



CommONEnergy



Final report

**European Commission
DG Research and Innovation**

SP1 - Cooperation

Collaborative project

Large-scale integrating project

FP7-2013-NMP-ENV-EeB

GRANT AGREEMENT No. 608678

CommONEnergy

Re-conceptualize shopping malls from consumerism to energy conservation



FP7 European Union Funding
for Research & Innovation

Technical References

Project Acronym	CommONEnergy
Project Title	Re-conceptualize shopping malls from consumerism to energy conservation
Project Coordinator	Roberto Lollini Accademia Europea Bolzano, Viale Druso 1, 39100 Bolzano/Italy roberto.lollini@eurac.edu
Project Duration	1 October 2013 – 30 September 2017 (48 Months)

This document has been produced in the context of the CommONEnergy Project.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n. 608678. The content of this document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the document lies entirely with the authors.

Contents

Executive summary.....	4
Summary description of the project context and the main objectives.....	6
Description of the main S & T results/foregrounds	11
Analysis of the context	11
Research and technology development	13
Demonstration.....	41
Communication & dissemination	48
Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.	50
Impact	50
Dissemination	53
Exploitation	55
Website and contact details	61



Executive summary

A shopping centre is a building, or a complex of buildings, designed and built to contain many interconnected activities in different areas. The main drivers for renovation action are: (i) improve indoor environmental quality and functionality to enhance the customers experience, (ii) reduce energy consumption, (iii) optimize building operation and relative maintenance costs, (iv) improve overall sustainability level reducing environmental, social, and economic impact.

The majority of European shopping centres are already built, but there is still huge potential for energy savings due to the practice of regular retrofitting and restyling (rate of more than 4%/year). This state of constant change offers regular opportunities to improve the overall energy efficiency and sustainability.

Improvements on equipment performance or reduction of building loads influence also other parts of the entire shopping mall system. We developed a structured modelling environment called Integrative Modelling Environment (IME), where the whole building system is divided into base blocks that represent the building and its sub-systems (ventilation, lighting, refrigeration, Heating Ventilation Air Conditioning) and is able to analyse their interconnections. A parametric definition of the components features and the modular structure of the model layout, eases the development of a shopping mall system model and the integration in it of different contributions, allows the optimization of the components size and the simulation of different scenarios and solution-sets as well as control logics to manage the whole shopping centre, facilitates sensitivity and uncertainty analysis, multi-objective optimization and model calibration.

We analysed 11 reference buildings and defined solution set as a result of an iterative process with the evaluation of energy savings and economic analysis aimed at obtaining a 75% of primary energy reduction and a 7-years payback. Solution-sets and related energy savings and economic analysis are available in the virtual IDP library, an online repository conceived to provide designers, owners and managers with relevant information to start a retrofitting process of a shopping centre.

Projects results include the following technology and methodology results: i) a façade system, able to support modularity, flexible to integrate lot of energy efficient strategies, adaptable to different climate conditions and comfort needs; ii) multifunctional coating, based on formulation for an additive suitable to be integrated to any aqueous based paint (for almost every substrate, excluding glass and laminated surfaces); iii) Greenery integration, through direct use of vegetation for improvement of thermal performance of building envelope; iv) natural ventilation and ventilative cooling, considering a possible cooling set-point adjustment, potentially modulated depending on outdoor conditions for ensuring customer comfort expectation; v) thermal&acoustic panels for improving acoustic environment, incorporating two different functionalities: acoustic absorption and thermal insulation; vi) retail lighting systems, also coupling artificial and daylight, managed by “Green Lighting Box” as a turn-key ready control solution. Perception study was additionally performed to match luminaire and lighting solutions with an improved customers’ experience; vii) optimization of refrigeration cabinets’ and HVAC system layout to save energy, improve thermal comfort for customers, and avoid mist formation on glass doors of closed display cabinets; viii) use of Carbon dioxide (CO₂) heat pump in different climate conditions; ix) application of Demand/Response (D/R) approach for refrigeration; x) Intelligent Building Energy Management System (iBEMS) with open communication protocols for data exchange, tailorable control algorithms, advanced graphical environment for effectively transform monitored data in clear and useful information and reporting tool; xi) continuous



commissioning (CC) platform, to characterize the operational performance of the building considering comfort, energy and economic aspects; xii) shopping centre as energy hub characterized by an increasing diffusion of Renewable Energy Generation (RES) and active loads, such as Energy Storage System (ESS) and Electrical Vehicle (EV); xiii) Shopping Mall Assessment Tool aimed at a rough energy-economic evaluations of shopping centres retrofitting in the very early stage of the decision process; xiv) Lean Construction and Operational Management guidelines to introduce lean principles in the challenging sector (for logistic and timing issues, as well as to balance energy efficiency and retail business drivers keeping an ever higher customers' satisfaction) of shopping mall renovation and organization; xv) coupling of Life Cycle Working Environment and Social Hotspots Database (LCWE-SoHo) with standard sustainability assessment and certification, to assess the whole life cycle related social and cultural risks of the shopping mall renovation process value chain.

Besides technologies and methodologies, the project performed several dissemination actions for different targets whose documentation is available on the web site (e.g. training modules, technology flyers, guidelines to approach energy-efficient retrofitting of shopping centres), as well as developed policy recommendations grouped under four main themes: engaging stakeholders, communicating the benefits of retrofitting, promoting energy efficient technology packages, and supporting the energy transition, with suggestion for recognition of the strong role shopping centres can play in achieving the EU energy efficiency targets.



Summary description of the project context and the main objectives

An EU-shopping-centre-stock analysis identified reference buildings representative of the whole stock, to complete the three demo-cases in Italy, Spain, and Norway already defined during the preparation phase. The stock was characterised in terms of architectural and constructive features, energy system layout, urban, social and economic context, as well as possible interactions with the surrounding energy grids. Collected data and the key architectural and energy figures were included in an interactive online data mapper.

We initially identified the main inefficiencies of shopping centres, as far as energy, comfort, operational (maintenance) and logistic are concerned, and defined shopping centres' typical functional patterns, the influence of stakeholders (owners/managers, tenants, customers) on energy figures and their interaction with the social context. With these elements, a parametric analysis was performed, aimed at identifying retrofitting drivers as the most promising solution from a cost and benefit point of view.

The following resulting trends were identified following the context analysis:

- the physical structure of shopping centres is in a state of constant evolution due to the changing requirements of the retail trade;
- energy retrofitting must be approached considering the state of continuous transformation (with possible exploitable co-benefits);
- opposing developments: smaller size and location, moving back towards the city centre vs adding leisure and pleasure functions, then increasing size and complexity;
- green retail is becoming more widely appealing, mainly connected to organic food and sustainable architecture, potentially attracting new kind of customers;
- awareness and knowledge (needing reliable data to be turned into information) as the first and cheapest action in renovation activities.

The majority of European shopping centres are already built, but there is still huge potential for energy savings due to the practice of regular retrofitting and restyling 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, having significant energy reductions and IEQ improvement. Three different types of drivers have been identified: direct, indirect, and potential. There exist four main direct drivers for energy use reductions in shopping centres; lighting (and other plug loads), HVAC+Storage, refrigeration, architecture and design, and these 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 primarily social challenges or influences which characterise shopping centres, such as changing shopping habits and user behaviour, and should be taken into account when planning a retrofitting process. They 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 main barriers and drivers for deep energy retrofitting in shopping centres were identified, as well as considering different types of driver and how their role and influence may be strengthened. Key predictor variables and performance indicators were identified and a



protocol for sub-metering of energy consumption and flows were defined as the main basis when tracking inefficient use. Finally, a parametric analysis of retrofitting drivers was used to assess possible cost-optimal retrofitting actions for shopping centre managers.

The identified drivers allowed to address the further research activities identifying solutions for the energy needs reduction and improving of energy efficiency.

Reduction of energy need were pursued in particular through: (i) possible exploitation of building context natural resources (ii) envelope and architectural optimization (iii) use of materials and components able to improve comfort and reduce energy and maintenance needs. The areas of our intervention are listed in the following.

- The recent trend in food stores is to adopt display cabinet closed by means of glass doors to reduce drastically energy consumption for refrigeration compared to open display cabinets, as well as customers' comfort which is strongly influenced by the cabinets' cold surfaces. However, product visibility can be affected by mist formation on the glass. Reduction or prevention of the risk of mist formation can be exploited by controlling relative humidity in the selling area or by increasing external surface temperature at the glass doors. Control of relative humidity implies dehumidification and re-heating by the HVAC system, which is a very energy consuming operation. Heating glass doors requires the use of electrical heaters whose energy consumption in the worst conditions can be even comparable to that of the refrigerating equipment. Adopting both strategies with an effective control can reduce the running costs but implies higher investment costs. In this context, we proposed and analysed two enhanced concepts for thermal zones optimization within the food store: the use of radiant panels as delivery devices in the refrigeration cabinets' zone; the use of specific air diffusers to prevent mist formation on cabinet doors.
- Potential application of ventilative cooling meant as the use of natural or mechanical ventilation strategies to cool common areas reducing energy consumption of cooling systems while maintaining thermal comfort. Natural ventilation components and strategies could be implemented in the façade system.
- Envelope renovation must be done reducing time and impact on users, in particular for shopping centres, which are dominated by retail needs. For this reason we studied a modular multifunctional and climate adaptive façade system, with a flexible light-weight frame structure fitting several building geometries. The frame system can also be configured in order to integrate different technologies such as different glazing systems, single or double skin façade, openable windows, greenery, shading systems, different cladding and photovoltaic modules.
- The green vegetation impact onto shopping mall energy balance is investigated in the holistic framework of energy circulation between plant, sky and earth surface. The heat island effect mitigation as climate protection issue and building envelope heat balance are distinguished and independently investigated. The components related with greenery are discussed in detail. The mathematical model is implemented into standalone simulation tool for further parametric sensitivity analysis, including different climate, environmental and hardiness zones and different plants exploitation.
- Commercial ordinary and specialized paints and additives were investigated, in order to cross check their performances according to manufacturer's specifications and then a fabrication in vitro of a novel series of multi-functional formulations is in a continuous process and progress.
- Daylighting strategies for shopping centres had the target to maximise the space quality by harvesting the right amount of daylight with an appropriate light distribution and



achieve energy savings by an aligned artificial lighting concept. 3 important building areas have been treated on the basis of our actual demo buildings: a) typical zone in a historic market hall; b) gallery in a shopping centre c) small shop in a shopping centre.

- We investigated new concept of thermal&acoustic panels dedicated to shopping malls (or more in general to commercial buildings), incorporating two different functionalities: acoustic absorption and reduced thermal conductivity. Although there are no specific standards on acoustic environment for shopping centre, there is a growing interest since the echoing in common areas of the commercial buildings can create discomfort and unpleasant psychological effects.

Increasing the overall efficiency of shopping malls meant designing, integrating and controlling set of active technologies by providing a core managing infrastructure within existing shopping malls. The areas of our intervention are listed in the following:

- Stated the complexity of the building typology and the related modelling and simulation challenges we conceived the development of an Integrative Modelling Environment (IME), where the whole building system is divided into base blocks that represent the building and its sub-systems (ventilation, lighting, refrigeration, Heating Ventilation Air Conditioning) and is able to analyse their interconnections.
- an intelligent Building Energy Management System (iBEMS) to monitor and control all the building systems, according to the Measurement and Verification procedures, enables to manage complexity in the operational phase.
- Considering the importance of shopping centres as partner of energy infrastructure, in particular in a vision of a meaningful reduction of energy needs we studied scenarios for local energy generation grid interaction and storage evaluating the economical implications. Moreover, experimental campaigns for micro-grid were designed and setup to evaluate the combination of different RES and energy storage systems to match energy demand profiles.
- With regard to energy production and distribution we followed two main addresses: a) increasing energy efficiency of heat pump using CO₂ as natural refrigerant gas also in warm climate; b) potential application of energy recovery coupling HVAC and refrigeration sub-systems with dedicated control rules.
- 3 types of effective artificial lights for retail shops were designed within the project and tested for their lighting performance. In addition, a perception study has been carried on analyzing the effects of different light scenarios of illuminance.
- A complete solution for charging Electric Vehicles using Energy storage as well as Energy from Photovoltaic panels were designed and tested. For this task, the communication between the different sub-systems was setup and the required control rules defined.

On the basis of context analysis and specific technology development, we pursued the definition of systemic renovation approach, including products and supporting methods with six main practical goals:

- to develop solution sets to be implemented in the demonstration activities;
- to define an economic model for evaluating shopping malls retrofitting alternatives;
- to define a Lean Construction and Operation Management methodology that reduces failures and waste of the construction, as well as optimises the operational phase;
- to develop a continuous commissioning platform, grounded on the iBEMS, for an overall supervision and performance monitoring of the shopping mall;

- to assess the environmental and socio-cultural impacts of different identified design and energy concepts;
- to define an interactive web-tool allowing to select different scenario at EU level and providing a rough energy-economic evaluations of shopping centres retrofitting in the very early stage of the decision process.

We targeted the definition of 10 to 20 most suitable solution sets potentially applicable to all the European shopping malls, but studied using 11 reference buildings, including the three demo cases (Mercado del Val, CitySyd, Modena Canaletto, Coop Valbisagno, Brent Cross, Katané, Donauzentrum, Pamarys, Studlendas, Waasland and Grand Bazaar).

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 also describes the main technology features that characterize the architectural archetype of shopping centres in different context and representative of different archetypes.

Finally we performed a study on standardization and compliance with national building codes, with the main goal to study non-technical barriers (normative and legislative framework, both at national and European level) for the application of the solutions developed within the projects that could make their application difficult.

Demonstration activities were aimed to transfer the renovation concepts in actual shopping centre and to test the technologies and solutions developed within the project. Three Local Demo Working Groups (LDWGs) coordinated by local partners: SINTEF (for Trondheim), CARTIF (for Valladolid) and by INRES (for Modena and Grosseto). The demonstration activities can be summarized in the following steps:

- preliminary and executive engineering documents for each individual technology;
- procurement, logistic, custom clearance, inbound quality control;
- selection of EPC (Engineering, Procurement and Constructions) approaches and contractors;
- installation and integration of physical systems (architectural, civil, mechanical, electrical);
- iBEMS programming for the integration of control and monitoring systems;
- evaluation of data for Indoor Environmental Quality and energy savings;
- Life Cycle Analysis.

The soundness of the technology and solutions developed were confirmed on three specific demonstration cases in Italy, Norway and Spain, which were also the basis to test and multiply our communication activities. The communication objectives, defined at the project start and followed all along the project lifetime, were to create awareness for the environmental, social and economic benefits of the energy-efficient retrofitting of shopping centres and to make these benefits visible/tangible by showcasing what happened in the pilot projects.

Key communication responsibilities and activities were to:

- establish the dialogue with the stakeholders from the key target groups and define specific communication objectives;

- coordinate communication activities with relevant research and stakeholder networks with a view to measuring the impact and community's impression of energy renovation and the work of CommONEnergy;
- coordinate and create synergies with EU policy development and other ongoing EU related projects and initiatives;
- ensure proper training of practitioners by developing appropriate tools and activities;
- assist other WPs in the identification of scientific experts and relevant stakeholders to identify, evaluate and harmonise the current systems regarding energy renovation and the ongoing research activities in this field;
- actively disseminate the results of the project to the defined target audiences and key stakeholders, including policy-makers, industry, manufacturers of the technical solutions and systems, real-estate companies, financial institutions, etc.

Different target groups were identified, and for each one a specific strategy and outreach planned.

The primary target group is the shopping centre stakeholders that include people working in shopping centres (tenants, employees, service providers), building professionals and technical experts, policy-makers at EU and MS level.

Secondary target group refers to the energy efficiency in buildings community and includes research, academia & consultancies actively involved in the development and implementation of national policies relating to the energy efficiency of buildings, working on the scientific and economic perspectives, as well as broader energy efficiency in buildings community (consumer associations, NGOs, financial institutions, etc.).

Tertiary target group refers to non-specialists and includes media (scientific, peer-reviewed publications, national specialized press, European and national industry magazines, local generic press) and Civil Society (shopping centres customers).



Description of the main S & T results/foregrounds

Analysis of the context

The consortium started investigating shopping malls features in the EU-28 and Norway based on an extensive literature review and on a broad and detailed data collection process. A definition and categorization criteria of shopping centres in their functional and social context provides a solid ground for the further project development. We selected ten reference shopping centres that were modelled and evaluated within the following activities of the project. The selection was done according to six predefined criteria in order to be representative of the European stock for different technology concepts and functions as well as covering main climatic zones. In particular, the six criteria were: climate condition, market saturation, location, retail typology, building typology, and the opening year. Following these criteria, shopping centres from seven European countries were selected. Finally, we performed an overview of national building codes, regulation constraints, and relevant existing policy frameworks for shopping centres. Most countries periodically update their building energy codes, some more frequently than others. This process ensures that codes reflect changes in technology and design that offer increased energy efficiency and cost-effectiveness. This holds true for shopping centres, the wholesale and retail sector as well as the whole building stock. Finally, our results may serve as a comprehensive basis for decision making among European stakeholders on their way towards sustainability.

The following achievement was a comprehensive analysis of systemic efficiencies and inefficiencies related to the commercial building and its technical systems as well as to the multi-stakeholder decision process and criteria for undertaking energy renovation measures in shopping centres. The research highlighted the systemic inefficiencies that might have a negative effect primarily on the energy-use but also on the building itself, including architectural composition, logistics, and other constructional properties. Complex processes among the main stakeholders were studied that may lead to the selection of inappropriate and energy-consuming technical solutions, building and land design, and choices of operations and maintenance. An in-depth analysis was dedicated to the building envelope and technical systems aiming to identify factors that influence the functional efficiency and energy consumption in shopping centres.

The primary focus of the study was energy use, but the fields of facilities, functions, management, ergonomics, safety and logistics, economic models were also studied, because sustainable shopping centers in addition to being energy efficient need to be commercially viable, accessible social arenas for all sections of society. Moreover, the social environment, behavioural aspects and their influence on the decision-making process when implementing energy renovation measures were assessed.

There are three main aspects associated with user behaviour and energy performance:

1. 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.
2. Energy efficiency does not influence customer choice of shopping centre. Location is the most important factor influencing customer choice of shopping centre. This is closely associated to car-parking availability.

3. The physical framework provided by shopping centres does influence customer choice. However customers involved in the CommONEnergy 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 as 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.

Furthermore, in order to define retrofitting drivers, an analysis taking into account the buildings as structures for retail and social activity, venues for experience, their interaction with the surrounding infrastructure, and their urban integration or interaction with the local built environment was performed. These aspects are often described as “socio-cultural and functional aspects” within building certification schemes and methodologies that address the sustainability assessment of buildings.

The interaction between the shopping centers and the electrical grids to which they are connected was also analyzed, to identify key aspects which allow to improve the current interaction and to identify the capacities that these types of buildings could give as suppliers/providers of services to the grid.

The first stage of the project ended with the definition of the drivers of retrofitting. The drivers provide the basis for developing energy retrofitting concepts, offering constructive technology, an understanding of typical function patterns and socio-cultural aspect and an understanding of potentials associated with interaction with local energy grids. The majority of shopping centres are already built and there are therefore large energy potentials to be achieved through redesign and reorganization of existing shopping centres. With a parametric study the most important variables were identified.

