EcoShopping - Energy efficient & Cost competitive retrofitting solutions for Shopping buildings

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Final report

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1. FINAL PUBLISHABLE SUMMARY REPORT

1.1 Executive summary

Commercial buildings show high energy saving potential by the refurbishment of envelope and applying easy-to-install and cost-effective building services solutions. Completed with an improved operation and maintenance, the EcoShopping brings affordable solution to the market, which can be integrated into building owners' and investors' portfolio while helping to reach a sustainable, clean and healthy environment.

"EcoShopping" project developed a systematic methodology and cost effective solutions for the holistic retrofitting commercial buildings. By bettering the insulation and lighting system, integrating additional RES based HVAC systems and exploiting the building as a thermal storage, developing an intelligent automation control unit, maintenance and commissioning technologies, the energy efficiency of the commercial building has an overall enhancement of about 58%, reducing the energy consumption below 80 kWh/m^{2}a.

What we provide:

- ✓ **A guideline and methodology** for holistic retrofitting solutions in commercial buildings
- ✓ **LED** solutions and **daylighting** measurements for tertiary buildings
- ✓ **Database**, including commercial insulating materials (traditional and innovative), solutions for windows, self-cleaning products
- ✓ HVAC retrofitting systemic solutions based on **harnessing the building thermal mass, RE powered HP, new generation of capillary tube** and **recovery ventilation**
- ✓ Simplified **building model**
- ✓ Integrated environmental and acoustic **sensor network** completed with mobile **robot platform**
- ✓ Intelligent Automatization Unit with **model based predictive control** to explore the building as thermal storage and optimization of energy consumption in commercial buildings
- ✓ Advanced **alarm system** integrated to web platform
- ✓ Evaluation and ranking of **environmental impacts** associated with refurbishment technologies
- ✓ **Direct current heat pump coupled with PV system and irradiance based control algorithm**
- ✓ Business plan

1.2 Summary description of the project context and the main objectives

About 18% of the total primary energy consumption in EU corresponds to commercial buildings by covering the needs for heating, cooling and electricity. Commercial buildings consume in fact an amount of 1137 TWh/a, producing approximately 336 Mt CO_2 yearly. The major part of this energy is produced from the combustion of oil and natural gas, the EU's commercial building sector is highly depended on imported fossil fuels. Global electricity use in commercial buildings has almost tripled since 1980 and is projected to rise another 50 percent by 2030. It will soon become the highest-growing end-use sector in industrialized countries. From this point of view, the existing commercial buildings are optimal candidates for energy efficient performance strategies. According to the commercial building technology roadmap suggests that a 30% improvement in energy efficiency could be achieved.

For achieving this a holistic concept has to be implemented:

- minimize the intrusiveness of retrofitting actions
- optimize indoor environmental quality
- increase commercial value of buildings
- integrate and implement innovative technologies
- efficient monitoring and controlling with the help of mobile and fixed senor networks

Development of common and less climate dependent technologies, such as low exergy systems, thermal insulation, Daylighting technologies, exploitations and integration of RES and Intelligent Automation Unit for Building control, technologies for maintenance and commissioning.

Beyond novel and optimized envelope and HVAC retrofitting solutions, and intelligent automatization completed with a mobile and fixed sensor network ensures the optimized energy performance and indoor environmental quality.

The ambition of this project is to reduce the primary energy demand to less than 80 kWh/m2 per year as an average, exploit the potential of renewable energy utilization, increase at least of 50% compared to the State of Art (according Eurostat 2009 18,30% average EU27), and shorten the return on investment to less than 7 years. Implementing such objectives for commercial building with present day technology faces a number of challenges:

1. The problems of high implementation time and long interruption caused by the retrofitting activities.
2. High initial investment, consequently, owners refrain of doing the refurbishment.
3. Retrofitting solutions maybe not systemic, sub systems may be considered separately, the potential of energy saving of the retrofitted subsystem is not fully exploited.
4. Not all technologies can be implemented in all commercial buildings, e.g. due to wind speed, access to ground, lack of space or other technical or non-technical reasons. Different buildings in different climate zones require different retrofitting solutions.

However, all these issues can largely be solved by a combination of the following measures:

1. Development of a low intrusive construction and integration methodology, such as off-site construction strategy, plug & play and easy to install technologies, summer or holiday period implementation and zonal deployment.
2. Investigation and implementation of the adaptive and cost competitive equipment based on technologies of state of the art, optimal coupling and integration of subsystems to reduce excessive cost in and enhance the efficiency of the entire system.

3. Development of a new systemic retrofitting methodology, which allows the identification of the ineffectiveness of energy efficiency and potential retrofitting area, considering the commercial building as a whole, subsystems like lighting, envelop, HVAC, RES, building control, architectural and aesthetics aspects, comfort and security will be considered and the interoperation will be optimized.
4. Development of common and less climate dependent technologies, such as low exergy systems, thermal insulation, Daylighting technologies, exploitations and integration of RES and Intelligent Automation Unit for Building control, technologies for maintenance and commissioning, etc.

Therefore, the objective of EcoShopping project is to deliver the following artifacts and solutions:

- ✓ **Objective 1. Systemic retrofitting methodology**. The ineffectiveness of energy efficiency and potential retrofitting area will be identify, subsystems like lighting, envelop, HVAC, building control will be issued as a whole, while in the meantime, user comfort, architectural and aesthetics aspects, building security are taken into account.
- ✓ **Objective 2. Reduction of primary energy consumption solutions**. Envelop optimization with better insulation, using the selected optimal (cost and performance) material, 10% will be expected in this project. By using a low cost novel daylighting system, 20% will be expected. Integration of photovoltaic solar technologies and/or wind turbine with novel speed varied DC powered heat pump and radiant ceiling system aims at a reduction of 20% of the primary energy consumption and a 61,4% increase of RES share.
- ✓ **Objective 3. Sensor network.** A combination of distributed fixed sensor network and Mobile Robot, will become a cheap, energy-efficient but capable and adaptable system which monitors the occupancy level, temperature, humidity, noise in buildings and surrounding areas and transfers the data in near real-time to the IAU.
- ✓ **Objective 4. Intelligent Automation Unit (IAU)** Serve as a brain of the building, intelligence is added, the system enables a much more accurate control in terms of time, cost (e.g. reaction according tariff of electricity) and demand, a better coupling of different subsystems, forecasting of weather and energy demand, resulting in at least 25% more energy efficient compare to rule base control system.
- ✓ **Objective 5. Maintenance and commissioning.** By monitoring the device state and comparing the system status with historic data, system fault and ineffectiveness can be detected and presented in the developed web platform, allowing the building operator to advance the maintenance schedule, thus an sudden interruption of service is avoid and system efficiency is recovered, consequently, the energy consumption is reduced. 15% of energy efficiency enhancement is expected.
- ✓ **Objective 6. Guidelines, manual for use, installation, integration and set-up**. Guidelines for commercial building retrofitting, including technologies with high replication potential, performance and economic data.
- ✓ **Objective 7. Operative Demonstrator.** Solutions will be deployed and validated in 1 pilot building (Ikva Shopping Centre in Hungary). This will be used in workshops and training seminars for professionals of the construction sector, building managers, investors, partners, journalists or potential customers. The visualization of the performance, before and after the installation, regarding energy reduction and cost savings will be locally or remotely via website.
- ✓ **Objective 8. Information-space.** Website with forums, best practices space, etc., workshops and network of engineering specialists, software companies, ICT equipment

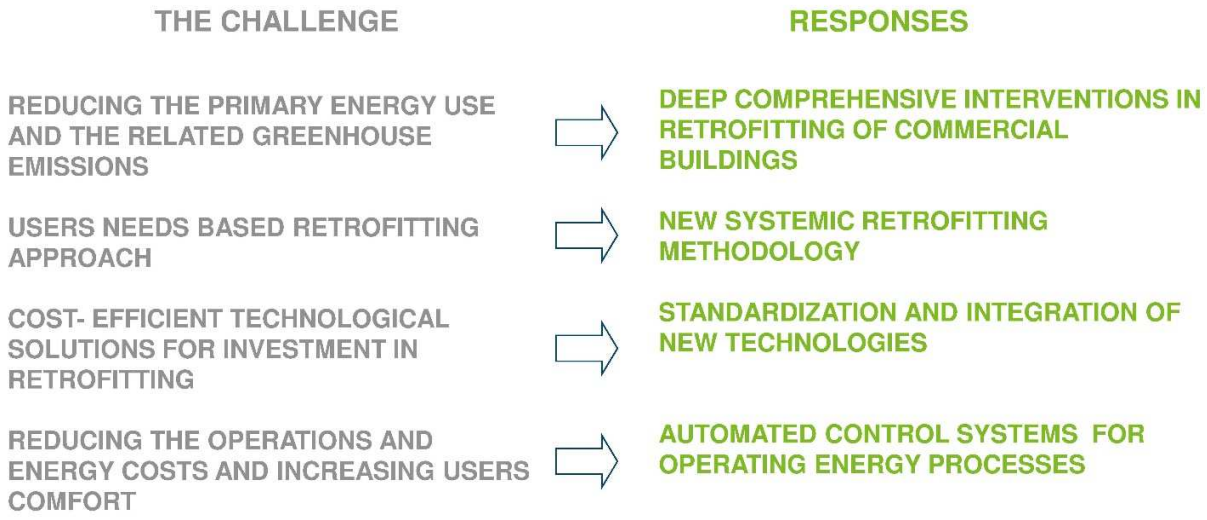
providers, construction companies, urban systems specialists, software companies, RES (Renewable Energy Systems) providers, utilities companies, public authorities (planners) and other stakeholders.

The innovative solutions developed by each of the Consortium partner are characterized by different competitive advantages (different types of solutions—methodologies, products, processes), and for that reason are approaching different market „niches", positioning it between other similar solutions or create new „niche" and being leader on the market.

The Consortium has a well-balanced knowledge (including specialists in all the technologies and areas involved in the project), as well as a precise commitment for each partner. Within the EcoShopping consortium there are two Universities (Yasar University and National Taiwan University of Science and Technology) and four Research Centres (The Fraunhofer Institute for Digital Media Technology, The Austrian Institute of Technology - AIT, Building Research Establishment - BRE and the Consiglio Nazionale delle Ricerche - CNR) specialized in application-oriented research and development of new energy saving technologies and reducing CO2 emissions by maximizing energy efficiency. SMEs occupy a significant position in the project as we have ten SME'S operating in the different fields and which six of them are leading eight of eight WP (Energosys, Solintel, RED, Symelec, Novamina, Ancodarq). The consortium is composed by 15 partners from 10 different EU-countries (Austria, Croatia, Germany, Hungary, Italy, Poland, Portugal, Spain, Turkey, United Kingdom) and one Asian University (Taiwan).

Picture 1 shows the main challenges and responses of the project.

Picture 1 Challenges-responses



1.3 Main S & T results/foregrounds

1.3.1 Guideline: Methodology for holistic retrofitting in commercial buildings

“EcoShopping” project developed a systematic methodology and cost effective solutions for the holistic retrofitting commercial buildings.

The Guideline provides this methodology for holistic retrofitting in commercial buildings for the interested stakeholders, along with different steps need to be followed.

The guideline considers technical, energy, legal and economic aspects forming a holistic retrofitting solution for commercial buildings, with the aiming to reduce primary energy consumption of the target building and increase the share of Renewable Energy Sources. Following the methodology of retrofitting, a consumption down to less than 80kWh/m^2 per year is achievable project and even more aggressive reduction could be possible depending on the solutions adapted in target building.

This guideline collects all the good practices from EcoShopping project, including the implementation of a pre-retrofit assessment of the building, identification of the most suitable kit of HVAC and Renewable Energy System, lighting and insulation solutions along with a proper Operation and Maintenance control through an Intelligent Automation Unit. Once the retrofitting solutions are chosen, the steps to be followed in order to correctly finalize the process of deployment on the site are explained.

After the implementation of the selected solutions for different retrofitting areas, a validation and verification protocol is outlined to evaluate if the real actuation of the retrofitted building corresponds to the expected performance and verify the achievement of the desired energy efficiency and comfort level.

This document is a handy and practical guideline which allows users to follow different steps of the retrofitting process, 18 appendixes are also included offering a wider picture of different retrofitting steps, aiming to enable the end user to have a well-informed decision making with information provided in details.

The aim of this guide is to offer the reader a guideline for the methodology to be followed in case of considering to address a retrofitting project of a commercial building. The main drivers for a retrofitting actuation are usually the cost saving and improvement of the building status, among the solutions, the energy efficiency improvement, reduction in energy demand and emission of the building are the main areas. However, the comfort level which is determined by an air quality and thermal comfort conditions is another key aspect to be considered in a holistic retrofitting solution.

Therefore, a user considering a possible retrofitting of a commercial building must assess not only the potential energy savings, the corresponding costs savings and aesthetical aspects, but also the improvements in terms of air quality and thermal comfort, making it a holistic retrofitting action.

This methodology for holistic retrofitting in commercial buildings is based on five steps:

The **Project Setup and Pre-retrofit Survey** reviews the building codes of different European countries within EcoShopping consortium, indoor air quality, building envelopes and equipment standards. European commercial building stock analysis for benchmarking and surveys for building owners and building end users are provided in order to define the scope of the work and set the project targets, survey templates are provided to collect the needs and requirements of both owners and end-users, and to identify current dissatisfaction or desired issues. Moreover, an explanation of typologies of economical funding and the economic/non-economic benefits obtained due to the retrofitting actuation is introduced.

Energy Auditing and Performance Assessment enables an identification of energy use and costs to identify areas with energy saving potential and provide the information needed in building performance assessment through energy simulation software.

Identification of Retrofit Options serve to make an overview of the main and most promising technologies in the following fields: Building envelope (insulation, windows, self-cleaning products), Lighting and Daylighting systems, HVAC solutions and Renewable Energy systems, Intelligent Automation Control Units, Operation and Maintenance plan for the installed equipment in commercial buildings.

Site Implementation and Testing are provided as practical steps to be followed in order to build up a suitable implementation plan for the selected retrofitting actions and to deploy the chosen technologies on the site.

Validation and Verification explains how the implemented solutions will be assessed to evaluate their effect and verify if the expected targets of equipment and whole building energy performance and comfort levels are achieved.

Picture 2 shows the described 5 steps in summary.

