for buildings where space conditioning is heavily influenced by the internal gains, such as shopping centres.
Buildings in heating dominated climates require a high contribution of light so they would have prevalence of glass surfaces, despite the consequent increase of transmission losses. Heat recovery in HVAC is extremely important in heating dominated climates. Often it is possible using of geothermal heat pump.
Buildings in mixed dominated climates have to balance energy consumption for air conditioning and heating. Free cooling strategies have in this case a high energy saving potential.
For buildings in cooling dominated climates, solar gain control needs to be carefully planned. Preferred HVAC system is the air-to-air heat pump.

3.2 Building features and functional layout

A well-planned shopping centre layout generally shows the size and location of each department and shops, any permanent structures, fixture locations and customer traffic patterns.
The principal elements of a functional layout are:

- Entrance (singular or multi);
- Connections (elevators, moving walkways…);
- Common areas, like gallery squares and paths;
- Shops and big selling areas;
- Food stores;
- Technical rooms;
- Parking area.

Each floor plan and functional layout aims at maximizing the sales areas within the shopping centre; usually, in a gallery, the continuous shop fronts are interspersed with plazas and/or clue points. Most of the restaurants/cafes face the central square, hence, making it the heart of the shopping centre.

There are many different layout options within a design floorplan, each of them is driving customer walking paths and highlighting areas in a different way. Floor plan and store layout depend on store design, which usually can be:

- *Grid/straight form*, usually designed when the cc has a rectangular or compact shape, with parallel paths and aisles; the straight floor plan is an excellent formal layout for almost any type of retail store and the most economical
- *Free form* (Free-flowing; informal; creates “friendly” environment); it is designed to offer excellent visibility for customers and it invites movement and traffic flow through the mall; it is characterized by organic/curved shapes.
- *Mixed form*, curves and angle of fixtures and walls mixed for a more flexible layout.

The **centre design** can be also:

- *Enclosed*, a commercial centre with a gallery and common areas closed, conditioned, with lighting and other big systems;
- *Semi-enclosed* commercial centre, with gallery and common areas covered but not conditioned, lightened and with each shop with own systems;
- *Open* commercial centre, where paths and common areas are open and connecting each shops.

The **building shape** affects the building energy performance:

- A building block, with a *compact shape* (S/V <1), has less heat losses through external walls, but also through pipes and ducts which are shorter in a compact building compared to an extended one.
- A building "in continuity / extended" (S/V >1), on the contrary, needs to limit/decrease the thermal losses due to longer pipes and to greater external wall area.

Building orientation determines the level of exposure to solar radiation during the day and along the seasons, affecting both energy performance and indoor environment quality. The orientation analysis of a SC can drive retrofitting actions: i.e. a wall facing north needs higher insulation or, conversely, a window facing north does not need anti-glare or shading devices.
Usually, parking lots of a shopping mall can be located at underground level(s) (a); at ground level (b); on the roof (c); on an external area (d); at ground and roof level (e); in an external multi-storey carpark (f). **Parking location** affects the energy performance and the sustainability of the shopping mall, namely:

- Parking lots located underground or on a covered parking (case a, b, e and f) need lighting, signals and connections with upper floors;
- In case parking lots are located on the roof (case c and e), the extensive use of the roof area may limit the use of skylights for daylighting and natural ventilation, as well as for photovoltaic or solar panel installations;

- Parking lots located on an external area increase the “heat island effect”, causing higher outdoor temperatures. From sustainability perspective, this kind of parking lots cause a higher soil use, compared to the other ones.

Sustainable mobility shall play also an important role in a sustainable shopping mall. Parking areas for public transport, bicycle roads and services for electric cars need to be included in the overall layout of the mall.
The use of green vegetation in the external parking area and around the shopping mall creates a **biologically active area** which effectively contributes to the reduction of the “heat island effect”.
We analysed the various parts that compose the building, associated with the different end uses identified in deliverable 2.5 (Haase M., 2015):

- Building perimeter
- Technical rooms
- Common areas
- Tenants (shops and food store)

3.3 Building perimeter

The building perimeter represents the architectural structure of the building and its protection against outdoor environmental conditions.

<u>Structure</u>

Generally, retail buildings built have a main frame made of precast structural concrete or prestressed concrete. Steel structures are generally not used because of the low fire resistance; instead of concrete, pillars can be made by steal and coated or specially treated to resist to fire loads. Old retail buildings can have masonry walls.

<u>Roof and floors</u>

The roof of a retail building is generally continuous, with waterproofing layer and surface protection. Sometimes it has a thermal insulation, preferably made of galvanized metal covered with a mantle of PVC.
The most common types are the classic industrial shed or laminated wood structures and panels or corrugated steel deck panels’ type (metal support base for waterproofing). Thus, we can identify few types: plan roof, pre-fabricated or made of wood; pitched pre-fabricated roof; shed roof.
For plan covering floors are also used extruded structures or extruded restressed concrete panels.
Often the roof area is used to accommodate technical rooms or HVAC plants, as well as photovoltaic system or solar thermal panels.
When the parking is at roof level, roof has to be covered by suitable pavers for vehicles.
Roofs can be also paved or designed with walkways and roof gardens (green roof covering).

Interior floors are mostly made by reinforced concrete prefabricated elements: T or double T shaped beams, or mixed prefabricated structure (reinforced concrete and bricks).
Several aspects need to be analysed: water tightness; fire resistance; air ventilation and load variations. During retrofitting design, it is important to consider the variations due to any change of use, the increase of overruns or equipment replacement.

Envelope

In the building industry there are a great variety of infill panels or ‘sandwich panels’: with skins in aluminium, stainless steel, etc. The panels can be produced with diversified finishes and texture, according to the needs of the designer. They can be used both as structural and decorative panels.
They are usually made of prefabricated panels without thermal insulation, or sandwich panels with polystyrene. Due to their aesthetic appeal and flexibility, ventilated façades are preferred in case of more structured interventions, or buildings with major architectural importance. Typically, external boards are made of grit, clay, alucobond or porcelain.

Insulation, waterproofing and coating

Existing retail buildings are usually not properly insulated: external walls are not insulated; floors and roofs use common insulating covers such as polystyrene, mineral wool and perlite etc; in some cases cork is added to the foundation.
In case there is an underground parking, ground floor needs to be insulated to reduce the energy demand of the building.
Waterproofing is important for roof and foundation.
The coatings or counter-walls on the existing facades may have three purposes: to create a better insulation of the walls; to enhance the architectural intervention and to install and hide some plants.

Windows/skylight

The Window-to-Wall Ratio can vary considerably depending on the type and format of the shopping centre.
Usually, because the shops are facing the shopping arcade, daylighting is obtained mainly through skylights or windows in the inner squares or through changes in volumes / interior heights.
Especially in small shopping centres, skylights are made by polycarbonate because of weight / roof loads and costs issues; supermarkets / hypermarkets have often 'spoilers'.
Usually windows and skylights are equipped with motorised openings, some of which are connected to the fire systems.
External shielding (fixed or mobile) or shadowing panels are usually not installed in existing building but they are being introduced in new building design. Their function is twofold:

- to create a 'wall filter' capable of ensuring transparency and daylighting;
- to reduce the solar gains.

3.4 Technical rooms

Technical rooms host systems and plants that provide heat, cool, ventilation, electricity, water, safety and control to the whole shopping centre. It is recommended to place them as close as possible to the conditioned areas, in order to reduce the thermal losses of the distribution system.
The interaction between the various systems plays an important role in the energy management. First generation shopping centres are not equipped with building management systems able to manage and control the interactions between the various systems.
In a shopping centre we find the following major systems:

- Electrical plants;
- HVAC systems;
- Water system;
- Fire extinguishing system.

Electrical plants
Electrical energy consumption is related mostly to:

- Lighting
- HVAC system
- Food refrigeration plants
- Special plants (security and surveillance system)

Recommended light levels to emphasize the internal structure and visual comfort are typically assured by the combination of natural and artificial light, direct and indirect. Energy savings can be achieved thanks to high efficient lamp technology (LED lamps) and an electronic control gear. The electrical consumption of the cooling and heating system and the other plants is lower than the electricity consumption of lighting. In a supermarket, the food refrigeration system uses the most energy (around 40-50% of a hypermarket energy consumption).
An optimal management of the electricity consumption has to deal with peak loads reduction and shifting through specific function of the BMS and power factor correction.

<u>HVAC Systems</u>

HVAC systems are designed to ensure thermal comfort in every area of the shopping centre.
Most common type of air conditioning system for retail buildings is the gas boiler for heating and a refrigeration system based on air-cooled chillers; an Air Handling Unit (AHU) provides for mechanical ventilation, while fan-coils are installed in the smaller areas of the building such as offices and small shops.
As an alternative, in mild climates, the heating-cooling system can be an air cooled heat pump.
Big and medium areas can be conditioned by rooftop units and small areas by direct expansion systems (split, multi-split, VRV system).
During the refurbishment of the existing plants, three main aspects have to be evaluated:

- The capacity to satisfy the energy needs;
- The compliance with the regulations;
- The cost-effectiveness of its maintenance (age, condition, expected service life, operating costs).

Components which have substantial remaining useful life to allow for steer selection and configuration of new systems can remain, otherwise they need to be replaced or modified.

The average lifetime of a plant can be around 15-20 years; the age of the existing plant and its status have to be considered carefully. Old plants are often not equipped with energy efficient devices such as: heat recovery system; inverter on fans and pumps; set up for the exploitation of renewable energy sources and passive solutions (i.e. natural ventilation).

It is important to install a BMS system able to control and manage the interactions between the various components of the HVAC plants.

From aesthetical point of view, exposed HVAC plants can be visually unappealing if improperly located or specified.

Water system

In old retail buildings, hot water was produced with electrical or gas boiler. More recent installations are integrated with a solar thermal system.

In a retrofitting plan, water distribution adapts to the needs of the new layout. Typically the existing pipes are changed or integrated with new ones. If the building is very old or the new layout is very different from the previous one, the water system is completely replaced.

Fire extinguishing system

The fire extinguishing system depends by national and European regulation. In particular, recently, the sprinkler plant regulation is having important developments, as well as its pumping stations, which require sometimes very high performing plants and volumes of water storage much larger than the one expected in the past. The adaptation to fire regulations has to be planned for each retrofitting: in some cases it may be just a simple shift of some hydrants or it can include the replacement of the pumping station and of the existing sprinkler system.

Food refrigeration system

Food refrigeration system is normally installed only in the supermarket, inside the mall. It is necessary analyse if the existing system needs to be expanded (i.e. the number of users served is increased) or if it is simply necessary to retrofit the distribution system.

Typical retrofit requires an increase of the users served and therefore an increase of the required power to the system; this involves the replacement of the generation system. Also the recent F-Gas legislation requires to consider carefully the maintenance of existing facilities; many of the older systems use R404a gas, the newer ones instead use R134a for TN and CO_2 for BT, which is considered 'environmentally friendly'.

iBEMS system

A building management system (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. A BMS consists of software and hardware.
Building management systems have been around for decades and have been installed to manage the building services systems. As technology has advanced, these systems have become more complex. With ambitious green legislation targets, rising energy costs and changing user and tenant requirements, it is becoming imperative that all building systems are integrated. This provides the required levels of control and monitoring and provides complete information.
The existing BMS can be updated or integrated with more sensors and functions during a retrofitting.

3.5 Common areas

Common areas of a shopping mall are the walkways and areas onto which the stores in a centre face and which conduct the flow of costumer traffic.

