Ecoshopping: energy efficient & cost competitive retrofitting solutions for retail buildings*

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Abstract: *"EcoShopping" project aims to build a holistic retrofitting solution for commercial buildings to reduce primary energy consumption down to less than 80kWh/m^2 per year and increase the proportion of Renewable Energy systems (RES) to more than 50% using state of the art solutions.*

The 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 Building Management System and full exploitation of the Building Thermal Mass, which serves as a "Thermal Battery" and stores the RES directly without using battery, tank or other expensive storage material and simplifying the system structure.

Keywords: ECOSHOPPING: energy efficient, retrofitting, Retail sector, shopping buildings.

The "EcoShopping" project (http://ecoshopping-project.eu/) aims to produce a systematic methodology and cost effective solutions for retrofitting commercial buildings. By improving the insulation and lighting system; integrating additional RES based HVAC systems; exploiting the building as thermal storage ("mass"); developing an intelligent automation control unit; and improving maintenance and commissioning technologies; the energy efficiency of the commercial building is expected to have an overall enhancement of about 58%.

The "EcoShopping" platform will integrate other existing HVAC systems, such as heating, ventilation, air conditioning, etc. and will interoperate with other ICT- based subsystems (e.g. for security, protection, gas-detection, safety and comfort). The control and management of automation systems will be based on advanced algorithms where the platform will be capable of learning from previous operations and situations; by means of a semi-automatic process of retraining from Internet-based repositories, which allows configuration, personalization and dynamic adaptation to the characteristics of the building and the weather.

The project cost is 4.10 million €; starting in September 2013 with a duration of 4 years.

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The phasing of the project is shown in figure 1 and this paper will present the initial results of Work Package 2.

The overall objectives of the project are:

- To reduce primary energy consumption down to less than 80kWh/m^2 per year and increase the proportion of RES (Renewable Energy Sources) to more than 50%.
- To investigate a retrofitting solution with innovative thermal insulation solutions and Day lighting technologies.
- To develop and install a RES direct powered DC variable speed heat pump and increase the Building Thermal Mass with a view to reducing the energy consumption.
- To integrate the Intelligent Automation Unit (IAU) concept with a Mobile Robot.
- To develop a solution for automatically identifying and predicting failures; and inefficiencies in HVAC system performance.
- To carry out a continuous assessment through the entire project.

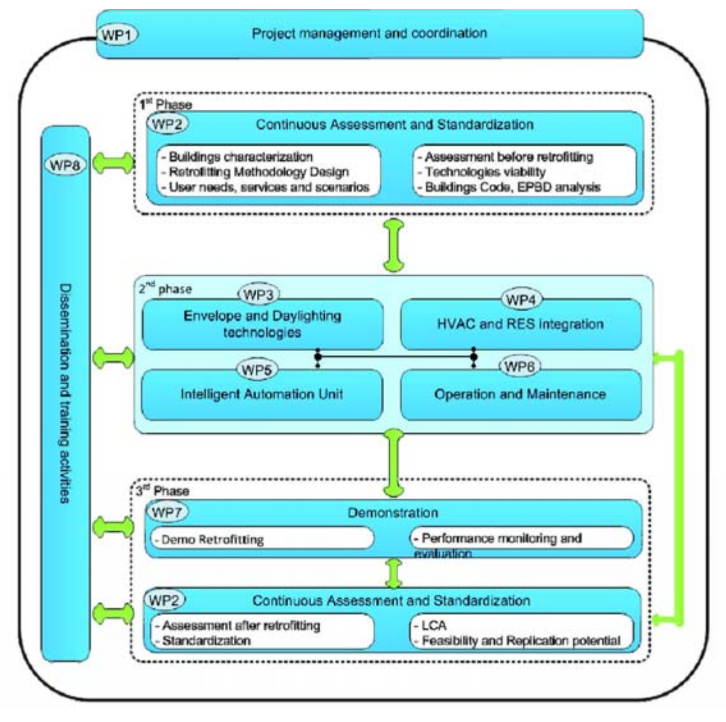

Fig.1. Ecoshopping work packages and phasing

The case study

IKVA Shopping Centre is a retail mall in the city of Sopron in Győr-Moson-Sopron County of Hungary. It was built in 1979 and has approximately 3,700 square meters leasable area. It is located within the city centre, in the outskirts of the Castle district. This part of the city has a historic atmosphere and a strong touristic appeal.