Picture 2 5 steps of the holistic retrofitting of commercial buildings

The document guides the user in the different processes and decisions as the assessment of the retrofitting needs, the evaluation of the different retrofitting actuation possibilities, the economic and energetic analysis of each actuation and the decision making of the suitable retrofitting level according to the economic conditions.

To further facilitate the use of the guideline, a web including the key information of the steps and an open wiki platform are developed. User can easily access the interested contents and even contribute to the community in improving and enriching the guideline. More information is available in http://ecoshopping-project.eu/index.php/guideline/.

1.3.2 LED solutions and daylighting measurements for tertiary buildings

The Natural Light Illumination System (NLIS) from, the National Taiwan University of Science and Technology (NTUST) evolved further during the project. New collimator technology increased the efficiency of the light collector part. The design of light pipes with Fresnel and micro-lenses are lower cost alternatives to fibre optic cables in the light-transmission sub-system but require straight connections between the light collecting part and the light transmission part of the system.

The costs of the NLIS system decreased with 50 % to about 17 €/lumen thanks to the developments during the Eco-Shopping project Costs remain however very high for such daylighting systems. For the demonstration case an artificial lighting system based on LED's, was designed and implemented, reducing the electricity consumption with almost 60 % when compared to the previous fluorescent based illumination system.

1.3.3 Database, including commercial insulating materials (traditional and innovative), solutions for windows, self-cleaning products

A database collecting the information on the conventional and innovative insulation products for walls, windows and roofs used in building construction has been created. The most promising ones have been selected and the assessment of the optimization in the applicability of insulation solutions has been performed. In addition, a research on efficient self-cleaning coatings to cover the insulating panels has been carried out, in order to add self-cleaning properties to the insulation solutions, improving at the same time Indoor Air Quality.

The database of the insulation materials currently available in the market, based on the data declared by the manufacturers or on literary data, is available at http://esdatabase.altervista.org/. The aim is to evaluate the best solutions from an energetic and economic standpoint. An available database query consists in finding the least expensive material after choosing a thermal resistance value of the insulation layer. In this case the software calculates the minimum thickness required for every record in the database and then orders the products from the least to the most expensive. Another implemented query is based on the optimum thickness criterion.

Similarly to the insulating products for walls and roofs, a database for the windows products is available at http://esdatabase.altervista.org/page_wshowall.php. Also in this case it is possible to view all the products and make queries.

For the self-cleaning materials, as for the insulating products, the database is downloadable at http://esdatabase.altervista.org/page_home.php.

The databases are open and free for public.

1.3.4 HVAC Retrofitting systemic solutions HVAC Retrofitting systemic solutions based on harnessing the BUILDING THERMAL MASS, RE powered HP, new generation of capillary Tube and heat recovery ventilation.

The HVAC solution covers the integration of ventilation, heating and cooling with novel capillary tube technology, newly developed direct current heat pump, which is controlled based on solar energy production and powered by local electricity generation with PV panels.

The project used exergy analysis during the development of HVAC solution, which is a useful tool for determining the locations, types and true magnitudes of energy losses, and therefore help in the design of more efficient energy systems.

The main advantages of the developed HVAC system reside on the high energy efficiency in the thermal energy production as well as in the renewable energy production on-site.

The capillary tube system enables working with mild generation temperatures for the heat pump system. Thus, the heat transfer fluid circulating through the capillary tubes is able to deliver the heating thermal energy by entering at 32 ºC and returning at 28 ºC, while for delivering the thermal cooling energy it enters at 15 ºC and returns at 18 ºC. This means that the set-point temperatures

for the generation of the heat pump system are 32 ºC for heating and 15 ºC for cooling, which are quite favorable conditions for the heat pumps and therefore they work with quite good COP.

Furthermore, the developed DC heat pump prototype works with a quite good COP thanks to the good performance of the DC compressor, which can be also easily controllable at partial a load by controlling the supply voltage. It has been demonstrated that a very good performance at partial load (COP>5) can be achieved with these heat pump unit given that the efficiency of DC compressors is more uniform and easy to be controlled for different speeds than for AC compressors.

In the study carried out for the integration of the DC heat pump with the photovoltaic system it has been realized that at least a controller and a converter are required in order to enable the Maximal Power Point Tracking (MPPT) of the solar system and convert the DC power generated from the solar panels to the DC voltage required by the HP according to the demand, as well as it has also been seen that a sizing optimization of the heat pump system is more easily achievable if the DC grid is able to provide constant power, instead of the unsteady renewable sources as the sun or wind. Thus, it has been demonstrated that DC HPs result a very interesting option for DC microgrids, especially for those which are not only feed by an only unsteady energy source, avoiding in this way problems of power availability, storage necessities or sizing optimization.

On the other hand, the on-site consumption of the renewable generated energy means several benefits: from one side the electrical demand of this point of the grid is reduced, meaning less generation and distribution requirements for the general grid and on the other side also less renewable energy is introduced to the grid, meaning less stabilization and quality control effort.

Finally, the management of the operation through the Intelligent Automation Unit uses the thermal inertia of the building in order to optimize the operation of the system. Thus, the radiant ceiling is activated before the building is opened to the public in order to pre-condition the zone temperature. Since the temperature measurements, the estimation of the temperature evolution and the comfort assessment, the Intelligent Automation Unit is able to calculate the optimal conditioning schedule and generation temperatures of the heat pumps in order to minimize the energy consumption, maintaining however always the comfort parameters within the desired values.

1.3.5 Robot + Acoustic + Fixed sensor network

Acoustic technologies and methods for pattern recognition are increasingly used in multiple areas. Examples for the detection and classification of emergency situations in public spaces based on IDMT embedded intelligent acoustic sensors are the detection of emergency vehicles, in-line and end-of-line testing applications in the automotive area, detection and classification of shouts for help [1], healthcare monitoring [2] and security. Key requirements for the successful use of acoustic technologies are their robustness against environmental influence, i.e. noise, sensor positioning and reverberation. IDMT showed in the past that by combining acoustic event detection/pattern recognition algorithms with suitable signal pre-processing strategies, a dramatic increase in

[1] P. W. van Hengel, M. Huisman, and J.-E. Appell, “Sounds like trouble,” in Human Factors - Security and Safety, D. de Waard, J. Godthelp, F. Kooi, and K. Brookhuis, Eds. Shaker Publishing, Maastricht, The Netherlands., 2009, pp. 369–375.

[2] F. Jin, F. Sattar, and S. Krishnan, “Log-frequency spectrogram for respiratory sound monitoring,” in Proc. ICASSP,Mar. 2012, pp. 597–600.

performance can be achieved [3]. Via the combination of multiple acoustic sensors in (wireless) sensor networks, additional solutions ware developed by IDMT covering areas such as Smart City, Internet-of-Things [4] and Energy Efficiency.

As an intelligent acoustic sensor, IDMT offers the so-called acoustic processing unit (APU). The unit consist of modular multi-layer PCBs: a 16-channel multichannel MEMS frontend + DSP for signal preprocessing, a system on a module SOM for machine learning based acoustic data analysis and a dedicated PCB for connectivity and an energy management system + battery for autonomous operation. Wireless communication capabilities at the moment include WiFi and Bluethooth. GMS and LTE. LORA and/or ZigFOX are foreseen in the next technological iteration (preferably a dongled version). The form factor for this reference platform is 5x5x5cm and ~200€ per sensor. Single-channel solutions with an application dependent optimized SOM + housing are expected to be <75€ in small quantities (<200). The usecases for the APUs can be defined by a recognition model for acoustic events and speech. Configuration of the APU is done using a GUI/web-interface. The application specific recognition models on the sensor are exchangeable and are managed by a dedicated sensor management and configuration software application. Out of a database, recognition models can be downloaded by the sensor, defining its application scenario. It is important to note that all the processing is done on the sensor. No internet connection is required for operation. Data and privacy-issues were taken seriously during development: no personal data is stored nor communicated by the sensor. Communication with a backend is restricted to anonymized status and location information and messages of recognized acoustic events/speech.

Intelligent stand-alone acoustic sensor nodes for monitoring applications

Starting point for acoustic monitoring technologies within EcoShopping was a wired, bulky and rather expensive distributed acoustic sensor frontend capturing raw audio data. This data was fed to a central processing unit for further analysis and the application occupancy level estimation for commercial buildings.

Over the course of the project, the acoustic processing unit has become an intelligent stand-alone acoustic sensor node for general monitoring applications. The reference platform now consists of multiple scalable layers of electronics and corresponding software components.

The first layer is a modular acoustic 8-channel-frontend based on MEMS technology feeding audio data to a DSP for static audio signal processing tasks such as filtering, denoising, localization and beamforming.

The second layer is formed by a cost-efficient compute module for dynamic computational operations. The software core consists of a scalable software framework for acoustic event detection and speech recognition applications. The application scenario is defined by exchangeable recognition modules.

The third layer is a baseboard holding a wireless M2M interfaces as well as a battery management

[3] Jens Schröder, Niko Moritz, Benjamin Cauchi, Marc René Schädler, Kamil Adiloglu, Jörn Anemüller, Simon Doclo, Birger Kollmeier, and Stefan Goetze. On the Use of Spectro-Temporal Features for the IEEE AASP Challenge 'Detection and Classification of Acoustic Scenes and Events'. In IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA), New Paltz, NY, USA, Oct. 2013.

[4] Hollosi, D., Nagy, G., Rodigast, R., Goetze, S. and Cousin, P. (2013). *Enhancing Wireless Sensor Networks with Acoustic Sensing Technology: Use Cases, Applications & Experiments.* IEEE International Conference on Internet of Things (iThings2013), Beijing, China, August 2013

system for autonomous operation driven by batteries. In its current form, the reference platform has a dimension of 5x5x3 cm excluding a housing.

The intelligent stand-alone acoustic sensor nodes have application scenarios in the area of care environments and clinical applications, home automation and smart buildings, smart city, security and industrial applications (Industry 4.0).

Fixed Sensor Network

The monitoring is employed to assess the performance of the building. The intelligent system is an important asset to improve the energy consumption and energy efficiency while maintaining or improving the comfort levels and the indoor environmental quality. The monitoring process follows a step-by-step approach, starting with a detailed technical design of how and where to locate the meter and sensor at each site. Then the monitoring is executed, and the results reported regularly.

The monitoring platform of the fixed sensor network was designed to be flexible to integrate with a wide range of market sensors using distinct communication protocols or a building management system that may be pre-existent in the building to monitor. The pilot building was fitted with the needed sensors to evaluate optimally the energy efficiency of the installed systems and, at the same time the environmental parameters such as the indoor air quality and comfort.

The fixed sensor network installed in the pilot building is comprised of wired and wireless sensors and meters. Wireless based monitoring system designed allows for maximum flexibility, so that the measuring devices can be more easily moved if necessary. The wireless sensing equipment requires virtually no maintenance for the period of three years. Those sensors can be easily replaced in case of faults or damage.

Also, the monitoring platform is fitted with a rich user interface, suitable for accessing the data collected from the building in an user friendly way. The user interface is web based and only requires a web browser to access it. Depending on the security policies, it may be accessible from the internet. This user interface is capable of showing the sensor and meter data in an intuitive and graphical way, allowing comparisons with baselines to evaluate the achieved savings and also the calculation of indicators such as the energy spent in a section of a building per area or volume.

The platform also makes available a very complete REST API, enabling the possibility for external systems to use the data collected from the building as input for its job. This API also permits external platforms to insert its own data into variables of the database.

In summary, the monitoring platform was developed to be suitable to be installed in virtually any building type and to be scalable and able to integrate with the maximum number of sensors and management systems that may already exist in the building.

1.3.6 Advanced alarm system integrated to web platform

Operation and maintenance is one of the most cost effective methods for ensuring safety, energy efficiency and reliability of a commercial building. Inadequate maintenance of energy using systems is a major cause of energy waste and good maintenance practices can result in significant savings, faster system recovery once faults are detected, reducing operation time in inefficient mode and avoiding serious interruptions.

An alarm management system for a building operation was created for effective building alarm management, with which it is possible to filter and priorities the alarms based on various alarm metrics. Then it is necessary to list all of the needed building alarms and then select the most beneficial ones. These essential alarms are then configured in the software implementation of Alarm Manager along with other important operation and maintenance information. This information then enables building operator to conduct operation and maintenance in efficient manner.

Most often the major usability problem in a commercial building is that there are too many alarms activated at once which commonly referred to as alarm flood or that important alarms go unnoticed, the task of alarm generation is to increase the usability of different building systems. Building and equipment alarms are added to alert the building operator to a condition that is about to exceed or have already exceeded a safe (allowed) limit.

The ultimate objective is to prevent, or at least minimize, physical and economic loss through operator intervention in response to the condition that was alarmed. For most users alarm system, losses can result from situations that threaten environmental safety, personnel safety and equipment integrity. A key factor in operator response effectiveness is the speed and accuracy with which the operator can identify the alarms and apply immediate action.

Developed Alarm Manager is a software application for alarm management; it collects data from building sensors (temperature, relative humidity, carbon dioxide level, etc.) and calculates needed parameters for diagnostic purposes. Alarms from HVAC systems are collected through IAU and can alert user in the case of equipment malfunction so that it cannot pass unnoticed.

Building Model calculates expected energy consumption and forwards this information to Alarm Manager in order to perform model based diagnostics. Alarm Manager can also log the activated alarms and build reports and notifications for building owner trough Web platform diagnostic services (REST web services, email, optional push notifications and sms).

Since the state-of-the-art building alarming systems generate big amounts of alarms that are difficult to respond to, within this work an effort was made to create a better management of the building operation alarms. For this purpose, an alarm management system for a building operation was created in which it is possible to filter and priorities the alarms based on various criteria.

Main results achieved during the Ecoshopping project were:

- Development of an alarm management system
- Definition of alarm metrics and KPIs to filter and prioritize the alarms
- Definition of alarm generation implementation architecture
- Validation of tests with the building operational data
- Web service integration (Ecoshopping Web Platform)

1.3.7 Intelligent Automation Unit with model based predictive control to explore building as thermal storage and optimization of energy consumption in commercial buildings

IAU is an overall guidance system for optimal utilization of available energy for consumption in building. Meaning that IAU in its core is a system that guides other system in order to be optimal in energy usage, i.e. heating and cooling system can use multiple energy sources (heat pumps, gas boilers, etc.) in optimal manner. IAU in Ecoshopping concept is configured from building

management system, optimizer system based on model predictive control and web service platform for data communication to users and machine to machine systems.