Entrance

Types and number of entrances can influence the air conditioning and distribution system and the infiltration control. Some of the most used systems are: automatic sliding doors, circular sliding doors, air sheets to block external air flows. Also the lighting design for atrium space helps to optimize the energy consumption for that area using a mix of artificial and natural light, mirrors and spotlight to emphasize and point out special zones.

Connections

The number of floors and connections among floor, in addition to defining more specific distribution of the spaces, can impact on energy consumption because of the use of electric elevators and escalators.
Their energy consumption can be reduced with occupancy sensors.

Gallery squares and paths

The interiors design has to consider higher productivity and efficiency. Besides, some elements of decoration and plants are integral part of any design. Here follow some recommendations:

- Light levels should be appealing to all customer's senses;
- Careful selection of colours can create the desired impressions among customers and employees. Besides, dark colours need more lighting than light colours. Light and tenuous colours, thus also for floor tiles, ceilings, decorations, are preferred both to drive customers' mood and to improve the visual comfort;

- Use of fixtures to create small spaces, within the square or big area, to create a more intimate atmosphere.

- The customers should be able to move freely in the gallery, without obstructions or risks. If your aisles cause congestion, then customers will feel uncomfortable and unsafe.

- Ceilings and false ceiling allow to use void or different height to place ducts and pipes.

The gallery inner central plaza is the refurbishment's clue point; usually optimal atmosphere is created by mixing artificial and natural light. Daylight is important for the human perception of the daily cycle (the circadian cycle). Moreover, besides the contribution of natural light, we have to consider the possibility to use natural ventilation within these spaces, by exploiting the height difference of various spaces to locate windows or skylights, to ventilate and cool the spaces.

3.6 Tenants and food store

Shops and big selling areas (tenants)

Usually each shop has its own system and interior design (except for windows and main HVAC system) and sales philosophy: for this reason it is important to raise awareness among tenants and managers about the energy efficiency and environmental impact of their design and management choices.
The large sales areas however, are a significant part of total energy consumption of the shopping centre; especially supermarkets and hypermarkets have a supplementary load due to the food refrigeration system (it absorbs 40-50% of the consumption of total energy demand).
Food court, with restaurants and bars, has also a great influence on energy consumption, since usually has longer opening hours than shops.

Table 3-1. Layout to the IDP structure, base component, See virtual IDP library at http://www.commonenergyproject.eu/integrated_library.html.

Reference building	Reference building	General data	General data	General data	General data	General data	General data	General data	General data	General data	General data	Building features	Building features	Building features	Building features	Building features	Building features	Perimeter	Perimeter	Perimeter	Perimeter	Technical room	Technical room	Technical room	Technical room	Technical room	Common areas	Common areas	Tenants	Tenants	Food store	Food store
Name	Location	Urban context	Climate	Building	Year of construction	Year of retrofit	GLA before retrofit [m²]	GLA after retrofit [m²]	Shopping centre size	Shopping centre sub-typology	Food store format	Centre design	Shape	Orien	Number of levels above ground	Number of underground levels	Parking location	Wall structure	Wall insulation location	Wall insulation material	Wall U-value [W/m²K]	Location	BMS lighting [Y/N]	BMS natural ventilation [Y/N]	BMS HVAC [Y/N]	BMS refrigeration [Y/N]	Installed lighting power density [W/m²]	Installed electric equipment power density [W/m²]	Installed lighting power density [W/m²]	Installed electric equipment power density [W/m²]	Installed lighting power density [W/m²]	Installed electric equipment power density [W/m²]
City Syd	Trondheim (NO)	Suburban	HD	purpose-built	1986	2000	19860	19860	Large	regional	none	enclosed			2	0,0	external area	pre-fabricated panels	interspace	mineral	(0,22 extens	vending area level	N	Y	Y	N	14	10	36	10		
Mercado Del Val	Valladolid (ES)	dense urban	H&CD	reconceptu	1882	2016	2280	4792	Small	speciality	supermarket	enclosed	0,1	NE/SW	1	0,0	external area	masonry	interspace	oil derivatives	0,738	vending area level	N	N	N	N	24	0	36	10	36	10
Coop Valbisagno	Genua (IT)	Suburban	CD	purpose-built	2006		7633		Small	neighbourhood/c	supermarket	enclosed	0,4	SE/NW	1	0,5	ground and roof level	pre-fabricated panels	none		1,156	undergrou nd	N	N	N	N	8	10	30	10	30	5
Ex officine Guglielm	Genua (IT)	suburban	CD	reconceptu		2017	0	24349	Large	regional	hypermarket	enclosed	0,9	NE/SW	2	0,0	ground and roof level	pre-fabricated panels	interspace	mineral	0,340	vending area level	Y	N	Y	N	8	0	30	10	30	5
Brent Cross	London (UK)	Suburban	H&CD	purpose-built			84200		Very large	super-regional	none				2		external multistorey carpark															
Katane	Catania (IT)	Suburban	CD	purpose-built	2009	-	27521	-	Medium	regional	hypermarket	enclosed	0,5	SE/NW	2	0	ground and roof level	pre-fabricated panels	interspace	oil derivatives	0,336	roof	N	N	Y	N	20	10	80	10	25	21
Donauzentrum	Wien (AT)	Urban	H&CD	purpose-built			133000		Very large	super-regional	hypermarket	enclosed	0.6	NE/SW	2	0,0	external multistorey carpark	masonry	none		0,512	undergrou nd	Y	N	Y	N	36-22	10	50-27	10	27	5
Pamarys	Silute (LT)	Suburban	HD	purpose-built	2004	-	6020	-	Small	neighbourhood/c	supermarket	enclosed	0,18	NE/SW	1	0,0	external area	masonry	interspace	mineral	0,542	vending area level	N	N	N	N	23,68	0	36	5	36	5
Studlendas	Klaipeda (LT)	suburban	HD	purpose-built	2006	-	12637	-	Small	neighbourhood/c	supermarket	enclosed	0,2	SE/NW	2	0,0	external area	masonry	interspace	mineral	0,105	vending area level	N	N	N	N	23,7	0	36	10	36	10
Waasland	Sint-Niklaas (BE)	Suburban	H&CD	purpose-built	1972	2002	47000	-	Large	regional	supermarket	enclosed	0,1	SE/NW	1	0,0	ground and roof level	pre-fabricated panels	interspace	oil derivatives	1,160	roof	Y	Y	Y	N	35	10	40	10	40	20
Grand Bazar	Antwerp (BE)	Urban	H&CD	purpose-built	1885	1990	20403		Medium	neighbourhood/c	hypermarket	enclosed	0,3	E/W	3	1,0		pre-fabricated panels	interspace	mineral	1,559						23	10	36	10	30	20
Coop Canaletto	Modena (IT)	Urban	CD	purpose-built		2016	1102		Small	neighbourhood/c	supermarket	semi-enclosed	0.5	NE/SW	1	1	external area	masonry	none		1,840	undergrou nd	N	N	N	N					40-45	5

4 Methods and tools to support IDP

4.1 Energy Audit

Energy audits are the starting point of an IDP that targets an energy efficient shopping centre. Thus, gathering information about the current building status and energy flows help designers to detect inefficiencies and energy saving opportunities.

Thanks to its simple structure and ease of use, energy audit templates for information collection can be easily created from the virtual IDP library and used as walk-through survey by auditors during their inspection.

On the other hand the energy audit can be also initial input information to start the comparison with similar cases, and to propose the energy efficient solutions potential to be adopted in retrofitting or potential certification process.

The data collected and the benchmarking with similar archetypes allow the auditors to easily identify potential cost-effective measures for improving energy efficiency.

The solution sets developed for the reference buildings and analysed by building energy simulation are an important source of inspiration for retrofit interventions in similar buildings.

In fact, the IDP library provides a quick overview of the best solution-sets matching the building features and context. In continuation see the paragraph 4.5.

4.2 Climate potential analysis

Climate potential analysis has been integrated during the analysis process on the definition of the technologies by different shopping centre cases.

The need to reduce energy use in shopping centres is one of the direct drivers to reduce operational costs and overhead cost. The idea is based on the improvement of thermal and comfort issues, related mainly to the building envelope, but also to HVAC equipment and lighting devices, influenced in the mayor measure by climate, building location, sun exposition as well as its surroundings characteristics, in continuation called *climate potential*.

Climate potential analysis refers to the concept of passive design and helps to define the utility of integration of a particular passive technology. The objective of the passive design is to increase the energy performance of the building relying on natural sources as sun and wind, and to influence positively the decrease of heating and cooling demands. Independently, it might be supported by a building energy management system in some cases.

Passive shaping of indoor comfort in any kind of the building is the result of simultaneous impact of many factors. The most important factors are related to location (climate conditions), construction and material properties of the building envelope, building orientation, building geometry and its functions. Basic items

of the building energy balance are transient heat and moisture exchange within building envelope assemblies, solar gains, air exchange (ventilation, infiltration) and internal gains (people, light, electric equipment). A climate-driven design involves the modelling, selection and use of appropriate passive technologies to maintain the thermal comfort at a desired temperature range through the sun´s daily and annual cycles. Building Thermal Environment is defined as indoor climate conditions suitable for human activities. In shopping malls and “tertiary” sector in general, it should be considered also food/other goods damage factors. The balance between both comforts may define at the end the effective and final comfort RH/temp zone. Building environment desired temperature and humidity range usually base around human thermal comfort, and depend on the factors and parameters like temperature, relative humidity, air speed, air quality, human activity.
The objective is the reduction of occurrence of both overheating and overcooling situations. Passive technologies application concerns mainly walls construction, windows and roof construction. Passive measures might lead to considerable energy savings and consequently operative costs. By general definition the passive strategies use is based in the mayor measure on natural energy sources, the same correctly designed should give the positive balance on energy comparing between the costs of renovation and costs from energy savings, defined by the pay-back time that should not exceed the 7 years.
Most of the passive strategies could be applied in any kind of buildings, including shopping malls. Most common passive technologies are:

- Insulation innovative materials
- New coating materials with thermal functions
- Daylight systems
- Thermal storage systems
- Ventilated envelope systems
- Cross ventilation systems integrated
- Green roofs and spaces
- Solar and wind chimneys
- Coupling between these technologies

Incorporating these tools from the design of the project could steer towards a very efficient and comfortable and sustainable building.
There are several tools which helps designers to define the most appropriate technologies to each case. The correct application of them will impact the energy retrofitting success or failure.

There are graphs that let us find the optimal temperature and humidity comfort ranges and identify the building thermal comfort zone. According to outdoor climatic conditions, different passive and active strategies, or a combination of them, can allow to maintain indoor thermal comfort.