The IKVA was built within the framework of a large scale urban development plan together with the Fenyő Shopping Centre next to it.

IKVA is a freestanding building. It is linked with an open passageway to the Fenyő Shopping Centre. Access from the parking lot and also from street level is ensured with a pedestrian ramp and staircases. From the bridge there is a direct access to the retail space on the ground floor. There is an open hallway around ground level store floor. Next to the building there is a city block which consists of mid-rise residential buildings with additional retail and service functions. A wide pedestrian passageway points directly to the Shopping Centre from the south.

IKVA due its larger department store size and its downtown location makes it ideally suited to meet the demands of larger retailers. Main part of the retail area consists of large open spaces with only a few pillars, which allows various uses.

Operation time: 0800-1900, 220 working days plus 0800-1300, 52 weeks*1 day which gives 2680 operational hours/year total.

The building has 2 main sections: common area, which consists of 2 storeys plus an open parking lot on ground level, and service/office area with 3 storeys and a basement. Geometry of the building follows functional separation recognizably. Service and visitor access is well-separated. The building has a reinforced skeleton structure, 25 cm thick reinforced concrete envelope and a flat roof with bituminous waterproofing and polystyrene insulation. There is no insulation on the external walls which results together with the large aluminium frame single-glazed portals in common areas a high overall heat transfer coefficient. Maximum height is 14.90 m.

Pre-retrofit building assessment

The survey has identified three HVAC systems:

- Heating system: 3 Viessmann Vitodens condensing boilers.
- Cooling system: local split air conditioners.
- DHW: only some local, electrical water heater.
- Ventilation: 2 AHUs, but these are operated only in summer, 2 hours per day. The heating pipe for heat exchanger of AHU was cut off so the AHU has no heating capability.
- Lighting system: Mainly fluorescent lighting with some tungsten. Many of the fittings are inoperative.
- There is only the basic level of control (on/off for time control plus thermostats) with maintenance staff carrying out this function.

Energy usage and calculations

Natural gas and electricity consumption was collected for the last 3 years:

- Natural gas: ~ 30.000 m^3/annum;
- Electricity: ~124.000 kWh/annum.

The first step was to carry out a static calculation in accordance with Hungarian legislation (Energy Performance of Buildings: 7/2006. (V.24.) TNM directive) which is harmonised with the EPBD (Energy Performance Building Directive, 2002).

The calculation expresses the primary energy consumption of the heating, domestic hot water, cooling, ventilation and lighting systems.

The primary energy factors in Hungary are: e=2.5 for electricity, e=1.0 for natural gas.

Static calculation

Primary energy consumption per systems:

- Heating: 93.71 kWh/m^2/annum;
- Cooling: 11.49 kWh/m^2/annum;
- Lighting: 62.5 kWh/m^2/annum.

The Primary energy consumption was calculated as **167.7 kWh/m^2/annum which gave an E rating on the Energy Performance Certification (EPC).**

When comparing actual to model consumption the following observations were made:

- Calculated natural gas consumption is 31.400 m^3/annum; which is close to the real consumption (30.000 m^3/annum).
- Calculated electricity consumption for lighting and HVAC is 96.000 kWh/annum. The real energy consumption much higher (124.000 kWh/annum), this is due to the additional usage of office equipment, IT technology, etc.

Target value for the IKVA case study is 80 kWh/m^2/annum; which is just over a 50% reduction in energy usage and would give an EPC rating of an "A". This is an ambitious target but one that is thought to be achievable.