Figure 1 shows the IAU concept's three pillars.

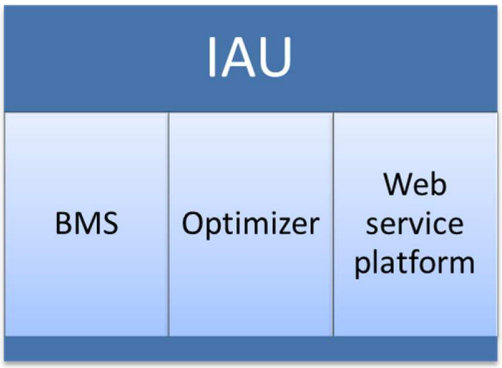


Figure 1 IAU concept

Optimizer is model based predictive control module which takes into account several key parameters (weather condition, dynamic energy price, adaptable human comfort parameters and building condition).The optimization of energy usage in shopping mall, mainly HVAC system is driven by global optimization parameter, 'minimum energy cost' . System has been developed as a generic solution for Ecoshopping project and has been customized and parametrized for use in IKVA demo site.

Model based and short term (1 day) weather forecast supported HVAC Optimization is proven as reliable and efficient service. Using of building mass as a thermal storage in a case of shopping centre specific conditions show significant energy savings (full validation results will be available after year operation).

Further improvements could be expected if it is combined with storages which are not directly coupled to comfort bounds of the people staying in the building. Combined usage with energy storages that is not having direct effect on people comfort (like; isolated water tank, isolated block of concrete in the basement, or phase changing materials (PCM) storage) is recommended.

IAU unit can be implemented (retrofitted) on existing BMS systems that uses standard communication protocols(BACnet ,Modbus RTU/TCP, LONWORKS,web services...) very easily due to support of all standards communications. Demonstration site at IKVA did not had BMS system integrated so IAU also acts as and controller to all building actuators like HVAC and monitoring system. It is of importance to say that IAU in its core is an software solution and can be implemented on variety of industrial computers/real time units based on customer requirements. This is a great advantage over industrial state of the art systems which are mostly propriety to the hardware.

Depending on the complexity of a building and building systems, it could be less or more difficult to adapt the control strategies and the optimization algorithms to another building. Implementation methodology and guidelines are as listed here:

IAU system implementation guidelines

1. Building identification and modelling ; based on the physical building properties mathematical model for predictive model control needs to be developed
2. Analysis of current installed subsystems and system which will be installed (i.e. HVAC, capillary tube system, illumination, existing BMS system)
3. Design of the IAU hardware system based on installed subsystems
4. Customization of the IAU software for use with installed building subsystems
5. Installation of IAU hardware or implementation of IAU software on existing building management system hardware (industrial PC, real time targets)
6. Installation of web services for remote monitoring and control including error and faults reporting
7. Calibration ,testing and validation period
8. Final commissioning and training provide for building operators

Commissioning guideline for the IAU system:

1. Implement IAU hardware to the site and connect all communications and electric wiring using best practices and specified procedures from the hardware manufacturer
2. Implementation and testing of all subsystem communications ; test all the communication (Modbus, Lonworks, …) with all subsystems and validate that all parameters are in correct format and values are validates against real values and values in subsystems manuals. This test also includes remote acess to the IAU unit and webservices in use (i.e. weather services).
3. Start periodical logging of all data as soon as possible
4. If system acts also as BMS (control system), identify system responses (i.e. CTS) and calculate or if possible auto tune all control systems for actuators and commission control system with operator based setpoints (scheduled temperatures, lightning levels,etc.)
5. Commision the alarm and warning diagnostic tools and commission for the web services for control and monitoring of the system
6. Commision of the Optimizer unit in parallel without control
7. Validation of the building system behaviour and validate it against optimizer unit
8. Calibrate the optimizer unit and transfer control to Optimizer
9. Validate system behaviour
10. Train operators of the building

Ecoshopping web platform

System requirements and solutions:

1. **Control and monitoring of the building subsystems in real time from anywhere in user friendly manner;** our system is internet based which provide for access to the building control system from any locations equipped with internet connection.
2. **Real time building status notifications (emails, sms, push notifications);** any abnormality in building behavior is notified in real time to the building operator through email by diagnostic service, push notifications and sms can also be easily implemented and

user will be able to subscribe himself to different messages and different priorities (i.e. alarms and warnings are send in real time while occupancy can be notified once a day)

3. **Comparison of building operation to modelled behavior or comparison of different buildings (analytics)**; system will enable user to compare building operation to modelled operation or by season or with historic data in example.
   Scalability and modularity of the system; because system is based on internet technologies (HTML,REST web services …) and cloud based technologies system is rather easy to scale globally. However adding building subsystems locally involves a little bit of more effort due to fact that building subsystem communication protocol need to be added (i.e. Modbus), subsystem control needs to be implemented and so forth to the IAU.
4. **Secure system;** protection of data and building subsystem from misuse by implementing state of the art standard security technologies (SSL, API keys…)

Ecoshopping webservices platform is developed service with main goal to create user friendly interface between building intelligent automation system and owner and building operator and also enable machine to machine communication for eventual third party software (i.e. Schneider Cloud BMS) or to provide data for big data services and similar applications. This is achieved by development of communication layer between building subsystems, database and operator.

Traditionally system operators would have SCADA systems on site and on designated PC's, our approach is to make SCADA more flexible and transfer this system on internet which enable operator to access building data for control and monitoring from any locations and anytime without having to lose any of the functionality.

Idea behind EcoShopping web platform is also to enable multi-building user environment where monitoring system for building portfolios could be accessed through building portfolio web app and also more SCADA like system for direct building control. Based on this we developed standard REST webservices for machine to machine communication and tested our services with cloud solutions (Google Cloud and Firebase).

1.3.8 Evaluation and ranking of, environmental impacts associated with refurbishment technologies.

We identified and analyzed the relevant standards and building codes and made proposals for improving these through the best practice solutions for the retrofitting of shopping buildings. Building regulations and their associated codes set a minimum level of performance for non-domestic buildings but do not attempt to prompt best practice. However, the building codes specify what the minimum performance requirements for building fabric elements and building services are; the exceptions being "true" renewables, i.e. solar, hydro and wind based technologies, where there were no performance criteria. In terms of existing standards building energy controls are one of the most effective solutions in realizing energy savings. In addition, energy audits are vital for underpinning the data to propose the energy efficient retrofit project and identify the best practice and most appropriate solutions to retrofit.

For the owner there is growing evidence that the market rental value /m2 associated with green buildings such as offices can be higher than less-energy efficient buildings. The savings in energy could in part be passed from the landlord to the tenant or the driver more likely is that the tenant will want to be associated with energy efficiency as it will fit with their core values and sustainability aspirations. This will motivate the move to retrofit for energy efficiency.

We were concerned with the embodied environmental impacts of the retrofit technologies. The pursuit of reducing the operational impacts of a building should not be at the expense of increasing the embodied impacts of the buildings through the retrofit technologies. A whole life carbon approach was deployed to model the embodied and operational carbon within the same units to capture savings and impacts across the life cycle of the building. The IMPACT methodology has been applied to the case study IKVA centre as a chance to incrementally improve the process of data capture for evaluating whole building and through performance environmental impacts.

The selection and procurement of construction materials makes a major contribution to the life cycle impacts of a building across the environmental, social and economic aspects of sustainability. The IKVA building shell was modelled for its whole life carbon (WLC) impact before refurbishment (Prior Retrofit) and included the substructure, superstructure and fabric of the building and operational carbon (*Figure X*.) but not the mechanical and electrical services (HVAC, water distribution systems, lighting systems, electricity systems) as insufficient data are available. The largest carbon impacts are the operational energy (52%) and the concrete superstructure (28%) of the shopping centre. The IKVA building was also modelled post-refurbishment (Post Retrofit) to investigate the benefit of the energy improvement works. The WLC approach is a clear way of evidencing the balance between carbon savings from operational carbon reductions and carbon gains from additional process and products being retrofit to the building.

Comparing the Prior Retrofit and the Post Retrofit, it was found that it was possible to achieve a 34% whole life carbon saving that equates to approximately 3,070 tonne CO_2eq or 990 kg CO_2eq/m^2. The Post Retrofit shows a significant operational energy reduction compared with the Prior Retrofit scenario. Considerable contributions are made by passive design measures (e.g. additional external wall insulation), electricity production by photovoltaic panels and by the installation of the BLUEMAT radiant ceiling. The WLC approach is a clear way of evidencing the substantial savings in operational carbon and the small embodied carbon gains from the additional process and products being retrofit to the building.

The Figure 2 shows the total Whole Life Carbon and its breakdown over 45 years for IKVA prior to retrofit.

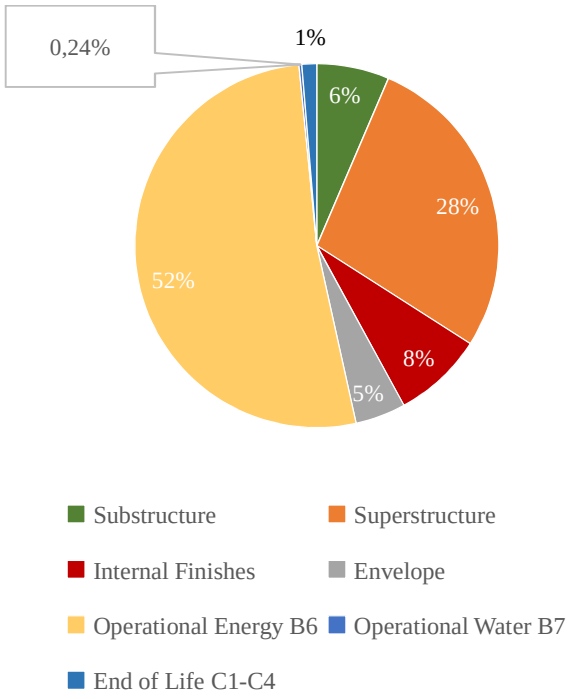


Figure 2 Total Whole Life Carbon and its breakdown over 45 years for IKVA prior to retrofit.

The evidence and learning from the project has enabled technical experts with standardisation responsibilities to improve input to enable wider replication and adoption.

It has improved the offering in the commercially available IMPACT compliant tools and helps tackle many of the barriers identified to retrofitting for energy efficiency such as motivation, lack of perceived value and immateriality of the savings. Issues around the ability to deliver low carbon buildings, non-compliance with Building Regulations and the slowness of the refurbishment time are practical supply chain issues that have been challenged by sharing, learning, inspiring and demonstration such as the Ecoshopping project has done at IKVA Shopping Centre in Sopron.

It is vital that the whole life impacts of buildings (both environmental and economic impacts) become more widely deployed to identify the most appropriate solutions for energy efficient retrofit. Linked with Building Information Modelling (BIM), this approach will enable architects and designers to innovate and create energy efficient spaces using low carbon impact technologies and products.

1.3.9 Simplified building model development - evaluation of three methodologies

In this part of the project methods for reduced modeling based on a simplified geometry were developed, as well as methodology to create dynamic thermal load models out of these reduced models is presented. Since the reduced models have limited accuracy, the building mass model represented as an RC model is calibrated during creation and operation. Finally, the calibrated RC models created using reduced models based on a simplified geometry are validated by comparison to TRNSYS and EnergyPlus simulations.

Using software tools to predict energy consumption in buildings is an established practice. The tools use different simulation methods to calculate energy needs of building systems, such as heating, ventilation and air conditioning (HVAC), lighting or other electric equipment. These methods require different information sources. For example, for thermal building simulations weather data, building geometry, material properties, internal gains, HVAC system components, and building usage information is needed. Some of this information can be provided by standards and norms, while the rest has to be manually generated or imported from other tools used during the building life cycle. Building geometry is often one of the inputs that require the most effort to be provided. It has to be either drawn manually using modeling software or imported from computer aided design (CAD) software. Having a tool that automatically generates these models is important when, for example: the time and costs need to be reduced, fast energy assessment of the building is needed, the availability of building information is reduced, or large number of buildings needs to be simulated.

A prototypical tool chain was developed which automatically generates simplified thermal building models. The tool can automatically generate internal building zones. Additionaly, each floor can be assigned with a different usage. This tool chain consists of tools to collect the information needed for modeling and simulation, a model generator and a simulation environment.

For the integration of the created building model within the building management system a simplified building mass model is necessary. On the one hand this model should be precise enough to forecast the building behavior in terms of e.g. room temperature on the other hand the model should have the capability being runnable on a building management system. To fulfil these requirements a building mass model represented as RC model was developed. The model consists of several RC networks of thermal resistances and thermal capacitances which represents the physical building parameters.

In order to get a more precise and realistic dynamic thermal building behavior the RC model needs to be calibrated to compensate effects caused by model simplification. Based on the given project situation two different calibration approaches were developed facing two different phases of the development. The first phase deals with the situation before the overall system starts operation and no or incomplete monitoring data is available. The second phase deals with the situation where the system is in operation and all necessary monitoring data of the building is available.

A validation of the dynamic response of the reduced models has been made through a comparison with the simulation results obtained with the TRNSYS and EnergyPlus models.

Considering the fact that the simplified building model should be on the one hand able to run on a building management system and on the other hand performing fast in terms of simulation time, the results show that the model is valid for this propose. The modeling process uses several simplifications, such as aggregation of the thermal behavior of several zones into one single zone, simplification of the building geometry and material properties to several numerical values represented as thermal resistances and thermal capacitances to meet an average thermal behavior. To conclude, the advantages compensate its drawbacks which could be further reduced by the calibration procedure.

1.3.10 Direct Current Heat Pump controlled depending on solar energy production

The main aim of this activity was the development of a small-medium DC powered Heat Pump to be introduced in the HVAC system of the IKVA shopping centre in Sopron (Hungary), being powered by renewable energy. Therefore, the processes of design, construction, test and evaluation

of the developed air-water DCHP prototype were done.

This DCHP was implemented and is part of the HP system in the demo building of the EcoShopping project. The DCHP has higher priority in usage, which means that it is switched on firstly in the cascade operation of the HP units system, getting a greater exploitation of this unit rather than the conventional ones.