The final considerations of the context analysis are reported in the following.

- Shopping centres are complex buildings which are subject to regular change, have complicated layouts, sophisticated utility plants and a high concentration of customers and workers. Efforts to improve energy efficiency and provide sustainable solutions for shopping centres must take its state of constant flux into account, by providing systems that may be easily moved, reused or redeveloped.
- Four main areas of energy use inefficiencies were identified: lighting, HVAC measures, plug-loads and refrigeration, and architecture and design. The need to achieve energy use reductions within these four areas may be considered major drivers for energy retrofitting in shopping centres. Architecture and design touches on a wide number of issues which have implications for the broader understanding of sustainability, and therefore includes issues such as accessibility, ergonomics and safety. The four main areas may also be considered drivers for energy use reductions.
- Reducing costs associated with energy use may be drivers for energy retrofitting, but since costs associated with retrofitting may be barriers it was considered in a net present value evaluation. In this way ensuring that costs of implementing energy efficient measures do not outweigh the costs achieved by energy use reductions.



- A list of variables has been developed for assessing the energy reduction of different shopping centres in Europe. These have been grouped according to different level of efficacy, called sets, to define several energy saving measures. Such measures have been applied to different shopping centres in European regions with different climatic conditions.
- The primary energy and the energy uses for heating, cooling and electricity use have been calculated. The calculation of the total PE of the selected shopping centres showed that the measures for reduction of the installed power density of lighting and appliances, has the largest PE savings.
- A cost analysis has been performed and the results show positive NPV for lighting, infiltration, thermal bridges and allowing increase in summer temperatures. Net present value results can be used to inform the stakeholders about investing in energy refurbishment. However, in the analysis, only single measures have been considered.

Research and technology development

The above described results on the analysis of the context addressed the technology and methodology development. The CommONEnergy deep renovation approach had to be systemic and comprehensive. For this reason we developed solution-sets, grouping advanced technology products to achieve requested high performance targets for the whole building system. The solution-sets are available in a structured framework, namely the virtual IDP library, we drafted in the early design stage of the project activities and finalised as a public repository in the last stage. The virtual IDP library collects the retrofitting solutions to reduce energy needs and increase energy efficiency in shopping centers according to their archetype and specific technology features, as well as climate context. The library is coupled to a general retrofitting approach including:

1. Principles of IDP, its concept and implementation, design and construction procedures
2. Main drivers for deep retrofitting
3. Peculiarities of shopping centers like functions, urban and social context interactions, architectural archetypes and technology features, functional layout depending on different climate conditions and specific needs
4. Methods and tools to support IDP
5. Analysis of possible integration of different functions of the shopping centres and relative systems

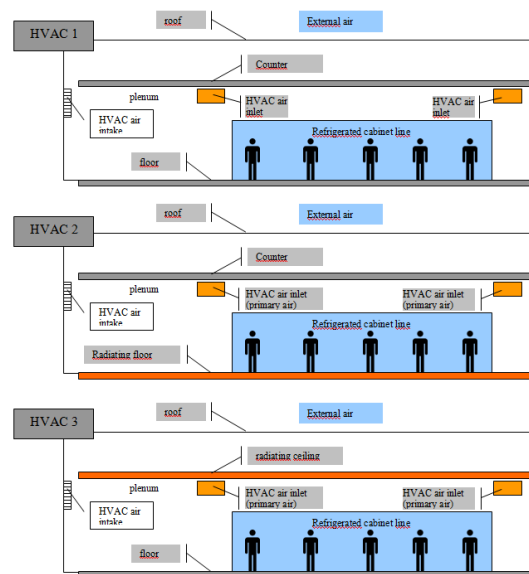
The virtual IDP library relies on a preliminary analysis of the state of the art of the shopping centers design and construction procedures also including the main figures and roles within the retrofitting process. Retrofitting drivers, identified in the mentioned preliminary analysis, guided the definition of solution-sets for effective requalification investments within European shopping centers. Peculiarities on shopping centers are identified by analysing the demo-case and reference buildings.

The library is a web-shared electronic sheet, whose structure allows (i) easy filtering and user friendly visualization of the collected information, (ii) adding further solution-sets based on different buildings (iii) extracting information in automatic way (iv) further informatics developing and moving the information in automatic way.



Because of building complexity it is important to optimise the different areas of a shopping centre considering peculiar boundary conditions and specific functions to perform. In particular, the refrigeration cabinets' area is quite critical because of the conflictual needs related to food conservation, customers' comfort, optimal display and accessibility of refrigerated goods, energy efficiency. Our findings enabled to define the optimal coupling of HVAC and refrigeration cabinets, keeping the highest possible comfort conditions in refrigeration cabinets' zones exploiting potential energy saving opportunities using several configuration. The interaction between refrigerated cabinets with closed doors and three kind of HVAC terminals were analyzed both from energy and from thermal comfort point of view: a) Pure vented system/ Radiating floor with primary air supply; b) Radiating ceiling and c) primary air supply. Two reference scenarios, representing common zone layouts in most food stores, were investigated by means of Computational Fluid Dynamics (CFD) in winter and summer conditions:

1. low temperature (LT) cabinets zone, composed of two lines of door closed vertical cabinets with a line of door closed horizontal cabinets in the middle of the aisle;
2. normal temperature (NT) cabinet zone, composed of two lines of door closed vertical cabinets facing each other.



HVAC analyzed scenarios

From the simulations results, better comfort conditions occur in case of radiant panels compared to full air HVAC, both in the low temperature and normal temperature cabinet aisles scenarios. Vertical and horizontal temperature distribution is more uniform using radiant panels and in winter season the difference between air temperature and temperature of the radiating surfaces is reduced. Analyses conducted in winter season show that, using radiant panels systems is possible to reduce the temperature of inlet heating water from 37.5°C to circa 30°C compared to full air systems. As a result, it is possible to increase the COP of the heat pump thermal unit of about 12.5%. In summer time pure vented system result in discomfort because of high operative temperatures. If an amount of radiating cooling is provided to chilled primary air, the level of global comfort goes from good to very good level. Nevertheless some local discomfort issues occur due to air stratification. A high

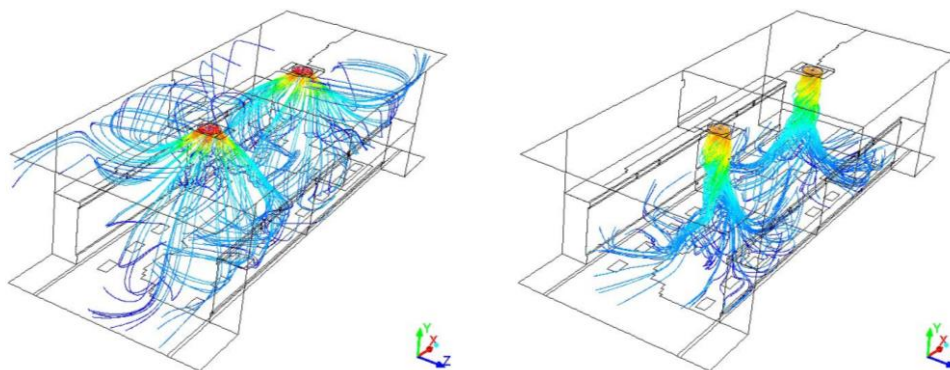


level of comfort results from the radiant ceiling scenario as vertical temperature gradients are reduced due to the lower temperature of the ceiling compared to the other two scenarios.

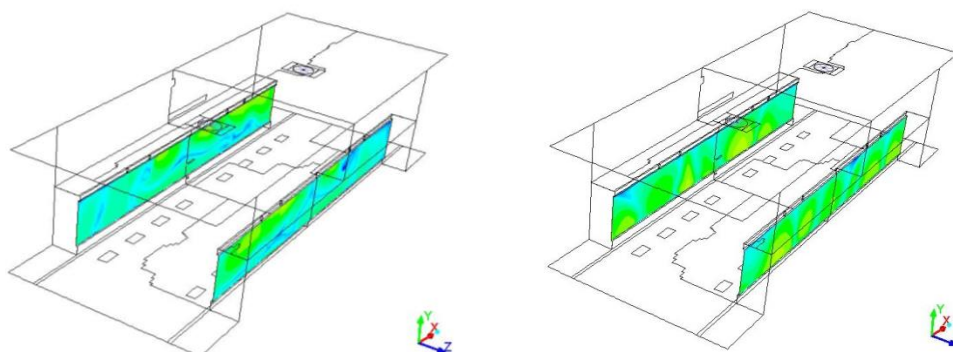
One drawback of using radiant panels is that, in order to provide good performances, their installation depends on the cabinets' layout, as they have to be installed in the area occupied by the customers of the store. In this perspective, radiant panels on ceiling provide a more flexible installation solution than on floor.

Cabinets closed by means of glass doors reduce drastically energy consumption for refrigeration. However, product visibility can be affected by mist formation on the glass. This effect takes place when the temperature at the external surface of the glass falls below the ambient dew point temperature, which is a quite common situation in humid climate in the mid-season, when neither indoor air heating nor cooling is performed.

Reduction or prevention of the risk of mist formation can be exploited by controlling relative humidity in the selling area or by increasing external surface temperature at the glass doors. Control of relative humidity implies dehumidification and re-heating by the HVAC system, which is a very energy consuming operation: heating glass doors requires the use of electrical heaters whose energy consumption in the worst conditions can be even comparable to that of the refrigerating equipment. Adopting both strategies with an effective control can reduce the running costs but implies higher investment costs. Therefore, possible solutions are investigated to reduce the risk of mist formation by promoting air movement on the proximity of glass surfaces, through the use and proper adjustment of specific air diffusers. In particular, ceiling circular supply diffusers are considered. CFD simulations allow to estimate the air path lines and the air velocity magnitude within the zone and the temperature at the external surface of glass doors taking into proper consideration the cooling effect from inside the cabinet through the glass. Temperature maps on glass doors allow to estimate the risk of mist formation through comparison with the indoor dew point temperature.



Air path lines coloured by velocity magnitude for a high (left) and low (right) deflection angle



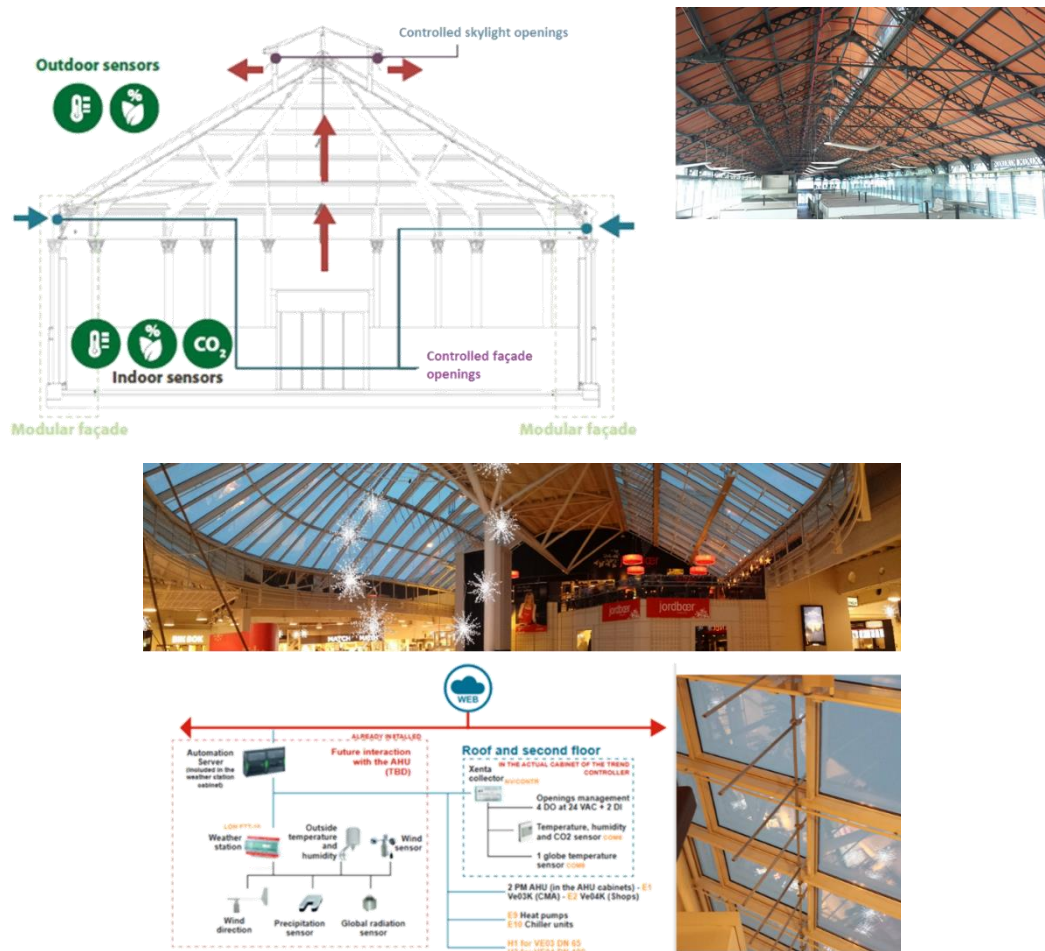
Temperature maps on the glass surface for a high (left) and low (right) deflection angle

Simulation results showed that air diffusers and their operating conditions have a significant effect on mist formation on glass doors. For the simulation scenario referred to normal temperature (NT) display cabinets, the risk of condensation on the doors of the closed display cabinets is far enough. The higher risk of mist formation exists for low temperature (LT) display cabinets. Assuming the thermal resistances would be the same as in the NT case, the temperature of the external glass surface approximate 10°C in winter conditions, and corresponds to the dew point temperature for an internal relative humidity of 51%. In summer operating conditions the situation is worse because of the higher content of water vapour in air. For LT display cabinets in summer it will be difficult to avoid the adoption of demisting resistances without controlling air humidity.

Proper choice of air diffusers and adjustment of their operating conditions can reduce the risk of mist formation, thus allowing to limit the operation of air humidity control and electrical glass heating devices. Significant electrical energy saving can thus be achieved with a very small extra investment cost if full air or ducted air HVAC systems are considered, which is likely to be the case of most supermarkets. No extra running costs are foreseen, and no extra maintenance is needed.

Typical architectural archetypes of shopping centres revealed to be suitable for the integration of natural ventilation strategies thanks to the possibility to place openings in the skylights and on the façade. Ventilative cooling applications were investigated, as technical and economical viable renovation opportunities to cool indoor spaces reducing energy consumption of cooling systems while maintaining thermal comfort.

Naturally ventilated buildings require a specific design service dealing with the building shape, internal layout distribution and airflow paths along the building. Following the developed design procedure, three ventilative cooling scenario solutions were designed and two of them were implemented on two demo cases: Mercado del Val (Valladolid) and CitySyd (Trondheim).

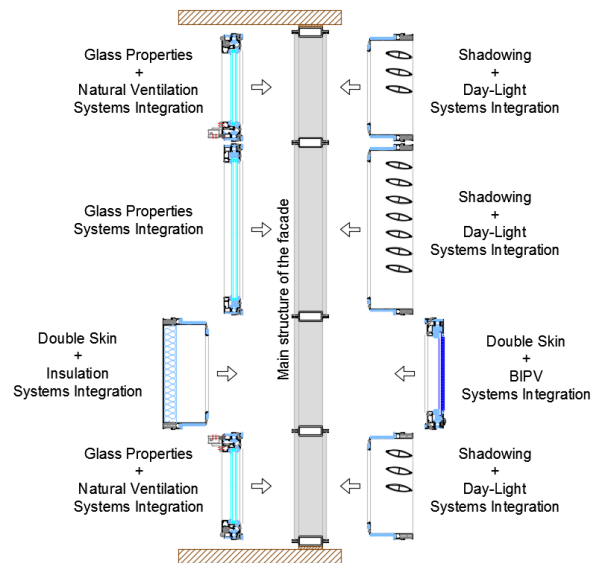


Natural ventilation strategies for shopping centres, as implemented in Mercado del Val (above) and CitySyd (below) demo-cases

Beyond the consistent energy savings and the power-peak shaving, natural ventilation design services will provide shopping centre owners with a mean to improve customers' thermal comfort sensation. A higher indoor environment quality offers opportunity for further profits from customers (through sales increase, higher dwell time, footfall etc.) and workers (through lower retail worker absenteeism, staff turnover, etc.) experience.

Natural ventilation strategies can be implemented in the façade system. Indeed, this is part of the industrialised prefab concept we developed, namely the modular multifunctional climate adaptive façade. The drivers for the façade system development were to make shorter and leaner (less failures and waste) the construction site, reducing the impact on customers and on usual retail activity.

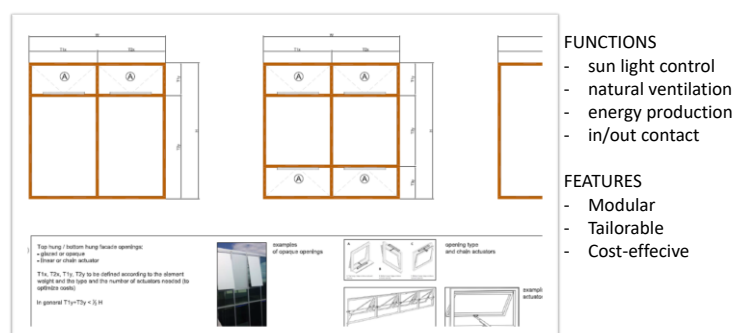
The façade system for retrofitting applications in commercial buildings has a parametric structure that allows tailoring the façade features depending on: (i) climate conditions (ii) building functions (iii) local building code (iv) and heritage constraints



Final schemes on design of the multifunctional façade energy concept

In terms of use, the façade has a light weight sub-structure and allows fast assembly possibilities, but also gives the unique opportunity to adjust the system to local climate conditions and to urban characteristics through its flexible and modular system. Some features of the technology include the adequate proportion between the opaque and transparent surfaces, shading systems to control and exploit solar gain, thermal storage, RES integration, single and double skin systems with proper air gap integration and giving ventilation possibilities. This creates a façade concept that can operate either actively or passively, depending on the climatic context and possibility for exploitation of local sources.

The innovative potential of the system is based on the possibility of integrating in an envelope component several energy efficient technologies. The technology configuration is determined by specific climatic conditions, building typology and possibility of architectural integration, also considering urban surroundings and investment approach. The constructive structure is compatible with other technologies, those accessible currently on the market, but also much more opened to the most advanced concept at a lower TRL yet. The façade element can be also connected to the building management system iBEMS (developed in CommONEnergy project), working as a high-level controller, and increasing the energy effectiveness and adaptation capacity to dynamic weather conditions.



Engineering and generalization of the façade system concept starting from the implementation in Mercado del Val

The benefits are justified in terms of energy and cost savings, as well as enhancement in building and built environment quality, with a higher residual value at the end of the life cycle. The system was evaluated in controlled boundary conditions through outdoor test facilities, and optimised from functional and constructive point of views. Collected data were also used to validate a detailed Trnsys model for performing dynamic simulation to study overall performances and replication potential.

