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

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Deliverable D2.9 Viability and feasibility report of retrofitting technologies

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PP	Restricted to other programme participants (including the Commission Services)	
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Description of the related task and the deliverable in the DoW	This task will evaluate the industrial viability of the renovation technologies to be implemented in the demonstration buildings. The viability of the new technologies developed in Envelope materials and Day lighting (WP3), HVAC Technologies (WP4), Intelligent Automation Unit (WP5) and Operation and Maintenance technologies (WP6) will be assessed by SOL with the collaboration of different partners involved in those WPs in order to study the possibilities of important investment decisions in industrial retrofitting solutions. SOL will also undertake Cost-benefit analysis, Return On Investments (ROI) of each option. For each option, technical feasibility and impacts, cost from viewpoints of budgetary, operational, schedule, environmental and social will be described. The Deliverable is D2.9 Viability and feasibility report of retrofitting technologies.								
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Disclaimer

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1. PUBLISHABLE EXECUTIVE SUMMARY

This study will evaluate the industrial viability of the technologies for commercial building retrofitting. Deeper analysis is carried out also for selected technologies which are possibly to be implemented in the demo building located in Sopron (Hungary).

This Deliverable is also an assessment of the new and emerging retrofit solutions and HVAC technologies and it is conducted through the identification of their strengths, weaknesses, opportunities and threats (SWOT). The assessment is based on the information collected from previous studies and scientific publications.

It is important to know that the data available to determine the efficiency of each measure are far from homogeneous, due to the large account of considerable technologies and their information source. Moreover, opportunities and threats analysis are directly dependent on the national context, the specific technology and model or trademark of each solution.

The report has been divided into these 5 sections: 1) Envelope materials; 2) Lighting and Daylighting technologies; 3) HVAC and Renewable Energies; 4) Building Management Systems; and 5) Maintenance procedures.

Conclusion of the SWOT analysis of the different technologies/materials is drawn out for each section. For technologies that are in development process within the R&D Work Packages (WP3, WP4, WP5 and WP6) are studied and anylized profundly regarding the main characteristics, energy savings potential, cost-benefit and Return On Investment (ROI) . Furthermore, the chosen options are compared with further alternatives in order to study their technical and economical viability, ideas about how the demo site could be improved are assessed and provided in each research field to the EcoShopping R&D partners.

2. INTRODUCTION

2.1 Purpose and target group

The aim of this report is to perform an assessment of the retrofitting (some new and emerging) solutions for envelope materials, lighting and daylighting technologies, HVAC and Renewable energies, automation systems and maintenance procedures, and to evaluate the industrial viability, the cost-benefit and ROI of the solutions to be developed during the project and implemented in the shopping center of Sopron.

2.2 Contributions of partners

The following partners have collaborated in this report with detailed technical and economical specifications of the technologies that they are developing in each Work Package:

- CNR-ISAC (Insulation materials)
- NTUST (Daylighting technologies)
- SYMELEC (PV and wind turbine systems)
- Yaşar University (DC powered heat pump)
- GeoClimaDesign AG (Radiant ceiling system)
- ISA (Fixed sensors and Environmental Data processing)
- FHG (Audio sensors and Mobile robot)
- ANC (Operation and Maintenance procedure)

2.3 Baseline

This deliverable is at the start of the EcoShopping project with the aim of evaluating the industrial viability and feasibility of renovation technologies, and analysing profoundly those will be implemented in the demo site.

The assessment and viability study of the studied technologies will base on the great variety of data sources, which include the online documents, characteristics of products, literatures, research papers and thesis, experiences and research results from different partners etc.

2.4 Outline

In each section, a list of considered technologies and solutions will be presented, the SWOT analysis will be carried out for the listed solutions. Then a conclusion will be drawn out comparing the key indicator of different technologies. Finally, technologies and solutions indicated in each technical research WPs will be further studied and compared with other alternatives.

This study will follow the order of the WP planned in the DoW (WP3 to WP6). By carrying out the detailed study of each topic, a final conclusion will be presented trying to picture the global view of integrating different technologies for a shopping centre, treating the combination of different alternatives proposed as a whole and integrated solution.

2.5 Relations to other activities

This deliverable has very strong interdependences with several Work Packages. This deliverable has needed the following information of the technologies that are being studied and developed in:

- WP3: Envelope materials and Day lighting
- WP4: HVAC Technologies
- WP5: Intelligent Automation Unit
- WP6: Operation and Maintenance technologies

The information collected about the technologies in these WPs is related to their main characteristics, their strong and weak points and the potential energy savings. The technologies and solutions indicated in the aforementioned WPs are compared with other retrofitting alternatives, Cost-benefit analysis is carried out for each one in order to evaluate the convenience of using these technologies and to see how they could work better and be holistic integrated to a shopping center. At last but not least, serving as a preliminary assessment for the technology developers of the above WPs and offering a global revision of the integration of these retrofitting solutions are always one of the objectives of this study.

3. ENVELOPE MATERIALS

3.1 List of Insulation materials

The following insulation materials will be evaluated in the SWOT analysis. Due to the great variety of insulation materials, we cannot address all in this study, they are available on the market with similar physical or technological properties and thus are not presented in this study.

Table 1 Insulation materials

INSULATION MATERIALS		
MATERIAL	**TYPICAL FORMAT**	**CATEGORY**
Wood fiber	Panels	Organic
Polystyrene	Panels	Inorganic
Polyurethane	Panels	Inorganic
Rockwool	Panels, rolls	Organic
Aerogel	Panels, rolls	Innovative
Vacuum Insulating Panels (VIP)	Panels	Innovative
Cellulose	Panels, flocks	Organic

3.2 SWOT analysis

3.2.1 Material SWOT analysis

SWOT ANALYSIS	WOOD FIBER[1]
Strengths	• High acoustic performance • Low to zero toxins, easy to reuse/dispose of, significant health benefits throughout life cycle • Offers some thermal mass • Protective clothing and masks not needed, more comfortable for installers and others coming into contact with it • Vapour permeable, works well with other low-impact materials • Concern about indoor pollution and allergies is particularly high. • Renewable • Low energy input • Biodegradable • Absorbs VOCs • Non-flammable • Breathable
Weaknesses	• Most products manufactured overseas and imported • Price currently significantly higher than oil- or mineralbased competitors (this may reduce as demand and supply increase) • Suitability of rendered external finishes limits application • Use limited to above damp-proof course or equivalent level • Few producers • Maybe treated with pesticides, fungicides, and flame retardants • Poor ranching practices
Opportunities	• Renewable materials store carbon throughout usable lifespan • Robust in handling, transportation and onsite construction • It is available as loose fill, flexible batts and rigid panels for all thermal and sound insulation uses. • It can be used as: 1) internal insulation: between studs, joists or ceiling rafters, under timber floors to reduce sound transmittance, against masonry walls; or 2) externally: using a rain screen cladding or roofing, or directly plastered/rendered, over timber rafters or studs or masonry structures as external insulation to reduce thermal bridges. • It is 100 percent recyclable, so it helps to reduce overall landfill waste
Threats	• Requires thicker walls

1 http://www.bre.co.uk/filelibrary/pdf/projects/low_impact_materials/IP18_11.pdf

SWOT ANALYSIS	POLYSTYRENE[2]
Strengths	• It can be cast into molds with fine detail. • It can be transparent • Very economical. Low Cost • Can be aerated (with CO_2) to make excellent insulator • Can be foamed between card to make lightweight rigid panels • Available in several forms. • In its various forms it is usually easy to work • It is versatile -uses range from cutlery to explosives • Can be recycled - thermoplastic so can be remoulded indefinitely • Non Hygroscopic • Good Optical Clarity • Easily Processed • Good Thermal Stability • Good Property Retention • Good Creep Resistance • Easily Decorated • Easily Bonded • Good Toughness (HIPS) • Chemically inert, it does not pollute the environment
Weaknesses	• Older types of Expanded polystyrene contain CFCs • Flammable (especially if oil painted) • It takes a long time to decompose. • Expanded foam is uneconomical to collect for recycling • Poor resistant to organic solvents. • It isn't bio-degradable and like all plastics is made from oil. • Low Impact Polystyrene (the usual type) breaks very easily and isn't very strong. • Thick Sooty Smoke • Poor Weatherability • Highly Flammable • Highly Notch Sensitive • Poor Resistance to Petroleum Solvents
Opportunities	• It can be produced in lots of colours.
Threats	• It can cause health concerns if ingested

2 http://swot.advisorgate.com/swot-p/30600-swot-analysis-polystyrene-foam-product-manufacturing.html

SWOT ANALYSIS	POLYURETHANE[3]
Strengths	• High Abrasion Resistance, Impact Resistance and Toughness • Low Viscosity • High Elongation • Good Flexibility • Good Tear Strength • Low Shrinkage • Hydrolytically Stable • Good Chemical Resistance • Minimizes air flow • Helps eliminate drafts and provides for comfortable, even heat • Provides better humidity control • High Insulation Value. Best R-value per inch of any readily available insulation allows you to fix more insulation in a tighter space • Moisture Resistant. Stops moisture driven elements due to its closed cell salability • Rigid. Adds structural strength • Seals cracks from unwanted gas and odor penetration • High degree of strength to weight ratio • Excellent Adhesion. Does not need fasteners to hold it into place • Code Approved. Materials meet building code requirements and are accepted nationwide
Weaknesses	• Poor thermal capability • Poor weatherability • Attacked by most solvents
Opportunities	• Performs in hot as well as cold temperatures • Quick, easy application by professionals • Provides a seamless layer of insulation • Adds very little weight to ceiling or roof areas
Threats	• Utilize toxic isocyanates • Flammable

3 http://swot.advisorgate.com/swot-u/40180-swot-analysis-urethane-and-other-foam-product-except-polystyrene-manufacturing.html
http://plastics.ides.com/generics/45/polyurethane-pur
http://www.dwyersspecialty.com/knowledge_spfbenefits.htm

SWOT ANALYSIS	ROCKWOOL[4]
Strengths	• Higher R-Value than traditional fiberglass insulation. • Better thermal barrier then fiberglass leading to less energy consumption. • Soundproofing qualities reducing noise pollution from noisy neighbors or noisy machinery. • More fire resistant than traditional fiberglass insulation, making for better protection against fires. • Holds water: Rockwool holds an incredible amount of water, which gives a "buffer" against power outages or pump failure. • Holds air: The consistency allows plenty of air, which supplies the root zone with plenty of oxygen. It's practically impossible to over-water Rockwool. The fibers of rockwool make it highly porous thus allowing a high air-porosity ratio in the root zone. • Variety: From 1" cubes to 3"x12"x36" slabs capable of holding the root systems of huge plants, Rockwool comes in dozens of shapes and sizes making it a versatile growing medium. It also comes "loose" so you can fill pots or containers of any size. • Neat and clean: Rockwool holds together very well so it can't spill. It's easy to handle and does not leave a residue like soil does. • The production process involving heat makes rockwool completely free of pathogens. • Rockwool is inert and contains some silica that can be available to plants.
Weaknesses	• Health concerns: The fibers and dust from Rockwool are bad for the lungs. Dust mask shall be worn when handling to prevent problems. • Long pre-soak period: Rockwool must be pre-soaked for 24 hours before use, which other growing media do not require. • Disposal and cost of rockwool make it less than sustainable in long term production. • Typically pH values of rockwool are high and will need to be reduced to maintain optimal pH values for plant growth. • Buffering capacity of rockwool is low and can be difficult to manage pH due to water retention characteristics of the fibers used.
Opportunities	• Lower health risk to humans versus fiberglass insulation.
Threats	• Not environmentally sound: Rockwool is hard to dispose of; like Styrofoam, it does not break down.

4 http://swot.advisorgate.com/swot-r/32726-swot-analysis-rockwool-international.html

SWOT ANALYSIS	AEROGEL[5]
Strengths	• High thermal resistance, achieve a relatively high level of thermal insulation with a limited insulation thickness. This makes it possible to save interior space (on walls or floors). • Can be easily cut to shape and are flexible enough to be fitted around complicated details. Mechanical resiliency accommodates thermal cycling and vibration without loss of performance • Reduced sensitivity to mechanical damage. • Variety of particle sizes • High surface area • High particle porosity • Surface chemistry: Completely hydrophobic • Resistance to moisture and UV ensures long-term performance even in harsh environments • Good for acoustic insulation applications, especially at low frequencies
Weaknesses	• The material can be dusty, and it is advisable to wear gloves, safety glasses and dust masks when handling it. • Since aerogel blankets are still very new and energy intensive, their cost may be high (appr. €20/m^2).
Opportunities	• Choice of product forms provides maximum flexibility in system design and installation methods • Low density offer space and weight savings in transport applications • It is an emerging technology that has a large energy saving potential. As this new emerging technologies go cheaper, the common insulation material will lose its interest and become obsolete.
Threats	

5 http://www.one-stop-shop.org/sites/default/files/FORM_11_aerogel%20insulation.pdf

SWOT ANALYSIS	Vacuum Insulating Panels (VIP) [6]
Strengths	• Increased energy efficiency • Reduction in greenhouse gas emissions • Faster building times and better buildability of structures • Lighter weight materials may offer safety advantages in construction • Potential cost savings • Improved health and wellbeing
Weaknesses	• High cost • Material availability • The set views of trades
Opportunities	• Implementation of new techniques and synergistic systems • Opportunity to adopt a more professional approach to managing construction sequences (instead of haphazard methods) • Opportunities to implement leading-edge technologies and to reduce substantial greenhouse emissions
Threats	• Not mainstream building materials • Resistance to change • Not mainstream techniques • Distribution and supply • It is an emerging technology that has a large energy saving potential. As this new emerging technologies go cheaper, the common insulation material will lose its interest and become obsolete.

6 http://issinstitute.org.au/wp-content/media/2011/04/ISS-FEL-REPORT-S-WEST-Low-Res.pdf

SWOT ANALYSIS	CELLULOSE[7]
Strengths	• Increased energy efficiency • Reduction in greenhouse gas emissions • Faster building times and better buildability of structures • Lighter weight materials may offer safety advantages in construction • Potential cost savings • Improved health and wellbeing
Weaknesses	• Possible cost • Material availability • The set views of trades
Opportunities	• Implementation of new techniques and synergistic systems • Opportunity to adopt a more professional approach to managing construction sequences (instead of haphazard methods) • Opportunities to implement leading-edge technologies and to reduce substantial greenhouse emissions
Threats	• Not mainstream building materials • Resistance to change • Not mainstream techniques • Distribution and supply

7 http://en.wikipedia.org/wiki/Cellulose_insulation

3.2.2 Conclusions

The studied insulation materials can be divided into two categories:

1) Traditional thermal building insulators: **Wood fiber, Polystyrene, Polyurethane, Rockwool and Cellulose**. Their thermal conductivity is around 30-40 mW/(m·K), decreasing to 20-30 mW/(m·K) only in PUR. It varies with temperature, moisture content and mass density.

2) New thermal building insulation materials are called "super-insulator": Aerogel and Vacuum Insulation Panels (VIP).

   - **Aerogel** is a low-density solid-state material in which the liquid component of the gel has been replaced with gas. Silica aerogels consist of a cross-linked internal structure of SiO2-chains (0.2%) with a large number of air filled pores on a micro and nano size scales (99.8%). Commercially available aerogels have a thermal conductivity between 13 and 14mW/(m·K).

     Aerogel applications have also important disadvantages: High production costs and the low tensile strength.
   - **Vacuum insulation panels (VIP)** consist of an open porous core of fumed silica enveloped of several metalized polymer laminate layers. These components are made by panels of solid material with a high porosity level and a very small pore dimension on which a technical vacuum is produced and maintained by enveloping the solid core with a plastic and/or metallic sheets.

     Vacuum insulation panels disadvantages: Puncturing the VIP envelope, which might be caused by nails and similar, causes an increase in the thermal conductivity to about 20 mW/(m·K). Moreover, the initial thermal conductivities increases from 3-4mW/(m·K) to typically 8mW/(m·K) after 25 years ageing.

Table 2 shows the main characteristics of the studied insulation materials. In order to be able to calculate the price of materials with different thermal conductivity, an assumption is made by fixing the thermal resistance to 3.5 m^2K/W. This assumption allows.

Table 2 Properties and costs of insulation materials

The table includes a selection of materials available on the market that are typical for each category.

Material	Typical format	Category	Thermal conductivity *($W\ m^{-1}\ K^{-1}$)*	Specific heat *($J\ Kg^{-1}\ K^{-1}$)*	Density *($Kg\ m^{-3}$)*	Fire resistance	Water vapor resistance	Price for thermal resistance = 3.5 $m^2\ K\ W^{-1}$ *($Euro/m^2$)*
Wood fiber	Panels	Organic	0.038-0.058	2000-2100	55-140	Bad	Bad	20-37
Polystyrene	Panels	Inorganic	0.032-0.045	1200-1500	10-80	Bad	Good	8.60-17.35
Polyurethane	Panels	Inorganic	0.022-0.035	1300-1500	30-160	Bad	Good	25-35
Rockwool	Panels, rolls	Organic	0.030-0.040	1000-1100	25-200	Very good	Bad	20-50
Aerogel	Panels, rolls	Innovative	0.013-0.021	900-1100	100-150	Very good	Good	70-200
Vacuum Insulating Panels (VIP)	Panels	Innovative	0.008	700-900	180-210	Good	Very good	140-170
Cellulose	Panels, flocks	Organic	0.038-0.040	2000-2100	30-70	Bad	Bad	25-30

3.3 Envelope materials in WP3

3.3.1 Available materials/technologies

Insulation materials are commonly used in the retrofit of buildings in order to decrease the thermal losses of the envelope. They can be applied on all the surfaces of the envelope as they are available in different formats.

These materials are therefore subdivided in categories based on the main component (organic, inorganic, nanomaterials etc.), where they are applied (walls, floors, roofs) and how they are applied (panels, flocks, rolls etc.).

3.3.2 Main characteristics of materials/technologies

The main characteristic that defines the thermal performance of an insulation material is the thermal conductivity, which is measured in steady state and affects the energy demand during the heating season.

More properties related to the thermal performance are the density and the specific heat that affect the energy demand during the cooling season. Other important properties are related to the safety (fire resistance), the comfort (water vapor resistance) and the environmental impact (toxicity, embodied energy).

A list of traditional and innovative insulation material is shown in Table 2 with their physical properties, costs and strong and weak points.

3.3.3 Strong and weak points of these materials/technologies

Standard insulation materials, such as polystyrene and polyurethane, are widely available on the market and don't require highly trained workers for the installation.

Innovative insulation materials, such as Aerogel and Vacuum Insulating Panels (VIP), due to their lower thermal conductivity, can give the same performance of standard materials with lower thickness; however, they may require highly trained workers for the installation and are much more expensive.

3.3.4 Cost benefit analysis

National and European standards promote the use of insulation materials as the limit values for the thermal transmittance of the building envelope are continuously decreasing. The most part of the existing building stock has been built in absence of such energy saving standards. Common insulation materials, in case of building retrofit, can lower the thermal transmittance of the building to the required level leading to energy savings in particular for heating energy demand that can be in a range between 10% and 30%.

Based on the building characterization analyzed in the Task 2.4, the following table shows the energy savings (and the ROI) that could be achieved due to decrease of the wall thermal transmittance (from the existing 1.02 to the 0.22 W/m^2K after implementing the insulation materials). In IKVA shopping center, we estimated that $1000m^2$ will be retrofitted, so the consumption due to the thermal behavior of this wall surface is estimated to decrease from 83,600 kWh/year to 18,300 kWh/year. The reduction in energy consumption will be around 65,000 kWh/year. The average price of electricity in Europe is 0.200 €/kWh and in Hungary is 0.140 €/kWh. Therefore, the economic savings in Hungary will be 9,100€/year, while with the electricity average price of the 28 countries in Europe the economic savings are 13,000€.