For commercial buildings, energy saving and return of investment, comfort, less maintenance, and stability are key aspects mainly valued. It is true that currently there are many advanced technologies available and tested, but from the point of view of reliability, most building owners still choose certain mature products without being a pioneer in testing latest technologies. Nevertheless, the development of a DCHP makes a further step beyond the status of the art in HP application in commercial building.

Considering the barrier that generally the lack of visibility and the lack of performance data in demonstration cases represent for the new technologies and also considering the need of evaluation of these new technologies in real conditions that the market is demanding, the development of this prototype and its integration and exploitation in the HVAC system of the IKVA shopping centre comprises an interesting demo site to observe and evaluate the performance of the DCHPs connected to RE sources. Thus, the implementation of this prototype in this project aimed to test its use, as well as serve as demonstration of its application and so encourage the growth of the DCHPs use.

On the other hand, the innovation of the development of DCHP, mix operation with ACHPs, radiant ceiling and direct connection with PV panels shows all the components working as an integrated solution, demonstrating the possibility in improving further the overall system efficiency with these latest technologies and could be used as good practice for other retrofitting or new building projects.

For the development and implementation of the DC HP, firstly the initial concept of a RE powered DCHP was formulated. It was seen that HP is becoming a more popular technology for HVAC system and DCHP has great potential in energy efficiency enhancement. Benefits and main advantages of having DCHPs were also concluded, which consist of enabling partial load maintaining good performance, and the possibility to directly connect to DC grids feed by RE sources as photovoltaic or wind power, which is interesting in the distributed generation systems and micro-grids and a potential consumer contribute the generation-consumption balance.

After that, the detailed technical design of the DCHP prototype has been provided, and the different components of the system were listed and described. The optimization in the equipment is important, but the system design is rather critical aiming at improving the overall system efficiency and integration with other systems. Hence, in EcoShopping, consideration in interoperability and interconnection with other HVAC system is given to provide an integrated solution.

Following the system design, a reengineering process describing the prototype development was provided. The experience learnt in the process is then written down aiming to be beneficial for future developments. An evaluation methodology was developed for the testing of the developed prototype, which included the definition of KPIs, measurements methodology and testing conditions. Since this methodology, the tests were carried out and an analysis was realized using energy, exergy and exergoeconomic (a combination of exergy and economics) analysis methods, enabling an evaluation and validation of the performance of the unit and obtaining the advantages and requirements for the integration of this typology of HPs. Finally, the conclusions were drawn

out based on the development of the task for the integration of this HP typology in the thermal energy generation systems.

As main conclusions, it has been seen that DC powered HPs present several advantages for their integration in RES systems, as the case of study at the IKVA shopping centre in Sopron.

From one hand, DC compressors present better efficiency than AC compressors and have a more stable performance, suffering a lower performance decrease in the range of compressor speeds.

From another hand, since the increasing exploitation of RE sources (which usually produce DC power), and the emerging concepts of DC micro-grids, the use of DCHPs will enable the connection to these DC grids, thus increasing the overall energy efficiency.

In details, DCHPs can bring more benefits compared to the conventional ACHP beside the energy efficiency improvements:

- Lower noise: thanks to the balance in spinning of the motor, the HP will have less vibration and thus reduce the noise.
- Increase the temperature control accuracy: the control heating/cooling production is realized by changing the speed of the compressor, the temperature control can even be realized with real ±1°C, thus increase the comfort control.
- Fast in changing temperature: when the target temperature is far from the current actual temperature, the HP can work in a full load mode and deliver the nominal power, hence the target temperature can be quickly changed depending on the power of the HP.
- Higher flexibility in adapting start-up voltage. Unlike conventional AC compressor, the DC compressor could adapt a wider range of input voltage.

Nevertheless, there are several challenges in DCHP development and application:

- Availability of commercially available DC compressors.
- Availability of high power DC compressor.
- High costs.
- Social acceptance (reluctance to not mature technologies).
- Technical challenges in power match.
- DC grids implementation.
- Dependency of power availability on unsteady meteorological sources, when connected to DC grids fed only by RE sources like sun or wind, therefore not always available at each moment if there is no storage system. In these cases there would arise also a sizing optimization dilemma, being necessary to prioritize between maximal capacity of the system and yearly exploitation ratio.

1.3.11 Business Plan

The business plan helps to establish new Joint-Venture companies to utilize the EcoShopping solutions and to bring its results directly to the market. The business plan involves ESCO-based financing.

The business plan lists relevant activities that are essential for and/or contribute to the Business plan creation, Customers identification and awareness, as well as contributions of all partners of the “EcoShopping” project. A strategic business plan is a tool helping the top management of the Eco-Shopping project to assess the economic viability of a strategy and its related development plans. It is a tool for justifying and setting the financing of future investments. A business plan

based on a financial model simulating the future activities designed for reaching the strategic objectives. In order to develop the EcoShopping project strategy, we done overall analysis and form alternative variances to select the best one.

The EcoShopping project intends to use and integrate available products and technologies along with a network of low-cost equipment to accurately monitor the environmental and occupancy parameters to have better control of the BAM (Building Automation Management) and full exploitation of the Building Thermal Mass, which serves as a "Thermal Battery" and stores the RES (Renewable Energy Sources) directly without using battery, tank or other expensive storage material and simplifying the system structure. To reach these targets, the basic condition is to be cost efficient considering market conditions. We have executed refurbishment project, which the Construction market can evaluate and implement. With generating value, we get the market approval and establish the basis for future developments. The "EcoShopping" project has several target groups (Stakeholders) that have to be addressed. Targeting the most relevant groups allows for raising the impact of the project results and enables the replication of solutions. EcoShopping technologies can strongly improve building performance in absolute terms and relative to peak load. By not only cutting total energy use, but also shifting the time at which electrical power is demanded by the building, such technologies woven into a whole building systems strategy can draw on the grid during low demand periods and reduce the load during peak or high demand periods – cutting the need for the added high-cost, high-carbon peak power generation otherwise required. EcoShopping mission is to offer for Facility Managers, building administrators, energy experts and other related AEC stakeholders within the European Union a retrofitting solution able to integrate energy efficiency considerations within the retrofitting stage of the non-residential building life cycle with integrated design applications as well as maintenance with optimized scenarios. In respect to the exploitation plan that was performed earlier in the project, the provenance of partners who would create an ESCO around the main key exploitable results of the EcoShopping project tend to naturally project us towards the Central Eastern European region or CEE from a geographic perspective.

There are two target groups of the Business Plan:

- Project partners - it is acting as a guideline for the Business plan creation of project partners. It assists them to choose the most suitable Exploitation Strategy, in order to commercialize each of the Exploitable results.
- Stakeholders/End-Users – it provides an overview on Business plan creation scattered over the whole "EcoShopping" project consortium, in order to enhance awareness of that target group (Customers) about the developed solutions.

The long-term aim of the business is reflected in its mission statement. This embodies the operational scope of the business with the definition of elements such as products, services, primary customers, markets and geographic areas of interest, along with the values that want to be promoted and the desired social and economic impact that want to be pursued. The trend in building construction is shifting from new construction to retrofits.

The developed EcoShopping Key Exploitable Results (KER's) are eleven (11), and each of the KER's was undertaken by different Consortium Member, therefore the Ownership includes several parties. For multi-ownership cases, it is recommended to sign Joint Ownership Agreement, which will indicate contribution of each partner and their equivalent share in cases of patenting, trademarks and design protocols. In respect to the exploitation plan that was performed earlier in

the project, the provenance of partners who would create an ESCO around the main key exploitable results of the EcoShopping project tend to naturally project us towards the Central Eastern European region or CEE from a geographic perspective. In order to properly assess the perspectives of any type of property market it is first necessary to observe macroeconomic indicators and see if they are favorable. Indeed, real estate markets, whether residential or commercial, are particularly correlated with economic growth levels and output.

Commercialization is the process of turning products and services into a commercially viable value. Concerning Intellectual Property (IP), this term can be more specifically defined as the process of bringing IP to the market in view of future profits and business growth. Financing necessities are defined by the need to cover initial salaries, launch costs and initial project costs to provide a cash buffer at the beginning when contracts and clients are absent.As a conclusion, it has been decided that considering the total cost per square meter explicated in the corresponding section above as well as other considerations and metrics on the market environment, EcoShopping would be ideally priced at the average cost level of 330€ per square meter specified before. Indeed, considering the total cost per square meter within the framework of our project and the value derived by customers, practicing average market prices should safeguard respectable margins.

Being a small sized ESCO company, it is natural for the EcoShopping based service to limit its communications budget and rather diffuse and promote itself by relying on the existing network of its existing parent ESCO companies and word of mouth. Every business model calls for a number of possible ways to exploit the results of the project, for example: bring to next TRL, sell it out, making it into a product, service, direct market exploitation, licensing, standardization, etc. During the project phase, obviously, the EcoShopping business model conceptualization, created the foundation and orientation for future business creation, by doing this exercise, the value proposition, channel and target customers are getting clear. For establish Joint-Venture (ESCO) of EcoShopping, the purpose of a partnership is to ensure that EcoShopping technology solution developers/provider have a product/services offering that appeals to the demanded target market, above mentioned. In other words, the partnership complements the resources and key activities as required to deliver EcoShopping value proposition. Most new ventures in the early stages are short on “credibility”.

1.3.12 Operative demonstrator

With the developed specific implementation and operation guide, the energy-efficiency interventions are inserted into the value-oriented commercial property development and facility management strategy. By bettering the insulation and lighting system, integrating additional RES based HVAC system and exploiting the building as a thermal storage, developing an intelligent automation control unit, maintenance and commissioning technologies, the energy efficiency of the commercial building has an overall enhancement of about 58%, reducing the energy consumption below 80 kWh/m^2a.

The EcoShopping project aimed to build a holistic retrofitting solution for commercial buildings. This is achieved by research and development of retrofitting processes and technologies.

One of the main tools of the EcoShopping project to be able to develop a comprehensive solution was to demonstrate the technologies and processes that have been developed during the project in a real, operating shopping centre in order to be able to face real-world issues, provide viable solutions for the market and validate the EcoShopping solution.

The demonstration building is called the IKVA Shopping Centre, and it is located in Sopron city, Hungary. The IKVA has been built in 1979 and needed comprehensive retrofitting. The building has a retail profile and 2 150 m^2 leasable area.

The aim of this report is to provide the documentation of the demonstration retrofitting activities of the EcoShopping project in the IKVA. The report describes the measures that has been applied for the purpose of the EcoShopping demonstration within the building.

The goal was to enhance the energy-efficiency of the shopping centre, increase the share of Renewable Energy Sources, simplify the operation and maintenance, and consequently reduce operating costs for generating return for the investment, while providing optimal indoor environmental quality and comfort; for a safe, healthy and sustainable environment.

The implemented measures are:

- insulation of façade of commercial area
- application of air cleaning materials in the interior
- lighting replacement in commercial area
- heat pump system implementation with integrating a prototype of a Direct Current Heat Pump (DCHP)
- implementation of a solar power system
- new generation of capillary tube system for radiant heating and cooling in ceiling
- replacement of air handling unit
- implementation of an environmental sensor network
- implementation of an acoustic sensor network completed with mobile robot platform
- Intelligent Automatized Unit with predictive control, completed with harmonizing control system of engineering subsystems.

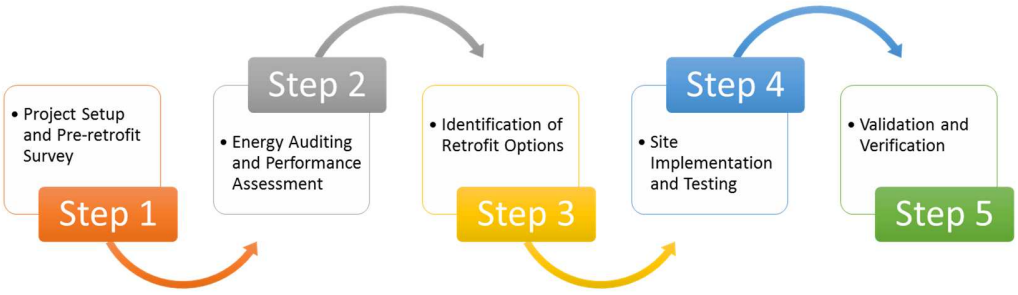


Figure 3 Steps of implementation of the retrofitting project

Figure 3 summarizes the steps of the implementation of the retrofitting project.

Through the demonstration project we could learn about implementation issues and how to overcome them. It provided us instant feedback from the market stakeholders and end-users.
The implementation of the small-scale demonstration project prepared us to be able to disseminate our results and replicate the EcoShopping solution on the market.

The concept of the demonstration was to establish a lab environment within the shopping centre, where the technologies can be easily implemented and the results can be precisely measured.

We have appointed a part of the shopping centre for the demonstration, after setting up and analysing the possible options. This area is the commercial area of the first floor of the Shopping Centre.

The stakeholders agreed that the Ecoshopping and the Owner investments will be financed for each party independent of each other.

The interests have been integrated between Tenants, Owner and the Research Team. As consequence of the joint working, the involved parties have understood that it is indispensable to integrate the interests and efforts of each other to get a successful implementation. Everyone embraced the Carbon goals and strategy and contributed to the development of a common implementation schedule. In addition, Energosys agreed to contribute free of charges to the Owner investment in the area of design, permissions issues and by the integration of the Owner implemented equipment, devices into a unique coherent operating and control system.

Considering the uncertainty factors the Owner of the IKVA Shopping Centre preferred a "staggered" project where the energy-efficient measures are not implemented at the same time and in all areas. In order to ensure the realization of the EcoShopping demonstration goals the Demonstration of the EcoShopping project is formed in a way that it will fit into the Shopping Centre's long-term energy efficiency goals and the chain of measures.