Data were collected from February to September 2017, with A/C active from May to June and switched off for the rest of the time. The monitoring results analysis clearly indicates the high energy saving potential, namely approximate 50% in specific periods of the year, and taking into account the particular technology configuration (the CommONEnergy façade test room consumed ca. 32 kWh in period May-June 2017, while the reference state of the art product room consumed ca. 60 kWh). To further investigate this aspect, we realized a second prototype focused on PV module integration and tested adding the following features:

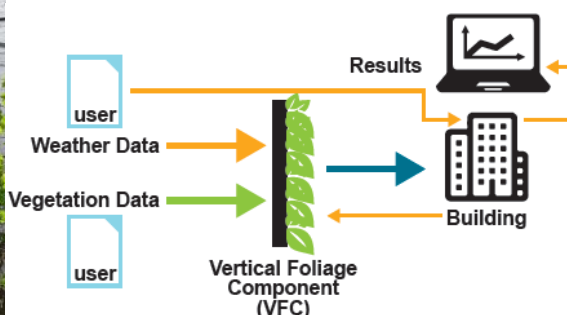
- mppt+battery system was integrated in the façade itself rather than placed in the test room;
- the facade was here conceived as a “stand alone system” with the window actuators connected to the battery fed by the PV module energy autarky, while in the first façade prototype the façade system was connected to the grid;
- the PV module had retro-ventilation and it was compared with a PV module without retro-ventilation.

This further experimental activity gave the possibility to compare different configurations of the PV façade focused on temperature-related issues (facade with and without PV module retro-ventilation) i.e. temperature assessment of battery, air in the gap between the PV module and the insulation panel, PV module, envelope surfaces; it was demonstrated that the presence of a retro-ventilated cavity behind the module can have positive effects on air temperature, avoiding possible damages of batteries and electrical components due to overheating. Moreover, also the indoor ambient adjacent to the cavity can be positively affected by the decrease in temperature given by ventilation.

The CommONEnergy multifunctional façade system, in terms of its concept and configuration, was successfully integrated into the real market in Valladolid “Mercado del Val” in Spain, first being positively accepted by the local design team, building owners and tenants.

Further than at system level we worked on the envelope materials too, investigating the greenery integration and developing multi-function coatings.

Green integration means direct use of vegetation for improvement of thermal performance of building. It may be applied on full façade or partially and reduce solar gains up to 35%. Vertical foliage on wiring is the most feasible solution for shopping centres and for shopping centre retrofitting in particular. It is recommended to use that solution on blind walls of shopping malls.



Example on green integration into the façade system connected to VFC components

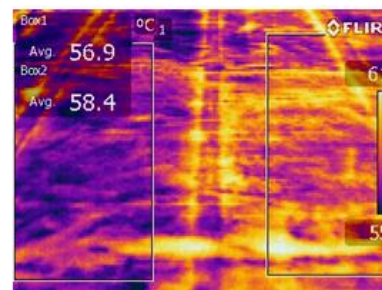
The efficient greenery integration must be supported by detailed feasibility study for final performance prediction, both technical and economical one. A supporting tool (VFC component for Trnsys software platform) was engineered, for proper parametrization of building heat balance versus type of plant and its coverage area. For engineering usefulness of software, the relevant data base collecting type of plants and physical data for climate and season impact matching is also available.

It is low cost solution. Estimated investment costs are within 120 €/m² threshold, yearly maintenance costs on av. 20 €/ m², and an estimated return of investment of ca. 2 years. The energy efficiency impact is reduction of fossil energy consumption for building cooling and partly heating. The social impact is the outdoor microclimate quality improvement thanks to natural regulation of temperature and humidity, air pollutants absorption and, indirectly, increasing “good mood”.

Even though coatings are in use mainly for aesthetic reasons, recently specialized coatings can be found on the market claiming to face several problems of the building envelope. Even so, no coating or paint exists to address multiple or combined properties. Therefore, in the framework of the project a new multi-functional formulation was developed for an additive with advanced surface properties suitable to be integrated to any aqueous based paint. For almost every substrate, excluding glass and laminated surfaces such as wood, plastics, etc., which were excluded from this research due to the synthesis of the resins used for their production, as, proved to be incompatible with the multi-functional formulation synthesis. Thus, the final user has the ability to pick from a list of properties, those suitable for the climate conditions of his area, and just add the formulation in the desired commercial coating product. The possible characteristics that the final user can chose from are, thermal behaviour enhancement, IR reflective or IR absorbing, anti-bacterial / anti-moulding, self-cleaning / VOC elimination, hydrophilicity / hydrophobicity.



Smart coating development



On roof thermal test in Modena



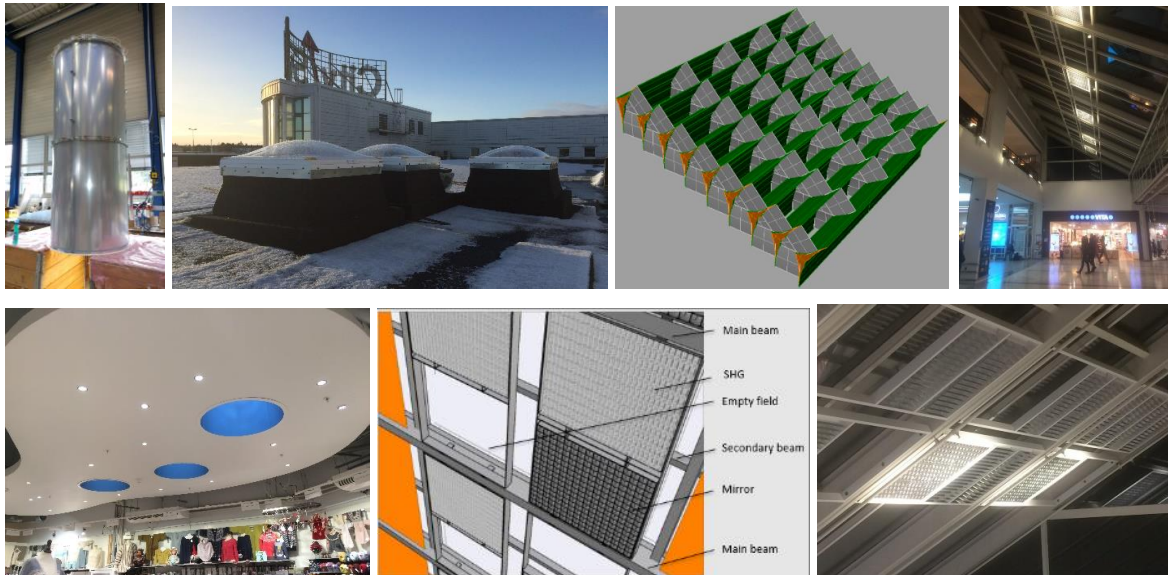
The conventional paint and smart coating comparison, 6 m after installation, in Modena

Example on smart coating paints implemented into the roof system in Modena “Canaletto” demo-case

The coating was tested and evaluated within the project. Tests were performed on visual properties, thermal behaviour, reflectance behaviour, porosimetry, water absorption, water vapour permeability, coating hardness, adhesion, anti-mould / antibacterial behaviour, drop shape analysis and for organic pollutants disintegration. The results were totally satisfying. For investigating and proving the gains that could be achieved a theoretical model, but also the results from whole building simulations of the reference shopping centre “Katané”, located in Catania (South part of Italy) were used. The coating was tested in real conditions in Modena demo-case where a part of the roof was painted with conventional and a part with the treated paint of the same type. For this demo case IR reflective, antibacterial, anti-mould, self-cleaning, hydrophobic and insulating properties were chosen according to local climate conditions. The performance was evaluated with thermal camera and surface temperature logging with very satisfying results, while 6 months after installation the conventional paint had already started to deteriorate because of the lack of self-cleaning and antibacterial property, in contrary with the treated paint which maintained its properties and aesthetic aspect.

Another aspect we investigated to enhance the envelope feature during the building renovation, was the control of solar gain to exploit daylighting, avoiding overheating and glare, while coupling with artificial light to maximise user comfort. The very high lighting energy consumption and rate in the energy final-uses break-down means also very high saving potential. Then, a new daylight strategy can have a strong impact on both energy savings and internal comfort of shopping malls, helping to maximise the space quality by harvesting daylight in the right amount and intensity distribution and using daylight for energy savings by an aligned artificial lighting concept. Basically two main areas of interest were identified in a shopping centre: indoor mall areas (atrium and corridor) and shop areas. For each area a specific daylight system was developed: a) for the mall area a louver system; b) for the shop a light tube system. In addition a specific concept for a market hall was investigated which is a mostly fully-glazed hall with special requirements for a heritage-protected building. The three systems are listed in the following.

- Light pipe with shading screen and integrated artificial lighting system for application in a shop.
- Solar Harvesting Grid (SHG) as part of the modular roof system for large glass-covered galleries.
- Modular Roof system.



Daylight systems implemented into the roof system. Light tubes under preparation and implemented (left) and modular roof (right).

Exploiting daylight in shopping centres significantly improves the environment by increasing visual comfort and non-visual (health) light impacts, as well by increasing architectural quality. As a side effect, the energy demand can be reduced, too.

Finally, we investigated a new concept for envelope elements with thermal and acoustic features, dedicated to shopping malls (or more in general to commercial buildings), incorporating two different functionalities: acoustic absorption and reduced thermal conductivity. Several concepts were manufactured and evaluated, combining the materials to compose different packages. The solutions were tested with a customized cement plaster, which should improve absorbing characteristics of the concept. The work, in its initial phase, clarified some facts that should be taken into account in designing shopping centre renovation:

- Although there are no specific standards on the matter yet, there is a growing interest in 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 typologies 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, in case of renovation of the building envelope, it becomes financially interesting to select thermal insulating finishing materials having at the same time a sound absorbing attribute.

There are few envelope materials available on the market with thermal and acoustic. Specific survey involving skilled market players, allowed finding the most relevant solutions and application for shopping malls:

- Wood wool boards with mineral wool insulation (in parking, also because of fire resistance feature).
- Glass mineral wool roll (in technical room).
- Melanine foams or panels (for false ceiling or internal wall cladding).
- MDF, Plywood Solid substrate, finished with real wood veneer, laminate leather, solid print or high gloss finishes (as high performance nice finishing for top level shopping centre).

We analysed several concepts as combinations of glues, paint and plasters with ISOBEL[®], also evaluating applicability and aesthetics. One of the most promising use ISOBEL[®] layer (with its thermal features) as the underlying layer of an additional layer fully dedicated to sound absorption, namely ARTOLIS[®] Acoustic by Barrisol.

Layers composition was the following:

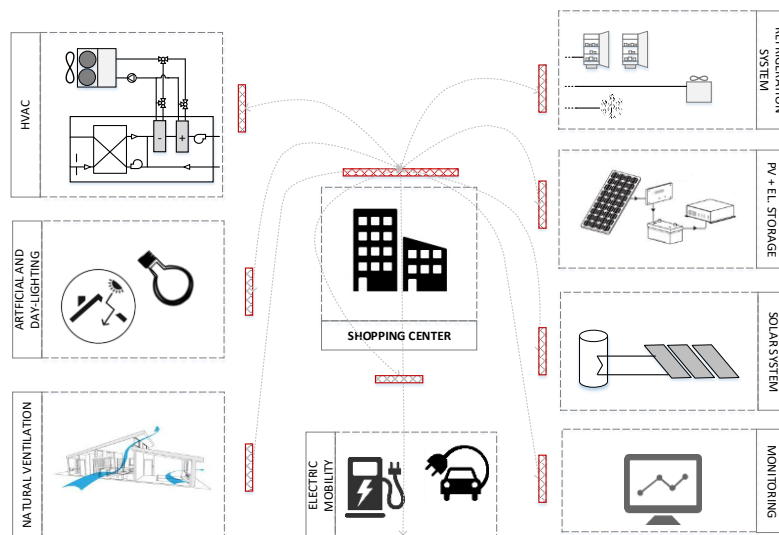
- TRADITIONAL WALL simulated by plaster board
- MECHANICAL FASTENING by using individual glue spots or specific nails or even lateral rails
- ISOBEL[®]: Bubble microsphere based-absorbing layer
- ARTOLIS[®]: Polyester knitted fabric coated with polyuréthane (PU), without air gap between ISOBEL[®] and, at the same time, without full adhesion (neither mechanical nor bonding)

The application trials of this solution demonstrated that, for practical and aesthetical reasons, the air gap between panel and structure must be zero. A recommendation in this sense was also given by designer, with the evidence that users do not wish to have a “soft feeling” when touching the wall.

The coupling of a sound absorbing fabric (having proven capability of sound absorption) with a thin layer of ISOBEL[®] (having thermal insulation and capability to close and repair small cracks) enable to achieve optimal combination results: the system keeps all benefits of ISOBEL[®] (thermal insulation and mild acoustic absorption) and moreover it is possible to classify this configuration as sound absorbing. The external finishing (ARTOLIS[®]) is already proven in the market, is very pleasant to see and may have infinite printing and shaping possibilities. One inconvenience of this solution is related to the obligation to hire specialized (expensive) contractors for setting the first layer of ARTOLIS[®] fabric.

The results achieved in terms of energy efficiency ranges from tools for managing complexity, and developing control strategies in design and operation phase, to technology solution for reducing main energy end-uses (refrigeration for shopping centre including food store and lighting for the others).

To manage the complexity of handling an organized energy system like a shopping centre we structured an integrative modelling environment (IME). It enables to make easier and faster building models and performing simulation campaigns, assessing and comparing energy performance with different renovation solution-set, developing control strategies and analysing the related effect, as well as supporting their set-up and implemented renovation solution-set commissioning.



Graphical illustration of the IME

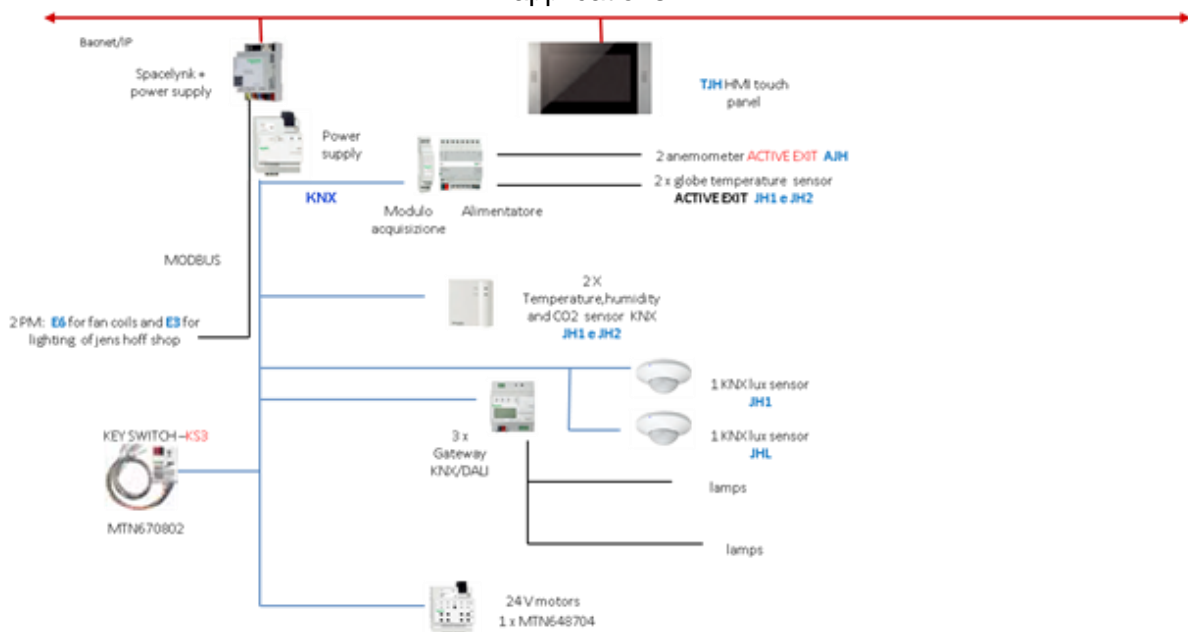
The modelling of a shopping mall before and after retrofitting through IME allows:

- i) to characterize energy savings in order to support decisions at different design stages;
- ii) to define and optimize control algorithms at whole building or sub-system level;
- iii) to address optimal scenarios by overall energy system parameterization;
- iv) to assess thermal comfort conditions.

The subsystems developed within the IME concern both solutions aimed to reduce the building demands (named “envelope solutions”) and the ones for enhancing the systems performance (active solutions). The formers developed within the CommONEnergy project include a multifunctional climate adaptive facade (with shading and natural ventilation control), greenery integration on the external walls, smart coating materials, daylight technologies and ventilative cooling strategies. Within the project, numerical models were developed for simulating greenery and smart coatings effect, while for the daylighting, ventilative cooling and shading systems, specific strategies have been created and implemented. In the IME, active solutions were implemented in terms of numerical model of each sub-system components. Base elements as the Trnsys-Types were used mainly for HVAC systems, RES, lighting and storages, while special components were developed within the project mainly for the refrigeration system (display cabinets, cold rooms, cascade and booster cycle). Each sub-system has an internal control to simulate the actual intrinsic functioning at single technology level, while a main control regulates the interaction of the different parts and guarantees an appropriate operating work of the whole system. A nomenclature developed within the project defines univocally parameters and set values of the technologies. Moreover, the elements are set in order to run parametric analysis for the optimization of the components size or control rules. The validity of the building models was verified by a calibration procedure, which aims at optimizing the most sensitive parameters against utility data. Equipment performance is defined following datasheets provided by manufacturers or based on lab-tests. The modularity of the modelling environment architecture and their “prefab components” enable a very high replicability, also reducing the possible failures in the numerical analysis process.

The mentioned complexity is also faced during the operation phase through the building management system, namely the iBEMS (intelligent Building Energy Management System)

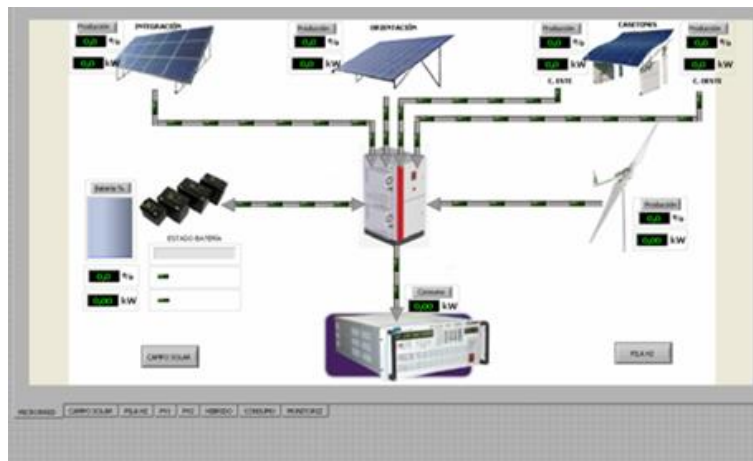
we developed in the project, enabling to exchange data and commands among building sub-system (machine-to-machine interface), but also featuring a user friendly user-to-machine interface for communicating the relevant information to different stakeholders. The iBEMS is a comprehensive solution that includes the management of power, lighting, HVAC and refrigeration systems for the entire shopping centre, as well as for building correlated services (parking, RES harvesting and local energy production, etc.), with a level of efficiency that involves system dynamics across all applications. The iBEMS works as a high level controller which allows for instance the energy exchange between the systems' applications.