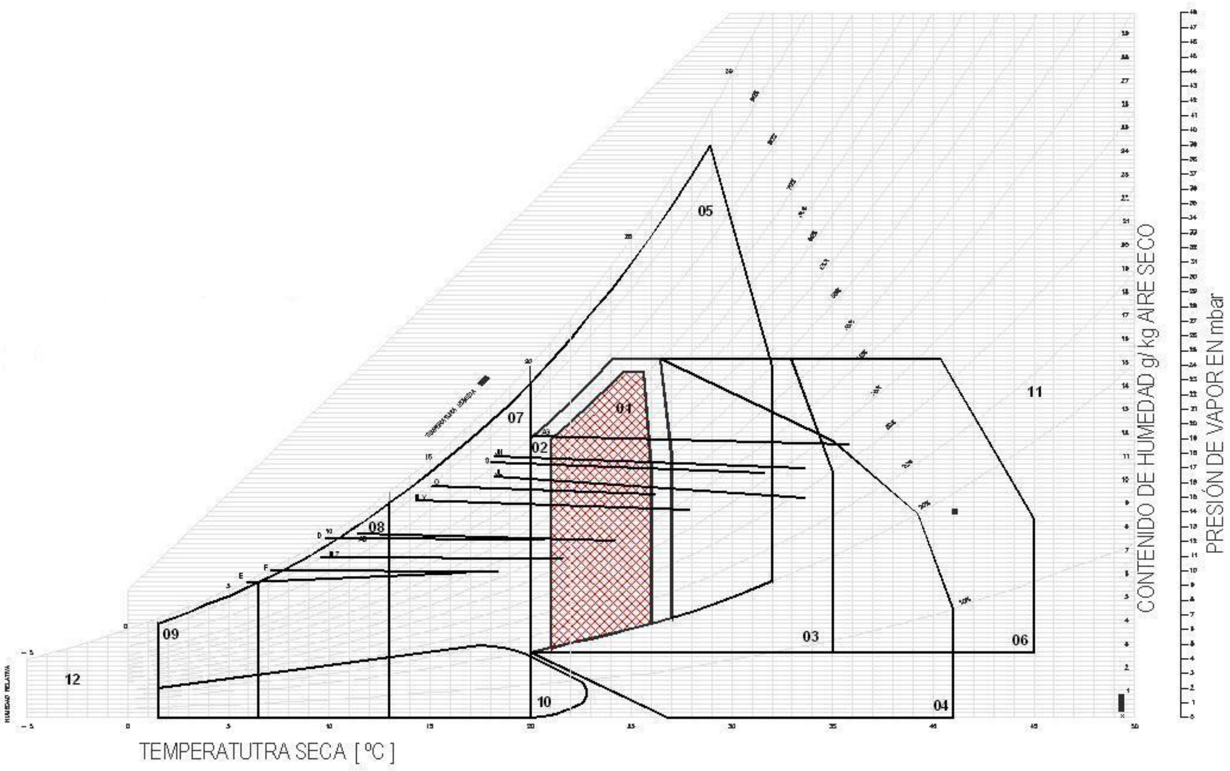


Figure 4-1. Example on climatic graph, referred to Givoni psychometric graph

Comfort zone ranges are based on the metabolism of the peoples and cloths level (Clo), different for each year season. The most commonly known psychometric graph represented in Figure 4-1, shows external temperature and humidity ranges for each month, also indicating the required comfort zone (in red) established for the selected building use. The horizontal lines correspond to typical outdoor temperature variation over months. These lines might be totally or partially out of the comfort zone, indicating potential discomfort situations and requiring the need for heating or cooling. It may be and usually it is difficult to reach a comfort temperature during the whole year, which means there is a need of design strategies able to ensure comfort temperatures without consuming a lot of energy. Design strategies will have to take into account the big necessity of conventional heating, humidification and wind exposition, and notice that conventional air conditioning is hardly useful if solar gains are not controlled in an appropriate way.

In order to define the most convenient passive technologies for the particular case, climate analysis shall be supported by other analysis concerning:

- Building and urban context

- Building thermographic
- potential of solar protection systems
- optic parameters for glass surfaces
- opaque components and materials
- thermal bridges
- natural ventilation and night ventilation
- possible infiltrations
- potential of wind technologies
- potential of evaporative cooling technologies
- indoor quality
- potential for daylighting use
- acoustics

The choice of energy conservation measures should take into account also the installation costs and the payback time of intervention. Installation costs are case dependent. Energy performance and operating costs are estimated by the building simulation models as described in paragraph 4.3.

4.3 Modelling and simulation approach and tools

When retrofitting a shopping centre, the decision process needs to have a holistic approach considering the actual state of the building architecture, its location and climate, and needs. In this perspective, an optimal re-design of a shopping centre shall maximize the benefits in terms of energy savings, functionality, indoor environmental quality, sustainability and economic feasibility.

In order to take successful decisions during the energy retrofitting process of a shopping centre, it is required the use of tools which help to evaluate the potential of each energy conservation and energy efficiency measure. The Integrative Modelling Environment developed within the CommONEnergy project (Dipasquale C., 2016) is a customized simulation environment for shopping centres with passive and active technologies modules which help us to evaluate design options and select the design strategies and technologies which lead to the highest energy demand reduction improving the overall energy efficiency of the building.

Following paragraphs describe a general approach for modelling and simulations of shopping centres.

4.3.1 Building energy model

Building modelling phase takes into account the main features of a building such as its geometry, orientation, shadings, construction materials, façade and skylight openings, air changes (infiltration and natural ventilation), schedule, air conditioning systems and settings.
Following steps shall be taken into account while modelling the building geometry.

Weather file

Weather files represent the climate conditions needed to perform the building energy simulation. Standard weather files derive from historical data series collected by local weather stations and are representative of the average weather conditions of a specific location. Therefore, it is applied to assess the baseline energy consumption and the energy reduction potential of solution sets. In case of model calibration, actual weather files based on a specific period are needed.

Thermal zoning

The building is divided into thermal zones according to space functions, internal gains level, orientation and floor height. Simplifications are needed in order to reduce modelling and computing time.
Therefore, building zones are grouped into thermal zones according to the following criteria:

- Usage: any rooms that are combined into a single thermal zone should have similar internal loads (people, lights, equipment) and usage schedules.
- Thermostat: any rooms that are combined into a single thermal zone should have the same heating and cooling setpoints and the same thermostat schedules.
- Solar gains: any rooms that are combined into a single thermal zone should have similar solar gains. Modellers should consider shading when zoning according to solar exposure. For perimeter zones with glazing openings, there should be at least one thermal zone for each façade orientation.
- Perimeter areas: perimeter areas should be zoned separately from interior spaces, with a depth of perimeter zoning typically within 3 and 5 meters from the exterior wall. This is important as the heating and cooling requirements can vary greatly.
- Distribution system: since the entire zone will be assigned to one system type, modellers should only combine rooms that will be served by the same type of HVAC system.
- Linkages: linkages represent flow resistances. Combining zones connected through openings involved in the defined airflow path causes an overestimation of the ventilation rates as the flow resistances due to those openings are not taken into account.
- Thermal stratification: in thermal zones with ceiling height higher than standard floor height

temperature differences (3 to 4 m) between the bottom and the top of the zone can occur and are potential drivers for stack driven natural ventilation. To allow ventilative cooling scenarios modelling thermal stratification should be represented setting multiple air nodes.

Due to the complexity of the shopping centres, the thermal zoning inevitably leads to simplifications in order to reduce at a minimum the number of thermal zones of the model. Therefore, area with different functions might be aggregated into the same thermal zone. For instance, the service room of each shop might be part of the same shop thermal zone. However, specific values of internal gains should always refer to the area portion of the zone referred to the main zone function.
On the other hand, thermal zones must follow an agreed nomenclature (Dipasquale C., 2016) which allows identifying easily these zones in the real map. The thermal zones of a shopping centre model can be categorized as follows, depending on their functions:

- shops, retail stores (SHP)
- common area, entrances (CMA)
- restaurant, cafes, food courts (RST)
- service room, toilets, changing rooms (SVC)
- technical room (TCR)
- parking (PRK)
- Food store (vending area only) (FDS)
- Medium store, big size stores, anchor stores (MDS)
- Food department, refrigeration rooms, food processing area (FDP)
- Warehouse (WRH)
- Office (OFF)

Specific information about which shopping centre area referred to these functions can be found in (Haase M., 2015).
As example, here follows the thermal zoning of the Katane' reference building model, developed within the project (Cambronero M. V., 2017).

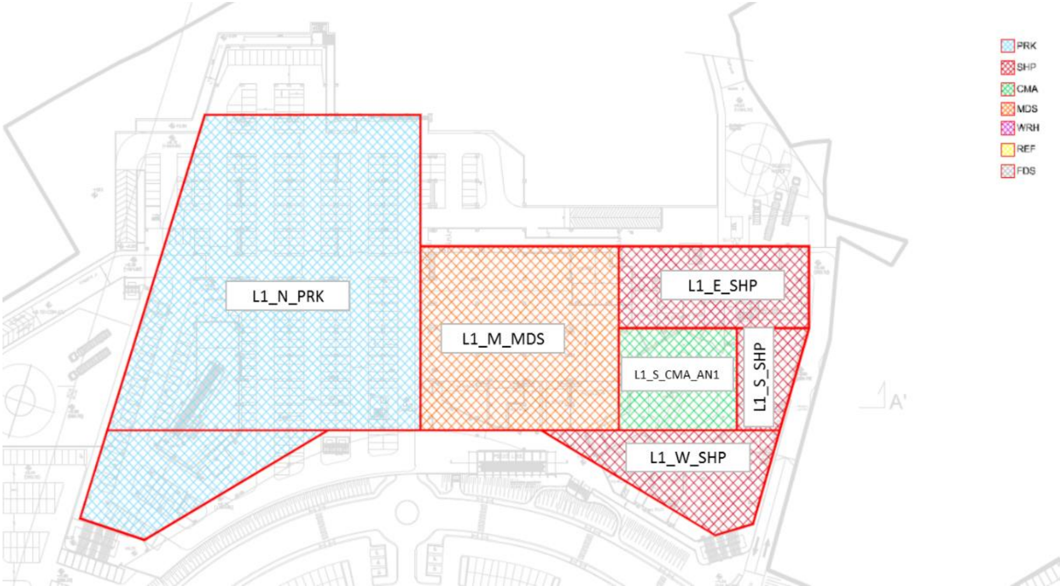


Figure 4-2. Katane' reference building: first floor plant with thermal zoning.

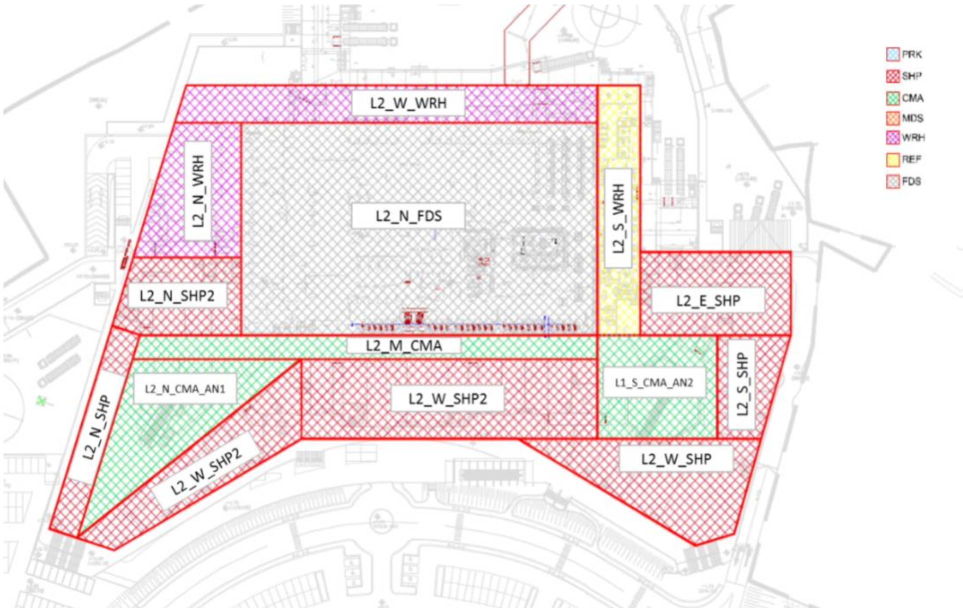


Figure 4-3. Katane' reference building: second floor plant with thermal zoning.