The construction plans were finished, and used during actual construction. The implementation process had been carried out according to the objectives.
The Fixed Sensor Network and Acoustic Sensor Network have been already implemented in the pre-retrofitting stage, to measure the environmental parameters and energy consumptions before renovation. An internet connection was built to have access and collect this information. Through this collection the energy consumption and IEQ data of the building is accessible. The second major phase of the implementation was to carry out the construction of the systems that produce, distribute, and use energy to achieve the previously planned comfort and energy usage data. The radiant heating / cooling ceiling (RC) system was constructed, together with the construction of the hydraulic unit. Parallel to this the photovoltaic power generating system (PV) was also completed and coupled with the thermal energy producing, renewable energy powered heat pump system. The Air Handling Unit that provides ventilation for the DEMO area was installed. The last major phase of the implementation was be the construction of the central building managing system, which controls all the subsystems. All these systems are currently active and operating.
In summary, we can say that optimal project management practice and protocols have been established and enforced by the stakeholders of the Demonstration investment project. We have set up an operational DEMO environment.
With the implemented measures we targeted the following calculated results of the demonstration project:

- 89.76 % energy savings compared to the pre-retrofitting status
- 680 kWh/m^{2}a energy savings in primary energy
- 53.39 to/a CO_2 savings
- 46.92 % use of RES
- return of investment from 16 years to 5.72 years based on the market conditions
- 100 % provision of adequate indoor environmental comfort parameters
- satisfaction of the majority of end-users with indoor comfort

1.3.13 Operation and maintenance plan

The energy consumption of residential and commercial buildings has increased in the last decades at rates ranging from 20% to 40%. Among building services, the growth in HVAC systems energy use is particularly significant (50% of building consumption) [5]. Among various driving factors to energy performance of building, operations and maintenance play a significant role. Different practices of HVAC system maintenance can result in substantial differences in building energy use. If a piece of HVAC equipment is not well maintained, its performance will degrade. If sensors used for control purpose are not calibrated, not only building energy usage could be dramatically increased, but also mechanical systems may not be able to satisfy indoor thermal comfort. Properly maintained HVAC systems can operate efficiently, improve occupant comfort, and prolong equipment service life.

The energy efficient designs have been the goal in the last years for the improvement of the energy performance of buildings. The weak part has been the omission of the operation and maintenance activities. In fact, among various driving factors to energy performance of building, O&M play a decisive role. HVAC maintenance keeps equipment in a healthy state in which HVAC system can function properly. This also includes troubleshooting of defective equipment to perform the intended function in a cost-efficient manner, thus extending life serving time.

To tackle this weak part and provide systemic retrofitting solution for the commercial building, Ecoshopping develops an Operation and Maintenance (O&M) plan for the IKVA shopping center and general templates for commercial buildings, mainly focused in HVAC equipment, identifying and describing the alarm system requirements and specifications.

The result includes the current practices of O&M procedures for HVAC equipment (reactive, preventive and predictive maintenance practices) and faulty operations are described.

An O&M assessment as methodology is also provided to identify ways to optimize the performance of an existing building. This methodology is helpful for buildings that have never undergone any type of systematic process to ensure they operate optimally.

Among the key outcomes, the Key Performance Indicators (KPIs) are identified and used as benchmarks that define the acceptance level of performance and measure the critical success factors which affect a desired outcome.

As part of the Plan, an “Operation and Maintenance manual” with instructions for the maintenance program management was elaborated. The data sheet structure and the required information are detailed. It is desirable to have an equipment data sheet prepared for each piece of equipment that will require operation or maintenance. This enables an effective method for collecting operation and maintenance information from the equipment suppliers in a form that is effective for preparation of operation and maintenance programs.

A key output related to the operation and maintenance is the “HVAC O&M Plan”, which is a detailed maintenance program that includes the required minimum inspection and maintenance tasks of most common HVAC equipment in commercial buildings and specially the equipment of IKVA, The first list is composed by 10 systems, some of them are installed in IKVA shopping center, such as Capillary tube system, Acoustic sensor network, Mobile robot platform, Fixed sensor network, Water source DC Heat Pump, Photovoltaic system etc.. Each equipment has a specific list with the “Inspection/Maintenance tasks” to be carried out and the frequency of these

[5] Luis Pérez-Lombard, José Ortiz, Christine Pout. “A review on buildings energy consumption information”. January 2007

inspections. The second list is composed by 20 common equipment that are often used in commercial buildings.

1.3.14 Infrared measurement technique development

A novel measurement technique, based on infrared thermography, is proposed to investigate dynamic thermal transmittance under solar loading. The state of art for thermal transmittance is done in stationary conditions, while the dynamic behavior is obtained with computational methods only. The knowledge of the phase shift of a sinusoidal loading through a wall, like the solar one, is particularly useful in planning or retrofitting a building to save energy in air conditioning during summer time.

The external surface of a building wall is usually stimulated by a periodic sinusoidal heat source (the sun) with a period equal to 24 hours. The temperature variation on the stimulated (outer) side of the wall is transferred through the wall to the internal surface and shows a periodic temperature oscillation that is time shifted and attenuated with respect to the original signal. To characterize the selected materials, the active source of the experimental setup is a 1 kW lamp that is controlled with customised software. The lamps delivers a sinusoidal heating on the back surface of the sample. A thermographic camera is placed towards the front size of the sample, looking also at a reflective mirror (aluminum foil) that is placed in a direction that optimises the reflected temperature of the back surface of the specimen. The time shift is calculated as the time difference between the maximum temperature value recorded on the front and on the back surface of the sample.

1.3.15 Self-cleaning paints as passive solution for Indoor Air Quality management.

EcoShopping research project aims to provide smart solutions for highly sustainable shopping buildings. Indoor air quality (IAQ) represents one of the most crucial aspects for a high level wellness and it needs to be strictly controlled. Different EU projects analysed the indoor and outdoor air quality in the past and in recent years, concluding that indoor air quality is often worse than the outdoor one. The reason for this apparent paradox, in the past times, was related to the concentration of outdoor pollutants in a poorly ventilated indoor environment. Nowadays, in modern buildings, the air filtration systems can guarantee an adequate purification of outdoor air from micrometric powders and common outdoor pollutants (such as NOx, HC, Volatile Organic Compounds - VOCs etc.). On the other hand, the almost perfect sealing effect of doors and windows does not allow the removal of the indoor generated pollutants. Indoor VOCs are produced from a variety of sources such as emission from adhesives and building materials, combustion processes or the utilization of consumer household products, furniture, electric and electronic devices. VOCs are adsorbed by the skin and mucous membranes, causing damaging consequences to organs and metabolic systems or asthma and cardiovascular illnesses; VOCs are also linked with Sick Building Syndrome (SBS).

The indoor air pollutant removal can be carried out by means of filtration through suitable filters. Nevertheless, this solution involves complex pumping systems and the periodic filters maintenance that adds energetic and fixed costs.

Self-cleaning paints, on the other hand, represent a considerable smart and economical solution for indoor pollutants removal. The self-cleaning action, indeed, involves the mineralization of organic compounds, thus obtaining carbon dioxide and water as final products. The oxidation process of self-cleanings paints, of course, is also applicable to biological contamination, such as moulds, by

degradation of cellular membrane. The overall oxidative mechanism involves, as first step, the activation of the photocatalytic material (the active compound of the self-cleaning paint) by means of a light radiation with adequate energetic content, thus producing a photo-electron and photo-hole pair. After that, a cascade process leads the electron-hole pair to the redox process for the mineralization of organic pollutants previously adsorbed on the photocatalytic paint.

CNR provided the study of the photocatalytic compounds both from available commercial indoor self-cleaning paints (three commercial paints were selected and analyzed) and by the study of new doped titanium dioxide-based compounds. The selected commercial photocatalytic paints and the home-made compounds were characterized by means of the most suitable analytical techniques in order to allow a correlation between the observed photocatalytic performances and their compositional characteristics. All the samples (both commercial and laboratory made) were investigated from chemical, physical and morphological point of view.

The evaluation of the photocatalytic self-cleaning products was carried out with respect to methyl red and methylene blue as reference pollutant probes, with different light sources, under different experimental set up (water suspension, paint as they are and by ISO 10678 and ISO 22197-1). The market of lighting systems offers a wide range of products with different specific properties and the collaboration with RED srl allows identifying the most widely employed lighting systems at the present time and in the near future ones. Among the different solutions, CNR tested four different systems, in particular fluorescent lamps, Light Emitting Diode (LED), Xenon and UV-C lamps.

The outcomes obtained from the characterisation section underline that all the commercial samples contains titanium oxide-based compounds (rutile and anatase).

The photocatalytic activity was investigated both in water suspension and as paint on a substrate stand (the lab-made compounds were embedded into a not-photocatalytic commercial hosting paint.

It was proved that the photocatalytic activity depends on the target molecule and, as a consequence, on the experimental conditions. Therefore, there are no universal standard conditions and the particular set-up should be optimized as a function of the target pollutant.

The choice of the most suitable self-cleaning paint for the application on the indoor walls in the demo site for EcoShopping project was established on the best compromise between the cost of the photocatalytic paint and its photocatalytic performance.

The evaluation of the photocatalytic performance appears as a difficult challenge because of the different results obtained under different conditions. It was chosen to calculate a sort of all-encompassing index, calculated as the product of the different single performances. The costs evaluation for the commercial paints was carried out taking into account the price list provided by the commercial supplier for the Italian market and processing them taking into account the yield per square meter provided into the technical sheet for each product.

The cost for the production of the lab-made compounds was determined taking into account the cost of the single chemical reactants employed in its synthesis. It is worth to point out that the cost of lab-made compounds is obviously out-of-market because it is calculated on a lab-scale production and the industrialization of the lab-made compound, indeed, is beyond the aim of the EcoShopping project.

Taking into account the overall photocatalytic index and the paint costs, the best photocatalytic self-cleaning paint for the application on the demo-site for EcoShopping project appears to be the commercial paint STO Color Climasan, by STO Color.

Finally, it is worth to underline that the performances of the lab-made photocatalytic developed compounds, judged taking into account the goodness of the photoactive material itself (test in water suspension with respect to methyl red and methylene blue at pH 2), are six to eight times faster than the commercial ones. This consideration induce to hypothesize that a deeper investigation carried out in order to achieve an ad-hoc specific formulation, optimised for maximizing the performance of the new compounds, can lead to a significantly improved photoactive paint.

The Ecoshopping leader Energosys, in agreement with the IKVA demo site owner, decided the application of STO Color Climasan on a selected area of the inner walls of the first floor of the refurbished site.

The VOC content was continuously revealed by a series of VOC sensors. The sensors locations were chosen in order to obtain a significant monitoring of the VOC content close to the photocatalytic and non-photocatalytic walls. The sensors started the monitoring permanently since the end of January 2017 and it will continue until February 2018 (one year monitoring). The IAQ was also monitored by two manual campaigns carried out by sampling the indoor air through the adsorption of the VOCs on specific adsorbing cartridges in continuous mode for seven days.

Several factors affect the presence and the VOC content. Taking into account their chemical nature, the main physical parameter that enhances the VOC concentration is the temperature: a temperature increase promotes a VOC increase. Even though the indoor environmental parameters, such as temperature, are strictly controlled by the integrated system, the indoor increment in VOC due to higher outdoor VOC-temperature cannot be completely avoided.

The 1st floor IKVA shopping centre monitoring by T-VOC sensors in the period February 2017 - date of the present report, joined to the two manual campaigns carried out in December-January 2016-2017 and February 2017, suggest the evidence for the STO Color Climasan self-cleaning paint effect, but also reveal its limited action.

The analysis of the environmental conditions in IKVA shopping centre also underlined that the available self-cleaning surface, with respect to the hidden portion by the exhibited merchandise and to the total air volume to be treated, appears scarce and not adequately lighted. These important aspects should be taken into account in the overall photocatalytic evaluation and appear as fundamental advices for an improved management of the self-cleaning paints.

1.4 Please provide a 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. The length of this part cannot exceed 10 pages.

1.4.1 Potential impact

By performing the evaluation and analysis in previous sections, Ecoshopping solution is expected to have different impacts on different areas, including energy and environment, social economic, market and standardization etc. This section, will further extend the evaluation results and analyse the potential impacts to the above areas and conclude the market potential, potential adapt of the community and ways to help to expand this new methodology and solution.

1.4.1.1 Energy and Environmental impact

The Energy Performance of Buildings Directive has determined that the potential for cost-effective energy savings in the EU building stock is about 30% in the period of 2020. Also, about 90% of existing buildings will be still in use by 2050 and the current average energy consumption needs to be reduced by a factor of four or five **Hiba! A hivatkozási forrás nem található.**.

There is an urgent need to improve current methodologies for a better adaptation of future retrofitting. Commercial buildings show the highest retrofit potential of all building types. Global electricity use in commercial buildings has almost tripled since 1980 and is projected to rise another 50 percent by 2030. It will soon become the highest-growing end-use sector in industrialized countries.

Ecoshopping includes the integrated retrofitting methodology and guidelines, technologies, best practice, knowledge platform and e-learning tools. Ecoshopping expects to increase the energy efficiency of the buildings by implementing such methodology and retrofitting solutions, demonstrating the possibility to have cost-effective and direct benefits for the building, thus to promote the replication of Ecoshopping solution in more buildings to maximize the environmental and social benefits.

Ecoshopping aims to reduce the primary energy demand to less than 80 kWh/m² per year as an average and exploit the potential of renewable energy utilization, increase it at least of 50% compared to the State of the Art (according Eurostat 2009 18.30% average EU27).

According to above analysis and D2.7, the reduction obtained in the demo building is over 60% counting the contribution from the PV system, the primary energy consumption is about 74 kWh/m², and thus demonstrating the possibility of achieving the goal of a maximal consumption of 80 kWh/m² per year in a commercial building with considerable investments. According to the research “Panorama of the European non-residential construction sector” done by Ecofys **Hiba! A hivatkozási forrás nem található.**, the extrapolated total floor area of the commercial building within EU27 is about 2291Milions of square meters, among them, over 50% are built before the year 1980 and over 78% are before the year 2000, summing to about 1929 Million m^2 for these old buildings. The average specific energy consumption in the non-residential sector is 280kWh/m² (covering all end-uses) **Hiba! A hivatkozási forrás nem található.**, reducing even to 80 kWh/m² per year, the saving will achieve 385,800GWh per year in EU27, the potential is enormous.

For the GHG reduction, as it is related to the primary energy consumption, and according to a scientific study, each percent reduction in power consumption would currently imply approximately 0.75% reduction in GHG emissions, implementing the consumption reduction of 60% obtained from IKVA shopping centre, this GHG emission reduction to could archive 45%.