The Ecoshopping consortium
The consortium consists of:

- EnergoSys Inc (Hungary);
- Fraunhofer Institute for Digital Media Technology IDMT (Germany);
- Solintel M&P (Spain);
- Austrian Institute of Technology (AIT);
- Intelligent Sensing Anywhere (ISA - Portugal);
- Novamina (Croatia);
- IZNAB Sp. z o.o.(Poland);
- GeoClimaDesign (GCD - Germany);
- National Research Council (CNR - Italy);
- Symelec (Spain);

- Building Research Establishment (BRE – UK);
- R.E.D. s.r.l. (Italy);
- Yaşar University (Turkey);
- National Taiwan University of Science and Technology (NTUST);
- LaGross Ltd.(Hungary);
- Ancodarq (Spain).

This consortium gives the project a wide range of expertise in terms of the construction process and technology areas.

The project is Co-funded by the European Commission within the 7th Framework Programme but has its own website and marketing with the following logo:

Work Package 2: Continuous assessment and standardisation

The first deliverable is an assessment of national building codes, EPBD implementation and standards identified (Lewry, A. J. and Garrido, M. D. C., 2013). This report compares and analyses the national building codes for non-domestic buildings from European countries (Austria, Croatia, Germany, Hungary, Italy, Poland, Portugal, Spain and the UK) within the project. It concludes that building codes lay down minimum levels of performance for building fabric elements and building services; but not renewables. The energy performance of non-domestic building as designed is calculated holistically by the use of approved software and this should be used to for quantifying options. The codes do not attempt to prompt best practice. In the context of this project this points to the best fabric u-values identified should be used as the backstop (minimum) performance levels and the static calculation method being used to assess the design options; the reasoning being that these are the most appropriate in terms of local construction methods and climate.

Best Practice for Technology areas was identified as lying within the EU Green Public Procurement (GPP) criteria and the UK's Enhanced Capital Allowance (ECA) scheme and it's Energy Technology List (ETL).

It is proposed that heat pumps are part of the refurbishment and their performance should match or exceed those laid down in the criteria of the GPP or ETL. This lays down best practice performance for Heat pumps, in terms of a Coefficient Of Performance (COP) in Heating mode and an Energy Efficiency Ratio (EER) in Cooling mode for:

- Air source: gas engine driven split and multi-split (including variable refrigerant flow);

- Air Source: Packaged Heat Pumps;
- Air Source: Split and Multi-Split (including Variable Refrigerant Flow) Heat Pumps;
- Air Source: Air to Water Heat Pumps;
- Ground Source: Brine to Water Heat Pumps;
- Water Source: Split and Multi-Split (including Variable Refrigerant Flow) Heat Pumps;

An example of the criteria is shown in Table 1.

Table 1:

UK ETL performance criteria for Water source: split and multi-split (including variable refrigerant flow) Heat Pumps.

Product Category	Heating mode (COP)	Cooling mode (EER)
Water source: single split (non-VRF) heat pumps	>3.70	>3.30
Water source: dual split (non-VRF) heat pumps	>3.70	>3.30
Water source: multi-split (non-VRF) heat pumps	>3.70	>3.30
Water source: split or multi-split variable refrigerant flow (VRF) heat pumps	≥4.10	>3.50

The ETL also contains criteria for Heat pump dehumidifiers; Heat pump driven air curtains and CO_2 Heat Pumps for Domestic Hot Water Heating.

Building Controls

The report and the documents it references (Lewry, A. J., 2014) recognise that the control of energy in non-domestic buildings is generally poor, despite the availability of a range of tried and tested systems incorporating both mature and innovative technologies. The installation of HVAC zone controls, optimising controllers (for Wet Heating Systems) and lighting controls is encouraged by the building codes, but their specifications are basic. As controls are one of the most effective solutions in realising energy savings, they should always be part of a refurbishment. The European standard on the Energy performance of buildings — Impact of Building Automation, Controls and Building Management (BS EN 15232, BSI, 2012), should be used as the methodology for estimating their effect.

EN 15232 has a series of classes describing the energy performance – see Figure 2.

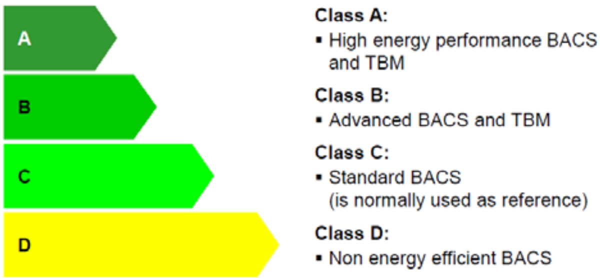

Figure 2: Energy performance classes

Note: Building Automation and Controls Systems (BACS) and Technical Building Management Systems (TBM) in the UK are known as Building Management System (BMS) and Building Energy Management System (BEMS) respectively.