As shown in Figure 4-2 and Figure 4-3, the complex building layout is divided into 22 thermal zones which simplifies a lot the simulation process.

<u>Building envelope</u>

Building envelope constructions and thermal properties need to be derived from building plans and energy audit information and input to the building model.

Boundary conditions

Although we are dealing with existing shopping centres, during a feasibility study, information on HVAC settings and management is not always available. Therefore, we defined standardized input assumptions that could be useful in feasibility studies:

- Heating and cooling set points depend on building management. According to common settings, indoor temperatures in retail buildings range between 20 ºC (heating setpoint) and 25º C (cooling setpoint).

- Lighting are generally fully on (100%) during opening time of the shopping mall. During closing time lighting power density could be set at 5%. Lighting power density is generally up to 40W/m^2. Each tenant has its own lighting design and operation schedules are related on the opening time of the shopping centre.

- Appliances refers to devices such as PCs, cash registers, monitors, etc. and are generally on (100%) during opening time of the shopping mall. During closing time appliances power density could be set at 15%, to take into account standby consumption. Higher power densities shall be considered in case of electronic shops.

- Infiltration, is the unintentional or accidental introduction of outside air into the shopping centre; typically through cracks in the building envelope and through entrance doors in common areas. Infiltration is significant in shopping centres due to the frequent door opening and closing, but no current study exist on its estimation. Infiltration and ventilation air changes should refer to the net air volume of the zones.

- Ventilation rates are generally set at the minimum required to maintain acceptable indoor air quality. For shopping centres and specifically for conditioned areas a suitable value could be above 7.35 kg/hr·m^2 which is the minimum required by the standard EN15251:2007.

- Refrigeration cabinets are modelled as negative internal gains to take into account of the heat extraction rate.

EPTA and UNIUD provided some reference values for refrigeration cabinets' heat extraction rate and electric power depending on refrigeration cabinet type and length. The values reported in Table 4-1 have to be multiplied by the number of refrigeration cabinets estimated in the food store area.

- Refrigeration rooms are located in the food storage and processing zone and are modelled with a simplified heat transfer equation:

$$Q = \frac{\lambda}{d} S \left(T_{ref} - T_{FDP}\right)$$

where

Q = heat extraction rate from the department zone by the refrigeration room [W]
λ = thermal conductivity of the refrigeration room walls [W/mK]
d = refrigeration room walls thickness [m]
S = refrigeration room walls surface [m^2]
T_{ref} = indoor controlled temperature of the refrigerated room (please refer toTable 4-2)
T_{FDP} = indoor temperature of the zone where the refrigerated room is located

According to the data provided by INRES, the thermal conductivity of the refrigeration room walls can be assumed as 0.023 W/mK. The wall thickness can be considered 0.06 m for refrigerated rooms at positive temperature and 0.10 m for refrigerated rooms at negative temperature.

Table 4-1. Refrigeration cabinets heat extraction rate and electric power. Source: EPTA, UNIUD

	Refrigeration cabinet type	**Open/closed doors**	**Length [m]**	**Heat extraction rate [W]**	**Total electric power (fans, lighting, anit-mist, defrost) [W]**
Medium Temperature	horizontal	open	2.5	1550	340
			3.75	2325	510
	semi-vertical	open	2.5	3150	77
	serve over	open	2.5	755	962
	vertical	closed	2.5	1625	166
			3.75	2440	252
	vertical	open	2.5	3195	174
			3.75	5815	260
Low Temperature	combined	closed	3.12	1725	4897
	horizontal	closed	2.50	520	2830
	horizontal	open	2.50	2000	3839
	vertical	closed	3.12	1540	4916

Table 4-2. Reference values for indoor controlled temperature of refrigeration rooms. Source: INRES

Stored goods	**Min Temperature [°C]**	**Max temperature [°C]**
Vegetables	2	8
Meat, fish	0	2
Mussel	4	6
Cheese, milk, cured meats	2	4
Pastry	2	4
Frozen food	-23	-25

- Occupancy: The internal gain due to the presence of persons is quantified by considering a specific density of person/m^2 which can be generally considered 0.2 person/m^2 in shops and common areas and 0.25 person/m^2 in food store and anchor stores. In this case it is important to neglect the area occupied by elements that prevent the circulation of people. Figure 4-4 shows the typical occupancy profile for a generic shopping centre. Although occupancy density should be different on weekdays and on weekend.

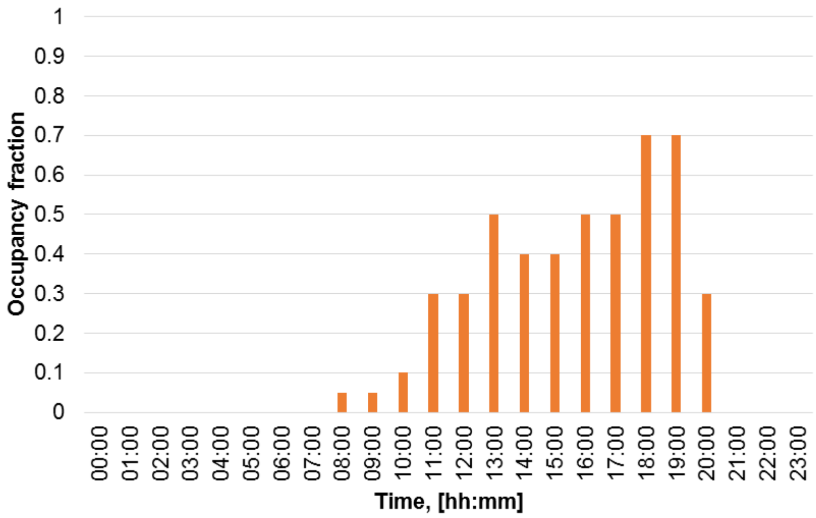


Figure 4-4. Typical occupancy profile on a weekday.

- It is important to consider the internal mass due to shelves and goods.

The Integrative Modelling Environment (Dipasquale C., 2016) include standardized input assumptions for building energy simulations, whether the required information is not available.

4.3.2 Building energy simulation

Building energy simulations tools allow to assess the impact in terms of energy, power and comfort performance of several retrofitting scenarios. This allows to support design options with quantitative performance indicators in a planned refurbishment intervention to transform the shopping centres into innovative buildings.
The simulations to be performed via Integrative Modelling Environment can apply the different passive/active solutions to be implemented in the shopping centres within CommONEnergy project:

- Passive solutions:
- Daylight exploitation
- Ventilative cooling solutions
- Smart coating materials
- Envelope (multifunctional façade)
- Green integration (shadings, roof, façade)

- HVAC systems (boiler, chiller, heat pump, AHU, artificial lighting, etc).
- Refrigeration systems (display cabinets, LT storage, NT storage and cold rooms).
- PV systems (PV panels, standard battery, hydrogen store, catalytic hydrogen boiler, etc.).

Simulation tools allow also to study the energy behaviour of a building under different scenarios:

- Baseline scenario: It consists of the actual state of a building and it is the point of reference for making comparisons with retrofitting solutions proposed;
- Retrofitting concept covers all the passive and active solutions to be evaluated in order to identify their influence in the shopping centres and select the best configuration in terms of energy savings and energy efficiency. The Integrated Modelling Environment allows to study the whole solution set or each single solution.

By means of energy simulations, it is possible to estimate the energy demand of the whole building as well as by each zone. Furthermore, energy simulations inform about thermal comfort conditions. Furthermore, it is possible to analyse the accumulated thermal energy over a certain period of time considering a system capable of providing all necessary thermal power to achieve the comfort desired during timetable in which shopping centre is open. Thus, maximum hourly heating and cooling peak power can be identified. Furthermore, it is possible to define control strategies which take into account the interaction between technologies.
In order to facilitate the understanding of results and have comparable models, following information is displayed by each technology option:

- Energy demand for heating and cooling:
- Maximum hourly heating and cooling peak power.
- Temperature trend in each zone Potential energy savings of each solution/solution set.

4.3.3 Building energy simulation of CommONEnergy demo-cases

The Integrative Modelling Environment (IME) (Dipasquale C., 2016) consists of a simulation environment where the different parts of a whole building energy system are implemented together. To this aim, TRNSYS (Klein S.A. et al., 2010) has been chosen as the simulation ambient for the IME thanks to its flexible structure that allows defining a modular and parametric modelling environment.
In the IME, the whole building system is divided into base blocks (see Figure 4-5) to work on a user-friendly modelling environment, making more effective the support of the shopping malls retrofitting phases (auditing, design, construction, commissioning and operation). Each block represents the building

and its sub-systems (HVAC, refrigeration, lighting, storage systems), in the following called subdecks. The subdecks are composed by Trnsys components that characterize that subsystem.

A parametric definition of the components features and the modular structure of the model layout i) eases the development of a shopping mall system model, ii) allows the optimization of the components size and the simulation of different scenarios and solution sets, iii) facilitates sensitivity analysis, uncertainty analysis, multi-objective optimization and model calibration. A common nomenclature has been developed for the parameters definition of building, technologies and control. Moreover, a common nomenclature helps in the integration of the single sub-system in a unique model (also called “deck”), when developed by different contributors.

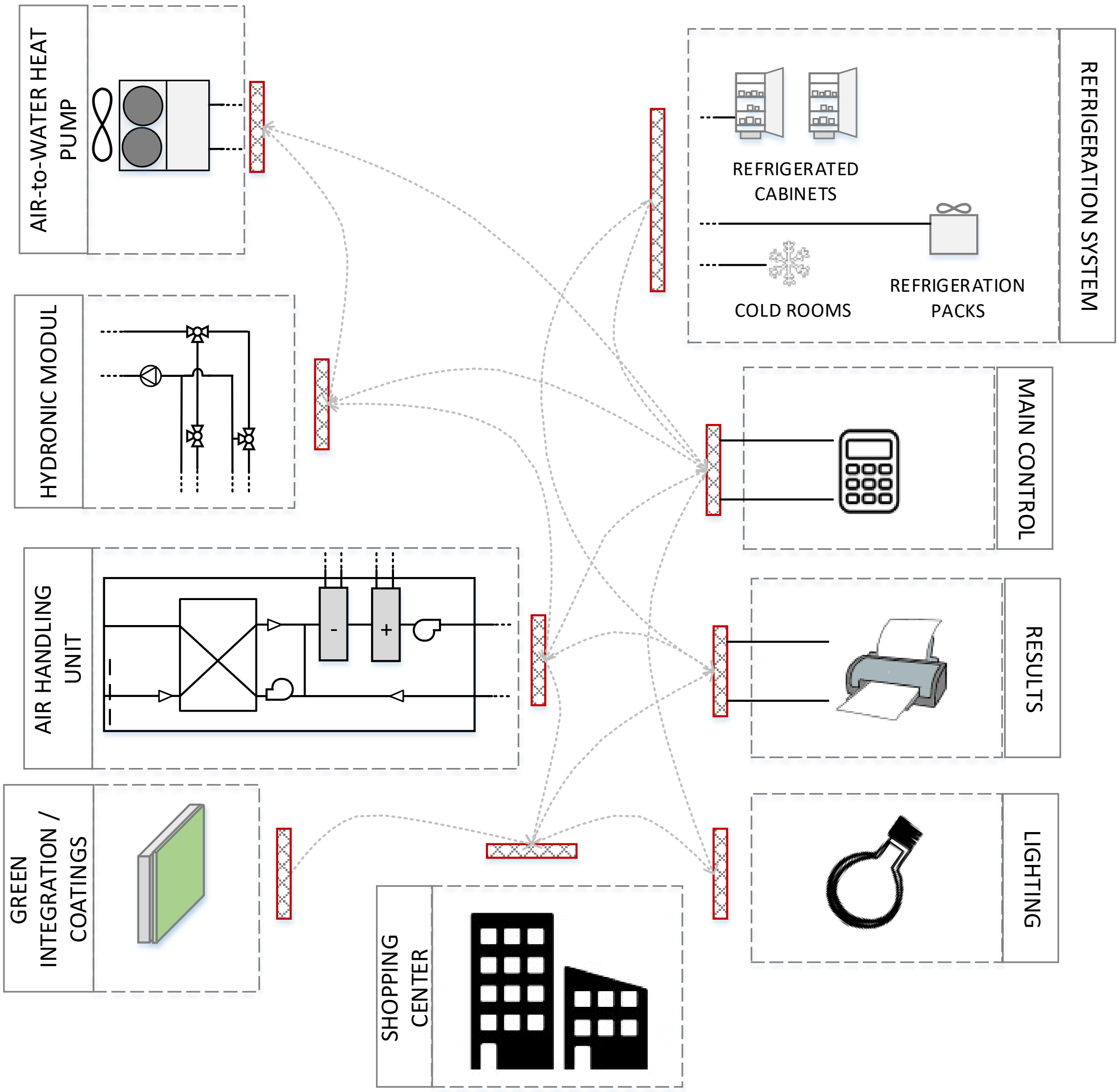


Figure 4-5. Modular structure of the Integrative Modelling Environment.