Ecoshopping methodology encourage the use of RES in retrofitting, exploit the potential of renewable energy utilization, contributing to the increase RES in the energy mix. For the case of IKVA, the generated electricity from PV system contribute 27% of the total energy demand, Counting the 11% of RES share is already included in the electricity consumption in Hungary **Hiba! A hivatkozási forrás nem található.**, the final share of the RES over the primary energy consumption will be about 33.1%, and thus twice increment is encountered compared to the state of the art in Hungary (11%), over 80% of increment compare to the 18.30% as average RES share in EU27.

Due to the use of PV system, the peak demand hour matches with the peak electricity generation of the PV system, thus the building itself could demand even less energy from the grid with the support from the PV system, furthermore, the strategy implemented in the IAU, aiming to exploit the building thermal mass as much as possible by converting the solar energy directly into cool/heat of the building, the demand during the energy high demanding hour could be shifted to earlier. Close working with the intelligent system, Ecoshopping solution contributes the peak reduction, together with the speed varied heat pump system which are capable of working in partial loads with good performance, offers favours the reliability and capacity of grid, reduce the cost for the power grid in providing peak demands and reduce the risk of momentary interruptions, which represent almost 1000€ for small-medium commercial buildings for one hour “blackout” in summer afternoon.

1.4.1.2 Social Economic impact

EcoShopping will achieve over 60% reduction of the energy consumption for the IKVA shopping centre. The EU-28 currently consumes around 1529.6 Megatons of oil equivalent (Mtoe) per year in 2015. About 40% **Hiba! A hivatkozási forrás nem található.** of the total energy consumption corresponds to buildings, in which the commercial buildings accounted between 12% and 18% by covering the needs for heating, cooling and electricity. Based on this data, a reduction of 60% of energy consumption equivalent to a reduction of 44.05 Mtoe and 66.08 Mtoe is expected by carrying out the deep retrofitting. According to the German Council for sustainable development more than 2000 full-time jobs could be created for each Mtoe that would be saved, which means, a reduction of 44.05 Mtoe to 66.08 Mtoe will derive in 88105 to 132157 full time jobs creation.

In other studies, Energy efficient renovation of buildings supports employment. It is calculated that for every million euros invested, 19 jobs can be generated **Hiba! A hivatkozási forrás nem található.**. Estimations of employment creation differ from source to source, probably due to the different depths of renovation possible and the different targets that are being explored. A 2014 study for Eurima, states that a ‘deep renovation’ scenario **Hiba! A hivatkozási forrás nem található.** would lead to the creation of an additional 1.4 million jobs by 2050 **Hiba! A hivatkozási forrás nem található.**. If an energy savings target of 40% is adopted for 2030, the EU energy renovation market could increase by almost half its current size, leading to more than one million additional jobs **Hiba! A hivatkozási forrás nem található.**. This implies that the number of jobs created in the sector is positively correlated to the ambition of the renovation and energy saving targets.

From the point of view of household investment and energy bills reduction, energy unit prices will increase dramatically when actual demand exceed forecasted demand. End-users have no incentive to change consumption during periods of peak demand because real-time prices do not exist at the moment. EcoShopping incorporate RES, the use of this energy in combination of the thermal mass storage (the building itself is a “Thermal Battery”) and accurate control strategy, during periods of peak demand will favour the deployment of smart grids, putting into practice cost-effective real-time pricing to manage the consumed energy and take advantage of a new framework in which energy price was adapted to energy demands. With the new solution, the existing buildings will need less electricity, gas and fuels to cover the requirements of the building.

EcoShopping increase the indoor comfort due to a better thermal insulation and better regulation by means of capillary tube coupled with RES powered heat pump. Furthermore, due to the intelligent control, the power needs of the entire HVAC systems will be reduced and therefore a direct noise reduction associated will be achieved.

It is clear that such a system largely contributes to the energy reduction of our economy. Approaches developed in this project, cannot only be used in commercial building, but also office or residential environment. The impact of RES integration will differ from one segment to another, as well as the intelligent control with robot integrated, the introduction of such systems in areas where a lot of people tend to circulate will have a large impact in making people more environmentally conscious and will trigger them to adapt their behaviour.

1.4.1.3 Market Impact

Ecoshopping dedicated efforts in different researches, including the insulation, lighting, integrated solution of HVAC by coupling RES, Heat pumps system and high energy-efficient capillary tube, control, acoustic technologies, communication, performance optimization and construction. The research enabled to find the best interoperation solutions between the retrofit options for RES, HVAC, lighting and envelope, taking into account the cost-benefit analysis of the gains obtained through interoperability, climate and building characteristics. A form of the intelligent control platform especially becomes a necessity with the rise of energy efficiency concepts, more than current conventional building automation system, more intelligent algorithm is needed and proved to be useful in consumption reduction. Furthermore, the integration of Robot concept into the commercial building is a good example demonstrating the application of latest technologies in daily live, not only serving as a part of the building, facilitates service to visitors, but also as a commercial measure to bring a higher attention and huge intangible value, improving the perception of an old commercial center, the adaptation of new technologies in an old fashion building create a high contrast. The usage of robot will not be only a dream, but closer to our life and have more and more contributions. While the research of RES powered DC heat pump will also overcome the barrier of renewable energy facilities and DC heat pump technologies, the outcome is in favor of the trend of the increasing RES share and the next generation of smart grid.

The renovation of existing buildings represents by far both a great occasion for the construction sector and the largest potential for energy and resources saving. Since generally renovations to improve the energy efficiency of the existing stock of buildings is imperative to meet the targets of reducing greenhouse gas emissions by 80-95% by 2050 in relation to 1990 levels and 20% and 27% improvement in energy efficiency by 2020 and 2030 respectively**Hiba! A hivatkozási forrás nem található.**. Indeed, considering other building typologies with an ageing building stock (35% of the EU's buildings are over 50 years old) and slow replacement rates, the renovation potential

of buildings in the EU is huge - up to 110 million buildings could be in need of renovation. Such numbers are extremely promising for EcoShopping as they give clear indications on likely growth rates of retrofitting and needs for ESCOs. Moreover, EcoShopping will also favour the deployment of RES at urban level and consequently the creation of new business for building sector, including the energy concept in the whole value chain of the construction process, from the design to the maintenance; new management services for SMEs and creation of energy service companies (ESCO's).

The wide implementation of the EcoShopping approach for envelope retrofitting will result also in an increase of turnover for the whole European construction sector, through new investments which couple structural retrofitting to energy efficient solutions. Assuming that a standard intervention with the EcoShopping approach over the whole building will combine the solution for the outer envelope and assuming again a penetration rate of 5% within 5 years after the end of the project, this will result in an increase of turnover and additional investments for the construction sector of almost 5 Billion €.

Especially, for the demonstration building in Hungary of this project, the concept of sustainability, high-tech perception, the improvement of energy efficiency and comfort are good sample for the solution of similar cases in the north-western region of Hungary. In fact, during the panel discussion in the final project workshop, key stakeholders, including property owner and president of commercial building association, the new concept and deep retrofitting showed its potential and great interest to the sector. The applied model and cost-effective retrofitting solution could offer an affordable way to solve the structural problems and concerns of the investor.

Ecoshopping benefits

In conclusion, Ecoshopping retrofitting solution will bring several benefits in addition to energy savings.

The environmental impact and other most relevant benefits are analysed in above sections. Apparently, the project and the future application in other buildings is expected to bring more benefits to the sector. Specially:

- Improving innovation capacity, integrating new knowledge:
- The demonstration of the new technologies and integration in Ecoshopping shows high interest and potential in energy reduction. The use of variable speed DC heat pump powered with PV system is one of the solutions answers to the requirements in future grid, contribution in peak-demand shifting and without compromising the system performance.
- The developed database for envelope and insulation facilitates the identification of best materials and thickness for insulation, enabling the reduction of the payback period for the investors.
- The developed Open EcoWiki and Moodle platform are another measure to widespread the project outcomes and a platform for the continuous co-innovation, collection of contributions from more end users and stakeholders.

Increase in property value & visitor satisfaction:

- Sustainable image for the building.
- Improving property attractiveness with higher EPC (Energy Performance Certificate). A commercial property with good energy consumption and ratings attracts more potential tenants and buyers.

- A building with improved energy performance has lower costs associated with energy consumption enable the premises to be sold or leased at higher prices which increases the value they add to the business.
- The higher EPC gives the business access to energy grants and loans that can help save money while enabling to meet the energy legislations and increase the value of the commercial property.
- Improvement of environment and comfort will increase the satisfaction of the visitors, and increase the time in staying the commercial centre.

The Figure 4 summarizes the relevant benefits from retrofitting using Ecoshopping solution.

Figure 4. Ecoshopping benefits

1.4.2 Main dissemination activities

1.4.2.1 Website

The website of EcoShopping project was/is to provide information to current Target groups, i.e. Building related professionals, and to future End-users. From the other side the website could promote the EcoShopping partners and enhance awareness of the relevant Stakeholders in the market. The official project website has been in place since February 2014 and can be found at the following address: http://ecoshopping-project.eu/index.html. The website was developed and is managed by IZNAB which updates the website on any progress of the project. It provides information on the reasons for undertaking the project, its objectives, background on the technology the project intends to utilize and expected outcomes. It is also continually updated with News and Events and details information about partners involved and contact details for anyone interested in more information. The website are going to be maintained one year after end of the project by IZNAB.

On Figure 5 the EcoShopping website can be seen.

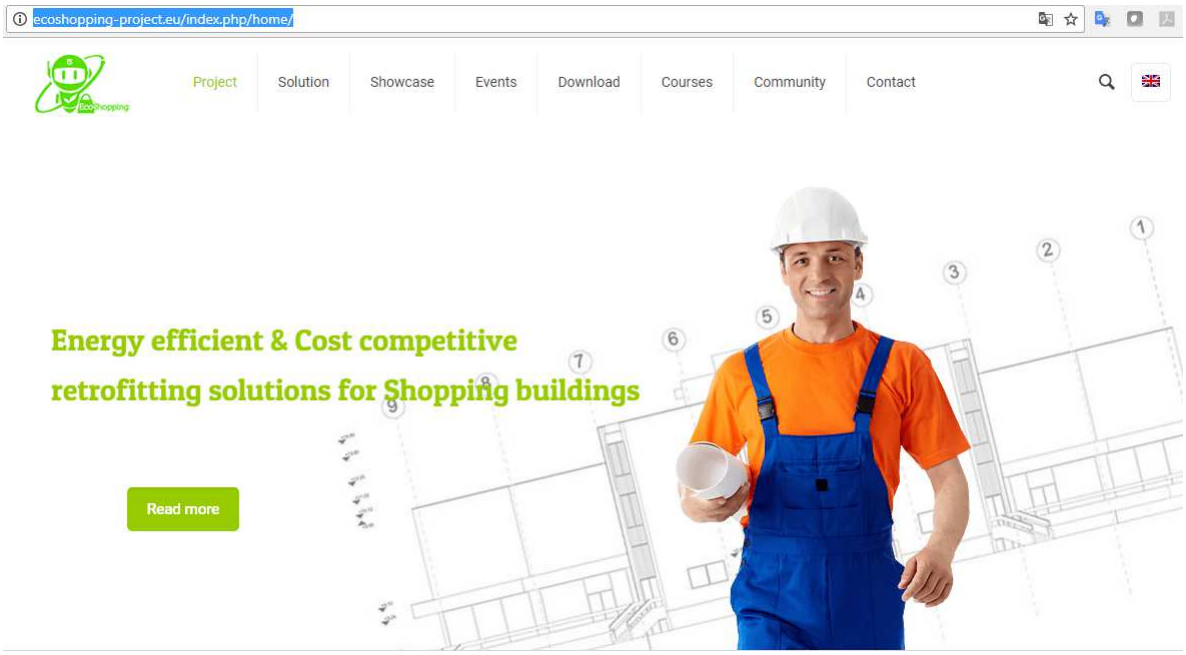


Figure 5. EcoShopping project website

The website is organized in eight main sections, namely Project, Solution (containing the description of the project partners), Showcase, Events, Download (download area for deliverables and other public documents developed by the consortium), Courses, Community, and Contacts.

1.4.2.2 Social media

In today's world of information overload, users are increasingly becoming all about the visuals. People need clear, concise dissemination of information, and visuals do just that. The brain processes visual information 60,000 times faster than text, and 90 percent of the information transmitted to the brain is visual. Ergo, visuals speed up comprehension and retention. What's more, the right visuals have the ability to enhance emotions and feelings. Enter: the importance of visuals to establish your brand's identity in the digital marketplace. Effective logos, infographics, photographs, animations and website design are all laying new foundations for enhancing brand identity, and they aren't likely to disappear anytime soon. In that way, the EcoShopping project have been used (and will be use) the following social media:

- **LinkedIn** – a social networking website for people in professional occupations. On the following address, the LinkedIn group of "EcoShopping" project could be found: http://www.linkedin.com/groups/EcoShopping-project-7451667/about

  Figure 6 shows the LinkedIn Group.