Table 3 Cost Benefit analysis and ROI

Material	**Price for thermal resistance = 3.5 m^2 K W^{-1}** ***in 1000m^2 (€)***	***Economic savings in Europe (€/year)***	***Economic savings in Hungary(€/year)***	***ROI in Europe (year)***	***ROI in Hungary (year)***
Wood fiber	20,000-37,000	13,000	9,100	1.5-2.8	2.2-4.1
Polystyrene	8,600-17,350	13,000	9,100	0.7-1.3	0.9-1.9
Polyurethane	25,000-35,000	13,000	9,100	1.9-2.7	2.7-3.8
Rockwool	20,000-50,000	13,000	9,100	1.5-3.8	2.2-5.5
Aerogel	70,000-200,000	13,000	9,100	5.4-15.4	7.7-22.0
Vacuum Insulating Panels (VIP)	140,000-170,000	13,000	9,100	10.8-13.1	15.4-18.7
Cellulose	25,000-30,000	13,000	9,100	1.9-2.3	2.7-3.3

SEVENTH FRAMEWORK PROGRAMME

4. Lighting and Daylighting technologies

4.1 List of technologies

The following Lighting and Daylighting technologies will be evaluated in the SWOT analysis.

Table 4 Lighting and Daylighting technologies

LIGHTING AND DAYLIGHTING TECHNOLOGIES	
LIGHTING	COMPACT FLUORESCENT LAMPS
	LED LIGHTING
	OLED LIGHTING
	MICROPLASMA LIGHTING
	SULFUR PLASMA LIGHTING
DAYLIGHTING	FIBER OPTIC LIGHTING
	NATURAL LIGHT ILUMINATION SYSTEM (NLIS)

4.2 SWOT analysis

4.2.1 SWOT analysis for lighting technologies

SWOT ANALYSIS	COMPACT FLUORESCENT LAMPS[8]
Strengths	• Elimination of prolonged lamp outages and reduced maintenance costs. • Improved lamp light output (four to five times more per watt than comparable incandescent lamps). • Longer rated life (10 to 20 times longer than for incandescent lamps). • Replacing incandescent lamps with CFLs would reduce energy use 75 to 80%. • Reduction in energy costs. The effect on GHG would vary greatly by country due to difference in electricity generation. CFLs used three hours per day can have a payback period of less than one year. • Increased efficiency of CFLs reduces the lighting heat addition, offsetting the energy and greenhouse gas benefits of conversion to more efficient lighting sources (assuming the electricity generation mix remains the same). • Warm white CFLs are available as well.
Weaknesses	• Initial Cost is greater than comparable products. CFL bulbs can range from €3 to €12 depending on their type. This is much more than typical incandescent bulbs, but their lifetime and energy savings are significant. • CFLs are ill-suited for recessed and enclosed fixtures • A typical CFL contains a very small amount (5 mg) of mercury, a toxic substance. Without an effective recycling program it is assumed CFLs will end up in landfills, which is a potential environmental issue if CFL use increases substantially. Conversely, electricity generation, particularly coal-fired, also releases mercury into the environment. Therefore reduced demand for coal-fired electric generation could reduce the amount of atmospheric mercury emissions. These effects represent both a cost and benefit; a fair comparison of these relative effects is required to evaluate the overall environmental effect of this regulation. • Consumer surveys and laboratory tests report premature CFL failure due to rapid-cycling and other operating conditions such as elevated temperatures. It is likely that increased use may result in a higher number of CFLs operating under less than ideal conditions. • Such use could lead to a higher number of CFL failures, thereby increasing costs to the consumer due to premature replacement as well as increasing the amount of mercury disposal relative to ideal lamp operation.
Opportunities	• Primary replacement technology because they already meet the proposed requirements and are a “drop-in” replacement for general service incandescent lamps.
Threats	• There are emerging technologies (LEDS, OLEDS) that have more energy saving potential. As these new emerging technologies go cheaper, fluorescent lamps will lose its interest and become obsolete.

8 CANMET, 2004. LRC, 2003.
Energy Star, 2007; Parsons, 2006: 9. LRC, 2003: 2-5; O’Rourke & Figueiro, 2001: 30

SWOT ANALYSIS	LED LIGHTING[9]
Strengths	• Low energy consumption – retrofit bulbs range from 0.83 to 7.3 Watts • Long service life – LED bulbs can last up to 50,000 hours • Durable – LED bulbs are resistant to thermal and vibrational shocks and turn on instantly from -40C° to 185C°, making them ideal for applications subject to frequent on-off cycling, such as garages and basements • Directional distribution of light – good for interior task lighting • No infrared or ultraviolet radiation – excellent for outdoor use because UV light attracts bugs • Safety and environmentally conscious – LEDs contain no mercury and remain cool to the touch, because LEDs generate much less heat compared to other lighting systems. • Fully dimmable – LEDs do not change their colour tint when dimmed unlike incandescent lamps that turn yellow • No frequency interference – no ballast to interfere with radio and television signals • Range of colour – LEDs can be manufactured produce all colours of the spectrum without filters, they can also produce white light in a variety of colour temperatures
Weaknesses	• Very expensive • Does not perform well under high wattage applications yet • Still in development phase of technology • High glare effect • High quantities of aluminum used for heat sinks • Re-lamping expensive – the whole LED arrays needs to be replaced • Single LED failures create negative visual effect
Opportunities	• Could replace all applications of light fixtures after some years of development • Continuing Energy-saving as LED light enrichment protection appeal for industrial and commercial lighting • Online opportunities worldwide • Government policy support in many European countries
Threats	• Still under development and may not reach reasonable price levels for years • Domestic market purchasing power of customer • The biggest limitation to LED for common residential use is the cost of manufacturing due to still-limited production runs. Manufacturers claim production will increase considerably in the near future, further lowering prices. Currently, there is a limited number of LED fixture manufactures, but this is changing. Retrofit bulbs range from €20 to €60 for night lights and small lamps. • The development of new technologies like Microplasma lightning

9 http://eco-system.in/home/products/4-led-lighting-systems

SWOT ANALYSIS	OLED LIGHTING[10]
Strengths	• OLED material is very light weight, thin and transparent. • OLEDs can be printed on a thin layer of film or even a sheet of paper, so its flexibility and small size is a determining advantage. • Displays applying OLEDs are generally brighter compared to other display solutions • OLED displays are more energy-efficient in general, and have a wider viewing angle compared to other display solutions. • OLEDs are easier to produce and can be made to larger sizes. Because OLEDs are essentially plastics, they can be made into large, thin sheets.
Weaknesses	• OLEDs are not used for lighting purposes at the moment. The brilliance of the diodes are not high enough for this application. • OLEDS slowly lose their light-emitting properties. The current materials use dare expected to last between 10,000 and 14,000 hours although this is expected to improve. Some would say this is long enough as it implies a screen usage of 5.5 years for a 7 hour per day usage (Conti, 2008) • Manufacturing processes are expensive right now. • Water can easily damage OLEDs.
Opportunities	• OLEDs are the fastest growing flat panel display technology today, with Europe playing a key role as a technology developer. • Success for OLEDs depends on two key technical advances: first, the operating lifetime, which is based on the stability of each colour; and second, the production process. If the latter can be developed, with consistent high quality at low cost by using low cost printing and room temperature processes, that combination could take unit costs well below other products. • NanoMarkets predicts that from zero in 2008, the general purpose market for printed lighting will grow to about $119 million in 2010 and to over $1.5 billion in 2014, consisting mainly of OLEDs.
Threats	• The market for lighting is potentially enormous but more uncertain. OLED lighting seems likely to remain a niche product for the foreseeable future, owing to investment in existing incompatible infrastructure. • Attempts have been made to use it as a main source of light: the first one was by Osram in 2009 November, but the Orbeos light panel, besides the above mentioned problems, had the disadvantage of high price as well. • OLEDs may not be suitable for main source of lighting at the moment; it allows a new range of unconventional lighting solutions, hopefully to appear on the market within a few years. Novaled OLED panels are a good example for this - these panels are transparent layers applied on a window for instance, letting in sun light during the day as a regular window, but serving as a source of light during the night. This background light solution can be obtained other ways as well. Since OLEDs can be printed on any thin layer or sheet, they are an alternative solution for wallpapers as a background light. OLED wallpapers - which are the combination of art and technology - are due to appear on the market in 2012. • These peculiar solutions of lighting are going to revolutionize our idea about home or commercial lighting, hopefully in the near future.

10 http://www.ledcentre.uk.com/newsletter/oleds-in-lighting.html

SWOT ANALYSIS	MICROPLASMA LIGHTING[11]
Strengths	• The lighting can be any shape or colour. • Flexible sheets • It is mercury-free, contains no toxins, and environmentally friendly • Ultra thin (less than 3mm) and flat form factors that can be flexible and formed, unlike fluorescent and HID sources • Eliminates the need for external reflectors to control the light distribution • Longer lasting light source: Offers long life of up to 50,000 hours • Surpasses functional LED system efficacy • Operates cool and generates less heat • Its plastic, glass and aluminum contents are easily repurposed and recyclable.
Weaknesses	• Currently, the largest arrays produced are 6 sq. in. • Because of the rate of production, the MCA is not cost-competitive with current lighting options
Opportunities	• Hold considerable promise as the next generation of lighting technology • US Congress mandated that incandescent lights be phased out in 2014. EU will possibly act similarly.
Threats	• It is not a fully developed technology

11 http://www.informlightworks.com/?p=146

SWOT ANALYSIS	SULFUR PLASMA LIGHTING[12]
Strengths	• Sulphur Plasma lamps are between 25% - 100% more efficient than any other artificial source of high quality white light. • The light is true full spectrum daylight and thus features all of the qualitative benefits of sunlight. • The light is almost 100% PUR and thus perfect for photosynthesis. • Light can be efficiently distributed over large spaces, superior to all arc-based lamp technology in every sense, and costing no more than lamps which are used extensively in the Film and Theatre industry. • Unlike all other artificial light sources, the light output and colour (light output quality) does not degrade over time and it is fully dimmable down to 30%. • It contains no lead, unlike most other lamps, no mercury, unlike all fluorescent lighting and no arsenic unlike most LEDs (Gallium Arsenide). • The lamp's output is low in infrared energy, and less than 1% is ultraviolet light. As much as 75% of the emitted radiation is in the visible spectrum, far more than other types of lamps.
Weaknesses	• Limited life – Magnetrons had limited lives. • Large size • Heat – The sulfur burnt through the bulb wall unless they were rotated rapidly. • High power demand – They could not sustain a plasma in powers under 1000 W.
Opportunities	• Suitable for indoor agriculture and indoor growing processes
Threats	• Its market is restricted to very specific needs

12 http://www.plasma-i.com/plasma-email3.htm

4.2.2 SWOT analysis for daylighting technologies

SWOT ANALYSIS	FIBER OPTIC LIGHTING[13]
Strengths	• Deliver natural light to spaces deep in a building. • Distributed day lighting through optical fibers is a high-tech approach to making use of natural light. • On the roof or an outside wall, there's a one-meter-square collector that track the sun as it moves across the sky. • The SP2 uses about 2 watts of electricity to operate this tracking, which is controlled by a photosensor and microprocessor. • The cables can be run through interior wall cavities, ceiling plenums, or wiring chases, and their bending radius can be as tight as two inches • The Fiber Optic Lighting can take the form of spotlights, fairly conventional-looking ceiling fixtures, and some hybrid fixtures that include both day lighting and high-efficiency fluorescent lighting. • The colour of the light changes throughout the day. In the early morning and late afternoon, it can be distinctly orange, while in the middle of the day, it can be quite blue, which gives the light a cool feeling.
Weaknesses	• The greater the length from the light source, the greater the light loss: at 33 feet (10 m) 64% of the light is delivered; at 65 feet (20 m), only 40%. • The system is quite expensive, with a system starting at about €8,000 for one SP2, four optical-fiber cables, and four fixtures, plus installation. • It can only be used in the daytime, and in certain daylight conditions
Opportunities	• If prices come down, this could become a practical strategy in the future.
Threats	• Not suitable for the lower floors • This technology is not easily available commercially in Europe

13 http://www2.buildinggreen.com/blogs/fiber-optics-daylighting

SWOT ANALYSIS	NATURAL LIGHT ILUMINATION SYSTEM (NLIS)
Strengths	• **Collecting:** There are two layers of the prismatic element and the innovative element improve the sunlight leakage and loss problem • **Coupling:** The new coupler is with high transmittance efficiency and suitable to assemble on the lightpipe • **Transmitting:** The efficiency of light pipe is higher than fiber on the long distance transmission. • **Emitting:** The new emitting component can used on light pipe and LED both to provide steady indoor illumination
Weaknesses	• **Collecting:** The innovative element has to coat AR coating. It will increase the cost and difficulty of mass production • **Coupling:** If the light source distribution is Lambertian (like LED), the transmittance will be lower. • **Transmitting:** The flexibility of light pipe is lower than fiber • **Emitting:** The weight is heavy and dimensions are large.
Opportunities	• The weight of PMMA is lighter than conventional glass material. • PMMA is easy to manufacture and the cost is cheap. • It is also much easier to mass production than glass.
Threats	• The hardness is low, easy to get scratched. Therefore, a cover glass should be used on the LightBrick module to avoid scratch and dust. • The guarantee period of PMMA is shorter than Glass. The guarantee period experiment is still on going. However, the default period of PMMA material is 15 years.

4.2.3 Conclusions

The integration and development of lighting technologies are not considered due to the large amount of research effort that the previous projects carried out, instead, this project will pay more attention to the daylighting technologies. In the renovation of the shopping center of Sopron, lighting technology is not considered either. However, this study of the lighting technologies will serve as an assessment of retrofitting solutions and can be used as a baseline for users who wants to implement it on his project. Specifically, according to the SWOT analysis of the available alternatives of lighting technologies, OLED technology has an enormous potential market in a long term of view, but at this moment they are not mature and cost effective enough to be used for lighting purposes. For the LED technology, in fact it is the most used technology in lighting refurbishment projects, since it has several advantages, such as a low energy consumption and long service life, but the price and the medium-long ROI could be subjects that the project owner should consider. As times go by and improvement in technological development, the LED will have a higher potential compare to other alternatives, the price is envisioned be reduced reasonably in a short term.

As the natural lighting technologies are concerned, the daylighting is considered the best source of light during daytime in buildings because it can save energy in place of using artificial lighting, which represents a major component of energy consumption in commercial buildings. Many research studies have focused on natural light illumination as a means of saving energy and creating healthy lighting.

Today, most daylight collectors use dynamic concentrators, but these designs are too expensive to be cost effective, need building remodeling to install and the existing daylighting technologies are impossible to expand to fulfill increasing indoors illuminance requirement.

The NLIS system developed by NTUST, that will be implemented in the EcoShopping demo site, can be adjusted according to the illumination needs by increasing the number of cascadable light collecting units. In addition, the novel system is made up of PMMA material and as it is easy for mass production and thus the manufacturing costs can be reduced for large scale production.

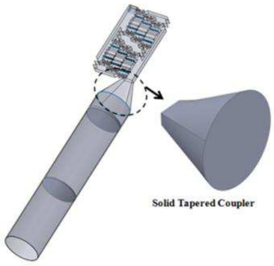
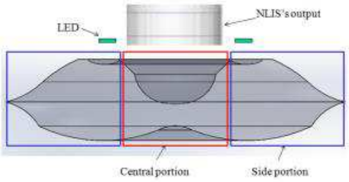
The NLIS system will be an all-optical daylight guiding system with modular structure which allows the flexibility to design and install the system in any part of the commercial buildings so to gain the optimization of energy efficient lighting systems. The efficiency of light pipe is higher than fiber on the long distance transmission.
During the night or overcast day, the system can be integrated with the artificial lighting system to simulate the natural light and be robust to be a light provider regardless of outside lighting situation. Furthermore, taking the advantage of light's reciprocal property, during night time when there is no sunlight to collect, the system is transformed to become an energy-saving artificial lighting system by transmitting the indoor light outside so the surface of the devices used for light collection emits, which can be served as exterior lighting fixtures of commercial buildings without using extra spot lights.

4.3 DayLigthing technologies in WP3

4.3.1 Scheme of NLIS technology

In the following figure it appears the NLIS technology scheme.

Table 5 NLIS technology

Collecting		**Transmitting**	
Coupling		**Emitting**	

4.3.2 Cost benefit analysis

Based on the construction cost of NLIS, we could estimate the unit price of NLIS is 1.1€/lm. After mass production, the price is expected to decrease 10% due to higher yields.

For example, when the NLIS is applied on 660 m2 basement, there are 200 fluorescent lamps needed at least. That will consume 1,152 kWh per day. The cost will be 2.150€ per mounth based on 0.06€/kWh in Taiwan.

The initial construction cost is around 71.200€. Regarding to the 15 years guarantee period, the unit construction cost is almost 400€ per mounth. Based on the condition of 10hrs usage per day of fluorescent lamps, if fluorescent lamps are replaced by NLIS, it will save around 885€ per month. Therefore, the ROI is around 11.8 years.

5. HVAC AND RENEWABLE ENERGIES

5.1 List of technologies

The following HVACR technologies will be evaluated in the SWOT analysis.

Table 6 HVACR technologies

	HVAC AND RENEWABLE ENERGIES
VENTILATION	MECHANICAL VENTILATION SYSTEM
	HYBRID VENTILATION SYSTEM
	PASSIVE STACK VENTILATION SYSTEM
	VENTILATION: BREATHING WINDOW
RENEWABLES AND HEAT PUMPS	BIOMASS BOILER
	WIND ENERGY (MICRO WIND TURBINES)
	SOLAR PHOTOVOLTAIC SYSTEMS
	SMALL SCALE HYDRO (MICRO HYDRO)
	SOLAR WATER HEATING
	MICROBIAL FUEL CELL
	GROUND SOURCE HEAT PUMP
	WATER SOURCE HEAT PUMP
	AIR SOURCE HEAT PUMP
	DC POWERED HEAT PUMP
COMBINED HEAT AND POWER (CHP)	MICRO-CHP STIRLING ENGINE
	MICRO-CHP RANKINE CYCLE ENGINE
	MICRO-CHP FUEL CELL
	MICRO-CHP INTERNAL COMBUSTION ENGINES
	COMBINATION BOILERS
	CHP WITH NATURAL GAS/BIOGAS
STORAGE AND DISTRIBUTION	THERMAL STORAGE / THERMAL ENERGY STORAGE WITH SUPERCRITICAL FLUIDS
	MODULAR THERMAL HUB FOR BUILDING COOLING HEATING, AND WATER HEATING
	RADIANT HEATING/COOLING SYSTEM
COOLING TECHNOLOGIES	ABSORPTION CHILLER
	MEMBRANE-BASED ABSORPTION REFRIGERATION SYSTEMS
	EVAPORATIVE COOLERS
	DUAL EVAPORATIVE COOLING FOR RTUS
	SOLID DESICCANT COOLING SYSTEM
	HIGH –EFFICIENCY SOLID-STATE COOLING TECHNOLOGIES

	HIGH-EFFICIENCY ADSORPTION CHILLERS
	REVERSE CYCLE CHILLER
	MAGNETIC REFRIGERATION

5.2 SWOT analysis

5.2.1 Ventilation

SWOT ANALYSIS	MECHANICAL VENTILATION SYSTEM[14]
Strengths	• Better Indoor Air Quality. Indoor air can be many times more polluted than outdoor air, and the people in cities use to spend 80 percent of the day inside. • Ventilation systems can significantly improve a home's air quality by removing allergens, pollutants, and moisture that can cause mold problems. • More Control. When indoor places rely on air flow through walls, roofs, and windows for ventilation, there is no control over the source or amount of air that comes into the building. In fact, air leaking into the building may come from undesirable areas such as the garage, attic, or crawl space. Mechanical ventilation systems, however, provide proper fresh air flow along with appropriate locations for intake and exhaust. • Improved Comfort. Mechanical ventilation systems allow a constant flow of outside air into the building and can also provide filtration, dehumidification, and conditioning of the incoming outside air. • Air can be supplied or removed at specific flow rates and for specific periods of time. • Excess ventilation can be minimized, lowering the amount of extra space heating required. • Airflow into and out of a building (that is airtight) is less affected by outside air temperature, wind velocity and direction.