The developed IME is able to give information on the building internal conditions (temperature and relative humidity), external weather conditions, sub-systems (HVAC, refrigeration, lighting, PV…) components

status, consumption and position, renewable energy production. Starting from these outputs, different indicators can be calculated: comfort, energy, environmental and economic indicators.
In order to homogenize the outputs obtained with the models of different cases, common excel-based work sheets and graphs have been developed. In particular, in the following a list of the metrics taken into account for the assessment of building behaviour and energy system performance is presented:

- % of discomfort hours considering the occupied hours;
- energy balance: losses-gains in different season for the whole building and for final uses;
- energy consumption by final uses, final energy and primary energy;
- efficiencies/performance of the specific system;
- production of RES and amount of self-consumption.

TRNSYS allows to translate a real building geometry into an energy model through an architectural modelling phase. Then, energy simulations with different technological scenarios can be carried out.
Some peculiarities have been found when this methodology is applied to the demo cases of the CommONEnergy Project.

Peculiarities in the energy simulation of the Mercado del Val demo case (Valladolid, Spain)

The energy retrofit of the Mercado del Val is integrated into a detailed refurbishment planning developed by a design team. The energy savings of technologies developed within the project will refer to the preliminary building design, before the intervention of CommONEnergy experts. This scenario will be considered as baseline since the goal is to achieve the development of a set of solutions with better performances compared to the common design practices.

Figure 4-6. Mercado del Val after retrofit (Valladolid, Spain). Source: AVA

In addition, the Mercado del Val is categorised as a historical building with consequent restrictions on the integration of passive solutions. Solutions to be implemented not only have to be efficient, but also must meet aesthetic requirements and local building regulations.

These restrictions influenced the definition of the solutions set. In fact, some technological solutions such as green integration, daylighting devices or multifunctional reflective coating have been rejected.

Others, such as façade system with shadings had to be applied to the overall façade in order to have a homogenous structure. Some degree of flexibility might be agreed with the local authorities for historical preservation, for example regarding the application of shading systems on a limited portion on the southern façade.

Building energy simulation model and solution set analysis are described in Deliverable 5.1 (Cambronero M. V., 2017).

<u>Peculiarities in the energy simulation of Coop Valbisagno demo case (Genoa, Italy)</u>

The Coop Valbisagno demo case project regards a deep retrofitting of an old Coop shopping centre of about 5600 m² (Figure 4-6**Error! Reference source not found.**). After the retrofitting, the mall will become a much bigger structure which will incorporate the nearby southern factory (OfficineGuglielmetti, about 24.000 m² of plan surface).

Figure 4-6. Actual Coop supermarket in Val Bisagno. Source: Google Map

The renovation project will merge the two structures into a single building with a semi-underground floor dedicated to parking lots and an upper store for the commercial floor. The new shopping mall will include a green park and a municipal theatre on the roof level, as well as a four stores hotel and a wellness centre on the southern wing. Parking lot and warehouses are in the underground floor; the southern zone is an entrance of the hotel. Commercial floor involves two common areas running on the main axes of the building (north to south and east to west), surrounded by shops and two media store on the south wing and northern wing. A big Coop food store (6350 m²) will be located next to the western glazed hallway, on the south-eastern corner of the store. The project proposal designed from the architects (Figure 4-7) involves a big glazed atrium located on the western facade, with an elevator placed on the southern side that will guarantee access to the open green park on the roof as well as the commercial gallery and the underground parking lot.

Figure 4-7. Render of the retrofit project with enlargement on ex Officine Guglielmetti area. Source: INRES, 2014.

The shopping mall size and the multifunctionality of the building represented a challenge from the building simulation point of view.

Due to the deep retrofitting and the significant increase of mall surface area, energy savings are difficult to be assessed. Therefore, the energy consumption of the new mall will be compared with a baseline model of the same size, but with features typical of the actual Coop supermarket.

Since hotel and wellness area are not part of the project target and therefore they are not subject to retrofit, we estimated boundary temperatures between these zones and the rest of the model zones with a first simulation run. In the following simulation runs, the hotel and the wellness area zones were not part of the building model anymore and we assessed boundary surface temperature of the adjacent zones thanks to the output of the first simulation run.

Since parking area is partially underground, we considered it as a building thermal zone to better estimate the effect of this transitional space on the indoor temperatures of the first floor zones. The infiltration rates in the parking zones are set at a high value in order to take into account of the direct connection to the outdoor environment.

Building energy simulation model and solution set analysis are described in Deliverable 5.1 (Cambronero M. V., 2017).

BIS Peculiarities in the energy simulation of Coop Canaletto demo case (Modena, Italy)

Coop Canaletto shopping centre (Figure 4-8) is owned and operated by Coop Estense. The supermarket (ca. 1000 m^2 selling area) is included in a residential neighbourhood, near to the Modena train station, also close to the city centre. In the last years such neighbourhood experienced a social degrade, with several illegal activities, undermining the inhabitants' safety, and bringing to the decision of the municipality to ask for a stable Police office there.

City of Modena defined a project aimed at the requalification of the area, both from social and functional point of view, starting from purchasing the largest part of the built volumes to promote new uses for the buildings. "Cambia-MO" is the institution is coordinating the project. It is owned 75% by the city of Modena and 25% by the regional social housing agency ("Azienda Casa Emilia-Romagna").

The supermarket retrofitting is then included in the overall neighbourhood requalification, with the idea to define a shopping mall including shops and further citizen services, both new and existing, to be integrated to the supermarket from the functional/organizational point of view. The new shops/services are: a bar, a pharmacy, a restaurant, further than some private offices, while the existing post office and gymnasium will be kept as they are now.

Figure 4-8. Entrance and parking lots at Coop Canaletto neighbourhood centre before retrofit intervention.

The re-designed neighbourhood is a shopping centre with a size around 5000 m^2, including supermarket, open shops gallery and further services (Figure 4-9).

Due to the small size of the supermarket, refrigeration in Coop Canaletto is responsible for over 50% of the overall energy consumption. Therefore, the solution set is focused on HVAC and refrigeration plant integration. Because of the small size of the supermarket, recovered waste heat can significantly contribute to reduce the supermarket energy use for heating if combined to other energy conservation measures (i.e. closed refrigeration cabinets, envelope insulation). In order to assess the energy savings of such a solution, a detailed model of HVAC and refrigeration system was needed.

Figure 4-9. Coop Canaletto after retrofit.

Building energy simulation model and solution set analysis are described in Deliverable 5.1 (Cambronero M. V., 2017).

Peculiarities in the energy simulation of the CitySyd demo case (Trondheim, Norway)

City Syd (Figure 4-10) is a suburban shopping centre, built on the outskirts of Trondheim. Opened in 1987 and covering an area of 28,500 m², it was redeveloped in 2000 and it is now 38,000 m², with 1,000 outdoor parking spaces.

The energy retrofit focuses on natural ventilation, iBEMS, as well as natural and artificial lighting. Part of the mall is owned by Storebrand (project partner) and part by TRONDOS, which did not joined the project. Therefore, the solution set was studied and analysed only for the mall part owned by Storebrand.
Key features and modelling implications are due to:

- large glazed areas at entrance (not shaded) and in the central common area (skylights). Skylights have manually operated shadings;
- openings in the building envelope, such as entrance doors, cargo port and skylight windows;
- Internal layout with minimal circulation (all shops face the central common area);
    - All shops have large openings towards the common areas.
    - Many vertical openings between 1st and 2nd floor (i.e. escalators).
    - Large internal opening to the TRONDOS part (second floor).
- No physical separation between the two mall parts with different ownerships;
- Main entrance is exposed to prevailing winds from the south.

Figure 4-10. Birds view of the shopping centre. The part owned by Storebrand is on the right side of the division line on the first floor, but on the ground floor it extends below TRONDOS part (mainly storage space).See additional photos of the facade in the appendix A.1.

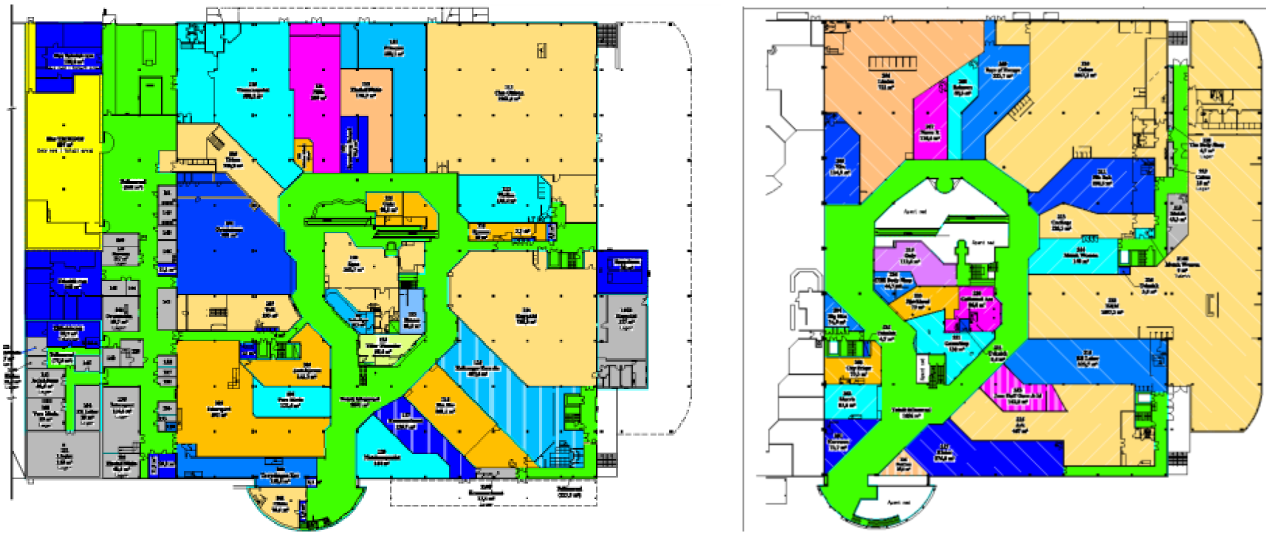


Figure 4-11. Floor plans Storebrand part, ground floor (left) and first floor (right). Common areas in bright green.