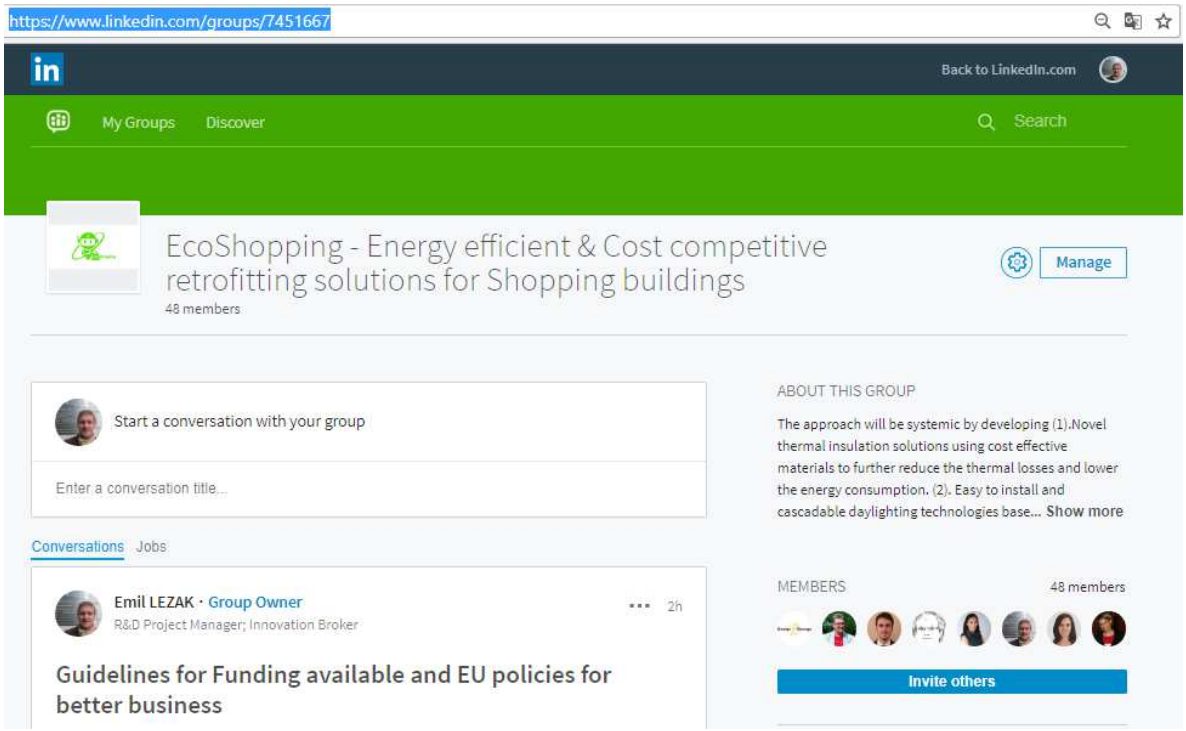


Figure 6. LinkedIn Group of EcoShopping project

- **Twitter** - a social online networking service that enables users to send and read short 140-character messages called "tweets" for people of any professional occupations. On the following address, the Twitter account of "EcoShopping" project could be found: https://twitter.com/ecoshopping_fp7

  Figure 7 displays the Twitter site of EcoShopping project.

Figure 7. Twitter account for EcoShopping project

1.4.2.3 Moodle courses

Nowadays, online courses are revolutionizing formal education, and have opened a new cathegory of outreach on scientific topics. The EcoShopping online courses deliver a series of lessons to a web browser and/or mobile device, to be conveniently accessed anytime, anyplace – support for the installation of the solution in buildings. An online courses are designed as a built environment for learning. It's constructed as an experience that can be followed sequentially and/or can be accessed throughout the designated time period by interested Stakeholders/End-users. It's a directed learning process, comprised of educational information (articles, videos, images, web links), communication (messaging, discussion forums) and some way to measure students' achievement. The courses section could be found at the following website: http://moodle.ecoshopping-project.eu/

Figure 8 shows the online courses of EcoShopping project.

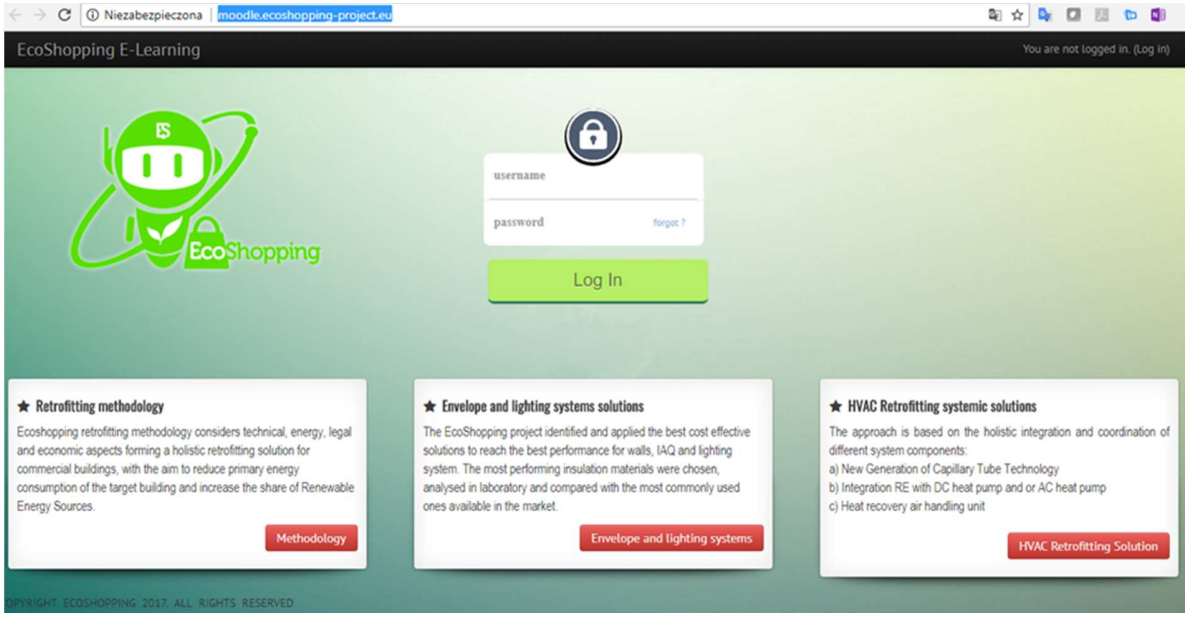


Figure 8. Courses (online) of EcoShopping project

1.4.2.4 Scientific articles

Scientific papers, like in the case of EcoShopping project are for sharing original research work with other scientists and/or for reviewing the research conducted by others. As such, they are critical to the evolution of modern science in the field of Energy-efficient Buildings, in which the work of one scientist builds upon that of others. To reach their goal, scientific papers have aimed to inform, not impress. They are highly readable — that is, clear, accurate, and concise. They are more likely to be cited by other scientists if they are helpful rather than cryptic or self-centered. In general, scientific papers typically have two audiences: first, the referees, who help the journal editor decide whether a paper is suitable for publication; and second, the journal readers themselves, who may be more or less knowledgeable about the topic addressed in the paper. To be accepted by referees and cited by readers, scientific papers of EcoShopping have done more than simply present a chronological account of the research work. Rather, they have convinced their audience that the research presented is important, valid, and relevant to other scientists in the same field (Energy-efficient Buildings). To this end, they have emphasized both the motivation for the work and the outcome of it, and they have included just enough evidence to establish the validity of this outcome.

1.4.2.5 Final standard presentation

The standard presentation contains the following parts: Concept; Project Summary; Objectives and Expectations; Challenge and Response; Consortium partners information; and Contact data. All the partners of EcoShopping Consortium, interested in presentation of achievements/outcomes of the project could customize the content with their own slides. In that way they could deliver effective and powerful presentations to achieve business success – making an impact that influence EcoShopping project audience, by focus of attention onto message on the slides, and know-how achieved during the execution of the project.

1.4.2.6 Videos

The main purpose of the video related to the EcoShopping project, presented by the coordinator or particular partner – is to use intuitive ways to show how retrofitting solutions, including acoustic sensing solutions in non-residential have been implemented, rather than using overwhelmed written materials. Therefore, video is an effective dissemination mean. All videos are available on https://www.youtube.com/playlist?list=PLT1epFyyKwF4vwm9K1g3IQiASnMCHuR23

1.4.2.7 Printed materials

Printed materials like Leaflets & Posters are a simple, relatively inexpensive knowledge translation intervention for dissemination of EcoShopping project achievements/outcomes, aimed at improving the conditions of non-residential buildings.

Leaflet

A brochure providing a brief presentation of the project and partners is worked out, printed and provided in “pdf” format for downloading on the home page of ”EcoShopping” project since mid of February 2014. The brochure has been addressed to the general public as well as served as an entry point for information for researchers, end-users and other target groups not directly participating in the consortium. It contains a short overview of the project, main objectives and expected results.

Figure 9 and Figure 10 show the leaflet.

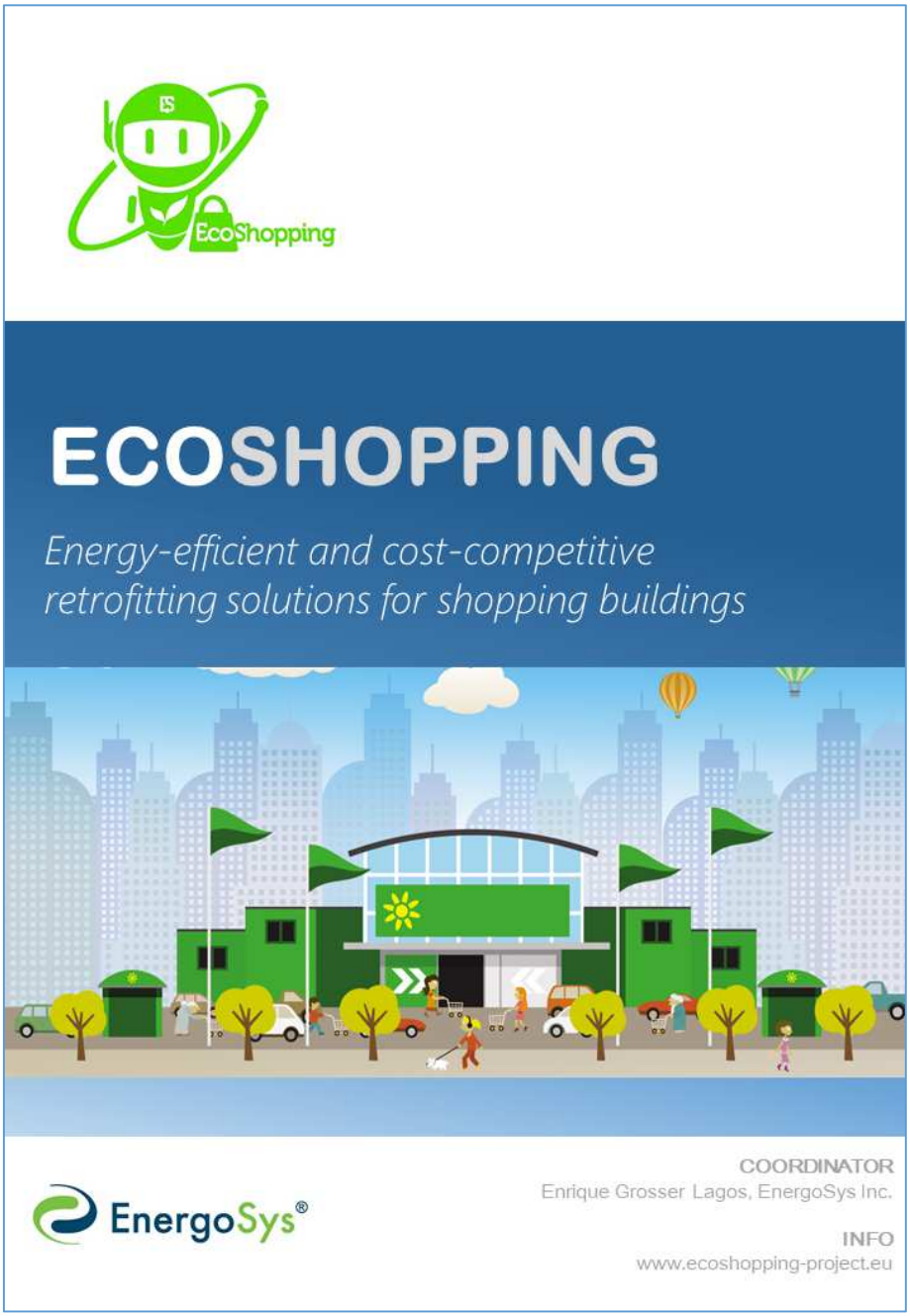


Figure 9 Leaflet of EcoShopping project/1

Figure 10 Leaflet of EcoShopping project/2

Poster

The main purpose of the poster related to the EcoShopping project, presented by the coordinator or particular partner – is to catch the audience attention. To reach this objective an eye catching poster has been designed. With regard to the layout and design, the poster should show the project's logo and the EcoShopping project colors emphasizing the link to the project´s graphic.

This poster is used in workshops, conferences and other events as a presentation of the project, where the consortium partners participate or hold the event. It is complementary to the flyer, since the latter provide more detailed information about “EcoShopping” project.

On Figure 11 and Figure 12 a poster of EcoShopping project can be seen.

Figure 11 Poster of EcoShopping project/1

ECOSHOPPING

www.ecoshopping-project.eu

CONCEPT

„EcoShopping" project developed a systematic methodology and cost effective solutions for the holistic retrofitting commercial buildings. Commercial buildings show energy saving high potential by the refurbishment of the envelope and applying easy-to-install and cost-effective building services solutions. Completed with an improved operation and maintenance, the EcoShopping brings affordable solution to the market, which can be integrated in building owners and investors portfolio while helping to reach a sustainable, clean and healthy environment.

PREDICTIVE CONTROL

Traditional building management systems (BMS) typically have stand-alone applications with separate monitoring and control stations for HVAC, lighting, energy metering, etc.
Real benefit lies in managing them as one, intelligent solution. In order to increase building's operational and energy efficiency, Intelligent Automation Unit (IAU) was developed.
IAU Supports:

- ✓ HVAC centralized control
- ✓ Energy usage optimization unit
- ✓ HVAC diagnostics and inefficiency reports

System diagram

The model-based predictive control helps to explore building as thermal storage and for the optimization of energy consumption in commercial buildings. The IAU takes the place of the standard BMS functions in order to optimize the operation of the HVAC systems corresponding to the weather conditions and helping to harness the building thermal mass. The IAU uses a simplified building model and weather predictions to optimally control the systems.

METHODOLOGY

„EcoShopping" project developed a systematic methodology and cost effective solutions for the holistic retrofitting commercial buildings.

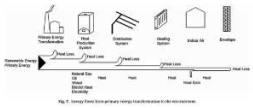
DATABASE

The database includes commercial insulating materials (traditional and innovative), solutions for windows, self-cleaning products.
The database is open and free to use for everybody.

INTEGRATED HVAC

The HVAC solution covered the integration of ventilation, heating and cooling with novel capillary tube technology, and included the development of a porotype direct current heat pump, which is controlled based on solar energy production, completed with local electricity generation by solar panels.

The project used exergy analysis while developing the HVAC solutions, which is a useful tool for determining the locations, types and true magnitudes of energy losses, and therefore help in the design of more efficient energy systems. An exergoeconomic analysis, which is a combination of exergy and economics, is also a good tool to be used for providing useful insights into the relations between thermodynamics and economics.