Weaknesses	• Compared to natural ventilation, it has some drawbacks:
	  • Using energy
	  • Causing noise
	  • Requiring extra penetrations in the envelope
	  • Being visually unattractive
	  • Investment cost
	  • Needing ongoing maintenance (filter-change)

Opportunities	• Higher building security than opening windows • Outside air can be sourced from a location where the air is fresher, cleaner, drier or warmer • Outside air can be heated or cooled before entering the space • Sufficient ventilation and air movement can be provided in hard-to-reach spaces (often in apartment buildings) or in airtight buildings
Threats	• Buildings that haven't considered mechanical ventilation systems in its designs can hardly qualify for retrofitting because these systems require major infrastructure modifications.

14 http://www.energystar.gov/ia/new_homes/features/MechVent_062906.pdf

http://www.bacorp1.com/greenbuilding.asp?topic=energystar

SWOT ANALYSIS	HYBRID VENTILATION SYSTEM[15]
Strengths	• Good technical idea for fresh air transport. • Simple way of system installation, • Easy to install, • Price competitive systems, • Easy to maintain.
Weaknesses	• Initial cost is greater than other solutions • High maintenance required • Some compatibility problems in the installation of combined natural and artificial ventilation system • Heat recovery is not possible
Opportunities	• High building market grows indicators • Large building renovation market • Rising customers awareness towards energy efficiency • Rising demand for indoor climate in residential buildings • Easy to explain and present to customers
Threats	• Active market penetration of Mechanical Ventilation systems, • Designers' attitude towards new systems. • Not enough marketing and promotion activities • Weak products and systems distribution • No education for designers and construction companies.

15 http://ecovent1.bf.rtu.lv/pdfs/reports/Interim%20report.pdf

SWOT ANALYSIS	PASSIVE STACK VENTILATION SYSTEM[16]
Strengths	• Improved air quality in the building • Improved ventilation in the building • Silent operation • Economical with low running cost • Maintenance free because it requires no moving parts and has no operating costs. After installation, the only maintenance needed is periodical cleaning of the filters. • Energy saving: Passive ventilation doesn't require electricity, so it saves energy and cuts down on carbon monoxide emissions. • Environmentally friendly
Weaknesses	• It's extremely dependent on the outdoor temperature • It functions best during colder periods of the year, when the difference between inside and outside temperatures is greatest • Passive ventilation used alone can't extract humidity from bathrooms and laundry rooms
Opportunities	• A low cost way of ventilating your home without reliance on mechanical or electrical extraction methods
Threats	• Passive ventilation systems should be used in conjunction with a heat-recovery unit. • Air must be allowed to circulate freely among rooms to get maximum performance from a passive ventilation system. • Low business opportunities

16 http://www.homeimprovementpages.com.au/article/passive_stack_ventilation
http://www.hgtvremodels.com/home-systems/passive-ventilation/index.html

SWOT ANALYSIS	VENTILATION: BREATHING WINDOW[17]
Strengths	• The breathing window functions well beside natural ventilation, hybrid or completely balanced mechanical ventilation (air-conditioning) • High efficient decentral ventilation 10 - 50 m^3/h • Personal control over air quality • Balanced ventilation, no air-ducts • No lowered ceilings needed, stone floors can be used as internal thermal mass by night cooling • No installation space needed - built in the outer wall • Minimum infrastructure required • Acts on wind, temperature, time, CO_2 (possibly radon) • No air-ducts, no air recirculation • Heat exchanger easily cleaned by dishwasher • Insect-proof / dustfilter • No traffic noise from outside • No draught (almost no temperature difference)
Weaknesses	• Wind pressure sensitive • Heat exchanger / dust filter is fragile • Power-supply needed • Condensation water outlets needed • One unit required for each room • Audible at night in silent areas
Opportunities	• Unique innovation with definite USPs • New product in existing market • Little or no icing in arctic climate • Patented innovation • Energy saving on heating new houses 35% • Less building-volume in offices 15% • Reduction of building costs by = 10% • Global market for several license holders
Threats	• Lack of acceptation due to being new and unconventional • Installation technology • Users have no experience • Reliability not yet proven • Investment in production is high • No market for a long period of time (app. 2-3 years) • Product is to be mounted in the outer skin of a building • Every country has its own building regulations

17 http://web.byv.kth.se/bphys/reykjavik/pdf/art_150.pdf

5.2.2 Renewable energies and Heat pumps

SWOT ANALYSIS	BIOMASS BOILER[18]
Strengths	• Biomass boiler is highly compatible with current technologies • Biomass boilers are very efficient. Using the best of modern technology, biomass boilers can achieve over 90% efficiency – dramatically more than conventional boilers. • The boilers have automatic ignition and can modulate between 30% and 100% of full load. • Easy to maintain and operate. Woodfuel boiler will last much longer than a conventional boiler (25 – 30 years rather than 5 – 10) • A biomass system is very competitive, ranging from approximately three and a half to six years. • It should be noted that oil prices are highly volatile and can fluctuate significantly. Utilising biomass therefore is far cheaper in terms of fuel costs. • Heating, district heating, Domestic hot water (DHW) • This type of energy production has a limited long term effect on the environment because the carbon in biomass is part of the natural carbon cycle. • Locally sourced wood chip heating delivers a 95% CO2 emissions reduction compared to a gas boiler. • Eliminates acid rain (biomass contains no sulphur)
Weaknesses	• High cost for Harvesting, Transporting, and Chipping System for Forest Biomass. • The biomass maintenance costs are slightly higher than that for the oil system due to the need for activities such as disposing with ash and cleaning the grate. • From viewing the capital costs it can be seen that the biomass systems represent a larger initial outlay than the alternative fossil fuel system. • Place of fuel storing and puffer tank. • Relatively high heating water temperature. • Acoustic effect of fuel storing. • Emission of pollutant material.
Opportunities	• Improved fuel security through added diversity and local sourcing. Reduces reliance on fossil fuels • Government grants the usage of this technology depending on the country and on the energy efficiency • EU Biomass Action Plan • Biomass heating is often the lowest cost way to reduce CO2 emissions after energy Conservation. Reduces greenhouse gas emissions • The impact on the creation of employment will be of 11 new jobs (10 in rural and forest medium and 1 in the industrial field) per 1MW generation of energy with biomass • Will help to minimize the impact of haulage costs • Reduces amounts of landfill (waste wood used as biomass fuel). Promotes biodiversity through the sustainable management of woodlands • Modern biomass boilers are computer controlled for optimum efficiency
Threats	• Space requirements to install the boiler and fuel storage

18 http://www.greenwarmth.co.uk/biomassboilers.asp

http://www.renewableinnovations.co.uk/biomass.html

http://www.homeenergysurveyors.co.uk/#!biomass/c18jo

	• Fuel not easily available everywhere
SWOT ANALYSIS	**WIND ENERGY (MICRO WIND TURBINES)** [19]
Strengths	• The manufacture's life expectancy is usually given as 25 years • Simple solutions – easy to plug in • Possibilities to reduce the electricity bill • Wind is an eternal natural resource. Wind is free of charge and does not get affected by other price trends in the world • Good solution where there is no commercial grid to connect to (islands, mountain areas) or properties located in good windy areas • Own generated energy can create a feeling of independency and secure the future electricity cost. • CO_2 savings: 1 tone per kW
Weaknesses	• Wind is intermittent, varying from zero to gale force speeds. • Planning application required • Limited scope for community project • It depends on the location. It is prudent to carry out wind speed monitoring during 6-12 months to confirm that estimated wind speeds are likely to be reasonably representative. The cost of this exercise is usually in the region of €3,500. • Wind turbine cost around €6,000 per kW. • Expensive in comparison to grid electricity • Lack of professionals with the right knowledge to design, install and make service on small-scale wind turbines • Lack of education in the wind power sector • No standards yet in the business regarding technology etc • Product quality questionable • Wind conditions are hard to predict • Not much research done within small scale wind turbines • Lack of statistics • Payback around 7-10 years • Operational and maintenance costs are typically in the range of 2-3% of capital cost
Opportunities	• Potential for individual properties to benefit from electricity bill and carbon savings and FIT • Highly visible and good promotional tool • Potential installation work for local businesses • Increasing energy prices in the world force people to look towards other energy alternatives-renewable • Increased interest for green energy and environmental issues • Possibilities to create a specific support system that can be applied on small scale wind power • Government grants and business loans available • Political support
Threats	• Land ownership issues • Wind monitoring advisable on some sites to confirm wind resource • A wind turbine would require annual maintenance. • A wind turbine may need some major parts replacing, such as gearboxes and blades after 5-10 years. • Planning permission would be required for the installation of a wind

19 Bute Renewable Energy Project. Renewable Energy Feasibility Study For Towards Zero Carbon Bute. November 2011

http://cvi.se/uploads/pdf/Kunskapsdatabas%20teknik/ovriga%20publikationer/SmallScale_Wind_Turbines_Erika_Thorstensson.pdf

	turbine • The commercial electricity to cheap, slows down the development of wind energy • Competition from other renewable sources such as solar (PV) panels, hydro power • New rules, permits and laws from the government might complicate for the planned expansion and hinder development • Noises, shadows and affected landscape view might slow the development and expansion down • Resistance among people in the society or from neighbours because of noises, shadows, disturbed landscape view

SWOT ANALYSIS	SOLAR PHOTOVOLTAIC SYSTEMS[20]
Strengths	• Solar energy is a locally available resource (amount depends on location). • Potentially suitable for a large number of properties • 0% small business loan available • Short project timescale • Most manufacturers offer a 25 year performance warranty on the panels which guarantees their performance after 25 years will be at least 80% of the initial performance (90% after 10 years). • Running costs associated with PV systems are minimal. There are no moving parts to service and the installation should be mostly self-cleaning, although likely to benefit from an annual wash. • Photovoltaic (PV) systems provide green, renewable power by exploiting solar energy. We can use photovoltaic (PV) panels as an alternative energy source in place of electricity generated from conventional fossil fuels. • PV panels can last up to 25 years or more, some with a maximum efficiency loss of 18% only, even after 20 years of operation. • Unlike wind turbines, Photovoltaic (PV) panels operate autonomous without any noise generation as they do not incorporate any moving mechanical parts. • Panels may be mounted on adjustable rotating basis which is mounted on a fixed pole and allows some movement for better and longer solar tuning – turning the solar panel to follow the sun.
Weaknesses	• Planning applications required for ground mounted systems • Likely that insufficient scope for community project • PV systems cost in the region of £2,500 - £5,000 per kw installed • It is likely that the inverter will need to be replaced at least once over the lifetime of the panels. • The feasibility depends on the location • Perhaps the biggest disadvantage of Photovoltaic (PV) panels is their limited efficiency levels; compared to other renewable energy sources – such as solar thermal – PV systems have a relatively low efficiency level ranging between 12-20%. • Photovoltaic PV panels produce direct electric current which must be converted to alternating current (AC) before it can be used for consumption (either to be transferred to the power grid, or directly for own consumption). To convert DC to AC, PV panel systems use inverters, expensive electronic equipment and with certain technological limitations, • Low voltage output or fluctuation in PV electric current may lead to increased waste of electricity since it cannot be transmitted onto the network (intermittent output). • Solar Photovoltaic (PV) panels' main disadvantage is that it delivers only in direct sunlight and it cannot store excess amounts of produced energy for later use. This is particularly important when energy is needed for the night when there is no sunlight or when weather conditions are fluctuating • Structural surveys required for roof mounted systems • Paybacks around 15-20 years
Opportunities	• Potential for individual properties to benefit from electricity bill and carbon savings and FIT • Highly visible and good promotional tool

20 Bute Renewable Energy Project. Renewable Energy Feasibility Study for Towards Zero Carbon Bute http://www.greenenergysavingtips.com/pros-and-cons-of-photovoltaic-pv-panels-solar-energy/

	• Potential installation work for local businesses • A typical 4kWp solar PV system would be expected to generate in the region of 3,000 kWh per year of electricity and therefore save 1.57 tonnes of CO_2 in replacing grid generated electricity. • A typical 2kWp PV system will comprise 8-10 panels depending on the panel size, and occupy around 14m2 of roof space • Reduce our impact to the environment by reducing CO_2 emissions into the atmosphere. • With respect to operating costs and maintenance costs, Photovoltaic (PV) panels, unlike other renewable energy technologies, require minimum operating or maintenance costs; just performing some regular cleaning of the panel surface is adequate to keep them operating at highest efficiency levels as stated by manufacturers' specs. • By maintaining relatively small power generation stations in a distributed power network, we can minimize energy losses in the network that are caused by the long distance between power generation and power consumption points • One of the most important advantages of Photovoltaic (PV) systems is actually inherited by all solar energy systems in general; solar energy peak power generation usually coincides with peak energy demand • Their high popularity has been driven on one hand by the ease of installation and use and, on the other hand, by reduction in PV costs (PV investment and installation) driven by industrial maturity of PV technologies. In the recent past, prices of Photovoltaic (PV) systems have witnessed a drastic decrease bringing the total cost around $1 to $1.3 per PV watt installed (cost for complete PV deployment) • Wide location possibilities: Roof tops, PV panels at building facades or through incorporated systems for PV on window glass • Solutions promoted by financial institutions (banks) through green-power financial incentives and green-projects.
Threats	• Solar PV energy is very subsidized in many European countries. Recently Spain and Germany, have drastically cut their subsidies, because they were unaffordable and unworkable. Some experts believe that alternatives to fossil fuels will be developed, but they will only work if they are affordable. Wind and solar aren't, and that isn't changed by shifting the costs from consumers and producers to the taxpayers. • Obsolescence equipment are expensive to eliminate

SWOT ANALYSIS	SMALL SCALE HYDRO (MICRO HYDRO) [21]
Strengths	• Efficient energy source: It only takes a small amount of flow (as little as 8 litres per minute) or a drop as low as one metre to generate electricity with micro hydro. Electricity can be delivered as far as a mile away to the location where it is being used. • Reliable electricity source: Hydro produces a continuous supply of electrical energy in comparison to other small-scale renewable technologies. The peak energy season is during the winter months when large quantities of electricity are required. • No reservoir required: Microhydro is considered to function as a 'run-of-river' system, meaning that the water passing through the generator is directed back into the stream with relatively little impact on the surrounding ecology. • Cost effective energy solution: Building a small-scale hydro-power system can cost from €1,000 - €20,000, depending on site electricity requirements and location. Maintenance fees are relatively small in comparison to other technologies.
Weaknesses	• Running costs will be dependent on the type of scheme, off-take and turbine used. As a minimum the components of the scheme will require regular inspection and annual serving of the turbine. • Suitable site characteristics required: In order to take full advantage of the electrical potential of small streams, a suitable site is needed. Factors to consider are: distance from the power source to the location where energy is required, stream size (including flow rate, output and drop), and a balance of system components - inverter, batteries, controller, transmission line and pipelines. • Energy expansion not possible: The size and flow of small streams may restrict future site expansion as the power demand increases. • Low-power in the summer months: In many locations stream size will fluctuate seasonally. During the summer months there will likely be less flow and therefore less power output. Advanced planning and research will be needed to ensure adequate energy requirements are met. • Environmental impact: The ecological impact of small-scale hydro is minimal; however the low-level environmental effects must be taken into consideration before construction begins. Stream water will be diverted away from a portion of the stream, and proper caution must be exercised to ensure there will be no damaging impact on the local ecology or civil infrastructure.
Opportunities	• Power for developing countries: Because of the low-cost versatility and longevity of micro hydro, developing countries can manufacture and implement the technology to help supply much needed electricity to small communities and villages. • Integrate with the local power grid: If your site produces a large amount of excess energy, some power companies will buy back your electricity overflow. You also have the ability to supplement your level of micro power with intake from the power grid. • A constant supply of electricity • Savings on the cost of buying diesel for diesel powered generators • Low environmental impact • Low noise and air pollution

21 Bute Renewable Energy Project, Renewable Energy Feasibility Study, for Towards Zero Carbon Bute. November 2011
http://wiki.answers.com/Q/What_are_the_advantages_and_disadvantages_of_using_micro_hydro_water_wheels
http://www.enggpedia.com/civil-engineering-encyclopedia/dictionary/dams/1740-benefits-of-micro-hydel-project

	• Does Not Potentially Cause The Submerging Of Forest/Agricultural Land, Reservoir Enlargement, Residential Relocation Or Seismological Threats. • Coupled with reforestation in the water catchments area, the project also aims to reduce the risk of flash floods in years to come. • Energy In Remote And Hilly Areas Where Extension Of Grid System Un-Economical • Small Scale Irrigation
Threats	• Planning permission will be required for the installation of a hydro scheme. • Few sites have suitable watercourses for the development of micro-hydro within their boundary or under their ownership.

SWOT ANALYSIS	SOLAR WATER HEATING[22]
Strengths	• A 5m2 solar thermal system cost around €5-6,000, including a new hot water cylinder with solar coil. • 5m2 of solar collector could be expected to provide 2,250 kWh of hot water per year (mainly during summer months). • Hot water throughout the year: the system works all year round, though is needed to heat the water further with a boiler or immersion heater during the winter months. • Cut carbon footprint: solar hot water is a green, renewable heating system and can reduce your carbon dioxide emissions. • Maintenance costs for solar water heating systems are generally very low. • Most solar water heating systems come with a five-year or ten-year warranty • Different types of collectors are available, which makes integration flexible for different building types
Weaknesses	• Savings are moderate - the system could provide most of the hot water in the summer, but much less during colder weather. • May not have as great of performance in climates that do not receive a lot of sunshine • Tank takes up more space than tank-less units, but comparable to (or slightly larger than) "normal" tank type units • Higher upfront cost for equipment & installation • High initial cost • Payback: depends on the climate zone.
Opportunities	• Solar thermal panels require minimal maintenance, although may require periodic cleaning to ensure optimal performance. An annual service is recommended alongside the main heating system. • CO2 savings Tones pa: 1 ton per m2 • Typical carbon savings are around 230kgCO2/year when replacing gas and 510kgCO2/year when replacing electric immersion heating. • Tax credits help lower upfront cost, and there are often local incentives that also help offset part of the initial investment • Use the free energy of the sun to heat your water • They are friendly to our environment since use the solar energy as the source power and don't produce CO or CO2. So it is reasonable if we call them as 100 percent of the clean heating technology. • Use them optimally during winter season with the right system. There are some popular systems that are based on the climate. • Financial incentives, especially if you live in Canada, USA, and some European countries.
Threats	• Tank can produce a significant amount of heat, so its location will need to be planned accordingly • They cannot be combined with radiators • Outdoor units that get the direct sunlight or other extreme weather require more maintenance and should be checked periodically.