Architecture of iBEMS designed for shopping malls

In the long-term, the iBEMS creates a report to demonstrate the proper operation of the systems or to detect systems' malfunctions and possible optimizations. Thanks to a continuous monitoring of all systems' operation, the facility manager can assess the actual performance, adjust the control strategies, and plan an effective maintenance programme to achieve and keep the required energy performance.

Taking in consideration the potential local energy production exploiting RES as well as potential integration of different kind of energy storage systems, shopping centres can be considered as energy hub for the local power grid. The interaction among mentioned systems was emulated in real time using a small micro-grid laboratory to evaluate the effect of different sub-systems integration in the power quality of the electricity distributed inside a shopping centre.



Graphical illustration of energy transfer in microgrid application

The micro-grid emulator, in particular when coupled with numerical analysis, can be used to verify how local energy production or storage systems could affect the power quality and the compliance of related requirements for different shopping centre sub-systems. Such a methodological approach can be used together with the IME for a more comprehensive analysis to support the design and performance assessment. Different scenarios for local smart grid solutions can be defined depending on size of included systems, load and local energy production profiles, type of energy consumption, location, generation/storage systems, energy tariff scheme and operation/control strategies.

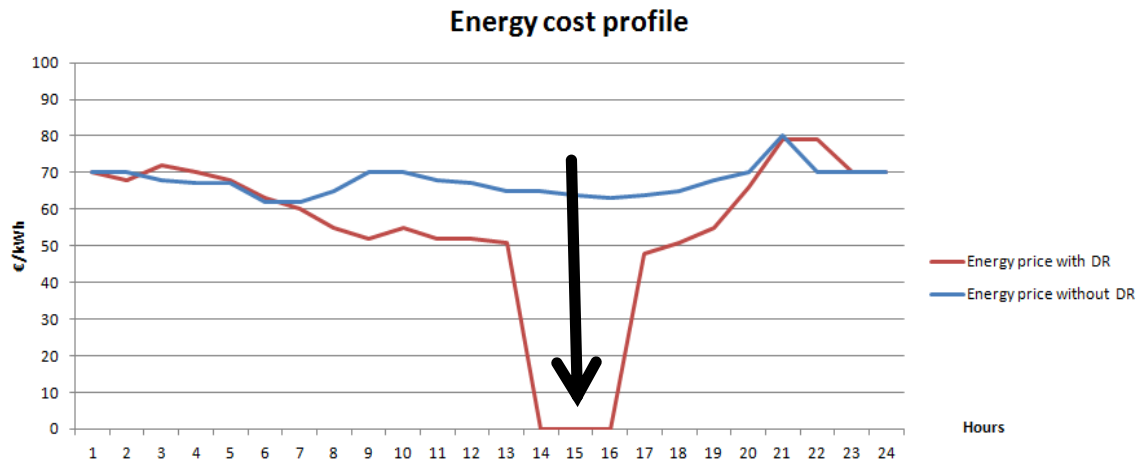


Elements of electrical smart grid scenarios for shopping centre

Within the smart grid scenarios, methodologies for the evaluation of the energy demand, following the energy forecasting and demand response approaches were identified, according to EU directives 2012/27 on energy efficiency. Demand/Response (D/R) enables to motivate end-use customers to reduce their energy usage at critical times, when energy price or energy demand are at their highest level or grid reliability is reduced. The participation of the end customers (e.g. tenants and owners) is a response to factors such as incentivizing pricing, new tariff schemes, greater awareness and an increased sense of responsibility. For example, when customers enrol a program based on D/R they will receive



a flat award budget per year just for participating. Moreover they will receive further financial benefits for reducing their energy demand during a specific event. It means that there are some hours during the day, when the energy cost can be assumed as zero.



Comparison energy cost profile with and without DR approach

The combination of different concepts will lead to the composition of different general scenarios, both electrical and thermal, which could be applied in shopping centres. Electrical scenarios based on PV-Wind Turbine-Storage or Electric Vehicle-PV-Storage were investigated. Different thermal scenarios mainly based on heating with storage and refrigeration were also assessed. Finally, electrical and thermal scenarios based on cogeneration and tri-generation with or without RES were explored, as elements of smart grid concept.

From technology point of view we detailed the technical-economic analysis, developed concept, prototyped and demonstrated the use of batteries as large energy storage in shopping centres, also coupled with eV charger. The transition from fossil fuel to low-carbon technologies, mainly through RES generation might require a wide utilization of energy storage systems (ESS). This technology is potentially able to improve flexibility both at shopping mall and at the distribution grid level. Thanks to the RES integration and the ESS, in the near future shopping malls will play a central role as energy hubs for smart energy district. In particular, the use of ESS can lead to different advantages under technical and economic aspects. Among these benefits, we can identify energy cost savings, consumption peaks shavings and increments in the energy produced and consumed on-site without transfer losses (i.e. self-consumption), and with a potential reduction of environmental impact. Moreover, ESS can be used to improve reliability (e.g. as backup generators) and to mitigate possible power quality issues due to harmonic distortion or rapid voltage changes. In some European countries the use of ESS is encouraged by the high-energy price or by the presence of high RES (i.e. PV) penetration. However, in some other countries the diffusion is hindered by the presence of different administrative condition and specific regulations, such as, for instance, the net-metering rule, which valorises the energy injected by PV in the grid. It is also remarkable that, currently, the price of the ESS, depending on the technology is still considerably high. Despite this, it is obvious the importance of this technology in the future not only on a large scale, but also at local and even building level.

Of course, our research work had not the ambition to address all the problems mentioned before. Nonetheless, it investigated the potential use of ESS. Ranging from more theoretical to experimental aspects, the main achieved results can be summarized as follows.



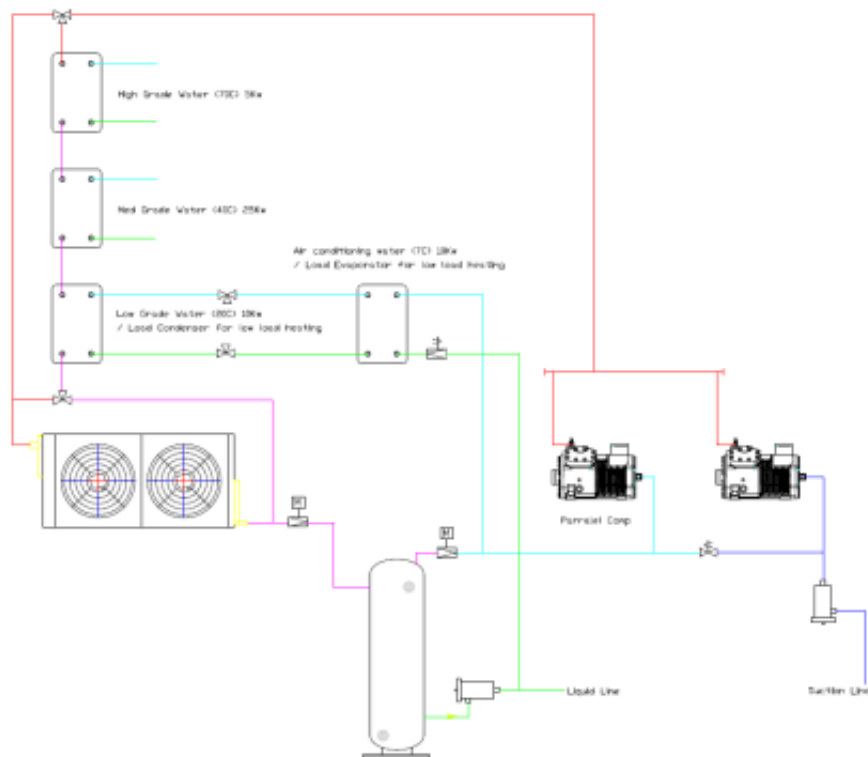
First of all, using the same modelling environment (common to the whole project), a feasibility analysis of the benefits and possible applications of both battery energy storage system (BESS) and hydrogen storage were evaluated through parametric simulations based on the energy consumption of some reference buildings. From the simulations, it results that due to the large energy consumptions of shopping malls, the advantage of using ESS to increase PV self-consumption is negligible with the current load profiles. However, it becomes interesting after suitable deep energy renovation actions. This result is less obvious when an economic analysis is performed. Indeed, considering the Italian context, the cost of the ESS is still too high to be competitive if net-metering rules are applied by authorities. However, this scenario could change if the ESS price decreases or if the net-metering rules disappear. In this case, it is demonstrated that the payback time would be shorter than seven years. Moreover, the parametric analysis was useful to identify one the best applications of BESS in Italian shopping malls i.e. sustainable electric mobility, as confirmed by the setup implemented in a demo-case shopping mall in Grosseto (Italy).

Several analyses based on another case-study developed in the UK allow us to conclude that another valuable application of ESS in shopping malls is the storage of hydrogen for internal mobility (e.g. to fuel fork lift).

An important experimental campaign on a downscaled prototype of PV-BESS-EV charger system was also performed in a special outdoor test facility, with the aim to check and to integrate in a smaller and controlled environment a full system in order to improve the design of each component, the communication compatibility, the proper control rules and the correct management of the battery and the whole system.

Finally, we faced power quality (PQ) issues, a topic of particular interest in the context of shopping malls (considering their future role as flexible energy hubs) due to the presence of large non-linear loads (e.g. refrigerators) and to the penetration of RES and storage systems. To investigate this topic, PQ measurement are collected in two real case studies and compared with the current technical limits.

Moving from power to thermal energy efficiency we started from the concept that in shopping centres, different sub-systems provide thermal energy at different temperature levels and they usually reject thermal energy to the environment. The heat exchange solution to couple different sub-systems (as HVAC and refrigeration) can recover the rejected energy and use it as the free source for other sub-systems.



Concept layout of three stages heat recovery system

Thus, this technology can reduce significantly the energy consumption of the systems as well as shave the peak loads if applied. Dedicated control rules are applied to assure that this energy exchange will not affect the operation level of connected sub-systems.

We started from the state of art of the refrigeration system, focusing on actual technologies with pro and cons of each solution:

- Today the trend of the building in the EU is getting closer to the n-ZEB (nearly - Zero Energy Building). This means that refrigeration is becoming, year after year, one of the most important, and one of the few loads in shopping mall buildings, characterized by the presence of a big food retail shop.
- Refrigeration systems are usually a standalone system with rough connections to other systems. The connections consist in most of the cases, in passive heat recovery based on heat exchangers. Only in a few cases, connections allow active heat production on demand.
- In southern European countries synthetic refrigerant with high GWP value are widely in use;
- In northern European countries natural, efficient and economically affordable solutions based on R744 transcritical systems have been widely used for some years.

As a consequence:

- In southern European countries, several efforts are on-going to develop solutions to allow the use of systems based on natural refrigerant or ultralow GWP synthetic refrigerant;
- Standardization of the coupling between mechanical systems to enhance thermal exchange. Optimization of thermal cascades through easy coupling of the refrigeration and HVAC equipment to define an HVAC+L+R synergy system.



Proposed concepts focus on:

- Long term solutions for environmentally friendly refrigeration as a standalone system also in a warm and hot climate;
- Integration of refrigeration with the most common HVAC system of a shopping mall.

Several concepts were investigated, the most promising were prototyped or installed in field tests for further analysis.

- R744 trans-critical system for a small store, consisting of an all-in-one solution able to actively provide three temperature stage heat recovery plus A/C thermal power;
- R744 trans-critical heat pump for domestic hot water production on demand. The unit has been investigated as standalone unit and as coupled with refrigeration system;
- R744 trans-critical heat pump for a heating system. The unit has been investigated as a standalone unit and is coupled with a refrigeration system;
- Prototyping of an R744 trans-critical, as well as R410A variable speed water loop technology. The unit has been investigated both for low temperature, and medium temperature application.

The following field test has been done:

- R744 trans-critical system with LPT technology has been tested directly in a real store in Northern Italy;
- Distributed refrigeration through water loop variable speed technologies has been tested directly in a real store in Central Italy;

The outcomes of the R&D activity is a guideline to select the correct solution based on the main boundary conditions:


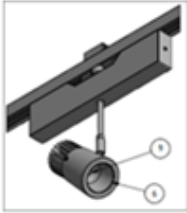
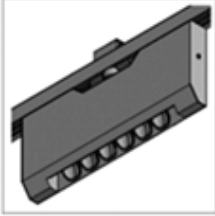
- Climate conditions of the site;
- Ratio between refrigeration load and heating load;
- Ratio between refrigeration load and cooling load;
- System size based on capacity installed for heating, cooling, refrigeration and DHW.

In southern countries, environmentally friendly refrigeration system were shown to be technically achievable with the actual technology. The improvement required to compensate the low efficiency of the environmentally friendly system in warm climates are not far away from a reasonable pay back. Further R&D and industrialization activities are required to simplify the components, reduce capital cost and payback time. Complexity of the system still remains an issue. Well engineered units shall reduce the effort during the maintenance but a training programme to prepare qualified technicians is mandatory.

For the integration of refrigeration with the most common HVAC system, two alternatives were shown as promising. In stores where there is a balance between cooling/heating and refrigeration power, it is possible to have an all in one solution able to supply all the thermal power required by the system with just one device. Such a balance between thermal loads is achievable with n-ZEB buildings and shall become the common scenario in the near future. In stores where cooling/heating power is higher than the refrigeration load, a heat recovery solution based on a natural heat pump can be used.

As it was already highlighted further then refrigeration, the end-use for lighting is one of the highest one, in particular for a shopping centre without food store. In this context, considering the specific needs of the shopping malls 3 specific types of luminaires were developed and tested. These lights can be applied either for generic use or for specific presentation of products in selling areas of shops. Moreover, the specific lights, incorporate 2 different colours of operation in order to satisfy potential requirements for warm or cold white light.



Luminaires types		
Ceiling-integrated spot	Spot @ powertrack	Wallwasher @ powertrack
CIS 1-19 (19 luminaires)	SPOT 1-14 (14 luminaires)	WW 1 - WW 21 (21 luminaires)
		
Light distribution 2x20° pivotal at 20° angle LED, CRI > 90 2700K + 5700K (1000lm + 1300 lm) (LED) Dimmable via DALI 230V / 50 Hz	Light distribution 2x20° Surface RAL 9010, Eutrac 7 LED 2 x 15W, CRI > 90 2700K + 5700K (1000lm + 1300 lm) (LED) Dimmable via DALI 230V / 50 Hz	Light distribution: Wall, 135° Surface RAL 9010, Eutrac 7 LED, CRI > 90 2700K + 5700K 4800lm @ 4000K (LED) Dimmable via DALI 230V / 50 Hz

The luminaires developed for the CommONEnergy project

The lights can reduce the energy consumption due to their led technology and also they can dim according to the needs of the illuminance incorporating also daylight energy savings.

Shopping malls consist of different main areas, i.e. the common mall area and the single shops, and present different architectures, i.e. multi- or single-storey, all posing different challenges. This lead to the development of four artificial lighting systems for shopping malls within the CommONEnergy project:

- General Retail Lighting: a luminaire for general lighting in the common mall area
- Projector/Mirror-System for glass-covered multi-storey galleries
- Wallwasher with high-lumen output for precise illumination of vertical surfaces in shops
- Integrated artificial light for light tubes in shops making a separate artificial lighting system superfluous and letting artificial light appear like natural light

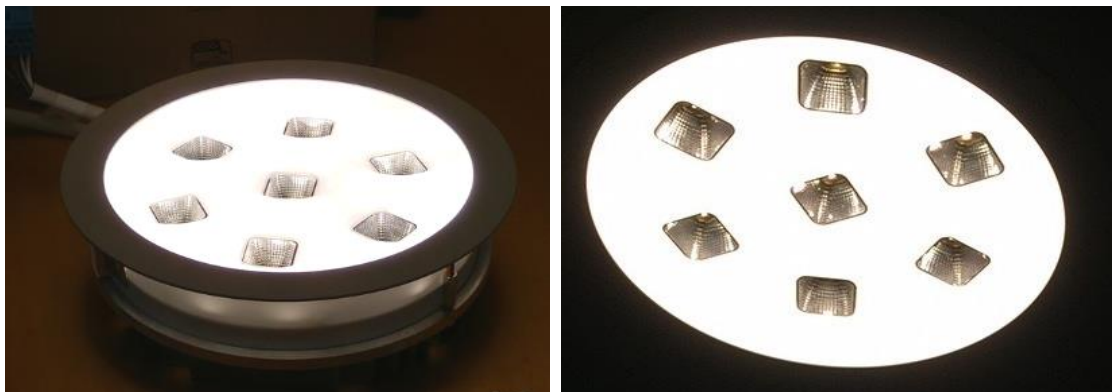
Common Mall Areas (CMAs) include the corridor, which connects the single shops and does often not possess access to daylight, and multi-storey galleries, which cut in an open space in the malls and allow daylight to enter deep into central courtyards. As to now several inefficiencies can be identified for CMAs. Older shopping malls rarely use daylight as a primary light source as they have few daylight openings, while in newer buildings daylight should and – in many cases – is already considered during the planning process. Secondly, many lighting systems used in CMAs use outdated lighting sources (including ballasts, drivers and controls). Many of those light sources, e.g. compact fluorescent lamps, lag behind the state-of-the-art LEDs that are used in new light installations. Furthermore, lighting systems with outdated luminaire design are still predominant in CMAs, e.g. the usage of inefficient filters to switch the colour temperature or suboptimal reflectors. In many cases there is a lack of an overall lighting concept between the CMA and the shops, leading to a “rivalry” in lighting intensity levels and excessive energy use. Further shortcomings of present CMAs concerning lighting are the use of inadequate surfaces, i.e. use of specular



surfaces that can misguide attention, disturbances by direct glare and the lack of support of biological rhythms.

The artificial lighting systems developed within the CommONEnergy project face these efficiencies. The developed solutions not only satisfy the customers' visual and non-visual needs but are also optimized in terms of energy efficiency. To achieve this, the new lighting concepts contain the replacement of outdated light sources and luminaires with dimmable LED technology, the restriction of the general horizontal illuminance target to 300 lx during daytime and 150 lx during night time, harmonizing the light intensities of the shops with the CMA and among themselves, the implementation of three different colour temperature milieus (daytime milieu, night time milieu, milieu in daylight zone) and a control strategy to dim the lighting according to lower requirements during service hours.

For the corridor three product ideas were developed with CommONEnergy: a Light Tile, which would provide a glare-free performance and possesses a specific cover that would add sparkle to the appearance and provide a high vertical illuminance, but was discarded due to the high investment costs and the average luminaire efficacy; a new LED Micro Downlight with special mounting options, that revealed a very good glare reduction, however, showed failing in terms of efficacy, cooling and uniformity; the GRL Luminaire that combines a backlit surface and downlights provided the optimal solution in terms of visual comfort and energy efficiency by combining functional lighting for visual tasks and diffuse light for the reduction of light pressure and provision of orientation and improvement of modelling.