To put this into context Class C is what would be required by the current UK building regulations published in November 2013 (UK Non-Domestic Building Services Compliance Guide).

The UK Energy Technology List (ETL) currently has criteria for:

- Heating, Ventilation and Air Conditioning (HVAC) controls (now Building Environment Zone Controls;
- Hot Water Systems Optimising controls (now Heating Management Controllers);
- Lighting controls; and
- Variable Speed Drives (VSDs).

The ETL Building Environment Zone Controls criteria are close to representing good practice when all the criteria are imposed. The criteria above fall slightly short in that summer/winter change over functionality and a requirement for 365 day programming, as defined in BS EN 15500 (BSI 2008), have not been included. Joining these together would represent good practice and a specification based on this would probably meet the requirements of Class B of EN 15232, a step up from the building codes but this still falling short of the most efficient operation of a building.

The indicative savings that can be achieved from the implementation of the EN 15232 classes are shown in the table 2. This considers Class D of the standard as the baseline; the reason for this is that the majority of buildings will be at this level or below.

If we look at the wholesale and trade service buildings line we can see that fitting Class C controls could realise 35.9% savings, whilst an additional 17.3% can be achieved through Class B controls. Pre-programmable BEMs would satisfy the Class B criteria but in order to achieve Class A of the standard, programmable BEMs would be required and then the final 8.3% of energy savings may be realised.

Table 2:

Indicatives savings for increasing the class of building controls from Class D of EN 15232

Non-residential building types	% savings from D			
	D	C (Reference)	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Offices	0.00	33.77	47.02	53.64
Lecture hall	0.00	19.35	39.52	59.68
Education buildings (schools)	0.00	16.67	26.67	33.33
Hospitals	0.00	23.66	30.53	34.35
Hotels	0.00	23.66	35.11	48.09
Restaurants	0.00	18.70	37.40	44.72
Wholesale and retail trade service buildings	**0.00**	**35.90**	**53.21**	**61.54**
Other types: - sport facilities - storage - industrial buildings - etc.		N/A		

[*] These values highly depend on heating / cooling demand for ventilation.

This indicates that approximately 62% of savings for a retail building can be achieved by fitting EN 15232 Class A controls (a programmable BEMs) which would achieve the target for the building without other measures.

Lighting controls are also included within the ETL but are technology specific; the specification covers products that are specifically designed to switch electric lighting on or off, and/or to dim its output. In addition to the functionality covered by the Building Environment Zone Controls described above, lighting controls cover presence detection and daylight detection – with and without dimming.

The result is that this could be used as an off the shelf specification for the building control systems.

Building Controls and zoning

The way a non-domestic building is subdivided into zones will influence the predictions of energy performance and how you set up the control of the building. Therefore, the zoning rules must be applied when assessing a non-domestic building for controls. The end result of the zoning process should be a set of zones where each is distinguished from all others in contact with it by differences in one or more of the following:

- The activity attached to it;
- The HVAC system which serves it;

- The lighting system within it;
- The access to daylight (through windows or rooflights).

To this end, the suggested zoning process within a given floor plate is as follows:

1. Divide the floor into separate physical areas, bounded by physical boundaries, such as structural walls or other permanent elements.
2. If any part of an area is served by a different HVAC or lighting system, create a separate area bounded by the extent of those services.
3. If any part of an area has a different activity taking place in it, create a separate area for each activity.
4. Divide each resulting area into "zones", each receiving significantly different amounts of daylight, defined by boundaries which are:
   - At a distance of 6m from an external wall containing at least 20% glazing;
   - At a distance of 1.5 room heights beyond the edge of an array of rooflights if the area of the rooflights is at least 10% of the floor area;
   - If any resulting zone is less than 3m wide, absorb it within surrounding zones;
   - If any resulting zones overlap, use your discretion to allocate the overlap to one or more of the zones.