22 Bute Renewable Energy Project, Renewable Energy Feasibility Study for Towards Zero Carbon Bute. November 2011
http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Solar-water-heating
http://www.proudgreenhome.com/blog/6277/Pros-and-cons-of-solar-water-heaters
http://moreheaters.com/solar-hot-water-heater-pros-and-cons/

SWOT ANALYSIS	MICROBIAL FUEL CELL[23]
Strengths	• Catalysts are inexpensive –essentially "free" • Catalysts are diverse and robust extreme conditions of pH, Eh, T, salinity, etc. • Catalysts are versatile –single type can use wide variety of substrates • Catalysts can self repair (proteins, DNA, membranes, etc.) • More than 50 different Shewanella species known. So far, all produce current • From -4ºC to 55ºC; wide salinity range. 65 different carbon sources • Very tough and robust organisms • If these fuel cells are optimized for usage in the real world, an extraordinary amount of waste could be diverted from landfills to instead produce clean energy.
Weaknesses	• Microbial fuel cells are still in the developmental stage • It will take about three to five years before the microbial electrolysis cell could be economically feasible to use as an energy source • Current density is low • Difficult to run and maintain • Sensitive to breakdown and decay
Opportunities	• Microbial Fuel Cells have the potential to produce heat and power very efficiently with low emissions and noise levels. • Interest on potential investors
Threats	• Still in an early stage of development, and years away from the market

23 http://www.ee.uconn.edu/SeniorDesign/projects/ecesd131/allpages/researchpapers/paperVI.pdf

SWOT ANALYSIS	GROUND SOURCE HEAT PUMP[24]
Strengths	• The constant temperature of the earth heats or cools the circulating water loop as needed to balance the building's year-round heating-and-cooling requirements. • The constant ground temperature provides, by correct dimensioning, a favourable seasonal performance factor and long lifetime for the heat pump; • A 25 to 40 percent reduction in heating and cooling costs. • No central system to fail or shut down the entire building. • Good Energy Efficiency, between 2 and 4.9 times the input energy produced • Most Efficient of the 3 types of Heat Pump • Highly durable piping (the life expectancy is between 30 and 50 years). • No high-maintenance, freezing-prone cooling tower. • No boiler to clean or maintain • No air conditioning equipment on roof to cause leaks • Standard, simple controls • No need for a highly specialized chiller technician or boiler operator • Costs vary from project to project. • Highly durable piping (the life expectancy is between 30 and 50 years) • No risk with transportation, storage, and operation • Leaks are rare, but the piping system is designed to make it easy to find and repair a leak. • Pipes can be grouped in clusters of 20, with each cluster having its own valve. Even if a leak occurs, the system will continue to run while one of the clusters is closed off from the system for repairs. • The underground piping often carries warranties of 25 to 50 years, and the heat pumps often last 20 years or more. • The GHP systems are installed in a decentralized manner, to fit individual needs. • No harmful chemicals • No danger of fire, asphyxiation, or explosion from coal, gas, or oil • No risk of groundwater contaminations • Emission free operation on-site
Weaknesses	• Will not work in section of building with existing radiators, or other type of high temperature heating system • Choice of location • Although the installation costs for geothermal systems can be higher than for other less-efficient systems, the cost is rapidly offset by substantially lower utility bills. • High Installation Costs • Take up facility ground space • Needs supplement to bring DHW to 60 degrees C
Opportunities	• There is spare ground on site that could be used • Standard, simple controls. • Can be used with Air Conditioning System • Runs from electrical grid, does not require other resource supply • Low operating costs (no oil or gas purchases, burner controls etc. as with fossil-fueled heating systems); • The system is emission-free on-site and helps to reduce greenhouse gas emissions like CO2. • No central system to fail or shut down the entire building. • Nothing outside to vandalize or steal.

24 http://geoheat.oit.edu/bulletin/bull25-3/art1.pdf
http://www.tva.gov/products/business/geothermal.htm
http://www.wbdg.org/resources/geothermalheatpumps.php
http://www.esru.strath.ac.uk/EandE/Web_sites/09-10/Hospital/Hospitals%20Website/Swot%20Analysis.html

	• Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.
Threats	• Choice of location • Take up facility ground space • Gas costs are similar 3.5p / 4p per kW • More developed technologies available

SWOT ANALYSIS	WATER SOURCE HEAT PUMP[25]
Strengths	• Relatively low installation costs • Good Energy Efficiency, between 2 and 4.9 times the input energy produced • Runs from electrical grid, does not require other resource supply • The heat transfer rate from water is far higher than that in the ground or air. • The flow/circulation of the water source provides constant energy replacement. • The use of a water source removes the need of digging large trenches, often reducing the cost of installation compared to a ground source. • The return temperature to the heat pump is usually higher than either the ground or winter average air, increasing the COP (coefficient of performance) of the heat pump. • Obtained excellent comfort • High efficiency • Low operating costs • Emission free operation on-site
Weaknesses	• It could have high maintenance costs • Requires damage protection • Will not work in section of building with existing radiators • Needs supplement to bring DHW to 60 degrees C. • Appropriate water-source is needed (ground water, river, etc.)
Opportunities	• There is a river on site that could be used • Can be used with Air Conditioning System • Water source heat pump systems are among the most efficient, economical and environmentally friendly methods to heat and cool buildings.
Threats	• May have trouble with river use due to environmental issues • Gas costs are similar 3.5p / 4p per kW • More developed technologies available

25 http://www.yougen.co.uk/blog-entry/1954/An+introduction+to+water+source+heat+pumps+and+how+they+work/

SWOT ANALYSIS	AIR SOURCE HEAT PUMP[26]
Strengths	• Air as a renewable heat source is accessible and practically unlimited • Good Energy Efficiency, between 2 and 4.9 times the input energy produced • Always available and inexhaustible source of heat • 10 year warranty • Low Installation Costs than geothermal heat-pump • Runs from electrical grid, does not require other resource supply • Can be used for heating, cooling, domestic hot water and swimming pools • Emission free operation on-site
Weaknesses	• Will not work in section of building with existing radiators • Least Efficient of the 3 types of Heat Pump, • Low efficiency (COP) below 7°C outside temperature • You can expect them to operate for 20 years or more, however they do require regular scheduled maintenance. • A yearly check by you and a more detailed check by a professional installer every 3-5 years should be sufficient. • Needs supplement to bring DHW to 60 degrees C. • Noise caused by external unit fan
Opportunities	• Can be utilised all year round between +35°C and -25°C. • No requirement for the cost and land area of ground collectors • Boiler room placement should give high efficiency • Can be used with Air Conditioning System • Ideal for retro fit applications, especially where space is limited
Threats	• Gas costs are similar 3.5p / 4p per Kw • More developed technologies available

26 http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Air-source-heat-pumps

SWOT ANALYSIS	DC POWERED HEAT PUMP
Strengths	• A novel future of the proposed approach is using DC powered Heat Pumps, which are more efficient than AC-powered Heat Pumps • Can utilize renewable energy sources directly. • It is very clear that renewable energy DC powered HP system is much more energy efficient than the classical heat pump system. • The strongest part of the DPHP materials is longer lifelong period since these materials are used at exact cooling or heating demand • It provides a variable frequency drive that allows the system to dynamically adjust its capacity based on conditions. • There is no loss associated with converting DC power from renewable sources into AC power to run a standard air conditioner. • It avoids the inefficient addition of an "inverter" that converts solar DC current into AC current. • It can greatly reduce energy consumption, and run with super low noise. • Relatively low installation costs
Weaknesses	• Limited capacity (such as >10 kW) of the available DC compressors. • Not suitable for big buildings where multiple sources of water might be used simultaneously
Opportunities	• New product in existing market • Used with any kind of renewable sources • Low maintenance costs • Can offer cooling and heating as base supply, reducing the usages of the conventional HVAC systems with significant energy reductions. This system can avoid batteries, which usually are needed for buffering DC power.
Threats	• Users have no experience • It is still in development stage in order to obtain higher capacity DC powered Heat Pumps.

5.2.3 Combined Heat and Power

SWOT ANALYSIS	MICRO-CHP STIRLING ENGINE[27]
Strengths	• Low maintenance (in theory no more than a boiler) due to hermetically sealed unit. • Low noise (constant rather than pulsed combustion), although vibrations must be controlled. • The noise created by a Stirling engine is considerably less than other technologies due to the low number of moving parts and the absence of internal combustion. • Low emissions. • High overall efficiency • Electrical efficiency: 10-25% • Power/heat ratio: 1:3 – 1:8 • CHP efficiency (%) based on gross calorific value: Up to ~ 90 • Multi-fuel capability (external heating), including solar and biomass. • Stirling engines can run directly on any available heat source, not just one produced by combustion, so they can run on heat from solar, geothermal, biological, nuclear sources or waste heat from industrial processes. • A continuous combustion process can be used to supply heat, so those emissions associated with the intermittent combustion processes of a reciprocating internal combustion engine can be reduced. • Some types of Stirling engines have the bearings and seals on the cool side of the engine, where they require less lubricant and last longer than equivalents on other reciprocating engine types. • The engine mechanisms are in some ways simpler than other reciprocating engine types. No valves are needed, and the burner system can be relatively simple. • A Stirling engine uses a single-phase working fluid which maintains an internal pressure close to the design pressure, and thus for a properly designed system the risk of explosion is low. In comparison, a steam engine uses a two-phase gas/liquid working fluid, so a faulty overpressure relief valve can cause an explosion. • In some cases, low operating pressure allows the use of lightweight cylinders. • They can be built to run quietly and without an air supply, for air-independent propulsion use in submarines. • They start easily (albeit slowly, after warm-up) and run more efficiently in cold weather, in contrast to the internal combustion which starts quickly in warm weather, but not in cold weather. • They are extremely flexible. They can be used as CHP (combined heat and power) in the winter and as coolers in summer. • Although the consumption of gas will be slightly higher, energy costs will be lower because the micro CHP provides for a substantial part of the electricity demand. The remaining electricity demand is simply taken from the net. • Micro CHP's reduce CO2 emissions and can be combined with other sustainable technologies like solar boilers or solar cells.
Weaknesses	• High heat-to-power ratio – therefore unsuitable for households with very low heat demands.

27 FORESIGHTING REPORT. Microgeneration Investigating the global market for microgeneration and opportunities for Scotland to commercialise related technologies. 31st March 2006
http://en.wikipedia.org/wiki/Stirling_engine
http://www.one-stop-shop.org/sites/default/files/FORM_21_25_Micro_CHP_with_Stirling_engine.pdf
C.M. Hargreaves (1991)

	• Length of start up time. • High mass as thick walls needed due to higher pressure of working fluid • Stirling engine designs require heat exchangers for heat input and for heat output, and these must contain the pressure of the working fluid, where the pressure is proportional to the engine power output. In addition, the expansion-side heat exchanger is often at very high temperature, so the materials must resist the corrosive effects of the heat source, and have low creep. • The materials and assembly costs for a high temperature heat exchanger typically accounts for 40% of the total engine cost. • All thermodynamic cycles require large temperature differentials for efficient operation. This means that the metallurgical requirements for the heater material are very demanding. • Dissipation of waste heat is especially complicated because the coolant temperature is kept as low as possible to maximize thermal efficiency. • It can sometimes require additional mechanisms. • Micro CHP's are still in the "early adaptors" phase, meaning that prices are still relatively high and that the systems are still being adjusted.
Opportunities	• For a range of fuel sources such as natural gas, biomass or solar energy. This energy source flexibility is one of the underlying advantages of Stirling engines. • Because they are fairly compact, micro CHP's can easily be placed on the spot of the old central heating system. They are also easy to connect to the existing heating and hot water installation. • As technology continues to improve, fuel prices continue to rise and "green" energy continues to gain more momentum.
Threats	• Their cost and electrical efficiency still need to be improved. • Many challenges such as cost and lack of government policy standing in its way. • The pollutants released from the system are an issue and therefore can be regulated by environmental agencies • Its drawbacks make it not very desirable for potential investors.

SWOT ANALYSIS	MICRO-CHP RANKINE CYCLE ENGINE[28]
Strengths	• No maintenance costs for some products under development. • Typically comprise low cost components, most of which have proven reliability. • Low noise and emissions. • High overall efficiency. • Electrical efficiency: 9-18% • Power/heat ratio: 1:4 – 1:9 • CHP efficiency (%) based on gross calorific value: Up to ~ 90 • They are considered due to their relative simplicity (low production costs) and known durability and performance characteristics. • The advantage of the Rankine cycle is that the working fluid is a liquid. Many times this liquid is water, which is a cheap and readily available resource.
Weaknesses	• High heat-to-power ratio – therefore unsuitable for households with very low heat demands. • Low electrical efficiency • Compared to other technologies, the Rankine cycle engines have one of the lowest electrical conversion efficiencies. • The thermal efficiencies of most other competing technologies are also higher than that of the Rankine cycle engines.
Opportunities	• Interest on potential investors
Threats	• Rankine cycle engine technologies for m-CHP are still under development • Few information about potential costs of small-scale Rankine cycle units for m-CHP

28 http://microchp.msstate.edu/pdf/m-CHP%20Instructional%20Module.pdf

SWOT ANALYSIS	MICRO-CHP FUEL CELL[29]
Strengths	• High electrical efficiency under varying load. • Electrical efficiency: 28-45% • Power/heat ratio: 1:1 – 1:2 • CHP efficiency (%) based on gross calorific value: Up to ~ 85 • Low emissions • Low noise: no moving parts (except fans).
Weaknesses	• Complexity of design - requirement to reform natural gas (some developers will use internal reforming) and inverters for power conversion. • Likely lower overall efficiencies compared to some other micro-CHP technologies. • Significant remaining challenges to demonstrate acceptable lifetime, reliability and competitive cost for micro-CHP applications.
Opportunities	• Fuel cells have the potential to produce heat and power very efficiently with low emissions and noise levels. • Interest on potential investors
Threats	• Still in an early stage of development, and years away from the market

29 http://www.hydrogen.energy.gov/pdfs/11016_micro_chp_target.pdf

SWOT ANALYSIS	MICRO-CHP INTERNAL COMBUSTION ENGINES[30]
Strengths	• Internal combustion (IC) engine systems are the most mature of all the Micro-CHP technologies. • IC systems are sensitive to both low and high water temperature • The electrical output of IC engine Micro-CHP is relatively high and in the range of 20-25%.
Weaknesses	• Engines in practice produce relatively high emissions as well as noise. • High maintenance cost • High level of noise and gas emissions. • The engine lubricating oil must also be changed frequently. • Due to their relatively large size and their levels of vibration and noise while operating, IC engine Micro-CHP systems are most suited to small commercial applications where they can be located in a plant room alongside additional heating equipment.
Opportunities	• They are viable for residential community heating situations where a central system provides for the needs of multiple dwellings and is located away from living areas.
Threats	• ICs are more often used in small commercial premises and in large residential developments such as care homes. • Operating hours in the range of 3,000 to 6,000 per year are required in order to maximise the economic viability of the system.

30 http://www.carbontrust.com/media/77260/ctc788_micro-chp_accelerator.pdf

http://www.ieadsm.org/Files/Exco%20File%20Library/Key%20Publications/micro-CHP_Final.pdf

SWOT ANALYSIS	CHP WITH NATURAL GAS/BIOGAS[31]
Strengths	CHP WITH NATURAL GAS • CHP system is technologically and economically proven • Technology can be applied to all scales • Greenhouse Gases are reduced • Technology can be retrofit • As an existing technology, it can start reducing carbon emissions today CHP WITH BIOGAS • AD & CHP technology is technologically and economically proven • Technology can be applied to all scales • Greenhouse Gases are reduced • Technology can be retrofit • Biogas can be used in duel-fuel engines with minimal modification • As an existing technology, it can start reducing carbon emissions today
Weaknesses	CHP WITH NATURAL GAS • CHP markets are in an early stage of development in some countries • The most efficient application is for district heating networks • Noise CHP WITH BIOGAS • AD & CHP markets are in an early stage of development in some countries • The most efficient application is for district heating networks • Biogas is explosive and needs to be stored carefully • AD process can be quite slow at start up and shut down • Biogas requires scrubbing treatments to make it a clean fuel • Noise
Opportunities	CHP WITH NATURAL GAS • CHP can help deal with the waste, heat and energy needs of any country CHP WITH BIOGAS • AD & CHP can help deal with the waste, heat and energy needs of any country • Biogas CHP can contribute toward the Part L Renewables Obligation • Biogas CHP could enhance local community stewardship • Increases in landfill tax will make AD more appealing • Waste anaerobically digested can help towards landfill diversion targets
Threats	CHP WITH NATURAL GAS • CHP has strong dependency on Gas prices are not particularly stable • Natural Gas is a finite resource and as a result will not be a completely long term solution as more usage such as CHP will drive up costs CHP WITH BIOGAS • Competing against a wide range of more well-known and established technologies • Public perceptions of energy from waste currently poor • Potential public opposition to AD plants • Waste processed by AD does not currently count towards local authority targets

31 http://www.sokratherm.de/htcms/en/our-compact-chp-units-1/natural-gas-chp-units-1.html
http://www.clarke-energy.com/gas-type/biogas/

5.2.4 Storage and Distribution

SWOT ANALYSIS	THERMAL STORAGE[32]
Strengths	• To reduce utility bills - largely through peak-shaving • To reduce equipment size, space and weight • To reduce compressor kW due to operating at more hours at full load and at nighttime lower condensing temperatures • Availability of cold air distribution when ice is used • Possible backup cooling or heating redundancy in event of power failure • When chilled water storage is used, availability of an added fire-protection water source. <u>THERMAL ENERGY STORAGE WITH SUPERCRITICAL FLUIDS:</u> • Energy storage at both moderate (100 – 200 ºC) and high (300 -550 ºC) temperatures. • Supercritical storage enables high volumetric energy density. • It can be used in different applications such as HVAC & Humidity control systems
Weaknesses	• May increase first cost of HVAC system • More complicated system design • Requires well-trained maintenance crew • Possible ambient heat gain to storage tanks • Specifying engineer has little incentive to use as it costs more to design and the firm may have little or no experience with the technology. <u>THERMAL ENERGY STORAGE WITH SUPERCRITICAL FLUIDS:</u> • Supercritical fluids have not been fully explored for heat-transfer applications • Existing data about supercritical fluid properties is limited • It needs further development before it is ready for use • The final product may increase fabrication cost and market price of the final product
Opportunities	• The utilities can gain from reduced peak use, improved load factors, added off-peak sales, deferred peak-capacity expansion costs, and improved competitive position over gas-fired alternatives. <u>THERMAL ENERGY STORAGE WITH SUPERCRITICAL FLUIDS:</u> • This technology is intended to increase energy density by over a factor of two compared to the two-tank molten salt system. • Supercritical fluid used for energy storage may reduce the cost of the system by 70% compared to state-of-the-art solutions • Further development of this technology may allow providing energy when needed by local utilities. • Tanks with cost-effective small storage footprint for solar thermal applications
Threats	• Some of the threats include night-time loads greater than planned, insufficient storage provided so on hot days demand is not saved, improper controls supplied, operator inattention or unskilled, condensation on ducts with low temperature supply air when a fan is

32 Press release, U.S. Department of Energy, "Secretary Chu Awards $9.6 Million for Transformational Energy Research Projects," Advanced Research Projects Agency – Energy, Sept. 10, 2010: http://arpa-e.energy.gov/Media/News.aspx?ItemId=23&vw=1

	out of service. <u>THERMAL ENERGY STORAGE WITH SUPERCRITICAL FLUIDS:</u> • The investment for the development and commercialization of such systems may not be worth for the next 5 years • People may be afraid of using new technologies since they do not fully understand how they work • Some of the required systems to achieved the supercritical states may not be compatible for its application on buildings due to their size

SWOT ANALYSIS	MODULAR THERMAL HUB FOR BUILDING COOLING HEATING, AND WATER HEATING[33]
Strengths	• Thermally activated hub • Modular, scalable, distributed cooling and heating in buildings • Working fluids with zero Global Warming Potential (GWP) • Can use diverse sources (combustion, low-grade waste heat, solar energy) • Reversible operation enables space cooling and heating, coupled with water heating • Long-term equivalent Coefficient Of Performance (COP): 2.5-8.3 • Reduction of primary energy consumption by as much as 50% • System enables changing capacity to meet design needs simple changing the number and dimensions of the internal features.
Weaknesses	• Under development funded by the US government ($2,399,765) • It is not currently available in the market and therefore there is a lack of knowledge on its cost • In the case of a building retrofitting it will require a great investment in order to adapt the utilities for the HUB use
Opportunities	• Significant size reductions over previous absorption cooling efforts • High COPs: integration of AC/Heating/Water Heating • Monolithic packaging offers small fluid charge, flexible placement and reduced labour
Threats	• The investment required for the use of the system will require to act on other systems and stakeholders may not be willing to assume that extra cost. • The primary energy consumption reduction may not be achieved due to its dependence on building occupants habits and energy consumption

33 http://arpa-e.energy.gov/?q=arpa-e-projects/innovative-miniaturized-heat-pumps-buildings

SWOT ANALYSIS	RADIANT HEATING/COOLING SYSTEM[34]
Strengths	• Radiant heating/cooling system is a very efficient method of heat transfer, which in turn keeps fuel costs at a minimum. • The portion of heat radiation is responsible because the convective portion of heat release is very low, so the necessity of tempering the ambient air directly is not required anymore. • The flow temperature of surface heating systems is correspondingly lower compared to convective systems. • Another advantage of the radiant heating/cooling system compared to the convective system is the reduction of the transmission losses of heat. • Radiant system is an efficient delivery solution when compared to small vents or radiators that try to blast enough heat into a room to warm it up. • No space is required in order to heat up rooms. • Can be installed under any type of flooring, walls and ceiling. • In many cases, the first cost of installation can actually be lower when all design impacts are taken into account. • It allows room by room temperature control, allowing more heat where you want it most. • Better indoor air quality (because ventilation air is not recirculated and there are no wet surface cooling coils, thereby reducing the likelihood of bacterial growth). • Better user comfort, even at room temperatures closer to outside air temperatures, than is possible with convective space conditioning (because radiant heat transfer is direct and draft-free; also, virtually no noise is associated with space conditioning). • Lower maintenance costs (because of inherent system simplicity—no space conditioning equipment is needed in outside walls, and a common central air system can serve both interior and perimeter zones).
Weaknesses	• Radiant system requires controls in order that the panels operate effectively and efficiently. • These controls require maintenance on the actuators. • Radiant heating/cooling system has a very slow heat up period of 5 to 6 hours. This means that careful monitoring must take place in order to ensure that the controls are set up correctly to overcome this disadvantage. • There are very few installations of this technology • Condensation: When cooling building surfaces below the ambient temperature, one always runs the risk of condensation forming, with all the associated building damage, mold growth, and so on. • Lower system capacity: Radiant cooling may not be practical with particularly high cooling loads.
Opportunities	• Possibly smaller sizes of chillers and boilers (because delivery temperatures are closer to room temperatures).
Threats	• Higher first cost: In some cases, first cost may be higher than an air system, because of the cost of the panels and plumbing. If this is more than the savings in pump, ducting, and fans, the first cost could be higher.