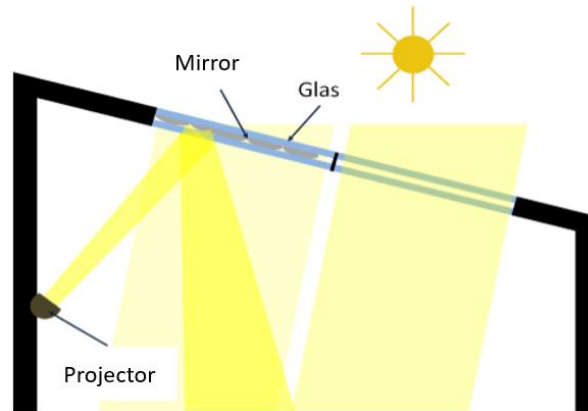


The GRL Luminaire

Design objectives of the luminaire are the use of very efficient LEDs as light source (125 lm/W), a high light output ratio of 85% due to special reflector design and the ability to adapt colour temperature from 2700K (evening scenario) up to 6500K (during day in daylight zones) in order to achieve synchronization of indoor ambience to daylight condition. Change in colour temperature supports positive biological impact on building user and simultaneously allows energy saving during evening scenario while operating luminaire with reduced luminous flux for better comfort (Kruithoff curve). The following control strategies ensure high energy-efficiency in operation:

- in daylight area the luminaire is dimmed according daylight condition;
- usually the system is oversized to compensate the light level drop while aging. With the “constant lumen output” control strategy the lighting system is tuned to the exact lux level desired from day one;
- during stocking, arriving and leaving of staff the intensity is reduced to 50%.

For multi-storey galleries an energy-efficient retrofit of old inefficient Projector/Mirror-Systems was developed. For this a LED projector with a beam angle of 6° using a hybrid principle that combines a multi-faceted reflector with a glass lens for high luminaire efficiency with an efficiency of about 85% was conceived as well as a mirror with aluminium facets with silver finish with efficiencies up to 95%.



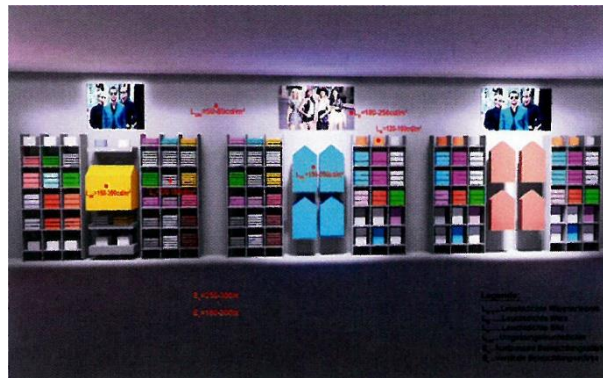
Function schema of projector-/mirror-system

Pilot Installations of the artificial lighting systems for CMAs were on one hand a demo building in Modena, where the open gallery was equipped with GRL luminaires and on the other hand a demo building in Trondheim, where a 230 m² CMA was equipped with the GRL luminaire and 6 mirror fields will be integrated into the modular roof system and 12 projectors that provided artificial light in a narrow beam towards the mirror fields.

Secondly, new artificial lighting systems were developed for application in shops, which often do not have daylight openings but have an open entrance at the store front. In many cases the merchandize is arranged by means of “visual merchandising” to achieve the best staging of goods. Here, the wall is an important element as it functions as a presentation surface with many potential height levels.

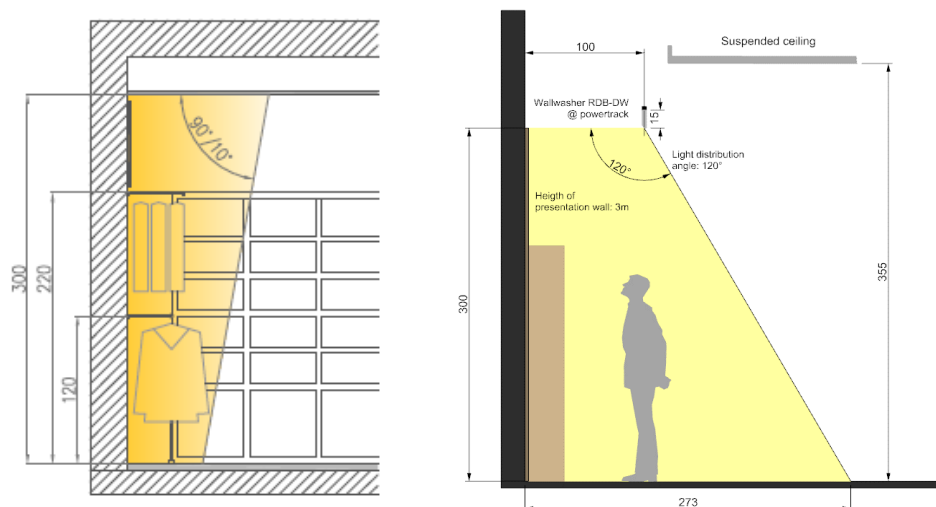
Common shop illuminations, however, have several inefficiencies that were analyzed within the CommONEnergy project. Small specialized shops often only have spot lighting which results in a quite cheap and unstructured display and a restless and irregular appearance with high mean illumination values, while some small areas have insufficient lighting levels. Furthermore, most spot luminaires use low budget technology and possess low efficiency below 60%.

The new lighting concepts developed in CommONEnergy should be promoted by the center management to create a common adaption and illuminance level within the CMA and the single shops. It is essential to include daylight through intelligent daylight systems into the shop lighting systems as much as possible. Through a newly developed zonal concept the perceived brightness is increased while at the same time the overall lighting intensity is reduced by creating zonal areas with higher intensity. The ideal illumination concept and the energy saving potential was determined by a laboratory perception study (30%).



Lighting Zonal Concept in shops

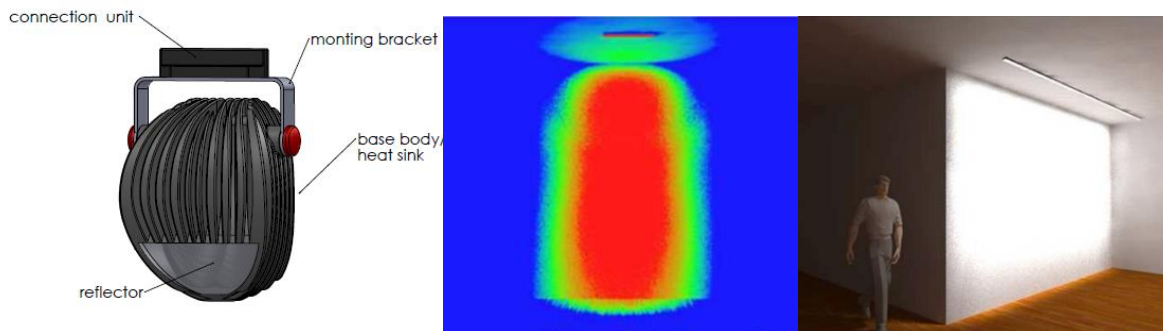
Furthermore, luminaires with enhanced properties for retail applications were developed during the project, three ideas for new luminaires were conceived: a flexible LED spot, which would allow to make the light distribution manually adaptable to different beam angles and therefore allow the shop owner to adapt the lighting themselves, however, the flexibility was too low compared to the costs; a flexible Light Shelf, that would allow to serve different rack heights and corridor width, however the user-friendliness was considered to be insufficient; a LED Retail Wallwasher, that allows a very homogenous illumination of the wall as well as the merchandize on the shelves in a very efficient way.



Comparison of conventional beam angle of a wallwasher with extended beam angle of the newly developed retail wallwasher

The Wallwasher luminaire consists of 6 micro-faceted free form reflectors of the type RDB-DW developed in the CommONEnergy project. It combines the precise illumination of wall segments or vertical arranged merchandise with a high lumen output for retail. To fulfil the ambitious standards in shops the luminaire fulfils these requirements:

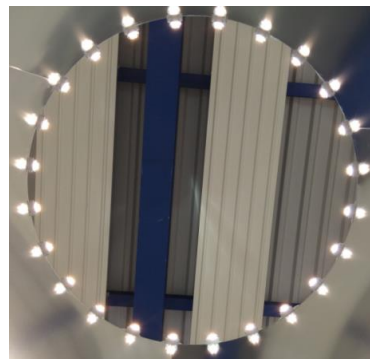
- High uniform light distribution and optimized longitudinal glare control
- High CRI
- Optional: Variable colour temperature to stage various types of merchandise or scenarios



The LED Retail Wallwasher

The ability of exact illumination provides a very energy-efficient type of luminaire. The LED Retail Wallwasher is controlled according to dynamic Human Centric Lighting, varying both colour temperatures and illuminance levels throughout the day. Typical periods with matching schedules are predefined to implement energy-efficient specific lighting operation conditions for lighting. A Green Lighting Box allows local shop lighting control to control the dynamic shop lighting scenes while a connection to the central Building Energy Management System will allow to monitor the energy consumption. The developed Wallwasher provides complete glare protection by indirect lighting via the walls.

Finally, an artificial lighting system for integration into the Light Pipe developed in WP 3 was developed in the project. It consists of a ring with sloped multi-faceted reflectors with LEDs circularly arranged on top of the Light Pipe.



Integrated artificial lighting system for the Light Pipe

In particular in smaller tenants' shops we observed a lack in lighting design philosophy: lighting is provided for the whole space in an undifferentiated way aiming for a high overall level of illuminance. Providing light at very high intensity to large room areas causes high-energy demand but also glare and high thermal loads. In the project we examined the effects of a spatial new lighting concept that utilizes a balanced lighting distribution with a reduced general illuminance and highlighted areas (by intensity and/or colour contrast) on perceived room brightness. Although we generally recommend to carefully review the needed (beneficial) mean illuminance level in shops (and potentially revise them in the direction to a more moderate level), in this study the achieved perceived brightness should not be reduced by the conceptual approach. We also raised the question if the traditional way to evaluate brightness – through the horizontal illuminance level – has to be adopted and found that vertical illuminance at eye level is a much better indicator for human perception of a space or a room scene. In the study, we used a scaled mock-up retail clothing store and

examined 24 different lighting scenes regarding the relationship between vertical illumination at eye level and perceived brightness. The lighting scenes varied in level of scene brightness, light distribution and colour temperature. Observer subjective assessments were examined using factor analysis for four lighting levels (200lx, 300lx, 400lx, 520lx), two different luminance distributions (homogeneous and zonal) and two colour temperatures (2700 K and 5000 K). A short questionnaire was used to examine the subjective response to different lit retail-models. Questions included light related factors, brand related factors and ratings due to room atmosphere and product estimation.

In the second part of our investigation, participants directly compared homogeneous and zonal lighting conditions. Various homogeneous lighting conditions were set as reference condition in one model and the subjects were asked to configure similar zonal lighting conditions in the second model. This comparison was made to investigate if different light distributions result in different perceived brightness ratings.

Especially the definition of horizontal illuminance values in retail store lighting norms may not be the most adequate metric for lighting standards. Our study showed that the vertical illuminance at eye level is a much better predictor for perceived brightness than horizontal illuminance.

From the results and analysis other key findings for this study were:

- lighting scenarios with mixed colour temperatures of the light sources gave the highest perceived brightness ratings when coolwhite light was used for accent light and warm-white light was used for ambient light
- zonal illumination is rated brighter than homogeneous illumination when cool-white light-sources were used
- Reduced lighting levels at zonal light scenarios were perceived as similar bright when compared to high homogeneous reference lighting scenarios. The proportion of energy consumption that can be achieved with zonal lighting scenes with identical CCT was ~ 31%.
- warm-white lighting scenes obtained better ratings due to room atmosphere and product estimation
- not the light distribution but the colour temperature of the light had a great influence when items were rated which are related to light factors, room atmosphere factors and price/style factors.

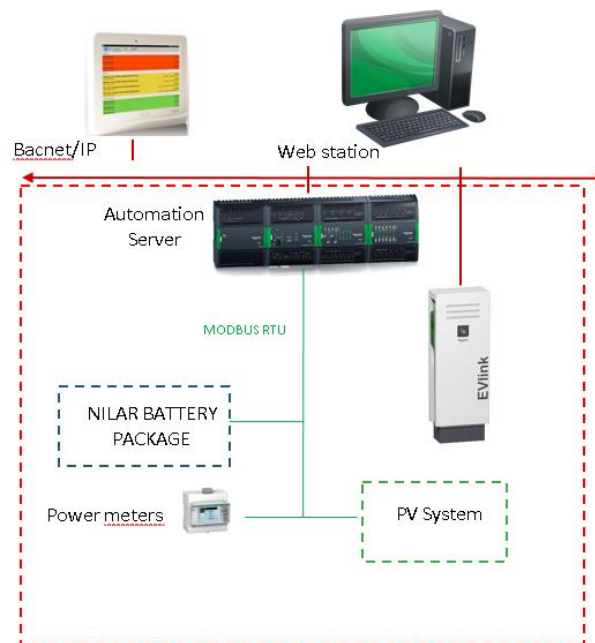


Photo of the scale model used for the perception study analysis

Another important aspect to be considered in the analysis of shopping centre deep renovation strategies is related to mobility infrastructure. The number of electrical vehicles (eV) is expected to grow more and more in the next few years, furthermore many countries have already introduced in their regulation a mandatory number of Electrical Vehicle Charger (eVC) for specific kinds of buildings (including shopping centres) to promote the use of eVs.

CommONEnergy investigated ways to make more effective the use of ICT (information and communication technologies) for the communication among sub-systems in shopping malls. A sub-system analysed in the course of the project is the charging station for electric vehicles connected to the power grid of a shopping mall, which integrates also renewable energy sources. The big challenge is to provide sustainable solutions that are also cost-effective with an acceptable payback period for this business sector. For this reason, the implementation of Building Integrated Electric Mobility in the shopping mall power grid (Commercial Facility) was evaluated as a suitable solution.

The integration of an eVC application in an overall system (the “BiEM”) allows to control the EV charge and to optimize the electrical local microgrid, maximizing the use of renewables. Collecting market energy price and use of predictive analytics allows the BiEM to minimize the running energy costs of the whole shopping centre.



Architecture of the proposed BIEM in CommONEnergy project

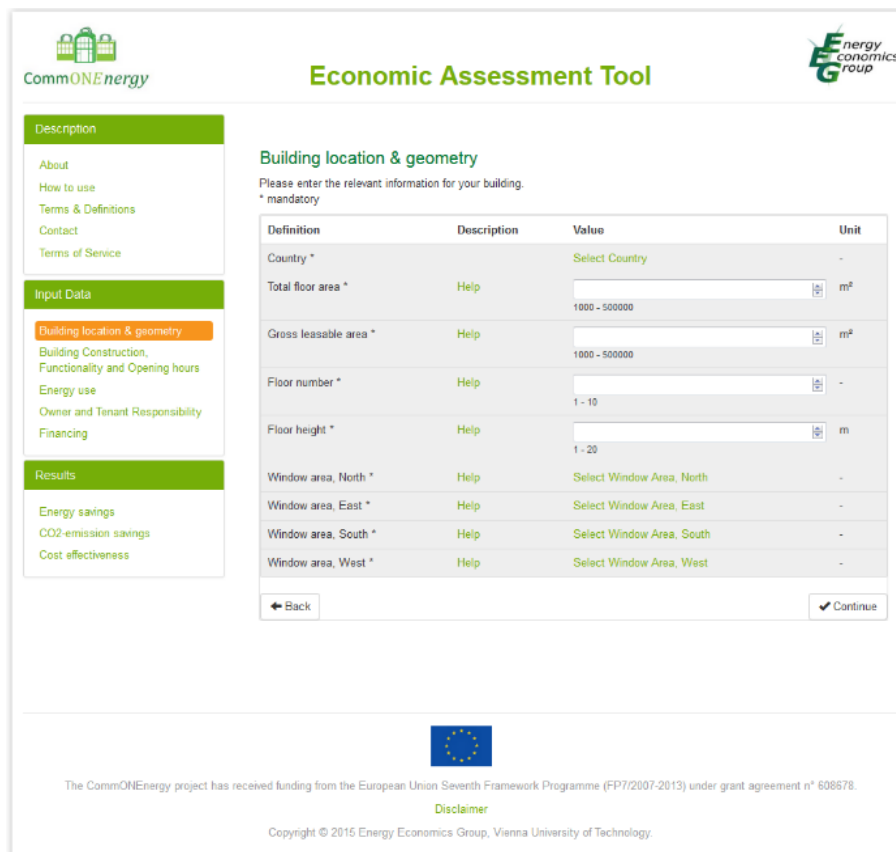
The use of renewable energy is monitored and the information is available to the different stakeholders to increase environmental awareness and to improve the eco-friendly image of the company.

Developed renovation measures were combined to define 14 systemic solution-sets. Such combinations looked for and exploited synergies among HVAC, lighting, refrigeration, energy use as well as for building correlated services (parking, RES harvesting and local energy production etc.). In general, the solution-sets chosen fulfilled the 7 years payback and the improvement of comfort conditions with vary percentages of primary energy reduction (up to 75% depending on the building and its needs). The development of the solution-sets followed a comprehensive approach considering energy, economic and environmental

impact, as well as the best strategy for implementing the deep renovation and managing the renovated shopping centre.

We developed a web-based Economic Assessment Tool as a convenient and useful instrument to estimate the energy saving potential and economic benefits of retrofitting of shopping centres in the very early design stage of the renovation process. The tool targets managers and owners of the shopping centre and allows entering relevant information about their shopping centre. It can be applied for shopping centres located in the EU and Norway and provides quick information on the energy consumption and options to reduce energy demand, CO₂-emissions, the environmental impact and provides an economic assessment of the investments. Several retrofitting solutions show areas of improvement potential in the shopping centres, benefits and potential energy savings. It is available via the CommONEnergy website:

http://eeg.tuwien.ac.at/commonenergy_economic_assessment_tool



The screenshot shows the 'Economic Assessment Tool' web interface. It features a sidebar with navigation links: Description, Input Data, and Results. The 'Input Data' section is active, showing a table for 'Building location & geometry'. The table has columns for Definition, Description, Value, and Unit. The 'Value' column contains dropdown menus for Country, Total floor area, Gross leasable area, Floor number, Floor height, and Window area (North, East, South, West). The 'Unit' column shows the units for each field. At the bottom, there is a 'Back' button and a 'Continue' button. A footer section includes the European Union flag, a disclaimer, and copyright information for 2015 Energy Economics Group, Vienna University of Technology.