The building is divided into thermal zones according to:

- Separate HVAC systems and building services;
- Different use, functions or operation schemes in the zones;
- Solar exposure, or location in the building (0, 0-1, >1 exterior facade) to account for shops in the entrance which are colder (higher heating demand, but no heating system..);
- The common area is divided into multiple airnodes to allow for thermal stratification and to simplify model (less convex geometry). Additional airnodes close to the entrance could be used to simulate the infiltration heat loss in that part of the mall.

4.4 Assessment of retrofitting potential by means of KPIs

Key performance indicators (KPI) are a set of quantifiable measures that can be used to gauge its performance over time. These metrics are used to determine a project progress in achieving its strategic and operational goals: those raw sets of values, which are fed to systems in charge of summarizing the information, are called *indicators*.
IDP integrates the concept, generally to select the best actions of a retrofitting for energy efficiency, the design approach involves: as a first step, the analysis of the current building energy behaviour, the identification of inefficiencies and a proposal of solutions that could be suitable for each building; in a second phase, the assessment analysis of consumption for the living comfort and for other functions, with the pay-back investment evaluations.
The intervention strategy in a retrofitting is hardly configurable with quantity indicators, so it is based on a *qualitative level* that can identify the applicable potential for each solution items of passive and active efficient proposals.

Qualitative indicators, identifiable and marked as possible candidates for efficiency KPIs for a retrofitting, assess the quality of the action according to certain standards; they can be divided into four categories:

- energy, or how the action affects the energy efficiency and energy savings;
- innovation, compared to current practices in use;
- accessibility, in sense of the integration possibilities, as due to the building codes restrictions, historical characteristics, etc.;
- costs, the economic investment level compared to market costs.

For each indicator, performance levels are expressed with three values: high, medium and low potential. A clarification: the library table shows the levels of potential in absolute terms related to each proposal, utility equipment and technology.

POTENTIALS (definition of the positive impact)			level of potential			
Item	**definition/materials**	**specification**	**ENERGY**	**INNOVATION**	**ACCESIBILITY**	**COSTS**
Building:	purpose-built		high	high	high	medium
	reconceptualized building		high	high	low	high
Year of build/build in:	before energy regulations		high	high	low	high?
	after energy regulations		Medium	Medium	medium	high
	new building		low	low	high	low
Restructured in:	before energy regulations		high	high	low	high
	after energy regulations		low	low	medium	medium
Orientation:	S/ SE/ SW		high	high	high	high
	N/ NE / NW		low	low	high	high
	E/W		medium	medium	high	high
Shape	building block		high	medium	high	medium
	in continuity		low	medium	low	medium
Position:	dense urban		low	low	low	high
	urban		low	medium	medium	medium
	sub urban		medium	medium	medium	medium
	isolated/ independent?		high	medium	medium	medium
Centre design:	enclosed	climatized	high	medium	high	medium
	semi-enclosed	not climatized	high	low	high	low
	open	not climatized	high	low	high	low
	multi-level	climatized	high	medium	high	high
Structure:	masonry		low	medium	medium	high
	Prefabricated		high	medium	medium	high
	historical building		medium	high	low	high
Envelope:	structured wall	opaque	medium/high	low	high	low
		glass	high	medium	medium	high
	traditional wall	brick	low	low	medium	medium
		panels	medium	low	medium	low
	precast panel	panels	medium	low	medium	low
Roof:	plane	deck	high	medium	high	medium
		prefabricated	high	medium	high	medium
		wood	high	medium	medium	medium
		carriageable	low	medium	low	medium
		green	low	low	low	high
	sloped roof/pitched	prefabricated	high	medium	medium	medium
		shed	high	low	low	medium
Floor:	ceiling/false ceiling		high	medium	high	medium
Internal wall						
Insulation:	yes		medium			
	no		high			
	material	natural	low	high	medium	medium
		mineral	none	none	none	none
		oil derivatives	medium	low	medium	low
	location: roof	out	medium	low	low	medium
		in	low	low	low	low
		termal	medium	low	medium	low
		acoustic	none	high	high	high
	location: foundation	out	medium	low	low	high
		in	low	low	low	medium
	location: wall	out	medium	low	low	high
		in	low	low	low	low
		interspace	high	medium	low	high
		termal	medium	low	medium	low
		acoustic	none	high	high	high
Skylight:	Gallery - %m^2 glass surface/roof area	<10%	low	low	low	low
		>10%;<30%	medium	low	low	medium
		over 30%	high	low	low	high
	Shops - %m2 glass surface/roof area	<10%	low	low	low	low
		>10%;<30%	medium	low	low	medium
		over 30%	high	low	low	high

For a more accurate indication of the effective savings result, in overall consumption of a shopping centre, each individual saving action/proposal has to be compared to the total consumption. So, if it is necessary to quantify/normalize the performance indicators, the reference elements to consider are:

- energy consumption, according to utilities (lighting, heating, etc.) that weigh in different ways according to the type of commercial centre;
- economic investment, according to the total cost of investment, still without considering the energy costs savings after retrofitting

A useful reference/consultation is the analysis of solution sets for reference buildings described in Deliverable 5.1 (Cambronero M. V., 2017), in which every action is actually weighing the overall intervention and is a valuable tool for defining the retrofitting strategy.

4.5 Benchmarking

Benchmarking, in sense of the systemic and continues process to evaluate and compare the products, services and processes of work, can be supported by the IDP library.
The aspects of IDP that are closely related to this analysis methodology for the retrofitting sector are:

- IDP is a kind of a data base including different examples on energy efficient retrofitting of shopping centres and potential energy impact. It is a sort of catalogue that takes into account different aspects like architectural archetypes, climatic typology, in continuation adapted to indicate times needed for retrofitting and pay-back time, and costs
- IDP enables stakeholders to compare the effectiveness of every retrofitting process from energy performance, economic and technical feasibility point of view
- IDP teaches and supports the integration of the best energy practices, giving information and specifications.

There can be identify different phases on integration of the technologies described by IDP that are closely related to the phases may be found in typical benchmarking process:

- Energy problems definition and representation by different real shopping centres situations
- Definition of the structure of IDP (by archetypes, features,…)
- Definition of the case studies, including retrofitting design
- Data collection, analysis and comparison

- Outcomes and recommendations

All outcomes, recommendation, results obtained can be used as a starting point for the retrofit design of similar shopping centres. In continuation it may be also used during the commissioning process in case any re-alignment of the strategy adopted is needed, as it offers the , base data and situation for future analysis.See chapter in continuation.

4.6 Commissioning

Commissioning is the design process phase which aims at assuring that all systems and components are designed, installed, tested, operated, and maintained according to the operational requirements of the owner or final client.

As the iBEMS controls and monitors all the system of the building, it plays a fundamental role in this design phase. In CommONEnergy we also developed a Continuous Commissioning tool (CC-tool) that acts as an interactive interface gathering and analysing monitored data coming from the iBEMS (Antonucci D., 2017).

Thanks to this, the operator could be able to receive automatic and immediate feedbacks on building performance both on energy, economic and comfort aspects. The tool could help to ascertain whether the building performance currently meets the requirements set or if it is necessary to change or fine-tune components and controls.

The role of IDP library in this phase is twofold:

- The IDP library contains predicted energy performance of reference buildings which can be used as benchmark during the commissioning phase;
- The commissioning can feed the IDP library by providing actual energy performance which can be useful to other users.

5 An added value of integration of different functions

This chapter provides an overview of the added values of integration of different functions beyond the energy performance and the thermal comfort aspects.

5.1 Security and safety

Security and safety is the first and most important requirement in building construction and retrofitting. The innovative components/systems must be adapted to the local legal framework, in compliance with national, regional and local regulations.
The norms, standards and regulations, commonly known to architects and engineers for traditional systems, may be extended with indications and guidelines for those innovative and new ones. The same from the early beginning may be performed the analysis on the risk, costs, by the energy impact the particular technology may have on our shopping centre.
In some cases a technical validation of the new innovative system might be required, necessary even in the case of a temporary intervention due to the requests of the participant companies, as a way to get a validation of a prototype. The idea would be to support the knowledge on those requirements; the same accelerate the integration of those top technologies, still not as much visible on the market.
The definition of the legal requirements should include:

- the product definition;
- tests definition according to the previous product definition;
- local requirements and mandatory tests definition;
- process definition.

Testing starts with the product definition, to found the correct standard to refer to, and in continuation it is used as a starting point for all requirements that must be evaluated and its verification method. At the end the characteristics should be defined according to national, regional or local regulation, and process to be followed proposed.
Companies developing the innovative materials, components and systems have to be insured, a part of complying with all other security and safety requirements during the design, manufacturing, and assembling and construction process.
IDP is constructed in such a way that allows the integration of the information related to security and safety, like guides and needs for the innovative technologies, and at the same time to offer the base information on basic requirements for different process phases.

5.2 Health

An integration of green, living elements with building's envelope and interiors leads to customers' space perception as more prestigious and elegant. Deep, long-lasting relationships between human beings and nature causes, that majority of people perceive plants as 'nice looking' elements. The "nice looking" expression means the good feeling caused by healthy neighbourhood impact. In fact, nature and green vegetation in this particular case influences humans' hormone system leading into holistic stress reduction and positive mood increase.

The good mood inspires for shopping willingness. That is at least important for two stackeholders of shopping centres: namely customers and tenants.

Opposed to most 'hard' engineering solutions, the urbanistic and environmental influence of green vegetation in the commercial area is not easy to count in qualitative way. The relevant impact onto microclimate characteristic may be observed both on urban and local scale, on building's envelope and in the inner space. Even if the retrofitting of shopping malls is mostly focused on energy efficiency aspects, there is an important impact on microclimate such as:

- air quality improvement (CO_2 and air pollutants level reduction, O_2 level increase, air humidity level increase),;
- airflow velocity reduction in next-to-wall space and relevant variation of local temperature and humidity;
- air pollution decrease thanks to pollution particles adhesion and absorption;
- richer flora and fauna biodiversity layer.

When considering the outer space, the health environment is mostly driven by hybrid façade design (foliage is particularly well suited for retrofitting case) and by well set ratio of green area on parking lots. The size of urbanistic and architectural intervention here suggest, that it should be considered as an important driver for Regional and Super Regional shopping Centres. The extended area of foliage, green roof and enlarged bioactive area on the Shopping Centre neighbourhood enhances microclimate on the suburban scale by outer temperature and humidity moderation, air pollution absorption and decrease of noise level. That directly improves the health of people being in the area with better respiratory conditions, blood oxygenation, lower absorption of air pollutants including those cancer genic and decreased level of excitation for nervous system – in particular through noise decrease and vision moderation in well accepted range of vision spectra.

Above listed features are beneficial not only for customers of shopping centres, but also for communities, which host the commercial areas.

When considering inner space of shopping centres, the vegetation solutions are recommended for full range of shopping centres types. Greenery enhances microclimate and improves microbiological safety. Furthermore, greenery moderates the air humidity, delivers additional oxygenation and decreases air

carbon dioxide values. These results in air purification and better respiratory conditions and blood oxygenation. Diversification of reflection area caused by leaves and foliage improves noise scattering; it decreases the noise level by few dB, which is beneficial not only for customer but also for shopping centre staff. The green isle concept is already exploited in inner areas with high amount of people traffic; best practice example is the Schiphol Airport, where certain green solutions for resting areas are exploited.
Finally, the scientific research on human health prompts, that live greenery presence improves the restoring the mind from work or studies stresses, it contributes to improved work abilities and satisfaction, encourages learning, inquisitiveness and alertness, helps children to develop connections to their nearby environments and encourage imagination, creativity, cognitive and intellectual development. Investigations disclose also some correlation between greenery environment and symptoms alleviation of Alzheimer’s, dementia, stress, and depression.
The best suited green solutions for retrofitting of Shopping Centre should be an object of dedicated design proceeded by those skilled in topic of healthy environment.