An example of this approach is given in Figure 3. Once the zoning has been carried out consideration can be given to placement of sensors (temperature, occupancy and light levels) with a view to controlling these zones in terms of the services provided.

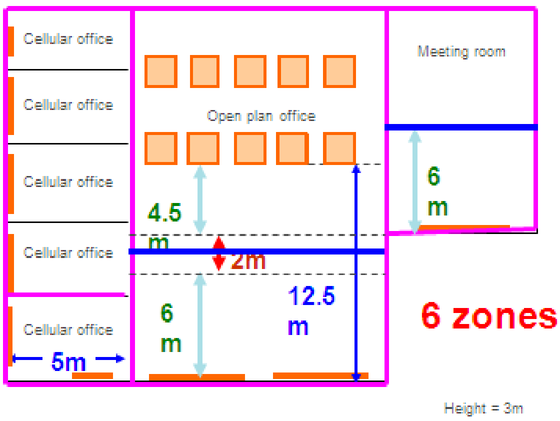

Figure 4: an example of a small office zoned by activity and then daylighting

Daylighting Standards

The only comprehensive standard found, for non-domestic buildings, was the British Code of Practice for daylighting (BS 8206-2, BSI 2008). This standard gives recommendations regarding design for daylight in buildings. It includes recommendations on the design of electric lighting when used in conjunction with daylight.

BS 8206-2 describes good practice in daylighting design and presents criteria intended to enhance the well-being and satisfaction of people in buildings, recognizing that the aims of good lighting go beyond achieving minimum illumination for task performance.

This revision of BS 8206-2 has been prepared to take account of the publication of two European standards (BS EN 12464-1, BSI, 2-11; BS EN 15193, BSI, 2007). In particular, some of the manual calculations that appeared in the 1992 edition have been omitted and a new annex on climate-based daylight modelling has been added along with a new clause on daylighting and health.

Simple graphical and numerical methods are given for testing whether the criteria are satisfied, but these are not exclusive and computer methods may be used in practice. Sunlight and skylight data are given.

In addition a new BRE guide (Ticleanu, C., Littlefair, P. and Howlett, G., 2013) provides essential guidance on how to achieve effective and energy-efficient retail lighting

Best practice guidance for daylighting in non-domestic buildings has also been identified along with the need to carry out an energy audit first in order to identify the most appropriate technology areas for any refurbishment.

Energy auditing and whole building energy savings

There is a new European standard for energy auditing (BS EN 16247-1, BSI, 2012) which should be used to identify opportunities for savings and barriers to implementation. Then the data collected can also be used to create meaningful improvement targets through the application of data analysis (Lewry, A. J., 2013).

For a case study such as this it is essential that the methodologies are comparable with those already in use and that technologies match or exceed best practice criteria already published. In addition, producing auditable numbers is essential to showing transparency in how the energy savings claimed are justified.

However, refurbishment is not treated consistently and for major works it is suggested the EU GPP criteria of an 20% improvement on the building regulations for new build is aimed for or at least the same performance as the minimum new build criteria, as laid out in the building codes, is reached.

If this is not technically feasible a minimum performance increase, such as achieving a final rating in the top quartile of energy performance should be considered. The top quartile level defined by analysing the database of Energy Performance Certificate (EPC) ratings within the country in which the non-domestic building is situated.

From earlier you can see that this project is far more ambitious and aims for an **EPC "A" rating**.

Best practice guidance

Best practice guidance on low carbon refurbishment of non-domestic buildings has also been identified; this covers both the refurbishment process and the use of renewable technologies (Carbon Trust, 2008). The guidance is structured around a roadmap for the refurbishment process, identifying the key intervention points during the preparation, design, construction and use phases of the project – Figure 5.