34 http://www.healthyheating.com/Radiant_Mythology/Radiant_Floor_Heating_Myths_.htm#.UxXIdOOvuzk

http://www.oregon.gov/ENERGY/CONS/Pages/res/tax/Radiant.aspx

5.2.5 Cooling technologies

SWOT ANALYSIS	ABSORPTION CHILLER[35]
Strengths	• Lower operating costs and higher efficiency • One main reason for the growing use of absorption chillers has to do with the fact that fluorocarbon-based refrigerants like CFCs (Chlorofluorocarbons), which are used in compressor-driven chillers, are harmful to Earth's ozone layer. • Safe operation • Reliable, low maintenance • Smaller footprint than an electric chiller with boiler • Effective for heat recovery applications • Initial costs quickly offset by energy savings • Sizes ranging from 5 to 1700 tons are readily available today. • The quiet, vibration-free operation of absorption cooling makes it an ideal choice for buildings. • It's simplicity of design assures high reliability and low maintenance, making it an excellent option for critical cooling needs.
Weaknesses	• Absorption chillers are inherently less efficient than compressor-driven chillers, primarily because water is a less efficient refrigerant than fluorocarbon-based refrigerants. • This lower efficiency necessitates larger components making absorption cooling systems larger than electric chiller systems of equal capacity. • Absorption chillers have a higher first cost than electric chillers.
Opportunities	• A recent innovation that is improving efficiency is the two-stage absorption process. Two-stage absorption chillers effectively use a given quantity of heat energy twice in the absorption cycle, making them up to 45% more efficient than chillers from just a few years ago. • Absorption cooling is particularly suitable to being packaged with a cogeneration system, which provides the heat needed to power the cooling system • Natural gas absorption systems are available as stand-alone chillers or chiller/heaters.
Threats	• Their size – weight, as well as their requirement for larger cooling towers. Absorption chillers are larger and heavier compared to electric chillers of the same capacity.

35 http://www.gasairconditioning.org/absorption_advantages_applications.htm

SWOT ANALYSIS	MEMBRANE-BASED ABSORPTION REFRIGERATION SYSTEMS[36]
Strengths	• New system based on Nano engineered membranes to allow for enhanced heat exchange that reduces bulkiness • Compact refrigeration system that allows for cheaper and more reliable use of Adsorption Refrigeration Systems (ARS) • Independency from electricity supply by the use of power obtained by natural gas combustion, solar and waste heat
Weaknesses	• It is only considered as an independent system when waste heat is available. • In the case of using alternative energy sources that are not waste heat, the product may not be cost-efficient
Opportunities	• Inexpensive high performance refrigeration in buildings that reduce reliance on fossil fuels • Reduction of electricity demand that can be covered by the use of renewable energy production systems such as solar power • Reduction on the overall consumer costs especially with regard to the energy bill
Threats	• Because of their size and sensitivity to disruptions, adsorption machines could hardly penetrate the market • Needs strong market research in order to make sure of its viability in the sector.

36 http://arpa-e.energy.gov/?q=arpa-e-projects/membrane-based-absorption-refrigeration-systems

SWOT ANALYSIS	EVAPORATIVE COOLERS[37]
Strengths	• Estimated cost for installation is about half that of central refrigerated air conditioning • Estimated cost of operation is 1/4 that of refrigerated air. • Power consumption is limited to the fan and water pump. Because the water vapour is not recycled, there is no compressor that consumes most of the power in closed-cycle refrigeration. • The refrigerant is water. No special refrigerants, such as ammonia, sulphur dioxide or CFCs, are used that could be toxic, expensive to replace, contribute to ozone depletion and/or be subject to stringent licensing and environmental regulations. • The only two mechanical parts in most basic evaporative coolers are the fan motor and the water pump, both of which can be repaired at low cost and often by a mechanically inclined homeowner. • The constant and high volumetric flow rate of air through the building reduces the "age-of-air" in the building dramatically. • Evaporative cooling increases humidity. In dry climates, this may improve comfort and decrease static electricity problems. • The pad itself acts as a rather effective air filter when properly maintained; it is capable of removing a variety of contaminants in air, including urban ozone caused by pollution, regardless of very dry weather. Refrigeration-based cooling systems lose this ability whenever there is not enough humidity in the air to keep the evaporator wet while providing a constant trickle of condensate that washes out dissolved impurities removed from the air.
Weaknesses	• It is also more expensive to maintain, particularly during cold weather and winter, because it can easily freeze burst. • Another disadvantage to using a swamp cooler is that the air it gives off is very humid, at around 80% to 90%. It is therefore not very advisable in high-humidity environments because it will eventually corrode your electrical systems and moisten surfaces. • High dew point (humidity) conditions decrease the cooling capability of the evaporative cooler. • No dehumidification. Traditional air conditioners remove moisture from the air, except in very dry locations where recirculation can lead to a buildup of humidity. Evaporative cooling adds moisture, but in dry climates, dryness may improve thermal comfort at higher temperatures. • The air supplied by the evaporative cooler is typically 80–90% relative humidity; very humid air reduces the evaporation rate of moisture from the skin, nose, lungs, and eyes. • High humidity in air accelerates corrosion, particularly in the presence of dust. This can considerably shorten the life of electronic and other equipment. • Evaporative coolers require a constant supply of water to wet the pads. • Water high in mineral content will leave mineral deposits on the pads and interior of the cooler. Depending on the type and concentration of minerals, possible safety hazards during the replacement and waste removal of the pads could be present. Bleed-off and refill (purge pump) systems may reduce this problem. • The water supply line may need protection against freeze bursting during off-season, winter temperatures. The cooler itself needs to be drained too, as well as cleaned periodically and the pads replaced.

37 http://www.streetdirectory.com/travel_guide/32511/home_improvement/the_truths_about_swamp_coolers_that_you_really_need_to_know.htmlhttp://www.coolmax.com.au/evaporative-cooling/advantages.htm
http://en.wikipedia.org/wiki/Evaporative_cooler

	• Odors and other outdoor contaminants may be blown into the building unless sufficient filtering is in place. • Mold and bacteria may be dispersed into interior air from poorly maintained or defective systems, causing Sick Building Syndrome • A sacrificial anode may be required to prevent excessive evaporative cooler corrosion. • Wood wool of dry cooler pads can catch fire even by small sparks.
Opportunities	• Some people prone to allergens find the wet air less irritating
Threats	• A swamp cooler is also not advisable if you have asthma because pollutants and other microbes from outside might be blown into the room if it has not ample filtering. • Asthma patients may need to avoid poorly maintained evaporative cooled environments. • High humidity in air may cause condensation of water. This can be a problem for some situations (e.g., electrical equipment, computers, paper, books, old wood).

SWOT ANALYSIS	DUAL EVAPORATIVE COOLING FOR RTUS[38]
Strengths	• Demand Reduction: varies with climate, refrigerant, and outdoor air, system configuration; typically 25 – 50%, or 0.25 to 0.50 kW/ton rating • Energy savings obtained through blower speed adjustments; typically 400-1300 kWh/ton-yr • Extends equipment life due to favourable compressor operating conditions • Increases capacity and efficiency of existing equipment • Societal: distributed generation, climate change, jobs
Weaknesses	• In Direct evaporative condenser cooling: condenser coil damage, system maintenance • In Indirect evaporative ventilation air pre-cooling: indirect coil freeze-up, inadequate vent air flow
Opportunities	• Does not require the implementation of major equipment pieces on the roof. • Uses least parasitic power and does not invade refrigerant lines • It is an important low cost alternative. • Flexible and secure installations • Standardization of designs
Threats	• No R&D development support which implies slow evolution of design improvements • If only small companies are involved in the development of this system it may be possible that no further development will take place

38 http://www.cacx.org/meetings/meetings/2011-06-09/Dual_Evap_Cooling_CCC_060911.pdf

SWOT ANALYSIS	SOLID DESICCANT COOLING SYSTEM[39]
Strengths	• The technology reduces regeneration energy by up to 30% and by means of cooler supply air the need of post cooling can be reduced by up to 70%. • Improved indoor air quality • Desiccant loading > 75%. • More than five different types of desiccant wheels, each with distinct absorption characteristics to meet the needs of all applications • Modular Units provide different implementation options • Reduction of the mechanical cooling load, allowing the use of smaller chillers and possibly even smaller ducting in new construction. • Corrosion protection • Condensation control • Mold and mildew control
Weaknesses	• Applications where there are limited or not on-site qualified operating personnel. • It is not suitable for applications that do not require extremely low humidity (less than 40% relative humidity) • There may be other methods that may be better and more economical to achieve the required humidity levels in places where external energy is not required for reheating
Opportunities	• It could be installed in hospitals, retail facilities, supermarkets, office buildings, clean rooms, industrial sites, and other dehumidification applications • Used with direct or indirect fired gas, electric heat, steam, and hot water regeneration. • Independent control of latent loads in the ventilation air. • It will virtually eliminate the growth of mold, mildew, and bacteria. The combination can reduce maintenance and help avoid indoor air quality problems. • Lower humidity levels in occupied spaces provide equivalent comfort levels at higher ambient temperatures. This could allow chilled water set-points to be raised and there-by save energy and reduce system operating costs.
Threats	• High implementation costs • Increased maintenance necessities for the new desiccant equipment • Cost of energy (usually natural gas) to regenerate the desiccant at a high temperature to drive off the entrained moisture. • In some cases, the need for cool water piping to remove the adsorption heat and precool the heated air from the desiccant units

39 http://www.novelaire.com/desiccant-dehumidification-wheels.html

http://www.munters.us/upload/Case%20studies/Dehumidification%20Units%20and%20Systems.pdf

http://cipco.apogee.net/ces/library/tdds.asp

SWOT ANALYSIS	HIGH –EFFICIENCY SOLID-STATE COOLING TECHNOLOGIES[40]
Strengths	• Improves state-of-the-art cooling technologies by achieving a product that does not have noisy moving parts or polluting refrigerants • Use of advanced semiconductor technologies that improve solid state cooling systems by using appropriate thermoelectric materials • New design displacing compressor-based technologies, improving reliability and decreasing energy usage • Less material use facilitates cheaper production
Weaknesses	• Under development funded by the US government ($1,465,118) • It is more suitable for its application on Hospitals, medical offices or research laboratories. • Only a limited amount of heat flux is able to be dissipated
Opportunities	• Replacement of typical air conditioners that use vapour compression to cool air • Cost-efficient system that can provide final users with significant cost savings on their energy bills • Non-pollutant air conditioning system accounting for reductions up to 10%-20% of global warming by 2050 • Energy efficient system decreasing overall energy demand and reliance on fossil fuels
Threats	• It may be relegated to applications with low heat flux. • It is possible that the system may not reach the expected energy efficiency behaviour in terms of coefficient of performance • It is a very uncommon technology and their behaviour on buildings may not work as expected

40 http://www.osti.gov/scitech/servlets/purl/1046674

SWOT ANALYSIS	HIGH-EFFICIENCY ADSORPTION CHILLERS[41]
Strengths	• Independent from electricity supply • Significant improvements in materials that adsorb liquids or gases (3 times higher refrigerant capacity and up to 20 times faster kinetics than adsorbents used in current chillers • Chillers smaller than state-of-the-art solutions with twice the energy efficiency • It can be powered with waste heat or through a connection to a solar energy source
Weaknesses	• Previous low energy efficiency and bulkiness due to the limited sorption capacity of the adsorbent material • Increase on the common assembly times • High costs due to expensive materials needed for the system
Opportunities	• Reduces pollutants from the combustion of fossil fuels (CO, NOX, SOX, Hg, Pb, Benzene) • A negative impact from chillers on water, may be overcome • The system does not require a waste disposal • There are not toxins produced in the operation or manufacture of adsorption chillers
Threats	• The system may not result in cost and even energy efficiency in the case of not being able to use a renewable source of energy, and therefore another installation is needed. • It may be less efficient than modern heat pumps adsorbent or absorbent chillers

41 http://arpa-e.energy.gov/?q=arpa-e-projects/high-efficiency-adsorption-chillers

SWOT ANALYSIS	REVERSE CYCLE CHILLER[42]
Strengths	• Reverse Cycle Chillers (RCCs) are a form of air-to-water heat pump technology that can produce hot water nearly three times more efficiently than electrical water heating. • Maintenance reduced cost with regard to the water heating system. • The modular design of the system allows multiple units to be piped together in order to achieve essentially any size load. • One of the great advantages of Reverse Cycle Chiller System is that it can use up to 10% fewer kw/hour when compared to a geothermal heat pump. • The modular design allows using multiple modules for staging, redundancy, and load sharing for facilities from 500 to 6,000 square meters. • Unlike ground source heat pumps, Reverse Cycle Chiller doesn't require digging a geothermal well for use as a heat source. • It achieves temperatures in the range from 5ºC to 50ºC.
Weaknesses	• Used only in warmer climates • A capacity control tank is needed to protect the system during times of low output and during defrost cycling, as well as to prevent the unit from short-cycling in summer.
Opportunities	• Reverse Cycle Chiller (RCC) technology is poised to emerge as a way to significantly reduce energy use for hot water systems in multifamily buildings. • It can be combined with several other technologies such as: under floor heating, fan coil units, and low temperature radiators. • It can be connected to: domestic hot water tanks, solar collectors and room thermostats quickly and conveniently. • It is able to achieve water temperatures of 100° f and higher, even when the outdoor temperatures drop below freezing. • The technology offers potential for lower winter electric bills and hotter air out of the supply vents for greater comfort
Threats	• The technology is not new and it may fail during the implementation in residential building units. • The simple payback on the additional cost in areas where natural gas is not available maybe 3-4 years longer than traditional systems • It is more expensive than a conventional air-source heat pump (about 25 percent at minimum)

42 http://e3tnw.org/ItemDetail.aspx?id=233
http://www.bpa.gov/energy/n/emerging_technology/RCChillers.cfm
http://www.evergreenhomeheatingandenergy.com/reverse-cycle-chillers.html
http://www.aquaproducts.us/products/reverse-cycle-chiller.html#article-id-16

SWOT ANALYSIS	MAGNETIC REFRIGERATION[43]
Strengths	• It is 50% more efficient than current vapour compression cycles • It eliminates the most inefficient part of today's refrigerator as well as reducing its costs. • Compactness: It is possible to achieve a high energy density compact device • Advantages over vapour absorption cycles • Magnetic refrigeration does not use conventional refrigerants • Achievement of simplicity on the design of machines (rotary porous heat exchanger refrigerator) • Low maintenance costs
Weaknesses	• Giant Magneto-Caloric Effect(GMCE) materials need to be developed to allow higher frequencies of rectilinear and rotary magnetic refrigerators • Need protection of electronic components from magnetic fields. • Electro magnets and superconducting magnets are (too) expensive
Opportunities	• Research in this field will provide the opportunity so that new industries can be set up and compete in the international market. • The technique will reduce the cost of equipment • The advantages of MR over Gas Compression Refrigerator are compactness, and higher reliability due to solid working materials instead of a gas • Being a noiseless technology would be an advantage in certain contexts such as medical applications
Threats	• Problems may arise in the regulation/control of such a system as well as the required pressure. • Multi-stage machines may lose efficiency through the heat transfer between the stages

43 http://es.scribd.com/doc/30733590/Magnetic-Refrigeration
http://iats09.karabuk.edu.tr/press/bildiriler_pdf/IATS09_03-03_942.pdf
http://e3tnw.org/ItemDetail.aspx?id=441

5.2.6 Conclusions

In this section, the SWOT analysis for HVAC and Renewable Energies has been divided into five categories: Ventilation, Renewables and Heat Pumps, Combined Heat and Power (CHP), Storage and Distribution and Cooling technologies.

Although the use of CHP is not considered in the research WPs, it could be an interesting technology for retrofitting the old commercial buildings where injection of electricity is possible. Investors need to take into account the available technology and energy source to adapt the necessity. For the ROI, which may be one of the most important factors and needs to be studied in detailed, it varies from case to case, due to the large number of factors, including the cost of bought-in gas and electricity from the utility provider, the demand for heat and whether this is continuous or cyclical, the distance that the heat will have to travel to reach the process should also be accounted for, as any heat losses will mean that CHP station efficiency will be lowered. Among the CHP systems, the Internal Combustion (IC) engine systems are the most mature of all the Micro-CHP technologies, while the other technologies are still in the development stage. The problems of CHP internal combustion engine is the high maintenance cost and the high level of noise as well as gas emissions. The combination boilers have many advantages but they are only an economical choice for smaller households with lower hot water demands.

With regard to the Renewables Energies and Heat Pumps, different renewable energy systems are evaluated. Especially, for the shopping center of Sopron, both Solar Photovoltaic system and Micro wind turbines are considered, providing green, renewable power by exploiting solar and wind energy. Although the combination of both technologies results attractive and better due to the larger load on day time when PV could offer more power while micro wind turbine could offer a basic supply in the night time, further research about the availability of the energy source needs to be done for the demo site, and esthetical aspect also needs to be studied as well.
The problem of the small scale hydro, the ground and water sources heat pumps are the availability of the resource and space. For places rich in the resource and space could be an option for retrofitting, while for the demo site of Ecoshopping, the space is limited, as well as the water source to implement this kind of resources is neither available.

The use of high COP heat pump seems more and more attractive and popular nowadays, and normally a heat pump is powered by AC. The idea of researching DC power heat pump is to exploit the free energy as much as possible to reduce the energy consumption of the building, partly covering the basic cooling/heating load and reducing the peak load. On the other hand, using renewable energy on a heat pump can be performed with AC or DC compressor, but AC compressor usage requires conversion from DC power to AC by using a power inverter. Inverter usage increases initial investment cost and also decreases energy conversion efficiency. Therefore, renewable energy powered heat pump, using DC compressor enhances efficiency and reduces initial investment cost due to the elimination of power conversion from DC to AC. Furthermore, the integration of variable speed compressor in the Heat Pump provides higher efficiency and should adaped better with the unstable renewable energy source.

As the heating and cooling distribution system is concerned, the radiant system is a very efficient method of heat transfer, that can save up to 30%, since the convective portion of heat release is very low and in order to maintain the indoor air quality, it requires less energy consumption. The transmission losses of heat are lower than in other system since the temperature of the water in pipes is not extremely hot neither cold. Besides, it can also be installed under any type of flooring, walls and ceiling.