5.3 Acoustic protection and quality

Thermo-acoustic panels, considered in the IDP library for their insulation properties, have improve the indoor environment comfort from acoustic point of view.
The thermal-acoustic panels developed within the project incorporate two different functionalities: acoustic absorption and thermal insulation.
The product development, in its initial phase, clarified some facts that must be used in the future by all designers of shopping malls, some of the guidelines attached to the library are presented below:

- Although there are not specific standards in this subject matter, there is a growing interest to acoustic in shopping malls since the echoing in common areas can create discomfort and unpleasant psychological effects;

- There are studies showing the impact on echoing for specific dome geometries, common areas, corridors layout for all topologies of shopping malls. All studies highlighted the importance of sound absorbing materials to correct discomfort;

- Sound absorbing materials may have a very wide surface to be effective and for this reason, during the refurbishment of perimetric walls, it is financially interesting to select thermal insulating finishing materials (which are indirectly requested by EPBD- 2002/91/EC) showing at the same time a sound absorbing property.

Few thermal-acoustic materials of this kind are available on the market and some of them seem not to be widely known by the architects and designers. The IDP library offers a good dissemination opportunity. Interviews with experts allowed finding the most relevant solutions for shopping malls with different interest for shopping malls:

- Proven track record for partings of shopping centres, thermal insulation and fire resistance interesting for top floor. Sound reduction in shopping centres technical rooms in conjunction with sound absorption beneath, proven track record for commercial buildings;

- False ceilings or wall coverings, proven track record for commercial building;

- Those with a nice finishing with interest for top level shopping centres, high costs.

In a second step this work delivered several concepts of thermal-acoustic materials starting from the past experiences in developing a thermal insulating product called ISOBEL®, being supposedly a good platform for developing thermal-acoustic functionalities.
Initially the technicians tried different combinations of glues, paint and plasters with ISOBEL® to investigate applicability and aesthetics. Then the team made lab characterization.
On the other hand, and going back to the second concept focused on the space characterization, assessing of the speech communication by mean of evaluation of the reverberation time and the speech interference level. There is more specification in the human influences where between the mayor parameters there are sound level (speech intelligibility) and Speech Transmission Index. It could be especially important for shopping centres where the noise is emitted by the customers, shops or installation activity. The good practice on those cases may be represented, and consider the integration once again the new technologies, materials and acoustic diffusors. Recommended levels of the acoustic may be referenced.

5.4 Natural light

To take advantages of the natural lighting is one of the requirements of sustainability and indoor environmental quality as it leads to supply part of the energy demand necessary for correct illumination and visual comfort.
The developed solution sets include daylighting exploitation strategies. These strategies adapts existing building elements of the roof, existing installation shafts or staircases to daylight devices such as light tubes. In this way the impact of this passive strategy on the building structure would be minimal and contribute to achieve relevant effects in the electrical demand maintaining indoor well-being into this sector. Innovation on the field of the natural light recollecting and ultra-reflection conduction applications will consequently bring new technologies models of passive illumination elements, totally integrated with the existing functions of shopping centres' constructions.
From the other side good design of shading elements plays a very important role in the hot climate zones. By analysing possibilities on building design, depending on climate and situation, shading/reflection panels and correct glazing parameters could be the solution to avoid overheating but also to avoid glare and reflections that could damage some goods or influence negatively the indoor comfort. Application of mentioned techniques, enable uniform natural light access in a space even during the cloudless days.

5.5 Smoke ventilation

So far, shopping centres' design has included a small proportion of automated windows, sized for smoke ventilation only. These automated windows can be exploited for ventilative cooling and integrated in a natural ventilation strategy which involve the shopping centre common areas.

This option is being effectively demonstrated in the CitySyd demo case in Trondheim. The retrofit design of the demo case involves the implementation of a natural ventilation strategy to cool and ventilate the common areas during mild temperature periods (Belleri A., 2017). The strategy combines the effect of opened sliding doors and existing skylight openings to enhance stack ventilation and ventilate/cool the common areas.

Figure 5-1. Skylights in the central atrium and the cafeteria located on the mezzanine below. Openable windows are present on both sides.

The existing openings were used for smoke ventilation only and their control was independent from the shopping centre energy management.

Thanks to the refurbishment, the skylight windows are now controlled by a window automation system connected to the iBEMS which switches off or modulate the airflow from the AHU whenever windows are opened.

The system still works as smoke ventilation since a fire signal overrides the whole control strategy by opening the windows in case of fire.

6 Kind of retrofitting

6.1 Approach for retrofitting of shopping centres

Renovation and refurbishment is a critical part of retail property performance. The work that applies to a retail shopping centre is much higher than a commercial or office building. The shopping centre needs to be carefully managed when it comes to appearance, renovation, and the overall shopping experience.
Moreover, the method of design approach depends on many factors, among which: the management of commercial choices; the economic investment; the facility management and maintenance.
Especially in regions with a highly competitive environment, higher and higher retrofitting quality is required in terms of re-layout, comfort, aesthetics and characterization of the centre; furthermore, thanks to a growing sensitivity to the environment, the commercial redevelopment supports a target of reducing energy consumption and saving resources.
The first analysis concerns the conditions of the building and its functions, moreover the intervention has to consider if:

- the building has been built to be a shopping centre (purpose-built) and needs to be refurbished;
- the building must be adapted to accommodate a shopping centre.

In both cases, it is advisable to check whether there have been previous retrofit measures and whether they resulted in extension or reduction of sales area or gross area; it must be deepened especially the status of systems and plants that might need to be partially or totally replaced (HVAC, refrigeration, lighting, etc.).
A first design approach is to define the type of actions that must be taken, to decide the timing and planning the construction site phases.
Summarising, the types of actions can be:

- extension of sales area
- partial renovation
- total renovation
- demolition and reconstruction

Sometimes, the rehabilitation and/or the introduction of new functions include the expansion of the existing centre, also due to the reduction of the free areas (*greenfield*) that limit the construction of new settlements. The partial or total renovation usually involves common areas, shops and exterior parts. If building structures are particularly outdated and inadequate, the intervention of retrofitting can be very important, with a total demolition and rebuilding.

The planning of construction phases is an important issue, both for the owner and the facility management of the shopping centre. Prior to any renovation commencing, it is recommended to communicate the fact to the broader customer community and tenants ("Let them know what is going on").

Owners and facility management requires to plan the retrofit interventions during less busy times. Understand the patterns of shopping throughout the year helps to understand the best times to undertake the renovation.

Renovation can also be partially undertaken in different zones of the property as the year progresses. That means to works in phases, to avoid the closing of the shopping centre: this approach depends on the shopping centre typology; it mainly causes issues related to site preparation and organization of the work and project management.

When total renovation or demolition and reconstruction is planned, it is preferable to totally close the shopping centre because the work can last few years.

In summary, construction phases can be planned as:

- single action;
- actions/interventions in various stages during shopping centre opening time;
- closure of the shopping centre during the period of retrofitting.

The timing of the building refurbishment defines the different phases and areas where the works take turns/alternate, to maintain the best functionalities and the greater number of services. It is important also to restrain and contain dirt, dust and hustle, to reduce customers' discomfort and complaints.

A renovation has a good welcome if it leads to improved comfort and atmosphere of the centre but it could be opposed by neighbours because they fear the discomfort, noise source and traffic, related to the construction site.

The direct involvement of people in the refurbishment process is the best method to push through the changes, showing the projects and the phases of the implementation and highlighting the improvements which will be achieved.

At a more general level, an example is the 'Otranto Urban Regeneration Workshop[2]', "neighbourhood workshop" originated as a program of historic centres rehabilitation, sponsored by UNESCO in 1979: essentially acted as a connection between the laboratory specialists and locals neighbourhood; a section

[2] 'Otranto Urban Regeneration Workshop', Otranto, Italy, 1979. That "neighborhood workshop" originated as a program of historic centres rehabilitation, sponsored by UNESCO, was commissioned to Renzo Piano & Rice by Wolf Tochtermann. It was a demonstration experiment performed in Otranto, in Apulia, to check whether the real interest and the possibilities of intervention forces craft to the recovery process of the ancient city. The intervention of the neighborhood workshop planned to not alienate people from their homes and using them to participate actively in the work. To this end were then introduced innovative technologies, lightweight and non-invasive. (Otranto Urban Regeneration Workshop)

was dedicated to the open project and to raise awareness of the practical and technical aspects of the project activity.

The demo Coop Valbisagno commercial centre is located on a suburban area of the city and wedged between existing buildings: the renovation project, of the existing building and the old warehouses, has the advantage of recovering an abandoned area and to enlarge that community centre. That project was initially opposed by citizens' committees, because of the size of the new shopping centre and the visual impact considered too intrusive for the district and the nearby monastery. Thanks to a diplomatic approach of the property, it has been defined a work-table for a participative planning that has allowed to bring forward the administrative processes.

The most delicate phase in a renovation is the construction period, especially when restructuring does not expect a total closure of the shopping centre: to maintain the mall open is one of the preferred solutions, to reduce the inconvenience to customers and the risk of losing market share, feared by management and tenants.

Once again, if the customers know the timing and the work progress, they can accept the temporary discomfort more gladly, because they will feel more involved in the project, also they know how long could be the distress time.

6.2 Retrofit of existing shopping centres

Retrofitting existing buildings is a proven high-volume, low cost strategy to improve energy efficiency, thereby helping us tackle one of the major causes of climate change.

The renovation of a shopping centre is complex and it is important to define the design approach for each action to take, based on the conditions of the building and the requirements of stakeholders (owners and managers).

The work can be divided into three main phases:

I. The first stage consists on a precise analysis of the actual situation of the shopping centre;
II. The second phase consists on the project definition, comprising both the architectural design and the type of the systems;
III. The third phase consists on planning the maintenance phase during the retrofitting operations and after the reopening of the shopping centre (after the retrofitting).

6.2.1 Analysis and measurements

General opinion is that mission, goals and objectives of renovation must be determined through a feasibility study, including assessment of the market's demands/market analysis, target on age group, financial status and space available; as well as reducing the environmental impact by optimizing the energy consumption and the implementation of new technologies to improve the environmental comfort. All successful projects start with a definite plan so that all parties understand their responsibilities and

performance requirements to ensure that renovation works are executed in safety with no accidents and risks.
The renovation process begins by auditing the physical structure and equipment considering also:

- equipment and plants to avoid any damages and to define which kind of design to apply (partial recovery, total replacement, etc.). including reports about flooding, leaks or damages or existing inefficiencies;

- records from staff, customers, contractors, and government department to analyse/resolve any possible risk problems like fire, security, etc.;

- specific regulations for commercial buildings that might represent an obstacle to the application of the technologies: for example, specific rules or any health restrictions.