Phase	Low Carbon Refurbishment Process	Page	RIBA Work Stages*
Prepare	Commit to a low carbon refurbishment	7	Preparation
	Establish a low carbon vision for the refurbishment	7	Appraisal
	Develop a low carbon outline brief	7	
	Establish the current carbon footprint of the building	8	Design brief
	Set carbon targets for the refurbishment	8	
	Undertake a pre-refurbishment assessment	8	
	Consult stakeholders	10	
	Consider a budget for low carbon elements	10	
	Appoint a carbon champion	11	
	Choose an appropriate design team	11	Design
	Empower the design team	12	Concept
Design	Keep the low carbon theme up front	13	Design development
	Develop an integrated low carbon design	13	
	Encourage exploration of a wide range of low carbon options	14	
	Allow flexibility in design	15	
	Use energy modelling data	16	Technical design
	Use whole life costing to support low carbon solutions	17	
	Manage the budget and scope	17	
	Approve the integrated design	18	
	Include targets in contracting arrangements	19	Pre-construction
Construct	Ensure effective project management	19	Production information Tender documentation
	Choose an appropriate contractor and subcontractors	19	Tender action
	Get buy-in from site workers	19	Construction
	Monitor site progress against objectives	20	Mobilisation
	Ensure high quality commissioning	20	Construction to practical completion
	Set up energy monitoring	20	
Use	Make sure the occupants understand the building	21	Post practical completion
	Make sure the building operator understands the building	21	Post practical completion
	Conduct a post-occupancy evaluation	22	
	Check energy use and comfort conditions and make changes	22	
	Make the most of the low carbon building	22	

Figure 5: Good practice roadmap for the Low Carbon refurbishment process

For renewables, the ETL has best practice performance criteria for Heat pumps; Solar Thermal; Combined Heat and Power; Biomass boilers and room-heaters.

The UK Feed-in Tariff (FIT) for generating electricity on-site, Renewable Heat Incentive (RHI) and the Microgeneration Certification Scheme ('MCS') contains technology requirements for:

- Solar thermal systems;
- Solar PV systems;
- Small and micro wind turbines;

- Heat pump systems;
- Biomass systems;
- CHP;
- Micro-hydro systems;
- Bespoke Building Integrated Photovoltaic (PV) Products.

These give full product specifications to the current EN and ISO standards. An example of the product certification scheme requirements for solar photovoltaic modules is given in Appendix 15.

MCS includes minimum performance requirements for heat pumps (COPs) and biomass (efficiency) and every MCS installation standard includes a methodology for estimating the annual energy performance of renewable energy systems. For example PV has the MCS Guide to the installation of PV systems which contains a method for estimating the annual electricity generated (AC) in kWh/year of the installed system.

Conclusions

This study identifies that building regulations and their associated codes lay down minimum levels of performance for non-domestic buildings but do not attempt to prompt best practice. However, the building codes laid down the minimum performance ("backstop") requirements for building fabric elements and building services; the exception being true renewables, i.e. solar, hydro and wind based technologies, where there were generally no performance criteria. This project aims to match the best of these backstop U-values and exceeded them wherever possible.

The building codes approach the energy performance of non-domestic building holistically where the overall performance of the building as designed is calculated by the use of approved software. This gives an asset rating which is then deemed as a pass or fail when compared to the performance level required by the individual building code, normally in terms of a target KWhr/m^2/annum. The Primary energy consumption was calculated as **167.7 kWh/m^2/annum which gave an E rating on the Energy Performance Certification (EPC).Target value for the IKVA case study is 80 kWh/m^2/annum; which is just over a 50% reduction in energy usage and would give an EPC rating of an "A".** This is an ambitious target but one that is thought to be achievable.

Best practice performance criteria were identified for the majority of technology areas. The project proposes the use of heat pump technology and the performance of said technology should match or exceed the best practice performance criteria described in the UK's Enhanced Capital Allowance (ECA) scheme and its Energy Technology List (ETL).

The control of energy in non-domestic buildings is generally poor and controls are one of the most effective solutions in realising energy savings. They should always be part of a refurbishment and EN 15232 used as the methodology for estimating their effect. Indicative savings of 62% may be realised by the installation of an advanced Building Energy Management system (BEMs).

For a case study such as this it is essential that the methodologies are comparable with those already in use and that technologies match or exceed best practice criteria already published. In addition, producing auditable numbers is essential to showing transparency in how the energy savings claimed are justified.

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