Below there is a summary of the main characteristics of the technologies that will be developed and implemented in the EcoShopping demo site: Capillary tube system as a very energy efficient radiant system and the DC powered heat pump coupled with Solar Photovoltaic system and /or micro wind turbines.

5.3 HVAC technologies in WP4

5.3.1 Capillary tube system

5.3.1.1 Characteristic of the capillary tube system

The capillary tube system is a very progressive radiant heating and cooling system. It can be integrated in nearly all construction elements such as flooring, walls or ceilings. The system basically consists of capillary tube mats, which enables a heat transfer through a very large surface compared to conventional under floor heating or heating element systems. The heat emission during the heating mode supplies a comfortable radiant heat and the heat absorption in the cooling mode supplies an effective and comfortable silent cooling without any noise, draught or dust. Compared to air conditioning units the energy consumption for cooling with capillary tube mats is very low.

Figure 1 Installation of Capillary tube system

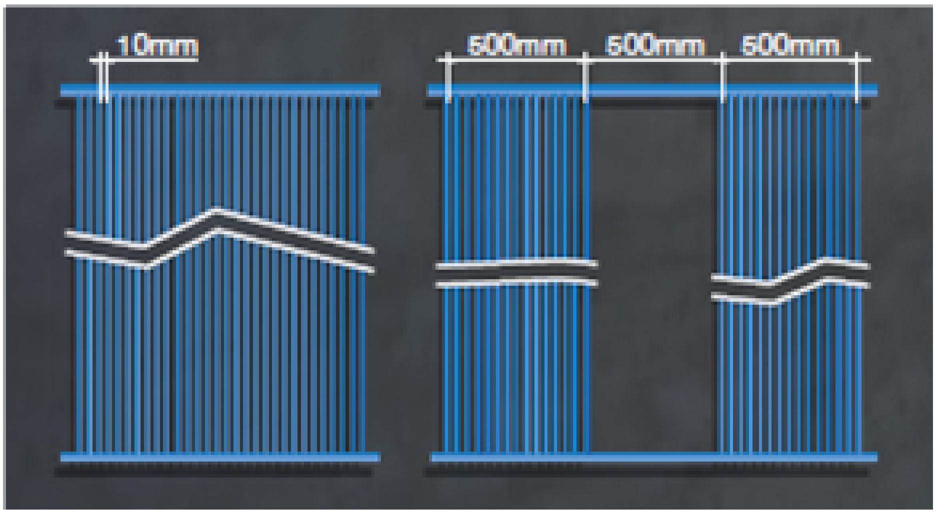
The capillary tube mats are meander-shaped and made of many single capillary tubes, which run parallel and end up in a main pipe. The whole mat consists of pure Polypropylene. Polypropylene (PP) is easy to handle and compared to composite material, which is often used for conventional radiant heating systems, the production of PP shows the better balance of embodied energy. Furthermore the synthetic material makes the capillary tubes very flexible, lightweight and cause of the very small diameter of the capillary tubes, the capillary tube mat has a thickness of 5 mm only. That is why the capillary tube system is suited especially for retrofitting of buildings.
Depending on the application the capillary tube mats have the following characteristics:

Table 7 Characteristics of the capillary tube mats

	unit	material integrated	non-material integrated
Tube Spacing	mm	20 - 30	10 - 15
Outer Diameter	mm	4.5	3.35
Inner Diameter	mm	2.,9	2.55
Wall Thickness	mm	0.8	0.4
Outer Diameter Main Pipe	mm	20 x 2	20 x 2
Length	mm	600 - 8000	600 - 8000

Widht	mm	150 - 1130	150 - 1130
Weight (Depending On Tube Spacing)	g/m^2	479 - 719	562 - 824
Surface (Depending On Tube Spacing)	m^2	0.452 - 0.678	0.71 - 1.067
Heating / Cooling Capacity		depending on material integration and flow temperature	
Properties		extra robust for integration into concrete, plaster	ideal for dry wall construction, flexible, versatile, low installation height, very quick heat transfer

Figure 2 Capillary tube mat



5.3.1.2 Strong / weak points of material / technology

The energy efficiency and energy saving potential of the capillary tube system compared to conventional under-floor heating systems was tested and certified by TÜV Süd in December 2012.
The results of TÜV Süd reports that surface heating (and cooling) systems are energy efficient generally. For this, the portion of heat radiation is responsible because the convective portion of heat release is very low, so the necessity of tempering the ambient air directly is not required anymore. The flow temperature of surface heating systems is correspondingly lower compared to convective systems.
Cause of the limited applicability of the conventional systems, the comparison of the systems is only possible regarding the under-floor heating mode although the capillary tube system can also be installed in walls and ceilings. But the result of the test is transferable to radiant heating and cooling systems in walls and ceilings. The capillary tube system was compared with a one-pipe-meander, which consists of polyethylene-pipe with a diameter of 16 x 2 mm and a distance of 100 mm between the pipes in the slab.
Compared to the capillary tube system the surface of a capillary tube mat will be 3 times more and amounts to 1.05 m^2/m^2. This leads to the conclusion that similar performances can be achieved with lower temperature levels.
Under testing conditions both systems are set so that they reach the same specific heat output of 81 W/m^2. The differences of the systems were found in the temperature spread and in the average heating

temperature. The average heating temperature is significantly lower at the capillary tube system and is compensated by the greater heat transfer surface area.

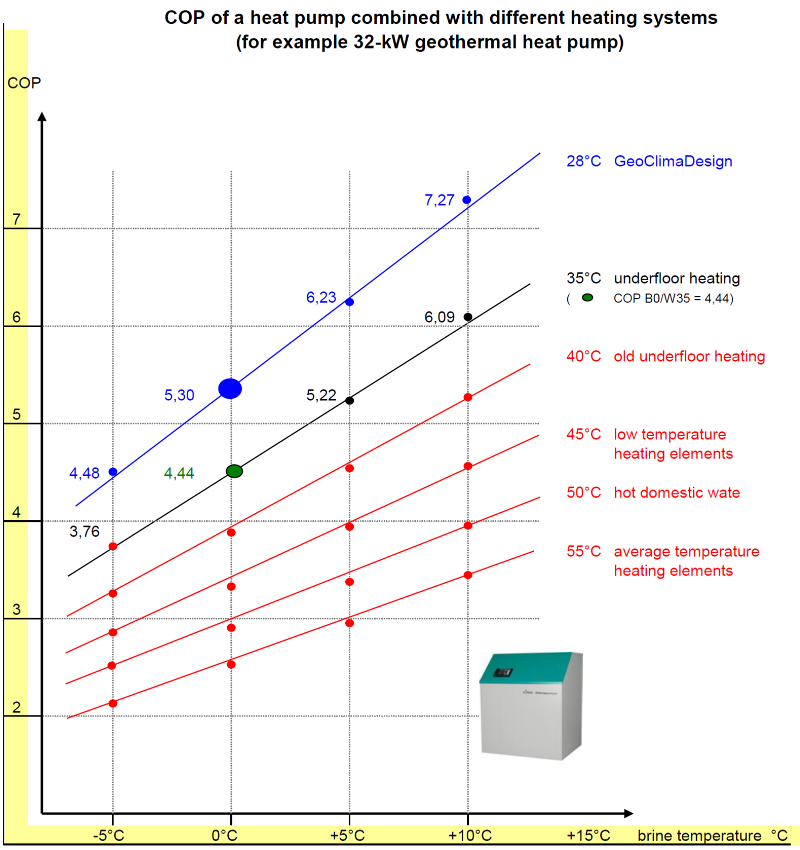
Table 8 Comparison between capillary tube mat and one-pipe meander

		one-pipe meander	capillary tube mat
Pipe Material		PE	PP
Pipe Dimension	mm	16 x 2.0	3.35 x 0.4
Tube Spacing	mm	100 / 150	10
Installation		integrated in slab	on the slab
Inlet Temperature	°C	38	32
Temperature Spread	K	10	5
Thermal Conductivity	W/(m*K)	0,43	0,22
Thermal Resistance	m²*K / W	0.0047	0.0018
Heat Output	W/m²	81	81

Also the physical properties of the pipe material were compared. As shown in the table, the thermal conductivity of the capillary tube is worse than the PE-pipe due to the material. But cause of the minimum wall thickness the thermal resistance of the capillary tube is still favourable.
Next to the contemplation of the temperatures, the mass flows of the systems are very interesting. Based on the above-named conditions, the mass flow of the one-pipe-meander will be lower than the mass flow in the capillary tube system. It follows that the specific pressure loss will also be lower in the one-pipe-meander than in the supply lines of the capillary tube mats. But due to the arrangement of the capillary tubes (many capillary tubes flows through parallel) the total pressure loss will be equal with the conventional system. And although the hydraulic conditions are unfavourable, no higher pump power is required.
It must also be mentioned that the capillary tube system is open for oxygen diffusion. It is necessary that all components in the system are non-corrosive. Often the heat generation / refrigeration is hydraulically separated by using a heat exchanger. Compared to conventional systems which are made of PE or composite material the use of higher quality material is required. This implies firstly a higher investment cost, but corrosive-resistant components increase the lifetime of the system enormously. And moreover there is no accumulation of mud compared to conventional heating / cooling system with corrosive components. Also calcification need not be considered cause of the low flow temperature while calcification becomes a problem in conventional systems after a certain time.

Regarding the energy saving potential, crucial energetic savings result from the low flow temperatures of the material-integrated capillary tube system.
The low flow temperature of the capillary tube heating and cooling system allows the use of heat energy from very low temperature levels. With a correspondingly large thermally activated surface also inlet temperatures of 28° C are possible with the capillary tube system (for example in component activation). Thus, higher coefficient of performance can be achieved in the operation of heat pumps for heat supply compared with conventional surface heating systems. The smaller the temperature difference between the heat source and the flow temperature is, the larger the coefficient of performance (COP). And the larger the COP, the better the relation of used electrical energy to heat output realized. This means that the COP is directly dependent on the flow temperature, which is the capillary tube system at an advantage. The low temperature heating improves the efficiency of the condensing boilers as well, such as the boilers on the demo-site building in Sopron.

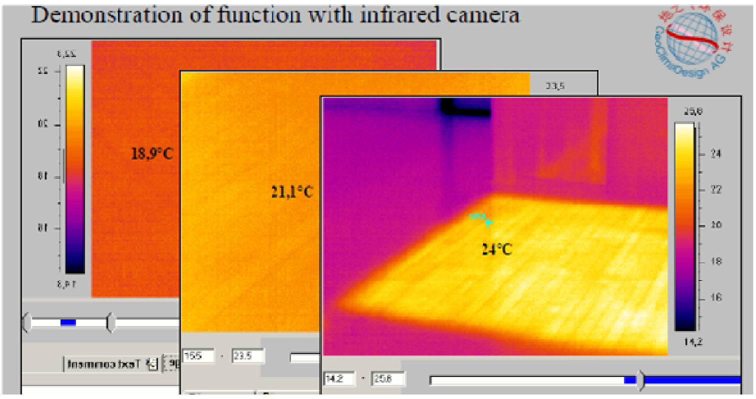
Figure 3 COP comparison



In addition, the radiant heat emission compared to convective heat emission allows a more comfortable indoor climate at lower ambient air temperatures. In order to create the most pleasant indoor climate, the large heating surfaces require the lowest possible surface temperature. Also the homogeneity of the surface temperature contributes creating a high standard of comfort.

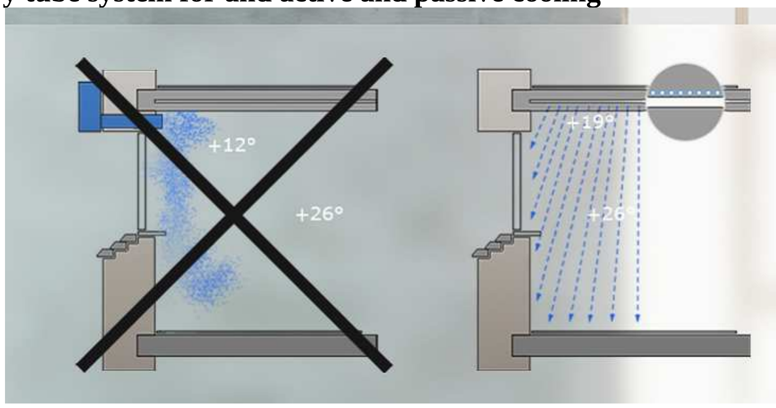
The very small diameter of the capillary tubes generate a high density of tubes in the building elements that the temperature spread is equal over the entire surface compared to conventional heating systems**.**

Figure 4 Demonstration of heating function with infrared camera



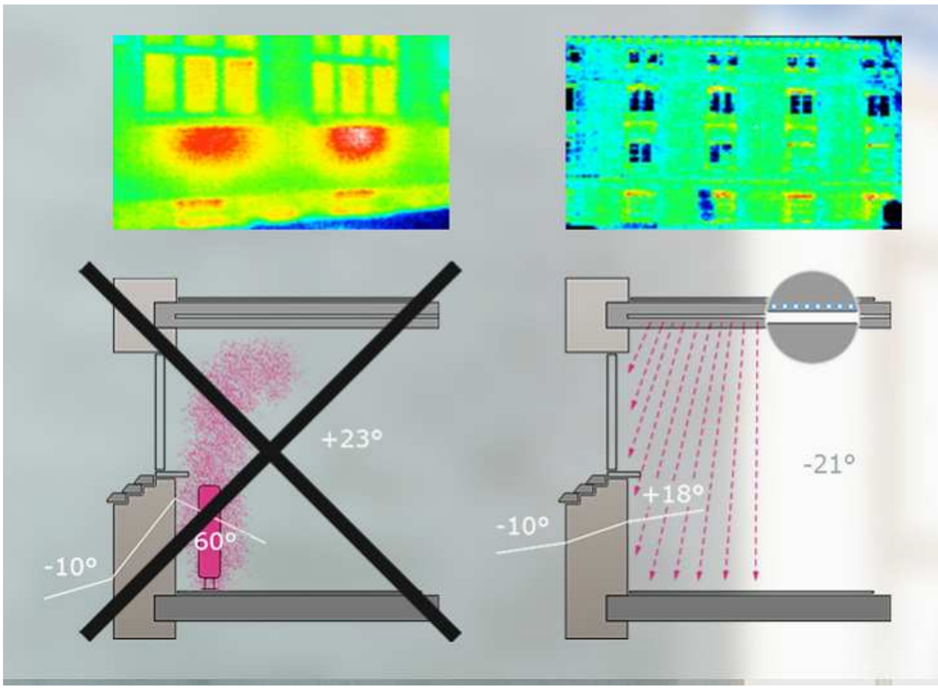
Also the capillary tube system can be used for active and passive cooling. It is recommended to use heat pumps or chillers for active cooling. A very energy efficient way of cooling is the passive cooling by using well water or river water. Both the active and the passive cooling are silent methods of cooling. Analogue to the heating, the cooling is achieved by cooling down the surfaces. And next to the energy saving potential, the way of silent cooling is very hygienic compared to conventional air conditioning systems. Again there is almost no air movement by using the capillary tube system. That means there is no noise or dust but a very comfortable indoor climate.

Figure 5 Capillary tube system for and active and passive cooling



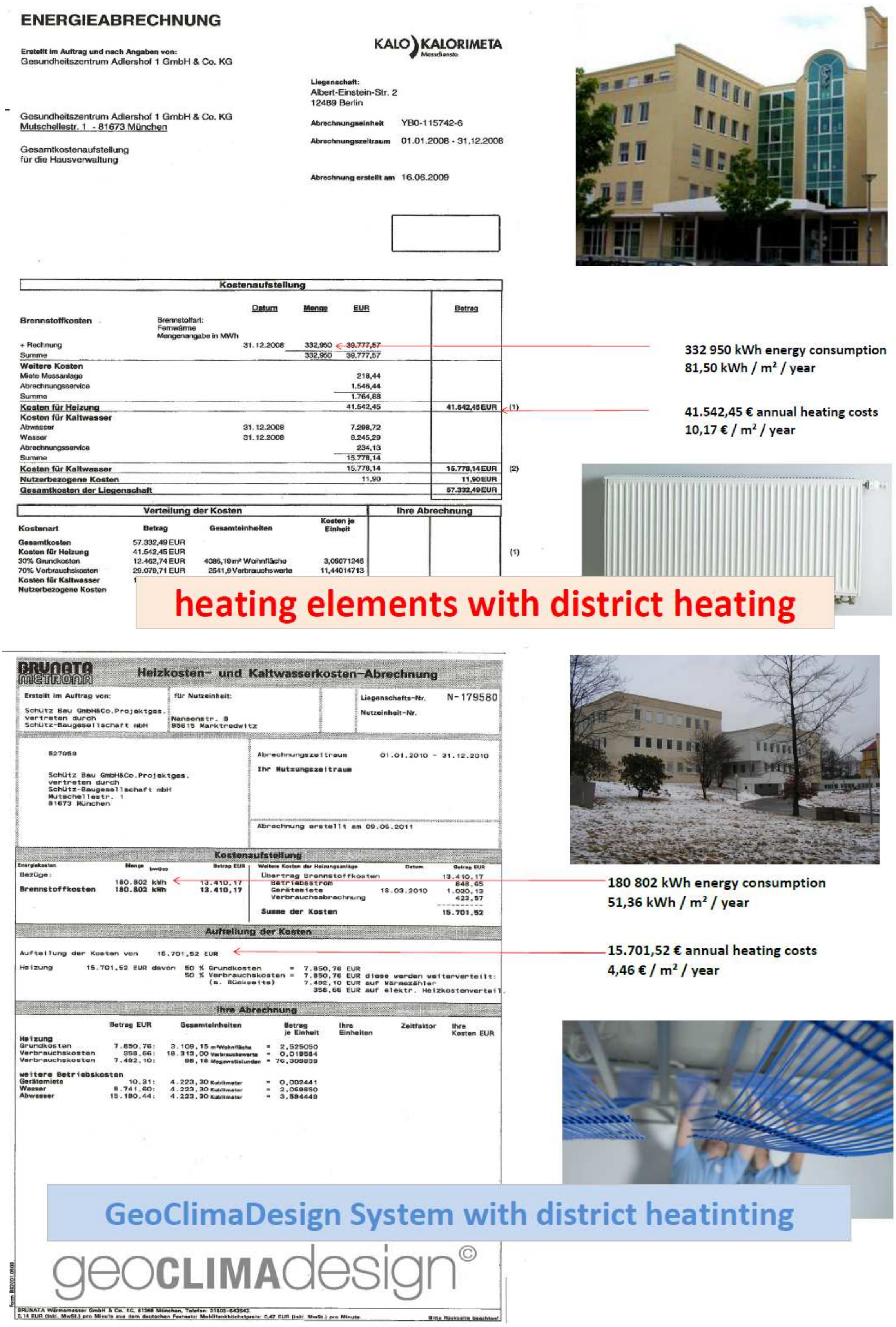
Another advantage of the capillary tube system compared to the convective heating system is the reduction of the transmission losses of heat. It is common to install heating elements on the wall directly underneath the windows to support the natural ventilation. At the same time this way of installation increases also the transmission losses of heat, as the temperature spread between the outside temperature and inside wall temperature is very high. By reducing the flow temperature by the use of the capillary tube system the flow of heat through the wall also can be minimized (see figure below).

Figure 6 Reduction of the transmission losses of heat



But the highest energy saving potential results from the reduced inlet flow temperature. The following figures show a comparison of annual energy consumption of a conventional convective heating system and the capillary tube heating (and cooling) system.

Figure 7 Comparison of annual energy consumption between a conventional convective heating system and the capillary tube heating (and cooling) system



5.3.1.3 Construction cost saving potential

As aforementioned in the characteristics of the capillary tube mat, the thickness is only 5 mm, which is not only advantageous for installing or retrofitting the system but also for reducing the building cost.

Thanks to the reduced thickness, less material (e.g. slab) is needed to cover the capillary tube mats thus saving material costs, facilitating the mounting of the ceiling system due to its low weight.