DEMONSTARTION

DEMO SITE
"IKVA" Shopping Center, Sopron (Hungary)

With the developed specific implementation and operation guides, the energy-efficiency interventions are inserted into the value-oriented commercial property development and facility management strategy. By bettering the insulation and lighting system, integrating additional RES based HVAC systems and exploiting the building as a thermal storage, developing an intelligent automation control unit, maintenance and commissioning technologies, the energy efficiency of the commercial building has an overall enhancement of about 58%, reducing the energy consumption below 80 kWh/m²a.

ENVIRONMENTAL IMPACTS

We identified and analyzed the relevant standards and building codes and made proposals for improving these by proposing the best practice solutions for the retrofitting of shopping buildings.
The project used a Life Cycle Analysis for the evaluation, and ranking of environmental impacts associated with refurbishment technologies and to identify the embedded environmental impact of the used technologies and materials.

BUSINESS PLAN

The business plan helps to establish new spin-off companies to utilize the EcoShopping solution and to bring its results directly onto the market. The business plan involves ESCO-based financing.

CONSORTIUM PARTNERS

Solintel, Fraunhofer IDMT, EnergoSys, Ancodarg, NTUST, bre, Red, IZNAB Sp. z o.o., novamina, lagross, VPS, ITC, AIT, YASAR UNIVERSITESI, geoCLIMAdesign

COORDINATOR
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CONTACT
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enrique.grosser@ecoshopping-project.eu

www.ecoshopping-project.eu

"This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 609180".

Figure 12. Poster of EcoShopping project/2

1.4.2.8 Events participation

Partners participated relevant conferences in their specific field within the scope of “EcoShopping” project. Scientific partners preferably participate to scientific conferences and symposiums, and Commercial partners focus on Trade Fairs and Exhibitions, as well as Expert workshops. The conference participation requires the presentation of project results and/or achievements. The list of events participation is provided within template A2-dissemination activities. The most important events highlighted as follows:

1.4.2.9 Energy week networking area booth

This networking event was a great opportunity to present and discuss the outcomes of the project Ecoshopping, including the retrofitting methodology, guidelines, accomplishment and recommendations of standardization, data base and innovative products for the most cost/performing envelope and lighting systems solutions, exergy-based approaches for HVAC Retrofitting systemic solutions based on harnessing the building thermal mass, RE powered heat pump, new generation of capillary tube and heat recovery ventilation, sensing network and mobile robot platform etc. trying to collect feedback from target stakeholders and share the knowledge gained from the project.

Beside the basic dissemination material, such as the poster, leaflets, video presentations of key technologies has been shown in the networking area. Specially, a 3D video of the implemented envelop insulation solution has been prepared for the event, the web based database tool developed will be demonstrated and short training on the usage will be introduced.

1.4.2.10 The Sustainable Building Challenge

The IKVA Shopping Centre, as the demonstrator of the EcoShopping project was awarded with winner of “Super Malls” category in the Sustainable Building Challenge Competition. The competition was organized by the CommONEnergy project. The project Coordinator Energosys participated the award ceremony of SBChallenge competition in Brussels on 7 September.

On Picture 3 a picture of the award ceremony can be seen.

Picture 3 Receiving the SBC Award

1.4.2.11 Workshop

Over 20 experts from the industry participated on the high-level workshop on the 30 August 2017 in Budapest, Hungary.

The Final Workshop has addressed each of selected components of energy-efficient retrofitting solutions for non-residential buildings. This one-day Workshop has been co-organized by ENR & IZNAB, as well as the other partners of the Consortium. The workshop provided the assessment as base of the Exit Strategy for responsible and sustainable Exploitation of the results and the maintenance of the activities that guarantee the dynamic update of the database on good practices in the Construction sector in EU. Moreover this workshop was oriented to create business opportunities and to guide the partners in learning methodology for analyzing and self-assessing their R&D results, acquiring knowledge on the main non-technical issues of their project and becoming aware of and understand the complexity of co-ownership in collaborative research project.

Picture 4 shows the group picture taken in the workshop.

Picture 4 Group picture from the workshop

1.4.3 Exploitation of results

The objective of the EcoShopping consortium is to implement an effective exploitation strategy and to be able to adequately promote the EcoShopping project and the developed products, services, and procedures, as well the scientific achievements. The completion of the project does not mean that its results disappear, on the contrary it reinforces its sustainability.

This exit strategy includes the issues of the sustainability of the EcoShopping, which in this sense means how we continue its existence and functionalities beyond its end. This also includes the use and the exploitation of the results in middle and long term. After the project's lifespan, the project's outcomes continue, entirely or partially.

It is important to create outputs that can survive the end of the project. This is achievable through the factor that the Consortium members integrated the project's developments into their **long-term company or other stable entity and research vision and strategies**.

Our objective is to keep the project's results visible and available. They should be accessible so the **community** can benefit them, let it be for the scientific community, the market, the end-users etc. It can be done by **websites, events and maintaining social networks** both online and offline. This way the target groups can access them, learn from them and use them, possible taking them to other contexts and activities. This is described in detail in Chapter 6. In EcoShopping, we have covered

all of these aspects and undertake to maintain this activities 1 year after the project end. This is done by:

- maintaining the online presence, including an educational website
- dissemination of the created standard presentation
- printed materials
- through the established collaborations with decision makers, associations, institutions, market stakeholders,
- and not at least by continuing the proactive communication and interactive cooperation among the members of the Consortium.

To get the message through more easily and to be recognizable, the project branding helps to keep the results identifiable, so they can be recognized more easily.

Involvement of target groups and potential customers is being done from the beginning of the project. The project partners are either research profile institutes or SMEs, and have contacts within the scientific community and market stakeholders. The consortium members let to use its public results by its partners and involve them in further developments and marketing activities.

It is important to create **outputs that remain after the project's end**. The exploitable results of the EcoShopping are suitable for further exploitation.

The research and development work materializes in development of products, services, scientific achievements as basis for further developments. From the point of view of the continuation of the project, the most important ones are the outputs that survive the end of the project: **innovative services and products** and the outputs that are durable and materialistic: **the operative demonstrator, the prototypes**. The plan to utilize them is included in Section 4.

The key factor for these outputs to actually having continuity is to be valuable in the long run. Parties need to be interested in utilizing them. The EcoShopping consortium's interest points are the followings:

- Research centers' case: scientific community involvement, and some level of connection and integration with the industry
- SMEs' case: seeking revenue generation most preferably in direct forms, innovation channels, access to innovation. Besides the preferences are:
    - obtain credibility
    - obtain references
    - obtain connections.

It is also recommendable to create **business plan.** The business plan should plan and describe carefully:

- key partners
- key activities
- key resources
- value propositions
- customer relations and segments
- distribution channels
- costs
- revenue generating plans.

In summary, the business plan should include every aspect that is key factor to the success of a new business, including the way to find capital, a plan for the first 3 year period of operation. It should also include a market research in sense of testing the acceptability of the market and the analysis of the replications potential. The EcoShopping created a business plan for utilizing its results. It is described in the deliverable D8.4 Business Plan.

After the project is over, and the obligations and the project money are over, it is important to be a community. The EcoShopping group established a fair amount of contacts inside and outside the scope of the consortium. This materializes in already established and planned future cooperation, with the prospect of many more, let it be **business or scientific cooperation**.

The generated **shared intellectual property** generates the necessity of further joint work. The detailed Intellectual Property issues are described in the EcoShopping deliverable called D8.1 Plan for Use and dissemination of Foreground. This deliverable has been prepared at the beginning of the project, but it is very difficult to foresee Intellectual Property and dissemination issues at the beginning of a project, so this deliverable is issued second time at the end date of the project.

The describes aspects of project sustainability and our established work and strategy help the maximum possible utilization of the project continuity, while also promoting them by interest chain. The next chapters describe in detail how the project results will live beyond the project at individual level and as joint efforts, completed by the issues of the Business Plan and the strategy for the operative demonstrator.

The list of exploitable results is provided within the Template B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND and the Additional template B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND.

Exploitation of the specific key exploitable results of the project by the project partners

1. **Guideline: Methodology for holistic retrofitting in commercial buildings**

The guideline will be integrated into SOL’s consulting services to improve our design process, and is expected to be integrated into the public tools of another project named Design4Energy and used in our new project "Accelerating Energy renovation solution for Zero Energy buildings and Neighbourhoods"

The guideline is supposed to open accessible, and it will be integrated into ANC's internal training document and working process.

At the meantime, ANC is open to have further collaboration with other partners in improving the guideline.

LAG’s goal for the future with the project results is to integrate the Guideline into our consulting service in Hungary. In our case, the primary target groups are the owners, developers and facility managements of the shopping centers and we offer them the developed methodology that includes the consumers into the evaluation process of energy comfort and environmental quality of commercial buildings. After the analysis of the surveys we have the necessary information to be able to offer them an appropriate renovation strategy.

The guideline will be integrated into IZNAB engineering and consulting services to improve our design process, and is expected to be integrated into the public tools of another project named Design4Energy and used in our future projects

2. **LED solutions and daylighting measurements for tertiary buildings**

LED based illumination systems have reached commercial maturity, hence TRL level 9. With the expertise acquired in Eco-shopping, including the advanced training on the DIALUX design software with subsequent use in the design of the demonstration case, R.E.D. S.r.l. is now in a position to exploit this expertise in the market place. R.E.D. S.r.l. also disposes of a portable spectro-fotometer, acquired by CNR for the work in Eco-shopping. Hence together with CNR, R.E.D. S.r.l. is in a position to perform monitoring campaigns on the performance of day-lighting and artificial illumination systems.

3. **Database, including commercial insulating materials (traditional and innovative), solutions for windows, self-cleaning products**

The database will be taken to the next TRL in order to offer it as a service to the market. Concerning the laboratory made photocatalytic compounds, further studies can lead to the improvement of the TRL CNR will maintain the database for one year after the end of the project. Evidently, this database, that was conceived as a collaborative result, where the partners from different countries should have added their own records, cannot be a responsibility of CNR alone, as it was until now. After one year the database will remain in any case alive. We will not switch off it. We are looking for funding to extend and improve/add records and functionalities.

4. **HVAC Retrofitting systemic solutions based on harnessing the BUILDING THERMAL MASS, RE powered HP, new generation of capillary Tube and heat recovery ventilation**

YASAR plans to continue research in this field and share our results via academic publications. In addition, we are planning to advance this technology with support from EC or national funding agencies, and are open to cooperate with our Ecoshopping partners in the future.

GCD's uptake is that the 3 central benefits of our capillary tube system (flat for retrofitting, heating and cooling, and energy efficiency key for heat pumps) fit excellently to RE powered HP and PV combination or PVT combination. GCD would like to focus on the ecoshopping experience in HP and PV. Therefore they will keep in touch with the WP partners and the Hungarian managers to find projects for replication and future standardization and widening of our product field to HP and PV.

Symelec will use the Ecoshopping solution as base design for further retrofitting and new creation of HVAC facilities in shopping centers, as well as for public buildings in Spain.

The solution generated in the Ecoshopping and installed in the IKVA center will be used as a demonstration for the customers, showing the benefits, utility and efficiency of the proposed system, as well as the capability of Symelec for addressing the installation of such a system.

This Ecoshopping solution will be used also as a design starting point in an interactive process together with the customer.

Cooperation with the rest of partners for the joined exploitation in other countries, being Symelec involved in the integration of the systems is also expected.

5. **Robot + Acoustic + Sensing network**

FHG aims to bring acoustic sensors to the next TRL using public funding, making it into a product by means of industry cooperation, licensing of software components and hardware layouts.

The project results developed by VPS are at market level readiness (TRL 8-9) and are integrated into VPS portfolio. Also, the know-how acquired on sensor network design and integration is also an advantage for further projects on building monitoring and energy management.

AIT is interested to work with VPS and FHG on future research projects.

6. **Advanced alarm system integrated to web platform**

NOVA's uptake is that the specific IP asset of this result (besides the know-how), is the possibility of licensing the alarm system technology and software platform. Failure detection, identification and fault tolerant system technology for retrofitted buildings has great potential for addressing the needs widens clientele. In addition to imminent marketing through licensing agreements there is the possibility of further improvements, based on market research. Business plan will need to be made in order to determine the cost-effectiveness of such investments and the right resources to be committed. Specifically, we are interested in collaborating with Partner FHG on future development of intelligent acoustic detection and alarms.

7. **Intelligent Automation Unit with model based predictive control to explore building as thermal storage and optimization of energy consumption in commercial buildings**

The know-how acquired in the pilot plant by the integration of bidirectional data exchange from and to the IAU and other external systems is an added-value asset to be potentially applied in VPS's other projects. Also the User Interface for evaluating energy consumption and optimization savings is also in the VPS portfolio of products and will be applied in the building energy management projects.

AIT is interested to offer its services to the other partners or work together for other customers.

NOVA's plan is that the system operational regimes will be extended with isolated power network mode, dynamic demand response and peak power shaving modes. In cooperation with relevant project partners we intend to offer licensing agreements to future end-user.

8. **Evaluation, and ranking of, environmental impacts associated with refurbishment technologies.**

The project results from the whole building lifecycle approach will be used to further refine the IMPACT methodology and communicate the results to encourage the whole building approach for environmental assessments by BRE. BRE anticipates IMPACT compliant tool providers may use the case evidence to further their tools. It will also help inform in part the debate about standardization of a circular economy approach that is being explored in the BAMB Horizon 2020 project. BRE plans to cooperate with CNR and RED on exploitation of an opportunity to integrate environmental impact data with technical qualities of insulation materials in the database (see No. 3) and with FHG on audiometry and controls (no. 5) in other work opportunities.

9. **Simplified building model development - evaluation of three methodologies**

AIT would like to offer this modeling service via website. User could login and start modeling different buildings. Cooperation with other partners from WP5 is possible depending on the use cases and business models.

10. **Direct Current Heat Pump controlled depending on solar energy production**

YASAR plans to continue research in this field and share our results via academic publications. In addition, we are planning to advance this technology with support from EC or national funding agencies, and is open to cooperate with our Ecoshopping partners in the future.

SYMELEC will consider from now on the DC heat pumps integrated to the solar PV systems as an alternative and will offer it as a product, not only in electrically isolated systems but also as an option to be considered in the placements where AC grid is available.

11. Business Plan

IZNAB & ENR would like to introduce it as service to their consulting line for commercial buildings in Poland & Hungary, respectively.