Definition	Description	Value	Unit
Country *		Select Country	-
Total floor area *	Help	1000 - 500000	m ²
Gross leasable area *	Help	1000 - 500000	m ²
Floor number *	Help	1 - 10	-
Floor height *	Help	1 - 20	m
Window area, North *	Help	Select Window Area, North	-
Window area, East *	Help	Select Window Area, East	-
Window area, South *	Help	Select Window Area, South	-
Window area, West *	Help	Select Window Area, West	-

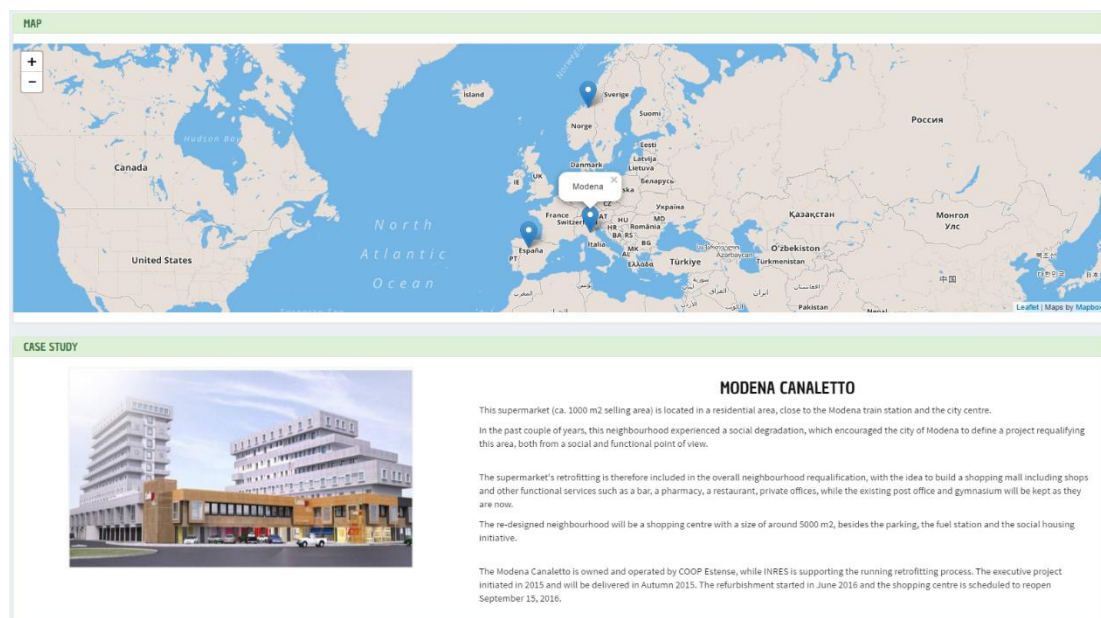
Economic assessment tool and description of main parts

The research investigated the application of lean concepts on shopping centres construction sites and operational phases. In the two diverse applications, using the main lean concepts it was possible to highlight the specific critical issues and propose solutions to overcome them. Again on the operational phase we developed a continuous commissioning tool (CC tool) that analyzes the performance of buildings in a holistic perspective, monitoring on one hand the energy performance of the building and on the other hand the indoor thermal and luminous comfort. It integrates specific KPIs to monitor the shopping centre performance taking into account energy, indoor environmental quality, and economic aspects and

normalised the absolute performance figures to enable comparison with other case studies. The benchmarking between different zones of the building and between different buildings are also introduced. This part together with the section related to the prediction of energy consumption is being continuously validated and updated.

In the case of Modena Canaletto, the CC tool includes a fault detection visualization on the operation of the mechanical ventilation. Depending on the control rules defined for the mechanical ventilation and thanks to the data analysis of monitoring data, the tool is able to detect potential system failures. In the Mercado del Val demo case, the CC tool detected faults on the cooling system set up. Indeed, it worked during the closing time, when the indoor temperature was higher to the external one, without activating natural ventilation.

The platform could be very useful to tune the mechanical system of the building in an efficient way. Reducing the energy consumption and improving or at least keeping in the same way the thermal and luminous comfort. The tool has an interactive and user friendly interface with appealing design.



Continuous commissioning tool front page

The methodology we developed to assess the environmental impacts was based on Life Cycle Assessment (LCA) of both specific renovation solution, and whole building. The developed and tested solutions and technologies were analysed and LCA models on product level were set up in the professional LCA software GaBi for the lifecycle stage production and End-of-Life. LCA models were also set up for the different reference shopping centers and a generic LCA shopping center model was developed for rehabilitation. This generic model enables other LCA practitioners to easily model the environmental impacts of their shopping center and tailor it to their needs. In addition specific LCA methodologies, e.g. dynamic LCA and regionalization of LCA, were enhanced and implemented in a first approach in the software tool. This allowed to set up dynamic LCA models for electricity mixes of all EU-28 countries based on the EU reference study. Furthermore the shifting of environmental burdens between countries was illustrated on the example of the use of electricity. These methodological developments could form a basis for further software developments.



The LCA profiles for the different technologies and shopping center were implemented in the tool for analysis of EU shopping centre building stock scenarios. Based on the in-depth environmental analysis some interesting conclusions could be drawn. Especially in countries with a high share of renewable energies, the materials used for the retrofit intervention gain importance and have to be evaluated from LCA point of view as well. In countries with high share of non-renewable energies the focus lies on the use phase (energy consumption) of the shopping center. These aspects could be of interest for policy makers in order where to focus on. For instance, in Italy newly built shopping centers will have to provide some information regarding the sustainability of the shopping centers. LCA information could be part of the sustainability assessment like it already is in sustainability assessment protocols such as BREEAM, DGNB or LEED.

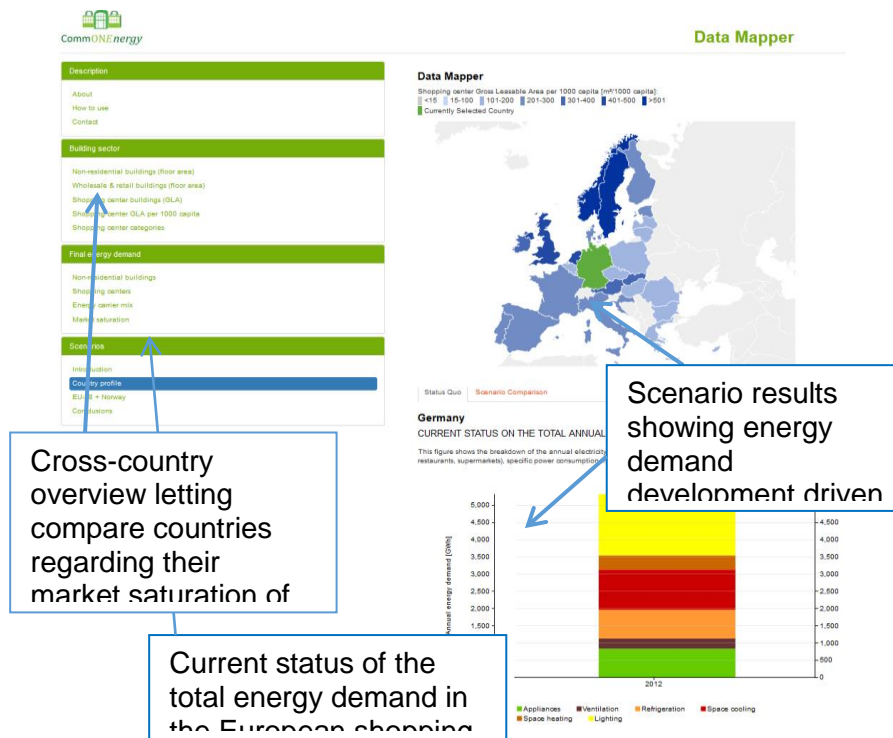
In addition, the developed communication forms for environmental impacts could be used in further applications and may be of interest for the currently running PEF (Product Environmental Footprint) communication of environmental impacts to end users.

The OPEN HOUSE socio-cultural and functional indicators were used to evaluate the potential of the retrofit measures in the shopping centers. In order to not only address qualitative measures such as most mentioned in OPEN HOUSE or other sustainability schemes, a methodological approach was developed within the system boundaries of an LCA and following the same life cycle thinking approach. Therefore the LCA models were enhanced by statistical data and the so called Social Hotspot database was implemented in the professional LCA tool GaBi. In future this approach and the database developed could enable LCA practitioners to broaden their analysis to social aspects using the same tools they already use.

As already mentioned the developed communication sheets and diagrams could be used in a later more enhanced stage of the PEF for communication of results to the end user.

The reporting of social indicators of products needs to have a reporting of social aspects also at company level. The approach of using statistical data could help to provide first information about social aspects. This information could later be replaced by specific industry data taken from GRI reporting.

To study the replication potential we produced a report on scenarios and developed an interactive Web-Tool, namely the data mapper, showing scenarios for the energy demand and uptake of renovation activities in shopping centres in the EU and Norway. The data mapper is an online tool which represents a quick, easy and tailor-made access of national and comparative international indicators on the commercial building stock. The interactive Web-Tool showing scenarios is available at <http://eeg.tuwien.ac.at/commonenergy/target>.



Data mapper and description of main parts

The scenario results can support policy makers and thus guide shopping centres to reduce their energy demand through clear and stable policies which provide long term drivers to increase energy efficiency. This task provides recommendations on how to increase the use of energy efficiency measures in European shopping centres, thus assisting the sector to contribute to the European 2030 climate and energy targets addressing the following stakeholders, owner/tenants, real estate investors and policy makers.

To complete the evaluation of the replication potential we performed an assessment of the existing and potential non-technical barriers, with focus on standardization and compliance with building codes, for the different solutions developed within the project and possible solutions to overcome the barriers. The experience gained within CommONEnergy project highlighted the need of harmonization in the future revision of national building codes, in particular to overcome the variety of calculation methods used to measure compliance and major differences in definitions. It should be also highlighted that a refinement of building energy performance labels or certificates is required to provide information to owners, buyers and renters that incorporate and promote the specific benefits emerging from advanced strategies for retrofitting.

Demonstration

The developed solution-sets have been installed in a time frame from 12/2015 (installation of the natural ventilation system in Trondheim) and 9/2017 (completion of the hand-over of iBEMS in Valladolid and modular skylight system in Trondheim).

In the following a list of implemented renovation measures per demo-case.

Mercado del Val, Valladolid:

1. iBEMS monitoring and control system for the implementation of continuous commissioning and integration of the solution set
2. Natural Ventilation / Free Cooling connected to HVAC (including advanced control rules based on dynamic simulations), specifically conceived for a shopping mall having huge extension of the façade orientated to south
3. Multifunctional façade with shading system (including advanced control rules based on dynamic simulations), specifically conceived for a shopping mall having huge extension of façade orientated to south

Coop Canaletto, Modena:

1. iBEMS monitoring and control system for the implementation of continuous commissioning and integration of the solution set
2. Standard static Light tubes in cooperation with artificial led lighting, specifically conceived to allow advanced food areas layout where natural light is far away (including advanced control rules based on dynamic simulations)
3. General Retail Lighting specifically conceived for and applied to commercial gallery (including advanced control rules based on dynamic simulations)
4. CO₂ based refrigeration system, specifically modified for tempered climates coupled with HVAC (including advanced control rules based on dynamic simulations)
5. Refrigeration cabinet with variable air flow fan and coupled with linear air diffusers as HVAC terminal units for the reduction of mist effects
6. Thermoreflective multifunctional white paint for the reduction of heat loads in summer time

Marema, Grosseto

1. Electrical Energy storage system coupled to electric car chargers and a portion of the resident photovoltaic system, specifically conceived for commercial buildings offering a service of car charging

CitySyd, Trondheim

1. iBEMS monitoring and control system for the implementation of continuous commissioning and integration of the solution set
2. Natural ventilation system coupled to opening of sliding entrance doors and air handling unit operating in the common areas (including advanced control rules based on dynamic simulations)
3. Advanced Shadow controlled Light tubes working in cooperation with artificial led luminaires and wall washers, specifically conceived for retail shops (including advanced control rules based on dynamic simulations)
4. Modular skylight system coupled with shadowing system and light reflective mirroring system, specifically conceived to control natural light area and reflect artificial light reducing dispersion of light during winter time

The field experience with the management of CommONEnergy demo-cases enabled the consortium to develop specific skills to face the complexity and the risks connected to the deep renovation of large commercial buildings. The implementation time resulted as a key aspect, together with a continuous management and the involvement of all stakeholders. In this way it is possible to handle the integration of innovative energy efficiency technologies without affecting too much the overall.



Risks related to innovation, sometime difficult mediation between research team and local practitioners with different working approach and language, as well as mentioned budget constraint, produced a high level of complexity in the relationships within the local demo-case working groups (LDWGs), especially because demonstration actions were real operative installations, and not small prototypes or pilot plants.

Coping the stated above challenges, establishing and managing heterogeneous but effective working team (aimed at planning and implementing advanced deep renovation solution-sets) requested a strong commitment by the local demo-case working groups (LDWG) managers and facilitators as well as by the project coordinator, acting together as project management team.

Implementing the deep renovation solution-sets in three different shopping malls was also challenging because, due to the different expectations of the owners, three completely different approaches had to be defined and adopted.

The Modena demo case was technically facilitated by the fact that the EPC contractor was a CommONEnergy partner. The main challenge was the timing: CommONEnergy was requested to provide the solutions sets in 12 months and install them with the same “timeframe” of the overall renovation. There was also an additional “organizational” challenge: the owner of the Modena Canaletto demo-case was not a partner of CommONEnergy and, even if strongly committed, it was not financed to cover the risks of innovative installation. For this reason there was a very high attention to the impact in terms of time and costs of the integration of CommONEnergy solutions in the ongoing renovation process. Finally, it is important to remember that the renovation of “Canaletto” supermarket (transformed in a shopping centre) was part of a general social requalification of the whole “Canaletto” district. Therefore there were other important stakeholders to satisfy: the municipality of Modena and the neighbours working inside the same infrastructure.

The Grosseto “Maremma” sub-chapter of the Italian demo-case was an extension of Modena “Canaletto”. The main challenge was designing and implementing a system complying with the local and national rules and requested certifications: in particular the electrical regulation in Italy for connecting battery to AC-grid caused severe limitation of components allowed to be used, also affecting the costs of the whole system, and efforts for his design and implementation.

The Valladolid demo-case was the most complex in term of project management due to the experienced communication problems with the local players. The management of the interactions between CommONEnergy partners, EPC contractor, and different local subcontractors, suffered the lack of a specific dedicated budget and expertise. The problem was solved shifting the coordination to a team composed by CommONEnergy partners. Another challenge for this demo-case was the budget: the solution-set was not applied in limited areas with specific scopes, but it was conceived and implemented in the building design as a whole retail and energy system. As a consequence the decision process within the LDWG requested a long negotiation supported by accurate cost/benefit analysis. Notwithstanding the commissioning phase highlighted some issues that only the very strong commitment of the municipality of Valladolid and CommONEnergy technology providers allowed to solve.

In Trondheim demo-case the attitude of the owner was very broad minded. The intention of the shopping centre owner was to learn from the applied solutions and to study the possible replication potential in other shopping malls. The owner required to minimise the impact on customers, reducing possible retail activity break. This request was particularly important because one of the most complicated CommONEnergy solutions (the creation of a combined natural and artificial lighting system) was agreed to be installed in an independent

tenant medium size shop. Also, the application of natural ventilation in the common area brought potential discomfort risks during set-up and commissioning, mainly for possible draughts needing a prompt continuous adjustment of the control rules in the first period.

Apart from technical challenges and some delays caused by the complexity of the structural design for opening the roof in winter time, the CitySyd renovation was smoothly performed thanks to the technical preparation of the local facility management and maintenance team, which worked in optimal collaboration with the CommONEnergy partners, through the LDWG. Minor challenges to remark for the demo-case in Trondheim was the high cost requested for “custom clearance” and the long journey needed to get to Norway for each LDWG meeting.

Timely management and implementation of deep renovation solution-sets enabled a meaningful validation period, with some exceptions like for example the final configuration of the control strategy of the façade system in Valladolid (fully re-designed and re-implemented in the last period), the implementation of the modular skylight system in Trondheim which were handed over in summer 2017, and the innovative PV-batteries-eV charging system installed in Grosseto and still under commissioning in the same period. Strong commitment of the parties involved in LDWGs allowed to define collaborative agreements ensuring to carry out the necessary activities for validation and following dissemination and exploitation of achieved results, also beyond the CommONEnergy project timeframe.

The overall energy performance of the retrofitted demo cases and the solutions applied was evaluated through a Measurement & Verification (M&V) plan defined for each demo case depending on the retrofit intervention. A specific M&V plan was selected for each demo case addressing the unique characteristics of the retrofit intervention. Thus, we referred to the four options defined in the International Performance Measure and Verification Protocol (IPMVP):

- Option A: Retrofit Isolation - Key Parameter Measurement. Savings are determined by measuring the performance parameters that will have the higher influence on the savings calculation and by combining measured values with estimates.
- Option B: Retrofit Isolation - All Parameters Measurement. Savings are determined by measuring energy use and all variables affecting energy use within the measurement boundary.
- Option C: Whole Facility: continuous measurements of entire facility’s energy use. Savings are determined by measuring energy use at the whole facility or sub-facility level.
- Option D: Calibrated Simulation: savings are determined through simulations of the energy use at the whole facility or sub-facility level.

The most suitable M&V Option to evaluate the whole solution set and each Energy Conservation Measure (ECM) depend on existing data about the baseline, the expected energy savings, the metering of isolated key parameters and the measured data available.

In all the three demo cases, Option D was selected as the most suitable to assess the energy savings of the whole solution set, while the energy savings due to each ECM are evaluated using Option A, B or D depending on the factors above mentioned.

Building energy simulation models, if properly calibrated, allow for the evaluation of the energy savings over the whole year and for a fair comparison between the building before and after retrofit. Measured data during the reporting period were used to assess the input data set of the simulation model of the building after retrofit intervention and to perform model calibration following a common calibration procedure.

When Option D is applied, the energy performance is assessed according to the following procedure:

1. Development of a simulation model of the reference building (demo-case as it was before the retrofitting process);
2. Evaluation of each ECM, implementing them individually in the reference building model;
3. Comparison of the results with the baseline case;
4. Evaluation of the effects of an ECM on the whole building energy behaviour;
5. Evaluation of individual ECMs based on real monitoring data compared with a suitable baseline.

In general, the implemented ECM influence directly the total energy efficiency of a building. Single ECM influence might also produce negative effects, even though in combination with other measures produces positive effects. Therefore, an evaluation of measures should always be made in the context of total energy efficiency.

All the renovation projects are divided into three timing periods: baseline, the period before the intervention, Energy Conservation Measures (ECMs) implementation, the retrofit intervention, and the reporting period, that represents the post-retrofit period. In the reporting period, the improvements provided by the ECMs are evaluated.

The Mercado del Val retrofitting process started in September 2013. Apart from the main steel structure the building was demolished and reconstruction started around November 2014 and the new Mercado del Val was inaugurated in December 2016.

Coop Canaletto demo-case retrofitting started in June 2016 and the supermarket was closed only during the month of August 2016. The Coop Canaletto neighbourhood shopping centre was inaugurated in September 2016 but the building management system set up and commissioning lasted until February 2017.

CitySyd retrofit interventions occurred between March 2016 and September 2017. The monitoring system is providing data since March 2017.

Mercado del Val demo-case

2013					2014					2015					2016					2017																																			
F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S												
							0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
BASELINE PERIOD					NO OPERATIVE BUILDING										ECMs IMPLEMENTATION															REPORTING PERIOD																									

Coop Canaletto demo-case

2013												2014												2015												2016												2017											
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S															
								0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48			
BASELINE PERIOD																																				ECMs IMPLEMENTATION												REPORTING PERIOD											

CitySyd demo-case

2013					2014					2015					2016					2017																																			
F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S												
							0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
BASELINE PERIOD																																ECMs					REPORTING PERIOD																		

Timing period for the M&V of the three demo-cases

The analysis done was based on the monitoring data gathered through the iBEMS installed in the buildings.