The installation of the capillary tube mats in the floor / ceiling or wall will increase the height between the floors and the gross floor area. The higher the floors and the larger the inside area, the more profit can be achieved by renting or selling the building.

Also the fact that the capillary tube system unites a heating and cooling system in itself will increase the value of the building and reduces the investment costs, as an extra cooling system is not required.

5.3.2 DC powered heat pump (DPHP)

5.3.2.1 Available materials/technologies:

A conventional heat pump system consists of compressor, condenser, evaporator, expansion valve, pumps and fans. On the other hand, a DPHP system has same components but the compressor and the fans are powered by DC energy source such as renewable or converted DC supply from grid line. Currently, all components of the DPHP system can be found in the market and also technology about DPHP system can be available easily in the open literature.

5.3.2.2 Main characteristics of materials/technologies:

Heat pump systems are very common in heating & cooling applications. Main components (as listed above) of the HP system are well developed and easily available in the market. A novel future of the proposed approach is using DC powered HPs, which are more efficient than AC-powered HPs, and can exploit renewable energy sources (like PV) directly.

5.3.2.3 Strong and weak points of these materials/technologies:

When we look at the strong points of the DPHP technologies: it is very clear that renewable energy powered DPHP system is much more energy efficient than the classical heat pump system. Similarly, the strongest part of the DPHP materials is longer lifelong period since these materials are used at exact cooling or heating demand (supply and demand is equal each other and there is no over capacity production) and also variable speed operation is applied instead of on-off operation. These operation modes extend the lifelong of the heat pumps' components.

The limited capacity (such as >10 kW) of the available DC compressors could be a weak point, but from the point of view of distributed energy system, the better scalability of the system and the coupling with the PV panels will make this solution be more suitable for the retrofitting project.

5.3.2.4 Cost benefit analysis

A DPHP system is much more energy efficient than a conventional heat pump system. The energy saving rate can reach up to 50% for both cooling and heating.

The cost benefit is analyzed based on the following conditions:

1. The annual solar radiation level in Sopron : 1,266 kWh/m2
2. The typical performance ratio of the PV technology: 0.7
3. The electricity price in Hungary: 0.140 €/kWh
4. The COP of standard heat pumps: 2
5. The conservatively estimated COP of DPHP: 3

Table 9 Cost Benefit analysis and ROI of DC Heat Pump coupled with the Renewable Energy sources (PV system).

DPHP Cost (euro)	Labor Cost	Renewable Energy System (euro)	Total Cost (euro)	*Economic savings in Hungary(€/*	*ROI in Hungary (year)*

		(euro)				***year)***	
16 kW	10,000	1,500	PV	50,000	61,500	9,900	6.2
25 kW	20,000	2,500	PV	80,000	102,500	15,400	6.6
75 kW	45,000	5,000	PV	225,000	275,000	46,300	5.9

6. Building Management Systems

6.1 List of technologies

In this section it will be explained a practical approach to the control of a Building Management System. The theoretical part of the different typologies of the BMS control is avoided to the detriment of 10 automation system solutions that allow the Building Management System to maintain thermal comfort conditions inside the shopping center, reducing the energy cost and enhancing a more efficient and sustainable performance of the HVAC and Lighting systems.

Fig. 12 Automation System Solutions

<table>
<tr><th colspan="2">BUILDING MANAGEMENT SYSTEMS</th></tr>
<tr><th>AUTOMATION SYSTEM SOLUTIONS</th><th>Benefits of these BMS control systems</th></tr>
<tr><td>1. Varying air handler fan speeds</td><td rowspan="10">Maintain thermal comfort conditions
Maintain optimum indoor air quality
Reduce energy use
Safe plant operation
To reduce manpower costs
Identify maintenance problems
Efficient plant operation to match the load
Monitoring system performance</td></tr>
<tr><td>2. Cooling and heating water supply temperatures</td></tr>
<tr><td>3. Enthalpy economizer controls</td></tr>
<tr><td>4. Carbon dioxide sensors</td></tr>
<tr><td>5. Carbon monoxide sensors</td></tr>
<tr><td>6. Cooling-tower water</td></tr>
<tr><td>7. Hot gas bypass</td></tr>
<tr><td>8. Lighting may be significantly dimmed</td></tr>
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6.2 SWOT analysis

SWOT ANALYSIS	VARIABLE SPEED DRIVE (VSD) [44]

Strengths	• A great energy saving between 20% and 35% is achieved during partial load.
	• Highly stable air net pressure
	• Low starting currents
	• A total absence of peaks and a high power factor.
	• Reduces power consumption significantly during the many hours of the year when peak fan speed is not needed to meet comfort and air quality requirements.
	• Even a slight reduction in fan speed of 15 percent can yield a noticeable drop in fan motor power demand — almost 30 percent — because of the inverse square law inherent in fan motor loading.
	• Energy efficiency. Independent studies have shown that energy can mount up to over 70% of a compressor's life cycle costs. In some cases the generating of compressed air can account for more than 40% of a plant's total electricity bill. Most production environments have a fluctuating air demand depending on the time of day, week, or even months of the year from 35 to 78%.
	• VSD reduces energy costs by:
	  ◦ Avoiding electricity surges by increasing flexibility with soft starting gradual motor up.
	  ◦ Avoiding operation at no load power compared with conventional compressors at light load. Eliminating the inefficient transition period from full to no load power.
	  ◦ Maintaining the net pressure band to within 0.10 bar, 0.01 Mpa
	  ◦ Reducing overall average working pressure.
	  ◦ Minimizing system leakage due to a lower system pressure.
	  ◦ Preventing components from early aging cause by prolonged full load operation currents, a total absence of peaks and a high power factor.
	• The benefits of this technology included reducing power cost, reducing power surges (from starting AC motors), and delivering a more constant pressure. The down side of this technology is the heavy expense associated with the drive, and the sensitivity of these drives – specifically to heat and moisture.
	• Efficiency over fixed speed machines is improved at part load conditions under 75%.
	• Pressure fluctuations are eliminated, which often reduces system generation pressure by up to 0.5 bar, giving extra energy savings.
	• Variable speed controls provide 'soft starting 'eliminating high inrush currents.
	• When more than one compressor is used on a single system. Giving one compressor a variable speed drive allows the other fixed speed compressor(s) to run at optimum efficiency on base load with the VSD compressor varying its output so the compressor
	• Installation precisely matches the actual demand. In these cases, fitting electronic compressor sequence controls maximises savings.
	• To save money by reducing the overall system energy being consumed.

44 http://augustcompressor.com/benefits-and-function-of-vsd-variable-speed-drive/

http://www.carbontrust.com/media/147017/ctl167_variable_speed_motor_driven_air_compressors.pdf

http://www.phelpsfan.com/pdfs/Variable_Frequency_Drives.pdf

	• Able to control the processes of the system better, giving the operator • A bypass option in the case of an inverter failure. • System starts up "softer" than normal, meaning it will decrease the • Average 6 to 7 up to 20 times inrush current during start up. • Saves money on the electricity costs of a system. • By better controlling a motor's speed, life of V-belt and or coupling • Devices is increased. • No appurtenance loss for using this control device in a system. • Device can include a breaking feature (Check with manufacturer) • Reduces the costs of a system eliminating the need to buy an antirotational device.
Weaknesses	• The reduction in energy cost over a typical life cycle might even surpass the initial investment cost of the screw air compressor. • Upfront cost of a VSD can be relatively high depending on how large your system is. • Adding a VSD device may lead to a system resonance at certain speeds, leading to; 1. Dramatically increased noise 2. Excessive vibration. • VSD device have been known to shorten the life • Can reduce the service factor on the motor it's used on.
Opportunities	• Fan speeds may be adjusted not only in response to heating or cooling needs but also to limit peak electrical demand. Most buildings exhibit thermal inertia, meaning that the mass of the structure and its contents tend to stabilize temperature changes even when heating and cooling systems work to alter them. • Some facility executives have taken advantage of this stabilizing effect by reducing air handler fan speeds and the cooling or heating inherent in circulating air for brief periods
Threats	•

SWOT ANALYSIS	HOT AND CHILLED WATER CONTROL WITH OUTDOOR RESET[45]
Strengths	• Built-in outdoor reset • Customizable reset ratios • Multiple controls that can fit every hydronic heating application • Built-in domestic hot water priority (DHW) control and priority • Can be powered by 120VAC or 24VAC without the use of external transformers • Can be controlled remotely using an Enable/Disable input • Self diagnostics • Solid state sensors can be extended up to 500′ from the control • Accuracy of ±1°F • For systems up to 300,000 BTU • Illuminated LCD display shows fuel consumption savings, operating modes, system diagnostics and operating temperatures • Patented process reduces fuel consumption—typically 10% to 20% • Short payback period—typically 12 to 24 months • UL listed, “Energy Management Equipment” • Increased savings without replacing or upgrading costly system components • “State-of-the-art” microcomputer controller • Reduces maintenance and extends boiler life • Fail-safe operation • Guaranteed to reduce fuel consumption • 15-year replacement warranty for breakdowns or defects • Connect outdoor temperatures to your indoor heating needs. • Easily save you 15%-20% on your energy bill simply because it takes outdoor temperatures into account when determining your indoor heating needs • Boilers of all kinds, heat pumps and even mixing devices can be controlled to provide Outdoor Temperature Reset to a system. • Reduced heat loss through pipes. • Increased boiler efficiency. • Boiler shutoff when it's not needed. • Energy used by boilers or chillers is reduced and distribution losses are cut when circulating-water temperatures are moderated.
Weaknesses	• Can increase Energy in variable-flow heating/cooling systems • Can cause loss of space humidity control • Complicates chiller sequencing control
Opportunities	• Simple installation by qualified installer • No programming or follow-up visits required • Maximum efficiency year-round • Easily installed plug-in sensor(s) (includes 1 required sensor) • Elimination of uncomfortable (and expensive) overheating.
Threats	•

45 https://www.staffordoil.com/energy-saving-controls

SWOT ANALYSIS	ECONOMIZER CONTROL[46]
Strengths	• An air-side economizer is an HVAC control system that can provide significant cooling energy savings when properly specified, installed, commissioned, and maintained. • It allows the unit to use outdoor air for cooling, provided the ambient air is below a certain temperature and the humidity is below a certain percentage. • To save money on electricity. • The longer outside air can be used for cooling, the longer the compressor can remain off. • Can extend the life of the equipment - provided the system is maintained properly. • Economizers can be used to provide ventilation to a building. The demand-control system uses a carbon dioxide sensor located within the building to initiate operation. If carbon dioxide levels rise, and they will as more people enter the space, the economizer opens and allows fresh air to enter for proper ventilation.
Weaknesses	• The economizer is one of the most often neglected components in an HVAC rooftop unit. It can be broken, and, as long as the damper is closed, the building owner may never know. • In the HVACR industry, the economizer is often misunderstood. • Some technicians are unsure of its operation and many customers have no clue • Not to use economizer when it is located in an especially corrosive environment • Not to use economizer when it is capable of producing only inconsequential energy savings due to building usage or location • Not to use economizer when the economizer components will be installed in a way that makes access for regular service difficult. • Not to use economizer when the maintenance department is too understaffed to supply a trained technician to service an economizer system • The economizer's collection of dampers, actuators, linkages, sensors, and controllers rarely achieves its savings potential. • Estimates indicate that only about one in four economizers works properly, with the remaining three providing sub-par performance or, worse yet, wasting prodigious amounts of energy. • Failures are a result of maintenance deficiencies, improper control, or systemic problems.
Opportunities	• Technicians who understand the economizer's operation can explain to the building owner how it can save them money in utility bills, creating a repair opportunity for themselves and their company. • Several types Of Economizers: Dry Bulb Economizer, Single Enthalpy Economizer, Differential Enthalpy Economizer, Integrated Differential Enthalpy Economizer.
Threats	• It is important to retest the system periodically. • Although advances in computer-based diagnostics can help identify malfunctioning systems, the human element is still essential to maintaining these systems.

46 https://www.cedengineering.com/upload/Economizers%20In%20Air%20Handling%20Systems.pdf

SWOT ANALYSIS	CARBON DIOXIDE DEMAND VENTILATION CONTROL SYSTEM[47]
Strengths	• Demand ventilation control systems modulate ventilation levels based on current building occupancy • A multiple-parameter approach using total volatile organic compounds (TVOC), particulate matter (PM), formaldehyde, and relative humidity (RH) levels can also be used to strong the benefits of CO2 demand ventilation control system • Based on actual occupancy in contrast to the traditional method of ventilating at a fixed rate regardless of occupancy. • Less energy demanding because non-demand ventilation control systems force to heat much more fresh air coming into buildings than is necessary. That air must be conditioned, resulting in higher energy consumption and costs than is necessary with appropriate ventilation. • DCV saves energy by avoiding the heating, cooling, and dehumidification of more ventilation air than is needed. • Energy savings has been estimated in the literature at from €.1,5to more than €3 per square metre annually. • Including CO2-based DCV in a new HVAC installation should not add significantly to the difficulty of commissioning the system. • Records of air quality data: Sensor readings can be logged to provide a reliable record of proper ventilation in a building. Such records can be useful in protecting building owners against ventilation-related illness or damage claims. • Reduced operational running times for the major HVAC equipment
Weaknesses	• Maintenance required: Calibration must be checked periodically by comparing sensor readings during a several-hour period when the building is unoccupied with readings from the outdoor air. Many sensor models are able to sense calibration problems • For a retrofit system, the installed cost will generally be about €500 to €900 per zone. • In addition to the installation of the sensors, other components such as variable frequency drives and control input and output hardware often are needed to control the whole building
Opportunities	• This works especially well for conference rooms and auditoriums with frequent low occupancy, • These systems are offered by all major HVAC equipment and control companies. • In humid climates, excess ventilation also can result in uncomfortable humidity and mold and mildew growth, making the indoor air quality (IAQ) worse rather than better. • An estimated 60,000 CO2 sensors are sold annually for ventilation control in buildings, and the market is growing. • CO2-based DCV has the most energy savings potential in buildings where occupancy fluctuates during a 24-hour period, is unpredictable, and peaks at a high level • CO2 sensors are the most widely accepted technology currently available for implementing DCV. • Improved IAQ—By increasing ventilation if CO2 levels rise to an unacceptable level. • Improved humidity control—In humid climates, DCV can prevent unnecessary influxes of humid outdoor air that makes occupants uncomfortable and encourages mold and mildew growth.
Threats	• Retrofitting an existing system for DCV may be more problematic, particularly for an older system with pneumatic controls.

47 http://www1.eere.energy.gov/femp/technologies/eut_vent_control.html

http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf

	• Applications in moderate climates, especially where economizer operation contributes substantially to cooling, may show little energy/cost savings. • Spaces where there are high levels of contaminants not related to occupancy may demand a higher ventilation rate than would be provided by DCV based solely on CO_2 levels.

SWOT ANALYSIS	CARBON MONOXIDE SENSORS[48]
Strengths	• To prevent carbon monoxide poisoning. • Early warning of gas leaking from the boiler room or bad ventilation in the garage of the shopping center. • CO detectors are designed to measure CO levels over time and sound an alarm before dangerous levels of CO accumulate in an environment, giving people adequate warning to safely ventilate the area or evacuate. • Can either be battery-operated or AC powered (with or without a battery backup) • Battery lifetime of over 6 years • CO detectors are available as stand-alone models or system-connected, monitored devices • Economic price per detector (below 40€ CO detector) • No maintenance required (with household current) during life of product (5-10 years). Detector sensor becomes more sensitive with age. • Reset time: current input detectors will rest immediately once CO problem is corrected • Ease of installation: The battery operated detectors can be placed anywhere needed.
Weaknesses	• When carbon monoxide detectors were introduced into the market, they had a limited lifespan of 2 years. However technology developments have increased this and many now advertise up to 5 years • Required maintenance in battery operated CO detector: Requires periodic replacement of battery/sensor module every 2-3 years at cost of aprox. 15€ • Reset time: Battery operated detectors depend on exposure concentration and duration. May require removal of sensor pack. A silence button, however, is now provided/required. • Ease of installation: The current input detectors have more difficulties than the battery operated CO detectors, since they require outlet near detectors or "hard wiring".
Opportunities	• Exhaust fan systems are typically designed to supply enough fresh air when many cars are running at one time in the garage. Even when such air is not heated, fans may run at full speed all the time to ensure that no health or comfort problems occur. By measuring carbon monoxide, however, a reasonable reduction in ventilation fan speed and power use for many hours of the day may be accomplished when vehicle traffic is less than peak. • Combination smoke alarm / carbon monoxide detector – save space by combining two main alarms. This also means you only have to be awared of the maintenance of one set of batteries instead of two.
Threats	•

48 http://www.hamiltonfd.net/cofaq.htm

SWOT ANALYSIS	COOLING TOWERS FOR FREE-COOLING[49]
Strengths	• Cooling towers are used to dissipate heat from air conditioning. Many of the air conditioning systems currently in use only operate during the summer cooling season, but some shopping centers require cooling year-round. • The chilled water is cooled by cooling tower water through the use of heat exchangers without the use of refrigerant compressors. • Free cooling systems are among the widely used energy efficiency applications. • Free cooling reduces refrigeration energy consumption by using evaporative cooling equipment to produce chilled water in cool weather
Weaknesses	• At reduced winter loads, it may not be necessary to maintain the design flow rate, and energy can be saved by reducing pump motor speed, operating smaller pumps, or using two-speed pumps. • Free cooling can be used to save energy whenever outside wet bulb temperature drops below the required chilled water set point and can save enough compressor electric power to pay for the cost
Opportunities	• When the tower is providing “chilled water” to the system, there are periods of time when it must operate in subfreezing conditions. During these periods, when the tower is subjected to very cold ambient conditions, there is greater potential to produce ice in the cooling tower or elsewhere in the system.
Threats	• If an inappropriate cooling tower design is chosen, or if the unit is not operated or winterized properly, excessive amounts of ice can form in the unit resulting in decreased capacity, operational difficulties, and potential damage to the tower.

49 http://baltimoreaircoil.com/english/resource-library/file/1473?dl=1

SWOT ANALYSIS	HOT GAS BYPASS CONTROL[50]
Strengths	• Hot gas bypass provides an artificial load on the evaporator by introducing a portion of high pressure, high temperature gas to the evaporator / suction side of the system. • Strength of HGBP to evaporator inlet: Merging the bypassed load and remaining system load within the evaporator in this manner, allows the expansion valve to retain suction gas superheat control, eliminating the danger of liquid carry-over. • Strength of HGBP to evaporator inlet: The retain of gas velocity within the evaporator maintains oil movement, making this the preferred method when the evaporator is located below the compressor. • Strength of HGBP to suction inlet: Hot gas bypass to the suction line is easy to add. Alteration of the evaporator piping is not necessary. • Strength of HGBP to suction inlet: The relatively small amount of piping required provides a cost saving over bypass to the evaporator – particularly if the condensing unit is located some distance from the evaporator, • Strength of HGBP to suction inlet: This is the only method that can accommodate evaporators with high pressure drop distributors and multiple outlet expansion valves.
Weaknesses	• Hot gas bypass to the evaporator inlet is limited to low pressure drop distributors. • Weakness of HGBP to evaporate inlet: The installation cost is directly proportional to the distance between the condensing unit and evaporator. • Weakness of HGBP to suction line: An additional liquid line solenoid valve and expansion valve are required. • Weakness of HGBP to suction line: At limited evaporator loads, the gas velocity within the evaporator may drop too low for satisfactory oil movement. • Weakness of HGBP to suction line: Challenges the designer to slope the suction line in two directions: toward the compressor during the on cycle, toward the evaporator during the off cycle. • For comfort cooling, however, the addition of hot gas bypass is seldom necessary. • A chilled water system without hot gas bypass requires less power than one that operates the compressors with hot gas bypass.
Opportunities	• It is recommended when the load on an evaporator varies and operation of the air conditioning system is desired at lower than design conditions. • It is recommended when the evaporator coil is designed for comfort cooling (latent and sensible loads) versus precision cooling (all sensible loading). • An oversized system quickly meets the sensible load without satisfying the latent load. Adding Hot Gas Bypass may mitigate this error.
Threats	• Hot gas bypass has the potential to modulate capacity or improve reliability, but these benefits will not be realized without careful evaluation of its appropriateness and painstaking attention to design, installation, control, and maintenance.