6.2.2 Design/retrofitting

The project involves the redesign of the retail gallery both for functional reorganizational needs and aesthetic renewal, or more customer services, and for an overall improvement of energy savings (reducing environmental impact).
An extensive program of variation and modernization of a shopping centre shall involve an integrated design process. We can underline the main items for which action/intervention is needed to obtain relevant energy savings:

- **Lighting**: The lighting design is a mixture of natural and artificial lighting that contributes to the centre’s commercial appeal and sense of place. The skylights continue to reinforce the concept of natural light. They allow the visitor to gaze up and out, and to maintain a direct relationship with the outdoor environment. It allows also to optimize the energy consumption for artificial lighting;

- **HVAC systems** have the greatest impact on energy consumption;

- **Building envelope**: further interventions regarding the restyling of the façade will permit to obtain a more sustainable shopping centre. For example, the brise-soleil/shielding for south facades to mitigate the irradiance, or a re-designed windows allow for a greater transparency from inside out, depending on the exposure. External facades renovation can improve the envelope insulation.

- **Interior common spaces**: Usually, the project concerns renovation of the shopping mall's interior spaces, in particular: ceiling heights and/or false ceilings; shop fronts with windows and signage; floors and pavement.

Retrofit interventions can also involve outdoor spaces and parking areas. Different approaches can be applied if there are one or more parking level or parking lots on the roof.

Interventions can also include the redevelopment of the inner square and common areas, elimination of architectural barriers, and plants/systems maintenance.

6.2.3 Maintenance phase

The wear and tear factor that applies to a shopping centre is much higher than the one of commercial or office buildings.
Preventive maintenance program and routine inspection of the building, ground and equipment are especially important for retail properties because of the heavy use they endure.
Moreover, tenants are responsible for a large part of energy use in shopping centres: the refurbishment can help to change attitudes and behaviours in the everyday activities to improve energy savings.
The installation of an iBEMS system, with sensors for monitoring and manage alerts, is a good way to manage energy targets and strategies.

6.3 Retrofit of existing building re-designed to be a shopping centre

Special architectural conditions and needs are common in shopping malls. Possible modifications of these conditions, in order to effectively contribute to buildings energy retrofitting, must be proposed as well as the definition of integrated approach for developing architectural solutions, including materials, components and systems conceived and realized within the CommONEnergy project.
Regarding the restyling of an existing building, normally the objective is to enhance the premises, thereby upgrading the real-estate value and consequently attracting top grade commercial activities. The proposal includes a significant interior renovation work: a general makeover of the interiors and an audit and upgrading of all the systems, when it is not necessary to replace them.
Again, the three drivers to plan a retrofitting are:

- reduction of energy consumption;
- increase of comfort level and functionality;;
- optimization of building operation and maintenance costs.

In order to reduce the energy consumption through a retrofit, usually it is necessary to act on the building envelope: existing industrial building or storehouses converted to shopping malls have a bad insulation of walls and roofs. If it is not possible to operate on the building envelope (i.e. historical buildings), the retrofit intervention shall focus on systems efficiency.
It is important to maintain the accessibility of technical rooms and adequate maintenance areas for the intervention of men and equipment dedicated.

7 Virtual Integrated Design Process library

The IDP library is an online repository conceived to provide designers, owners and managers with relevant information to start a retrofitting process of a shopping centre. In particular, the tool collects information about shopping centres' archetypes and specific technology features, as well as climate, social and urban contexts connected to the reduction of energy needs and increase of energy efficiency in shopping centres. The identification of peculiarities of each building is the starting point for the identification of the most suitable retrofitting solution-set.

7.1 IDP structure and contents

The IDP library layout is structured as follows:

- description of general, architectural and technological features
- baseline simulation model results
- analysis of inefficiencies
- retrofit solution set description
- estimated energy and carbon savings, cost analysis of each retrofit solution set

The description of general features refers to the criteria developed within CommONEnergy to select the reference buildings (Bointner R., 2014). These criteria include location, type of development, size and Gross Leasable Area (GLA), type of anchor stores and trip purpose.
Architectural features take input from the practical constraints to technology implementation identified by each technology partner. For instance, a parking lot located on the roof might prevent the installation of PV panels or green roof or high reflective coatings.
Technological features and building energy simulation models support the inefficiencies analysis by describing the building envelope features, the HVAC system efficiencies, the average installed electric power density in the tenants and common areas and the energy consumption.
The library also collects and enables to select among the inefficiencies identified in deliverable 2.2 (Woods R., 2015) at envelope, lighting, HVAC and refrigeration level.
The identification of peculiarities of each building is the starting point for the identification of the solution-sets (Cambronero M. V., 2017). Building energy simulation models are used to identify the more suitable solution-set for a shopping centre retrofitting and to estimate the relative energy savings, in order to ensure an effective investment, while effectively exploit, for each case, local natural sources and infrastructures.
Each retrofit solution set is evaluated according to the following Key Performance Indicators (KPI), which are calculated by means of building energy simulations and reported in the library database:

- Primary energy savings

- Carbon emission savings
- Comfort level
- Investment cost
- Operational energy cost
- Payback time
- Net Present Value
- Maintenance cost

Starting from the assumption that the reference buildings represent the retail building stock throughout Europe, each library row refers to one of the reference buildings and proposes a retrofit solution set suited to that its peculiarities.

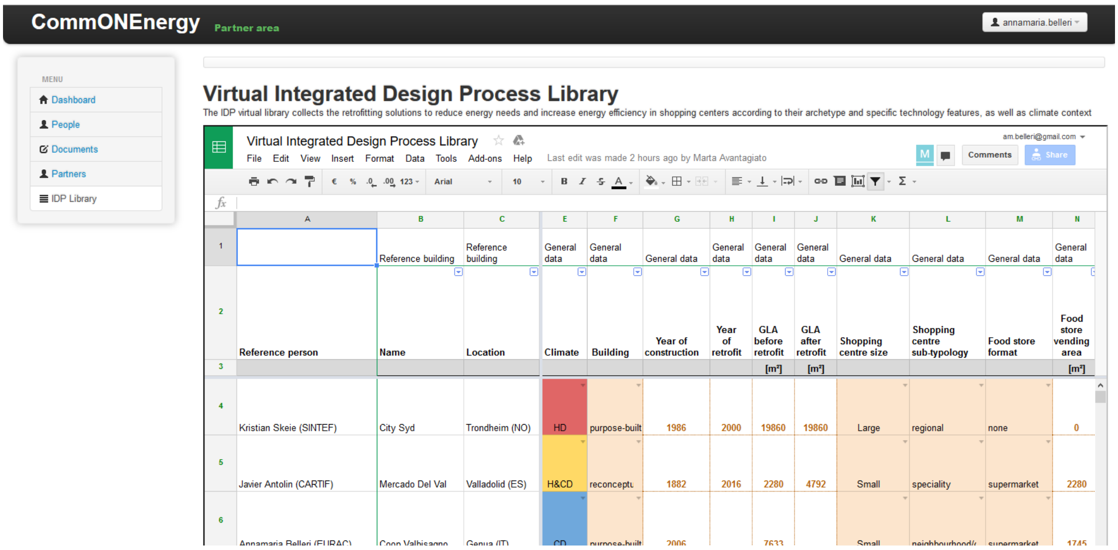


Figure 7-1. The IDP library.

Inputs are organized in several columns that are grouped as in Table 7-1. Input can be either numeric or selected from a drop-down list of pre-defined options. Each input field is described in the info sheet.

Table 7-1. Virtual IDP library inputs.

General data	Urban context Climate Building type Year of construction GLA before retrofit GLA after retrofit Shopping centre size Shopping centre typology

	Food store format Food store vending area Tenants vending area Common areas and galleries Number of opening hours per day Number of opening days per week Number of closing days per year
Building features	Centre design Shape Orientation Number of levels above ground Number of underground levels Parking location Number of parking levels Biologically active area
Perimeter	Wall structure Wall insulation location Wall insulation material Wall U-value Window to Wall Ratio (WWR) – north / east / south / west Windows U-value Window glazing g-value Basement/Floor structure Basement/Floor insulation location Basement/Floor insulation material Basement/Floor thermal transmittance Roof structure Roof insulation location Roof insulation material Roof U-value Vehicle accessible roof covering Green roof covering ST roof covering PV roof covering Skylight to Roof Ratio (SRR) Skylight U-value Skylight glazing g-value
Technical rooms	Location BMS lighting BMS natural ventilation BMS HVAC BMS refrigeration BMS solar thermal system BMS electric storage Ventilation specific power Heat recovery thermal efficiency SPF heating SPF cooling
Common areas/Tenants/Food store	Installed lighting power density Installed electric equipment power density
Primary energy consumption	Lighting Refrigeration Plug loads HVAC

	Tot. primary energy
Carbon emissions	Tot. carbon emissions
Inefficiencies	Envelope Lighting Refrigeration HVAC

Last columns of the library report the solution set studied for each reference building within the CommONEnergy project and the predicted performance of the building after the retrofit intervention. Selected Key Performance Indicators are:

- Primary energy consumption
- Energy savings obtained
- Carbon emissions
- Carbon emission savings
- Comfort level
- Investment cost
- Operational energy cost
- Payback time
- Net Present Value
- Maintenance cost

7.2 IDP guide of use

The structure of the excel sheet allows (i) easy filtering and user friendly visualization of the collected information, (ii) to add further reference building and solution-sets based on those buildings (iii) to extract information in automatic way (iv), and further informatics developing, moving the information in automatic way.

Shopping centre designers, owners and managers have been identified as main target users. Once populated with technical, environmental and economic features and their associated performances of the retrofitting architectural archetypes, the gathered information can be filtered in a graphical user interface according to each target group's needs.

The online repository is going to be published on the CommONEnergy web-site (http://www.commonenergyproject.eu/integrated_library.html), as a free online tool available to help shopping centres owners and managers in planning malls retrofitting, providing a quick overview of the best solution-sets matching the building features and context. The repository can then be populated by users and become a reference point for shopping centres retrofitting design.

8 Conclusions

The concept for a library to support the “Integrated Design Process” of shopping centres is based on two main targets: to increase the energy savings and to improve the indoor environment quality with cost-effective retrofit interventions. The idea was to create a reference repository, we called virtual IDP library, which allows the comparison between shopping centres on energy efficient retrofitting, and provides designers, owners and managers with relevant information to start a retrofitting process of a shopping centre.

Every retrofitting involves a careful analysis of the building peculiarities. The analysis of technology features and the functional layout supports the retrofit design: first of all, the basic information about the building, such as general data (location, year of construction, shopping centre typology, climate, area of intervention), building features (design, shape, orientation, parking location), building envelope (structure, materials, glazed and opaque surfaces, thermal transmittance), HVAC plants and equipment and internal gains (lighting and electric equipment power density).

The Virtual IDP library describes the main technology features that characterize the architectural archetype of a shopping centre. Building energy simulation models are used to identify the more suitable solution-set for a shopping centre archetype retrofitting and to estimate the relative energy savings, in order to ensure an effective investment, while effectively exploit, for each case, local natural sources and infrastructures.

The development of the Integrated Design Process (IDP) for retrofitting shopping malls, have been defined by different analysis:

- identification of architectural archetypes by functional layout and technology features;
- identification of synergies with other method and tools that support IDP;
- analysis of co-benefits, beyond the energy performance and the thermal comfort aspects, due to the integration of different functions like security and safety, health, acoustic and lighting environmental concept;
- analysis of possible further impact for benchmarking and commissioning that will be a base output to the exploitation analysis of the retrofitting concepts.

The IDP library will be publicly distributed on the CommONEnergy web-site (http://www.commonenergyproject.eu/integrated_library.html) as an online repository, a free online tool available to help shopping centres owners and managers in planning malls retrofitting, providing a quick overview of the best solution-sets matching the building features and context.

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