The performances of the applied solutions at the three demo-cases were carried out in comparison with a baseline (before retrofitting):



- Mercado del Val demo case: whole building performance is analyzed by comparing the building before retrofit and the building after retrofit. Since no monitoring data about the baseline (building before intervention) was available. The baseline is represented by a building simulation model with input coming from the energy audit. Each ECM including CommONEnergy solutions is evaluated by comparing the retrofit project as defined by the local team with the retrofit project including CommONEnergy solutions.
- City Syd: demonstration areas performance selected for the retrofitting as they were before and after the implementation of the CommONEnergy approach. The individual CommONEnergy solutions are evaluated by comparing them with the conventional systems installed before the retrofitting.
- Coop Canaletto: whole building performance is analyzed by comparing the building before and after the deep retrofitting following the CommONEnergy approach. For the individual CommONEnergy solutions the comparison is with the conventional systems installed before the retrofitting.

More specifically the assessment comprises:

- Assessment of overall energy performance of the demos (thermal and electrical);
- Assessment of overall energy savings in each retrofitting measure and the CO₂ emissions avoided as well as simple payback time;
- Evaluation of the renewable energy facilities performance, calculation of energy contribution and system yield and match with load profile.

The demo case of Modena Canaletto includes a supermarket and a gallery which connects some shops. In the gallery, the replacement of the existing lamps with dimmerable lighting brings improvement on the visual comfort and on the energy consumption. The light intensity is regulated according to natural light; the lighting concept implemented reduces the electrical consumption of 15% with respect to the existing case.

The intervention on the supermarket also includes: an envelope insulation reduces the thermal losses with savings on the order of 7%; the replacement of open cabinets with closed ones reduces the refrigeration loads of 50%; improvements on the HVAC system and the coupling of this system with the waste heat of the refrigeration circuit saves 35% of energy used for space heating, cooling, hot water preparation and refrigeration.

The implementation of a control system able to communicate with all the parts of the supermarket, together with other retrofit measures reduces the total primary energy consumption of 46%.

Thanks to the retrofit intervention, the Mercado del Val has electrical savings of around 75%, if we compare the building before and after the retrofit. Primary energy and CO₂ emissions avoided are proportional to the electrical energy savings. For the renewable energy production, in the new building all the heating, cooling and DHW demand is fully covered by renewable energy sources (geothermal heat pump system).

For the individual ECMs implemented in the new building we can assume only savings in terms of energy consumption for heating and cooling, as energy consumption for lighting, appliances and refrigeration could be assumed to remain unchanged. Compared to the building standard retrofit (without CommONEnergy solutions), the electricity consumption for heating and cooling after the retrofit with the multifunctional façade and the iBEMS control (ECM1+ECM2) is predicted to be reduced by 26%. Additional 28% less energy consumption can be obtained with the use of geothermal heat pumps (ECM3). Totally, the retrofit project including CommONEnergy solutions reduced the electricity consumption for heating, cooling and ventilation by 43% compared to the retrofit project as defined by the local team.

The retrofit intervention in CitySyd regards four demonstration areas where different lighting concepts have been tested. An efficient lighting concept was tested on a shop and the common area in front of the shop. The modular roof skylight, combining different elements with the aim to enhance the daylight impression in the atria, was prototyped and installed over part of the common area. Due to several issues occurred in the prototyping phase and consequent delay in installation, it has not been possible to perform measurements on the modular roof skylight performance. A natural ventilation strategy was developed and implemented in the whole common area.

The potential energy savings have been assessed by assuming the lighting solutions were applied to the whole building, resulting in 31% of primary energy reduction. Even though the overall primary energy savings are positive, the lighting solutions cause an increase of heating demand as a result of reduction of internal loads. This is specific for the different zones and it remains difficult to generalize. It remains a challenge to distribute energy savings in specific zones (which are interconnected) of the shopping centre according to functional and/or organizational pattern.

The additional demo-cased, namely Maremà in Grosseto (Italy) had the aim to design, develop and install a system able to increase the share of renewable energy (i.e. photovoltaic) with the combination of battery energy storage system (BESS) to cover the energy demand of the EV-link. The PV-BESS-EVC system is the first prototype in a shopping mall in Italy able to cover the e-cars energy demand completely by the combination of PV and BESS making shopping centers a possible driver for the diffusion of the sustainable mobility not only in Italy but in all Europe.

The renovation process improved thermal comfort conditions in both Modena Canaletto and CitySyd. Retrofit solutions affected the thermal environment by reducing the number of occupied hours not in compliance with standard regulations (EN ISO 15251, 2008). For Modena Canaletto, thermal comfort is notably improved after the retrofit in the supermarket area with the exception of the check-out zone. The check-out area, even though it is located in a different position after the restyling, it is affected by a high variability of conditions being closely connected with the outdoor environment. Because of the features of these areas, personalized comfort system like heated and cooled chairs, could be a solution to improve thermal comfort of workers.

For Mercado del Val, a fine-tuning of the HVAC system control is needed to guarantee better thermal conditions to the costumers. The high temperatures recorded under summer conditions during occupied hours makes the market not in compliance with standard regulations (EN ISO 15251, 2008).

The acoustic measurements performed in Mercado del Val suggested also some improvements as the increase of the sound absorbing surfaces and solutions able to improve the intelligibility of the market (how comprehensible is the speech under given conditions).

Generally, the indoor air quality of the three demo cases is quite good with the exception of some VOCs that undergo an increase of their concentration. This issue occurred in particular in the CitySyd demo-case where a significant increase of indoor-outdoor concentration differences of formaldehyde and toluene was observed, especially near the Jens Hoff store. The reasons of these incremented values are still under investigation.

On the other hand, the new lighting concept improved the visual comfort inside the Jens Hoff shop. According to costumers' feedback, the new lighting concept with the integration of natural light (installation of three light-tubes in a suspended ceiling) makes the room appearance more modern. Good level of illuminance are guaranteed thanks to the new wall



washer luminaires. After retrofit, the room is rated generally attractive, beautiful, clearly arranged, colourful, and not glaring.

Communication & dissemination

All communication and dissemination activities were thought of in order to reach out the objectives set per target group, and to ensure reaching all target groups whenever possible at different project stages. Various channels and tools were chosen, selected and adapted to the intended audience or target groups, and presented to the project partners regularly, to involve them in supporting the activities. Over the past years, they have been refined according to the project stages: social media and articles on the website have thus become one of the major tools to increase outreach in the first years, when the demo cases were not yet renovated and communication onsite was not possible, with the use of more hashtags on Twitter or groups on LinkedIn for instance, and with a regular newsletter being sent every six months. After the technologies were developed and applied onsite, it became easier to communicate on them and how they were improving shopping centres' visitors and employees comfort as well as having a positive impact on the environment, and to train practitioners on how to use them / why.

Activities targeting shopping centres stakeholders and results

- A database of contacts to reach out digitally to this category of stakeholders was created from the project start, involving all partners. A section on the website also allowed them to subscribe to the newsletter, sent every six months.
- The website population with news and editorials was also targeting them.
- Specific media (Across, ILQI, etc.) was reached out with input articles focusing on their expectations and needs.
- Participation to / organisation of events: the events ranged from sector-specific events (such as MAPIC targeting the retail and real-estate sectors) to events inside the centres, involving the stakeholders.
- Training activities: practitioners were selected as a key target group, and therefore focus was put on organising training activities for them at the end of the project. Training workshops and visits of the renovated shopping centres / market were organised in many countries and several times, flyers and brochures focusing on each technology and solution developed were designed and distributed, webinars were also organised, and videos produced to explain how to use some of the tools developed in the project, a partnership was set with a targeted media (Largo Consumo), a software for demand / response was developed, and more.
- Policy-makers were reached out through two events organised in Brussels, one during the EU Sustainable Energy Week and one final conference in September 2017, a policy paper highlighting the important role these commercial buildings could have to reach European sustainability goals if properly included in the EU Directives, and several articles in specific publications, such as the EU Energy Innovation magazine. They were also of course reached through the mailings and inclusion in all partners' newsletters, such as BPIE's, sent to over 1000 policy-makers at EU and MS level.
- Finally, the production of a comprehensive publication, the project "Guidelines on how to approach the energy efficient retrofitting of shopping centres", allowed summarising all project key findings directed to facility managers, architects, owners, investors, designers and more.



All these activities have proven successful, reaching out to many stakeholders, and allowed presenting the project and the solutions and tools developed, as well as prove the results that could be reached through a deep renovation, in terms of energy savings, comfort and payback time.

Activities targeting the Energy efficiency in buildings community and results

- This category of stakeholders was mainly reached throughout most partners' communication tools (newsletters, websites, social media, etc.), as well as:
 - Media inclusions (scientific publications mainly, in journals, and in dedicated magazines or online news portal such as Build UP, Construction 21, Ecostruccion, etc.
 - The project "guidelines".
 - Participation to fairs and events such as the World Sustainable Energy Days, EuroBuild, etc. with material distributed and posters created.
 - The project brochure, created at the project start and updated after 2 years in 5 languages, widely distributed on and offline.
- The final conference allowed gathering different stakeholders, with many coming from this target group.

These activities, performed all along the project lifetime, allowed raising the interest about the project and its outputs, and finding networks where to share the information.

Activities targeting non-specialists and results

- Media (at MS, EU and global levels) and journals were regularly involved and reached out to share news about the project. Spanish media particularly have been very active in that, updating regularly the civil society with the market works' progress.
- Civil society was reached through social media posts and many activities organised onsite the demo cases ("Un dia nel Mercado" with kids getting a tour in the renovated market with explanations and games in Spain, the "Earth day" in Modena, Italy, with activities for kids, or other activities organised more largely for the visitors: a photobooth and stand where the project retrofits were explained and material given, etc.), the project video distributed widely digitally and screened in Valladolid's city, on Social media, etc., the production of dedicated booklets in the national languages of the demo cases, activities with tourists (by training tourism offices workers) and having outside panels with photos and explanations about the retrofit, aa permanent plate inside the market and pop ups in the Italian demo cases, and much more. To increase outreach of shopping centres' customers and other stakeholders, targeted material was produced (dedicated leaflet, posters, cotton bags, bamboo reusable cups, trolley coins and posters, etc.).

Results of these activities have been very encouraging, and allowed to reach out to many stakeholders, mostly in the target countries. Even if we tried to have a roll out of the activities and organize them in non-involved shopping centres, we faced refusals, mostly due to this "non-involvement", and unwillingness to share results of what others had done, that could show they were not doing enough.

Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.

Impact

Because the retrofit intervention in Mercado del Val involved advanced envelope solutions, the impact on thermal savings was higher than in the other demo-case and has been assessed to 394 kWh/m²/y by comparing the baseline model with the model of the building after retrofit. Electrical savings involve also the savings related to the geothermal heat pump and to the new efficient lighting system and amount at 405 kWh/m²/y. The renewable energy production is the one provided by the geothermal heat pump systems installed in the new building and cover all the heating and cooling needs, DHW included. The old building did not have any renewable system installed. Finally, the retrofit intervention resulted in a reduction of 75% of primary energy corresponding to 973 kWhpe/m²/y saved and 145 kg/m²/y of CO₂ emissions avoided with 54 €/m² of annual operational costs avoided.

Since Coop Canaletto demo-case has a small supermarket, most of the savings are due to the refrigeration system replacement, as well as the overall restyling of the lighting concept resulting in 84 kWh/m²/y of thermal savings and 326 kWh/m²/y of electrical savings. Primary energy savings amount at 589 kWhpe/m²/y which correspond to 144 kg/m²/y of CO₂ emissions avoided and 40 €/m² of annual operational costs avoided.

In CitySyd the potential energy savings were assessed by assuming the lighting solutions were applied to the whole building. Even though the overall primary energy savings were positive (232 kWhpe/m²/y), the lighting solutions caused an increase of heating demand as a result of reduction of internal loads. Therefore, the lighting concepts applied in CitySyd do not have any thermal savings, but rather have an increase of thermal demand by 70 kWh/m²/y. Overall, the solutions avoid 30 kg/m²/y of CO₂ emissions and more than 7 €/m² of annual operational costs.

Energy and cost savings and CO₂ emissions avoided due to the retrofit intervention in each demo case over a reference year.

Demo	Thermal savings [kWh/m ² /y]	Electrical savings [kWh/m ² /y]	Renewable energy production [kWh/m ² /y]	Primary energy savings [kWh/m ² /y]	CO ₂ emissions avoided [kg/m ² /y]	Cost avoided [€/m ² /y]
Mercado del Val	394	405	100%*	973	145	54.3
Modena Canaletto	84	326	N/A	589	144	40
City Syd	-70	104	N/A	232	30	7.4

N/A: Not Applied

* of the Heating and Cooling needs + DHW

The savings related to individual ECMs implemented in the new Mercado del Val were difficult to assess because of the high differences between the building before and after retrofit. Therefore, we evaluated each ECM effect by comparing simulation outputs the new building with and without each ECM individually. In this case, we assumed lighting, appliances and refrigeration consumption stay constant and savings are related to air conditioning and ventilation. The multifunctional façade controlled by the iBEMS leads to around 15 kWh/m²/y electrical savings compared to the façade planned for the retrofit intervention without the technologies developed in CommONEnergy. The geothermal heat pump (COP = 4.8) leads to electrical savings of 16 kWh/m²/y compared to the air to water heat pump planned before (COP = 3).

The measures related to lighting systems implemented in Modena Canaletto were evaluated by comparing measured data after the retrofit intervention with the assumed lighting consumption of the luminaries before the intervention knowing the installed lighting power. The advanced lighting concept of the supermarket enables electrical savings of 106 kWh/m²/y. The savings related to the General Retail Lighting installed in the gallery amount at only 10 kWh/m²/y, but the illuminance level of the gallery is significantly increased due to the change in gallery use.

The savings related to the other implemented measured were estimated by a calibrated simulation model: envelope insulation leads to around 2 kWh/m²/y of thermal savings, refrigeration cabinets replacement to 110 kWh/m²/y of electrical savings, the coupling between HVAC and refrigeration system to additional 10 kWh/m²/y of electrical savings and the use of iBEMS to control the building system to additional 13 kWh/m²/y of electrical savings.

The artificial lighting concept in the Jens Hoff shop in CitySyd reduces the lighting consumption of the shop by 86 kWh/m²/y, but increases the thermal energy demand by 11 kWh/m²/y. The GRL installed in the CitySyd common areas reduces the lighting consumption of the common areas by 18 kWh/m²/y, but increase the thermal energy demand by 8 kWh/m²/y.

The savings related to natural ventilation are smaller (1 kWh/m²/y) compared to lighting, but the cost of this solution was almost negligible because all the systems were already in place. Further savings are expected on ventilation consumption by the proper control of the AHU. The savings of the iBEMS measure are calculated assuming lightings activation is regulated by schedule and there is no dimming control. This calculation resulted in 27 kWh/m²/y of electrical savings and also additional 8 kWh/m²/y of thermal savings.

An additional demo, called Marema' in Grosseto (Italy) is also considered. The aim has been to design, develop and install a system able to increase the share of renewable energy (i.e. photovoltaic) with the combination of battery energy storage system (BESS) to cover the energy demand of the EV-link. The PV-BESS-EV link system would be the first prototype in a shopping mall in Italy able to cover the e-cars energy demand completely by the combination of PV and BESS. This make shopping centers a possible driver for the diffusion of the sustainable mobility not only in Italy but in all Europe.



Summary of the results per each retrofitting measure.

Demo	Retrofitting measure	Thermal savings [kWh/m ² /y]	Electrical savings [kWh/m ² /y]	CO ₂ emissions avoided [kg/m ² /y]	Cost avoidance [€/m ² /y]
Mercado del Val	ECM1: Multifunctional façade controlled by ECM2: iBEMS	N/A	14.7	5.3	1.9
	ECM3: Geothermal heat pump	N/A	16.1	5.8	2.2
	ECM1 + ECM2 + ECM3	N/A	31.7	11.4	4.3
Modena Canaletto	ECM1: Envelope retrofitting	2.1	7.3	4.2	0.9
	ECM2: Advanced lighting concept in the supermarket	0.0	106.2	54.1	12.7
	ECM3: Replacement of refrigeration cabinets	10.3	110.5	58.7	13.5
	ECM4: Linear air diffusers	No measured data available			
	ECM5: HVAC efficiency	78.2	-15.5	11.0	-0.2
	ECM6: HVAC-R coupling	0.0	11.4	5.8	1.4
	ECM7: General Retail Lighting in the galleries	0.0	10.6	5.4	1.3
	ECM8: iBEMS	0.0	12.7	6.5	1.5
	ECM9: Smart coatings	0.0	7	3.5	0.8
CitySyd	ECM1: Artificial lighting concept in Jens Hoff shop	-10.7	86	26.3	6.40
	ECM2: Light tubes in Jens Hoff Shop	No measured data available ¹			
	ECM3: General Retail Lighting (GRL) in common areas	-8	18	3.5	0.85
	ECM4: Natural ventilation	N/A	1.44	0.51	0.12
	ECM5: Modular roof skylight	No measured data available ²			
	ECM6: iBEMS	-8	27	7.0	1.70

N/A: Not Applied

¹ During the spot measurement campaign it was not possible to open the sun shading screens integrated in the skylight dome and thus only little daylight could enter the demonstration area.

² The modular roof skylight installation was just finished in M48. Thus there was not enough time to measure and analyze the data.



Dissemination

The impact of the activities can be demonstrated with figures (website statistics, number of tweets with the #commonenergy hashtag, number of mentions in media, number of events where partners presented the project, all available in the different project reportings and deliverables), as well as through the change seen inside shopping centres.

For this reason, it was very interesting to organise trainings with practitioners and activities with kids, tourism offices employees, and the broader civil society: it allowed perceiving the interest and explaining how to replicate the good practices home. Making the retrofits visible and tangible was very important, and some installed technologies are awakening interest: e-vehicles charging stations in Italy, light domes in Norway and Italy, etc.

A new class of workers, with additional skills, is furthermore created, with different modules of trainings developed (digital and physical events, software, videos, printed material, etc.).

The exploitation activities also demonstrate the impact: some partnerships are already foreseen between the technology developers, and some of them have already defined strategies to penetrate the market quickly (especially on e-vehicles and batteries).

The project played an active role in shaping EU policy by providing well-structured information on suitable retrofitting solutions for shopping centres, “icons of the consumerist society”, reflecting the challenges of modern life styles and our societies.

Communication and dissemination activities play an important role all along the project life, and as the material produced will remain available on the website for at least two more years, we hope that the project results will keep being used for a long time!

We had for instance, still after the project closed, requests for inclusion in magazines, posts on social media, and activities planned in Spain with kids.

The impact of the project was boosted by continuous and specific dissemination activities. They aimed at creating awareness for the environmental, social and economic benefits of the energy-efficient renovation of shopping centres and to make these benefits visible/tangible by showcasing what happened in the demo-cases. The project played an active role in shaping EU policy by providing well-structured information on suitable renovation solutions for shopping centres (often considered “icons of the consumerist society”), reflecting the challenges of modern life styles and our societies. The dissemination activities were driven by the following goals: (i) to establish a mutual trust dialogue with the relevant stakeholders from the key target groups and develop a specific messaging (in line with the project results); (ii) to coordinate communication activities with relevant research and stakeholder networks such as policy makers, related EU research project groups, professional organizations, industry stakeholders, standard bodies and manufacturers etc. with a view to qualitatively measure the impact and community’s impression on the CommONEnergy energy renovation approach; (iii) to coordinate and create synergies with EU working group dealing with policy development, as well as other high level ongoing initiatives on deep renovation of EU building stock; (iv) to identify scientific experts and relevant stakeholders to contribute at the identification, evaluation and harmonisation of current practical energy renovation approaches; and (v) to actively disseminate the results of the project to the defined target audiences and key stakeholders, including policy makers, industry, manufacturers of the technical solutions and systems, real estate companies, financial institutions, etc.

Different target groups were identified, and for each one a specific strategy and outreach were planned:

Primary target group: Shopping centre stakeholders, which included:



- People working in shopping malls such as tenants, employees, services.
- Building professionals and technical experts related to the planning and construction of shopping malls, such as contractors, architects, engineers, energy efficiency experts, energy auditors and managers, real estate managers and building professionals, providing the energy-related technologies used in the buildings like heating and cooling, lighting, ventilation as well as the envelope materials and technologies and their respective associations at EU and MS level.
- Policy makers at EU and MS level responsible in the field of buildings construction, buildings performance and energy consumption of buildings at all different levels from EU wide to national, regional and local.

Specific communication objectives for the group:

- demonstrate the marketability and technical feasibility of innovative renovation solutions for shopping centres;
- convince shopping centre stakeholders that larger scale and deep renovation projects can be realized while maximising social, economic and environmental benefits;
- (only for policy makers) make a tangible demonstration of the usefulness of energy retrofitting of shopping malls;
- create awareness on systemic renovation solution-sets for shopping centres;
- enable building experts to plan and realize innovative/optimal renovation projects (training aspect).

Secondary target group: Energy efficiency in building community, which included:

- Research, academia & consultancies: representatives from European universities, research institutes and consultancies actively involved in the development and implementation of national policies relating to the energy efficiency of buildings, working on the scientific and economic perspectives.
- Broader energy efficiency in buildings community (consumer associations, NGOs, financial institutions, etc.).

Specific communication objectives for the group:

- create awareness for innovative technologies;
- inform in detail about the scientific and technical specifications of the project (research focus).

Tertiary target group: Non-specialists, which included:

- Media (scientific, peer reviewed publications, national specialized press, European and national industry magazines, local generic press (demo sites)).
- Civil Society (shopping malls customers).

Specific communication objectives for the group:

- create awareness on the several opportunities to save energy (and need to save energy) in retail sector;
- demonstrate that shopping is even more fun in an environmentally friendly environment.

Various channels and tools were chosen for the dissemination of results, selected and adapted according to the intended audience or target groups, such as brochures and leaflets, e-newsletters, posters for scientific conferences, videos, scientific publications and articles for the general public, etc. Over the years, these tools have been refined: social

media have thus become one of the major tools to increase outreach, with the use of more hashtags on Twitter or groups on LinkedIn for instance, and with a regular newsletter being sent every six months.

Several workshops for practitioners and stakeholders were organized by the project team, and an innovative “lean pool” was conceived as a game to train about the application of the “lean construction” principles to shopping centre retrofitting. Furthermore, two public high-level events were organized in Brussels (one in parallel to the EUSEW16 and the second at the very end of the project to present the results), and in November 2016 the project was also presented at MAPIC fair, the most important European retail property trade show.

In the last stages of the project, a sustainability award for retrofitted shopping centres in Europe was organized, aiming to identify, showcase, and disseminate the best practices in the field. The shopping centres selected for the final shortlist and the award were brought to the attention of a wide public, turning them into European best practices presented in publications and events. Participants also became part of a network with other teams working on sustainable retrofitted shopping centres, learning about best practices across Europe, and comparing their work with like-minded teams. The winners were presented to the public during the project final event in Brussels in September 2017.

Finally, the scientific results achieved during CommONEnergy were gathered into a final document, the “Guidelines on how to approach the energy-efficient retrofitting of shopping centres”. This booklet, launched in September 2017, aims at reaching out / training stakeholders such as designers, facility managers, owners and investors, energy managers and more. The guidelines are a treasure box for many different stakeholders, providing from the early stages of renovation technology inspiration for effective solutions and methodological approaches. Starting from an analysis of shopping centres’ features and drivers for their renovation, CommONEnergy guidelines go through processes, modelling and tools developed by the project, focusing in particular on the several technologies enabling the aggregation in cost-effective solution-sets, like greenery integration, multifunctional coating and demand-response approach for refrigeration. The tools described by the guidelines include the Economic Assessment Tool and the Integrated Design Process Library.

Thanks to the comprehensive approach, ensuring that all target groups were reached, the overall result of the dissemination activities can be considered positive, taking into account the good feedbacks received by the different stakeholders. Further actions are still in progress, taking advantage of many events organized in the very last stages of the project life, and thanks to several promotional materials that have a growing impact.

Exploitation

As far as the exploitation is concerned, innovative solutions, tools and strategies were conceived to improve the energy efficiency in existing shopping centres or existing buildings redesigned to be a shopping malls. This includes, on one hand, solutions and methodologies already available, based on their interpretation and adjustment for the retail sector. On the other hand, new materials, components and systems for reducing energy needs and enhancing energy efficiency to achieve the target of factor 4 reduction of primary energy demand. The results of the project were mainly achieved in a cooperative work and not by single partner, however partners developed individual components and systems designed to enhance energy efficiency that are part of the project’s overall solution. These products will include for example heat pumps, PV panels, ventilation systems, lighting components, cooling and heating systems, coating, etc. Each component contributing to the overall



solution has its own exploitable potential, so special care was given in how the IP was managed and applied to the overall solution.

The exploitation strategy, which contains a variety of activities, was updated throughout the project, starting from a tentative list of exploitable results already identified during the proposal stage. To brainstorm on how the projects could address exploitation opportunities, related risks and potential obstacles, enhance the team and deal with IPR and standardisation, an exploitation seminar was organized at the very beginning of the project: offered as free service by the European Commission, it took place during the sixth month of the project life ((March 2014). The EC expert acted as facilitator to help partners to build a common “exploitation culture” and to understand IPR points and exploitation claims, need and usefulness of the PUDF, risk analysis and mitigation, dissemination, protection and disclosures. Moreover, the seminar suggested possible strategies to solve potential conflict situations and clarify pending issues, as well as to set-up targeted exploitation instruments developing a methodological approach for minimizing risks and maximizing exploitation prospects. One year later, a second exploitation seminar took place during a project meeting, when partners were gathered in small groups according to the involvement in the development of specific results, and the group discussions were focused on shared ownership and possible exploitation opportunities. During the final stages of CommONEnergy, several discussions about exploitable results were held in a bi/multilateral way, gathering only partners having a direct involvement in the result.

The detailed list of final exploitable results was shared with the European Commission, and includes:

- 5 Patents
- 13 R&D results with commercial exploitation
- 10 General advancement of knowledge
- 1 R&D result exploited via standards

As most of the information included are confidential, we can offer here only an overview of the results:

TECHNOLOGIES DEVELOPED WITHIN COMMONENERGY PROJECT

Ventilative cooling:

- Enhanced stack ventilation: automated openings located in the skylights to enhance stack ventilation. Application: common areas with skylights and openable parts at lower levels.
- Wind catcher: wind catcher integrated into light tubes to naturally ventilate shops. Application: shops at last floor with no parking on the roof.
- Single-sided ventilation: automated openings located in the facade to exploit natural ventilation. Application: common areas/shops with external façade.
- Fan assisted ventilation: increased mechanical ventilation rates to reduce cooling need. Application: common areas/shops/food store.

Thermal zoning optimization:

- Radiant panels: air conditioning in the refrigeration cabinets zones by means of radiant panels. Application: supermarkets with closed refrigeration cabinets.
- Full air with air supply diffusers for anti-mist formation: use of specific air diffusers to prevent mist formation on cabinet doors supported by a control system for the activation of electric resistances. Application: supermarkets with closed refrigeration cabinets.

Modular multifunctional climate adaptive façade:



- Configuration 1: bottom and top openings with integrated PV in the bottom part and shading system. Application: shops, supermarket, food court in cold/mild climates with envelope air tightness constraints.
- Configuration 2: ventilator louvres with integrated PV and shading. Application: atrium, transitional spaces in warm climates with no air tightness constraints.

Green integration:

- Surrounding trees, bush, pavement/lawn proportion: change microclimate characteristics (temperature, humidity, oxygenation etc.) in building's surroundings up to 1000m extends. Application: building's exterior unbuilt areas like parking, lawns etc.
- Intensive/active vegetated roof: bigger plants, higher initial and exploitation costs, weight- up to 1300kg/m², soil substratum thickness min. 30 cm; change microclimate, improves building heat balance. Application: common areas/ common green spaces.
- Extensive/passive vegetated roof: smaller plants, lower costs, weight- 50-300kg/m², climbing plants rooted in ground directly or in pots, change microclimate, improves rain water management, improves building heat balance. Application: horizontal shading systems, e.g. parking sheds.
- Direct vegetated wall: the greening system uses the facade as a growing guide; improves rain water management, change microclimate, improves building heat balance. Application: east-, south- and west-oriented exterior facades.
- Indirect vegetated wall: the greening system and the facade are separated with an air cavity; improves rain water management, change microclimate, improves building heat balance. Application: east-, south- and west-oriented exterior facades.

Smart coatings:

- IR-reflective/absorbing, self-cleaning, insulating, anti-mould: all possible combinations from these characteristics may be selected. Application: all substrates of roof or façade that could be painted with a conventional paint.

Daylight strategies:

- External solar lamellas: static opaque lamella, adjustable to climate and indoor requirements by different lamella distances. Application: in front of vertical glass areas of common mall area, also restaurants, etc.
- Modular roof, solar harvesting grid: grid structure which harvests direct sun while redirecting in uncritical directions (avoiding glare), is part of an overall concept, called modular roof, which can react to project-specific conditions (e.g. position of sale area, climate,...). Application: main atria in common mall area.
- Light-tube: daylight system which guides daylight from the roof into room by excellent light transmission properties, improvement in visual comfort and benefits for higher turnover. Application: shops, common mall areas.

Thermo-acoustic envelope components:

- Flexible mat without finishing; flexible mat with additional sound absorbing layer; flexible mat with additional finishing; flexible mat with additional sound absorbing layer and with additional finishing.

iBEMS (intelligent Building Energy Management System):

- HVAC + shading + artificial lights + natural ventilation + energy and environmental condition monitoring + refrigeration system: the iBEMS provides the required communication means between the installed systems and respective sensors. It incorporates control rules (higher and lower level) for the optimization of the system. In parallel it measures the energy consumption of the connected systems in order to calculate their efficiency. Application: all areas of demo case and reference buildings.

Electrical energy storage:



- PV + battery: use of PV+battery storage to increase self-consumption for the all shopping mall consumption or to cover dedicated load or EV-charger. Application: PV on the roof of shopping mall or parking area on platform roof. Suitable area for battery (space, ventilation, temperature).
- PV + H2: H2 for hydrogen car mobility or with FC for electricity consumption. Application: suitable area for H2 (space, ventilation, temperature, security issues).
- PV + Storage + electro mobility: use the storage for EV-charger. Application: possible station in shopping mall parking area (open or close).

Refrigeration system:

- Transcritical system for warm climate: transcritical system with features able to manage high external temperature in an efficient way. Application: Warm climates.
- Transcritical system with HVAC integration: the refrigeration system actively recovers the waste heat of the condensing side to satisfy heating and cooling demand. Application: small supermarkets in warm climates.
- Transcritical system with Solar Integration: Solar and refrigeration systems work together to maximize the heat production and running the adsorption machine in stable condition. Exciding solar thermal power is used by refrigeration to sub-cool itself. Application: supermarkets in warm climates.
- Transcritical heat pump for Heating and/or Domestic Hot Water (DHW): heat pump with natural refrigerant producing heat and DHW. Application: supermarkets.
- Thermal storage to manage refrigeration load peak: fire-prevention tanks used to shave cooling peak request. Inertia principle. Application: shopping malls with area fire-prevention tanks.
- Integral refrigeration based on water loop within the refrigeration system: integral cabinet with water condensed system and a water loop able to remove the heat outside the store. Application: supermarkets.
- HVAC&R water loop distribution inside building: water loop system linked with w/a heat pump, balanced to maintain stable temperature during year. Application: supermarkets.

Artificial lighting systems:

- General Retail Lighting (GRL): energy-efficient light source: LED, precise distribution by 7 downlights, backlit area to prevent glare, 3 light colours, constant light output control. Application: common mall area, main traffic zones in larger shops.
- Projector/mirror system: energy-efficient light source: LED, improved maintenance (longer life time, luminaires easier accessible), pleasant "architectural" light, glass roof will be visually closed at night by mirror. Application: main atria in common mall area.
- LED wall washer: energy-efficient light source: LED, precise illumination for merchandise arranged at wall, longitudinal glare protection energy-efficient light source: LED, precise illumination for merchandise arranged at wall, longitudinal glare protection. Application: in shops, merchandise arranged at walls.
- Integration of LED artificial light in light tube: supplements artificial light to daylight via 24 micro LED luminaires at the upper rim of the light tube, uses the distribution body of the light tube. Application: shops, common mall area.
- Green lighting box: turn-key ready control solution for shops that implement high-quality lighting scenes for retail applications, energy-saving strategies and monitoring possibilities. Application: device (control unit, shop control panel, DALI gateways) that can be installed quickly in shops; connection to central iBEMS possible.

Building Integrated Electric Mobility system:

- Charging stations: the Electric Vehicle (EV) charging station provides a refuelling point for electric vehicles. Required power can be provided from either the grid, or a



storage system (hydrogen or chemical). The electric vehicles can be of customers or mall employees. Application: parking area.

- The number of plugs and the power is related to the diffusion of the BEV (battery electric vehicle). The diffusion is driven mainly by the national incentives.
- Electrolyser and storage: the hydrogen storage system transforms available power to gas and stores it for future use; the opposite transformation provides base power for charging electric vehicles. Application: parking area with a natural gas grid connection for store hydrogen.
- Hydrogen mobility: parallel to the previous description the stored hydrogen can be used to refuel hydrogen cars, which can belong to customers or mall employees. Application: parking area in countries where there is a hypothesis of hydrogen mobility diffusion.
- Battery for industrial vehicles: the chemical storage system using batteries is applied for storing excessive energy from the renewable energy systems or low cost energy from the grid. When required the energy is transferred back to the grid or to Electric Vehicles. Application: parking area.

Customised photovoltaic technologies:

- Customisable photovoltaic strips for use in facade systems: flexible PV strips that can be fully customized in accordance of the requirements of a given application. Application: commercial buildings.
- Autonomous Photovoltaic Building block for multi-functional facades: the system consists of a thin-film PV module, a basic charge control system and a battery. Application: commercial buildings.

METHODOLOGIES DEVELOPED WITHIN COMMONENERGY PROJECT

- The virtual IDP library: a web-based platform collecting relevant data about the architectural archetypes and the energy performance of several shopping centres representative of the EU retail building stock. The IDP library is already available online and open to free use. It collects the retrofitting solutions to reduce energy needs and increase energy efficiency in shopping centers according to their archetype and specific technology features, as well as climate context. It is coupled to a general retrofitting approach including: principles of IDP, its concept and implementation, design and construction procedures; main drivers for deep retrofitting; peculiarities of shopping centers like functions, urban and social context interactions, architectural archetypes and technology features, functional layout depending on different climate conditions and specific needs; methods and tools to support IDP; analysis of possible integration of different functions of the shopping centres and relative systems. The structure of the platform enables (i) easy filtering and user friendly visualization of the collected information, (ii) to add further solution-sets based on different buildings (iii) to extract information in automatic way (iv) further informatics developing moving the information in automatic way.
- Integrative modelling environment (IME): it performs building energy simulations for studying the shopping centre as a whole (envelope + HVAC + Refrigeration + Lighting + RES + Storage), taking into consideration different aspects simultaneously: climate, building architecture, Heating Ventilation and Air Conditioning systems (HVAC), lighting (L), refrigeration (R), renewable energy sources (RES), and storages(S). The IME can be used in different shopping malls as tool for easing the design of new renovation measures or for testing new control strategies for the ventilation and lighting or even for following the whole process, from the design to the operation, of a shopping mall renovation.



- Economic assessment tool: it allows estimating the energy saving potential and economic benefits of retrofitting shopping centres. The tool targets managers and owners and allows entering relevant information about their centre. It provides quick information on the energy consumption and options to reduce energy demand, CO₂ emissions, environmental impacts and provides an economic assessment of the investments.
- Data mapper and scenario tool: it is an online tool which represents a quick, easy and tailor-made access to national and comparative international indicators on the commercial building stock. The main aim of the tool is to give a comparative cross-country analysis of the most relevant commercial building types with a specific focus on shopping centres throughout Europe. It gives direct access to scenario results on the energy demand development until 2030 of the European shopping centre building stock.
- Environmental and social impact assessment tool: it is based on the Life Cycle Assessment (LCA) and allows to assess a shopping centre's detailed or simplified sustainability, after or due to a refurbishment. The following environmental impacts can be addressed over the entire lifecycle, from the resource extraction in mines, over the production of intermediates and the use phase, until the end-of-life: global warming potential, eutrophication potential, acidification potential, primary energy demand, and fresh water consumption. Likewise, the following social aspects can be estimated: labour rights and decent work, health and safety, human rights, governance, etc.
- Lean Construction Management procedures: guidelines to implement the Lean Principles to the design, construction, renovation, and operation of retail outlets in shopping malls.
- Lean Pool methodology: namely "WE_Build", the Collaborative Planning Simulation Game applies a "customer perspective" in the construction site management approach, helping construction managers to reduce waste and failures, avoiding efficiency losses. It ensures that multiple processes, including diverse actors, technologies and equipment, are smoothly connected, the accurate tools and equipment are available when needed, workers do not have to wait for proper conditions, and the accurate measures are taken in a precise order.

Continuous commissioning platform: a continuous commissioning platform useful to show the real performance of the building (including Desktop and Web application). It considers the energy and comfort aspect not as two disconnected indicators but as a single one; in this way, the information of the energy consumption is enriched by the effectiveness of its use. The tool targets manager and owner of shopping centres providing detailed information on the energy performances, comfort levels achieved, economic aspects, and options to predict the trend of a selected output such as indoor temperature or energy consumption. Furthermore, the benchmark option allows comparing building energy performance with its energy baseline, or comparing a metered building energy performance with the energy performance of similar types of shopping mall.



Website and contact details

Project website: <http://www.commonenergyproject.eu/>

Project Coordinator: Eurac Research

Contacts:

Roberto Lollini
Accademia Europea Bolzano,
Viale Druso 1, 39100 Bolzano/Italy
roberto.lollini@eurac.edu