50 http://www.morganizer.com/hot-gas_bypass_control.pdf
http://astro.berkeley.edu/~plambeck/CARMAdocs/WaterChiller/TraneHotGasBypass.pdf

SWOT ANALYSIS	LIGHTING CONTROL SYSTEMS[51]
Strengths	• When done in conjunction with outdoor light entering a space, significant savings in both lighting and cooling may result. • Even without dimming ballasts, a portion of lighting may be controlled as a result of on-off schedules, occupancy sensing, daylight response or dimming on a schedule, or in response to peak building power demand. Where many fixtures are present in open common areas (as it happens in shopping centers), temporarily turning off every third or fourth fixture is rarely noticed. • Light control increases comfort and may improve productivity. • Save energy because of reduced wattage. Light sources use less energy when dimmed. • Dimmers Extend Bulb Life. • Flexibility for the use of lighting <u>Strenghts of Diming Fluorescent Lamps with DALI ballast protocol:</u> • Easy to wire and install • Very flexible after installation • Wiring does not have to be segregated from mains supply cable • Lamps switched off via control signals • Full, accurate control of load (0% - 100%) • Fully addressable • Signal cable is not polarity sensitive <u>Strenghts of Analogue diming for Fluorescent Lamps:</u> • Simple • Cheap controllers <u>Strenghts of Analogue diming for LED:</u> • Robust, well understood technology which works well with LED. • Simple to diagnose if problems as you can test the voltage. • Low voltage so can run with low diameter cables. <u>Strenghts of Diming LEDs with DALI ballast protocol:</u> • Each lighting device is assigned a unique static address in the numeric range 0 to 63, making possible up to 64 devices in a standalone system. • Complex switching arrangements can be made from the system. • Has two way communication and will give status reports on the light fitting. • It dims to off, so does not require mains switching equipment to turn them off. • Reconfiguring lighting is easy as each is individually addressed – especially useful in open plan offices.
Weaknesses	• Bulbs won't work that well with a dimmer switch. As you turn down the current it becomes harder and harder for the bulb to kick-start itself into life. • Due to the fact that LEDs have comparably low loads to conventional halogen technology they are often incompatible with standard dimmer.

51 http://www.lutron.com/en-US/Education-Training/Pages/LCE/GreenBenefits.aspx
http://thelightingdesignstudio.co.uk/dimming-led/
http://www.apollolighting.co.uk/products/Technical/Dimming%20Fluorescent%20Lamps/

	• Typically minimum loads should be above 10-30 watts to dim. • They don't always dim down to 0% • One way switching and no feed back. <u>Weaknesses of Diming Fluorescent Lamps with DALI ballast protocol:</u> • Can be expensive compared to other dimming systems • Control components cannot be mixed between manufacturers <u>Weaknesses of Analogue diming for Fluorescent Lamps:</u> • Control wiring has to be separated from mains wiring, or screened cable used. • Lamps cannot be switched off form control signal <u>Weaknesses of Analogue diming for LED:</u> • Limited number of 0-10 dimmer manufactures which work well (so often a control system is required) • Difficult to combine 0-10 switch plates with mains dimming. • Not every one is familiar with the methodology. • Requires additional signal cable -which can increase the cost. • Has no feed back. • Polarity dependent • Each circuit or device needs to be connected with the signal cable which for large systems can potentially be expensive. <u>Weaknesses of Diming LEDs with DALI ballast protocol:</u> • Can be expensive. • Requires programming to address each ballast. • Requires a central control system. • Requires a programmable ballast so even for a mains supply LED lamp will require additional interface to enable it to link to the system. • If the ballast goes it loses the address. • Needs to be updated if the function changes.
Opportunities	• Lighting control systems typically provide the ability to automatically adjust a lighting device's output, that can be based on several parameters, such as 1) Chronological time (time of day), 2) Astronomical time (sunrise/sunset). 3) Occupancy using occupancy sensors, 4) Daylight availability using photocells, 5) Alarm conditions, and 6) Program logic (combination of events)
Threats	• It can cause flickering, buzzing or premature failure if incompatible.

SWOT ANALYSIS	AUTOMATED SYSTEM THAT SENSES BUILDING DEMAND AND SEQUENCES LOAD REDUCTIONS[52]
Strengths	• Building peak electric demand will be reduced • The automated and predictive system will meet a set level. • Such control will be applied to loads such as fans, lighting, heat pumps, packaged air conditioning units and electric heating coils, integrating them some of these options in a programmed sequence. • Peak load are cut when it is most cost effective to do so, thereby saving on peak demand charges, or when called upon to do so by the local utility. • By sequencing brief — 10 to 15 minute — service reductions in spaces that people continuously occupy and for longer periods in other areas, such rotation avoids or reasonably shares any minor discomfort. • The system can improve fire, security and other emergency and contingency procedures • Improved standards of plant/building performance • Improved management of building systems • Lowers utility costs – typically saving 15% of the operating equipment costs. • Maintains measured comfort – Computerized controls help to maintain even temperatures and lighting levels within the facility to provide measured comfort. • Avoids unexpected equipment breakdowns
Weaknesses	• Operation and maintenance costs might be higher compared to simpler management systems. • Small amount of qualified professionals for system installation • Requires commitment at all levels throughout its operational life to maintain maximum effectiveness
Opportunities	• Enhances property value • Reduces occupant complaints – A more comfortable building means fewer occupant complaints. • Simplifies building operation – Computerized controls and real time graphical displays let you see exactly what is happening with the equipment in the building without having to go up on the roof or crawl up into the ceilings. • Increased energy efficiency • Improved environmental conditions
Threats	• Energy potential savings could only be achieved if the system is properly used and managed • Higher initial costs for design and installation

52 http://www.alternegy.com/tabid/283/Default.aspx

http://www.mepc-mn.org/Understanding%20Your%20Utility%20Bill/Benefits%20of%20Building%20Automation%20Systems%20with%20EMS%20Logo.pdf

SWOT ANALYSIS	Fixed Acoustic Sensor Network supplemented by a Mobile Robot Platform
Strengths	• Installation of the fixed sensor network can be very cost efficient and unintrusive. • Using a mobile robot unit as an integrated part of the sensor network compensates the possible weak-points of the fixed sensor network. • While the sensor data doesn't generate any energy savings on its own, it provides vital intelligence to the Intelligent Automation Unit (IAU). Thus it is the part of the backbone that enables the IAU to optimize the overall energy saving potential. • Acoustic sensors give the possibility to detect not only people presence but also the occupancy level, so the HVAC system will interact with the occupancy level in order to reduce the energy consumption while mantaining the indoor quality comfort. • Good control of internal comfort conditions • Possibility of individual room control • Effective monitoring and targeting of energy consumption
Weaknesses	• Building's layout and available infrastructure may restrict the placement of sensor nodes, introducing certain weak-points to the network, • Surveillance and audio recording capabilities may raise concerns regarding privacy issues. • Being expensive to buy and install • Needing ongoing maintenance
Opportunities	• Mobile Robot is a very innovative system • Mobile Robot is visually very interesting and could attract customers for the commercial building.
Threats	• The mobile robot is a very uncommon technology and its behaviour on buildings may not work as expected

6.2.1 Conclusions

In this section the conclusions are not so clear because these practical solutions are not restrictive to others (with the possible exception of acoustic sensor network and Carbon dioxide sensors), they could be implemented at the same time. This approach is to explain and evaluate some solutions/systems that can be upgraded in the Intelligent Automation Unit. They are all focused in the reduction of energy consumption while maintaining the indoor air quality and the comfort of workers and customers.

In the Hungarian shopping center the project will focus in three of these Automation System Solutions: Variable Speed Drive, Lighting Control Systems and Fixed Acoustic Sensor Network supplemented by a Mobile Robot Platform.

The DC Heat Pump will have a variable speed compressor integrated, which will provide higher efficiency. It will reduce power consumption significantly during the many hours of the year when peak fan speed is not needed to meet comfort and air quality requirements. The achieved energy savings with this technology are around 30% during partial loads.

The Lighting Control System will ensure the fulfillment of illuminance requirements by adjusting the illumination needs by increasing the number of cascadable light collecting units. To optimize the indoor lighting condition, the system will adjust indoors lighting condition according to data collected from various light sensors, including luminance sensor, color temperature sensor, etc., so the simulated natural light will be very close to the real sunlight. During the night or overcast day, when the outside sunlight is absent, the system will be integrated with the artificial lighting system to simulate the natural light and be robust to be a light provider regardless of outside lighting situation.

As the Fixed Acoustic Sensor Network supplemented by a Mobile Robot Platform is concerned, the sensing network for EcoShopping will be a flexible, cheap and easily adaptable multi-sensing prototype system for buildings composed of a configurable network of wired or wireless environmental sensors, microphones, and hubs of connections that register and transfer data in big spaces. Using a mobile robot unit as an integrated part of the sensor network compensates the possible weak-points of the fixed sensor network. The acoustic sensors give the possibility to detect not only the level but also the occupancy level, so the HVAC system will interact with the occupancy level in order to reduce the energy consumption while mantaining the indoor quality comfort and enhancing the possibility of controlling each space indoor air properties independently. For the EcoShopping demo site, both the centralized (fixed distributed sensor network) and de-centralized (autonomous robot) approach will be used to circumvent the necessity to use huge numbers of sensors to capture environmental data. It will be investigated how a mobile sensor unit can contribute to the development of a more accurate parametric model in terms of environmental control. Furthermore, an autonomous mobile robot can be used as a platform for other application scenarios (security and safety, provide information to visitors) as well.

6.3 Intelligent Automation technologies in WP5

6.3.1 Fixed sensor network

6.3.1.1 Available materials/technologies

In the Ecoshopping project, there will be deployed a number of sensors to gather the needed energy consumption and environment air quality. The available sensors for this objective are:

- Electrical meters – For measurement of electrical consumptions of installed equipment (such as HVAC systems, motors, elevators, or others), lighting system and socket circuits;
- Heat meters – For measurement of heat production by the facility's boilers, renewable heat sources (such as solar panels or geothermal sources) and consumption of heat in the facility's systems or spaces/rooms;
- Air temperature and humidity sensors – For measurement of the air temperature and relative humidity inside the building's spaces or rooms;
- Air CO_2 concentration sensors – For measurement of the air CO_2 concentration inside the building's spaces or rooms

6.3.1.2 Main characteristics of materials/technologies

The following table describes the main characteristics of the sensors to be used:

Table 10 Main characteristics of the sensors

Sensor	Communication	Power source	Measured variables
Electrical meters	Modbus RTU	Self-powered from measured circuit	Total consumed active energy Total consumed reactive energy Power factor Frequency Voltage Current intensity
Heat meters	MBus	Battery powered	Total delivered heat energy Total liquid flow Flow temperature Return temperature
Air temperature and humidity sensors	ISM Radio (868 MHz)	Battery powered	Air temperature in Celsius degrees Air relative humidity in percentage
Air CO2 concentration sensors	ISM Radio (868 MHz)	Mains powered	Air CO2 concentration in PPM

6.3.1.3 Strong and weak points of these materials/technologies

The strong and weak points of the presented sensors are indicated in the following table:

Table 11 Strong and weak points of different sensor types

Sensor type	Strong points	Weak points
Electrical meters	Valuable energy information measured Multiple energy variables measured Capability to measure a wide range of circuit nominal power Don't need on any additional power source as they feed from the measured circuit	Deployment difficulty: Need of qualified technician (electrician) for installation of the meters in the electrical boards
Heat meters	Valuable heat energy consumption information Capability to provide flow and temperatures information	Deployment difficulty: Need of a qualified technichian (plumber) to deploy the meter; need to interrupt the heat supply for cutting the heat circuit Usually need of a protocol bridge/converter from MBus to other protocol (one gateway can be shared among several heat meters)
Air temperature and humidity sensors	Can be installed anywhere because they communicate by radio Does not need external power source as it is battery powered	Need yearly maintenance to replace batteries
Air CO2 concentration	Can be installed anywhere because they communicate by radio	Need a mains power source

6.3.1.4 Cost benefit analysis

Despite of the sensors are not used for direct energy saving, the deployed sensors network is fundamental to identify the opportunities for energy saving while preserving the needed air quality and for the evaluation of the results of the applied retrofitting in the energy consumption of the building.

Table 12 Commercial prices of different sensor types

Sensor type	**Approximate price**
Energy meters	200€ to 300€ on typical applications

Heat meter	300€ to 600€ for the heat meter on typical small pipe size applications 200€ to 400€ for the MBus protocol bridge
Air temperature/humidity sensor	120€ to 180€
Air CO2 concentration sensor	200€ to 300€

6.3.2 Acoustic sensor network & Mobile robot platform

6.3.2.1 Available materials/technologies

A sensor network of several acoustic sensor modules will be deployed to the building. These modules are installed at fixed locations and connected to a central processing unit via "Cat 5" Ethernet cables. Each node contains an array of eight microphones, and transmits raw audio data to the network's processing unit.

The fixed sensor network is supplemented by a mobile robot system, based on the MetraLabs SCITOS G5 platform (http://metralabs.com). The basic G5 robot module already includes an industrial PC with Wi-Fi, and it conforms to the European CE-guidelines for the public indoor sector and is approved by the German Technical Inspection Agency (TÜV). According to the requirements at hand, it will be extended with optional components and equipped with custom-build modules. This includes a laser scanner for navigation, cameras for surveillance, a touchscreen display unit and acoustic sensors.

6.3.2.2 Main characteristics of materials/technologies

Acoustic data, acquired by the sensor network, is collected and interpreted by the network's processing unit. This results in an estimation of the building's occupancy level, which is sent to the IAU, so the building's systems may be adjusted accordingly.

The mobile robot unit runs on differential high torque gear-motors, enabling driving speeds up to 1,4 m/s, or rotations up to 200 °/s. Equipped with acoustic sensors and preprocessing capabilities, the robot acts as a mobile sensor module within the fixed sensor network, thus adding a dynamic component. Such a mobile module can improve the sensor network reliability by putting sensors right where they're needed. The robot may compensate for weak-points within the fixed network, thus the fixed sensor network can be implemented with fewer sensors, while the robot substitutes missing sensors on demand. This makes the installation of the fixed sensor network less invasive and reduces its costs. Just like the fixed sensors, the robot features microphones that are used to record acoustic data. Similar to the network's processing unit, the robot will processed the acquired data and estimate the occupancy level at the robot's current location. Via Wi-Fi, the occupancy level data will be transmitted to the IAU for interpretation.

Using acoustic event detection algorithms, the robot unit may perform safety and security duties. Acoustic events (e.g. someone yelling for "help") can be detected and a notification is send to an operator. The (remote) operator may use the robot unit's cameras to assess the situation.

During business hours, the robot's touch-display unit may provide information on the EcoShopping project, current energy consumption.

6.3.2.3 Strong and weak points of these materials/technologies

In case the existing infrastructure is adequate (i.e. "Cat5" cables and power supply in suitable locations), the installation of the fixed sensor network can be very cost efficient and unintrusive. However, the building's layout and available infrastructure may restrict the placement of sensor nodes, introducing certain weak-points to the network, which may have an impact on the sensor network performance. In addition cable connections to sensor modules are supposed to be no longer than about 70 meters.

Placement of fixed sensor modules depends on the existing infrastructure, e.g. network cables and power supply. Using a mobile robot unit as an integrated part of the sensor network compensates for possible weak-points of the fixed sensor network.

Surveillance and audio recording capabilities may raise concerns regarding privacy issues. This relates to the fixed sensor network as well as to the mobile robot unit. However, the issue may be more prominent with the robot unit, since its surveillance capabilities seem to be more obvious.

6.3.2.4 Cost benefit analysis

While the sensor data doesn't generate any energy savings on its own, it provides vital intelligence to the IAU. Thus it is the part of the backbone that enables the IAU to optimize the overall energy saving potential.

The sensor network will be deployed on a single floor, only. It is planned to install 9 acoustic sensor modules, at a price of 700€ per module, i.e. 6.300€ in total. The actual positions of the sensor modules need be determined on-site. Processing of the sensor data will take place on the network's processing unit; a workstation PC for 3,000€. Additional hardware for connecting all network modules (i.e. cables, switches, Wi-Fi, etc.) will be about 500€.

Depending on the actual sensor coverage, two or three mobile robot units (35,000€ a piece), will be used to supplement the fixed sensor network. Total costs for the mobile robot units will be 70.000€ to 105.000€, depending on the number of units. While the mobile robot platform is more expensive than additional fixed sensor modules, it may also perform security duties. Thus by replacing a security employee, it has a quick "return of investment" of less than 3 years considering 1.000€ an average salary of a security employee in IKVA shopping center.

Table 13 Commercial prices of the acoustic sensor network and Mobile robot

Component	Count	Price (per piece)	Total Price
Acoustic sensor module	9	700€	6,300€
Acoustic sensor network processing unit PC	1	3,000€	3,000€
Cable connections, network switches, Wi-Fi, etc.	1 (pile of items)	500€	500€
Scitos G5 mobile robot unit (incl. extension modules)	2-3	35,000€	70,000-105,000€
Total			79,800-114,800€

7. OPERATION AND MAINTENANCE PROCEDURES

7.1 List of procedures

The following Operation and Maintenance strategies will be evaluated in the SWOT analysis.

Table 14 Maintenance strategies

OPERATION AND MAINTENANCE PROCEDURES	
Maintenance typology	**Planned / Unplanned**
Reactive Maintenance	Unplanned (Reactive)
Preventive Maintenance	Planned (Proactive)
Predictive Maintenance	Planned (Proactive)
Reliability Centered Maintenance	Planned (Proactive)

7.2 SWOT analysis

7.2.1 SWOT analysis for different technologies

SWOT ANALYSIS	REACTIVE MAINTENANCE[53]
Strengths	• Lower start up cost – the first main advantage to running a reactive maintenance system is the lack of initial cost involved. • Less staff. Due to the reduced planning, management and organization time involved with reactive maintenance, the approach requires fewer staff to manage a portfolio or client. • Reduced maintenance costs – a reactive maintenance approach sits inline with a 'run until it fails' concept, whereby equipment is used as much as possible without spending any further money that its cost price.
Weaknesses	• Increased cost due to unplanned downtime of equipment. • Increased labor cost, especially if overtime is needed. • Cost involved with repair or replacement of equipment. • Possible secondary equipment or process damage from equipment failure. • Inefficient use of staff resources. Reactive maintenance doesn't protect or look after equipment and therefore reduces the lifespan of the unit. Rather than preserve the equipment and ensure it is running in optimum condition, a reactive maintenance approach does the bear minimum to keep equipment operational. The negative effect of this is that the equipment won't fulfill its potential or return on investment. • Further indirect costs are found with reactive maintenance with equipment downtime or unreliable equipment causing negative effects on reputations, safety and the ability to run a business efficiently and productively. Furthermore, • Reactive maintenance can be an inefficient use of employee time. Both for the operators of the equipment and the management personnel who will have to work hard to arrange repairs to be made.
Opportunities	• Advantages to reactive maintenance can be viewed as a double-edged sword.
Threats	• Unpredictability: One of the main disadvantages of reactive maintenance is the unpredictability of when issues may occur. This lack of knowing may well result in either labour or materials being unavailable immediately and therefore delay the time taken for a repair, increasing equipment downtime..

53 http://www1.eere.energy.gov/femp/pdfs/om_5.pdf

http://www.gnbsoftware.co.uk/blog/the-advantages-disadvantages-of-reactive-maintenance/

SWOT ANALYSIS	PREVENTIVE MAINTENANCE[54]
Strengths	• Cost effective in many capital-intensive processes. • Flexibility allows for the adjustment of maintenance periodicity. • Increased component life cycle. • Energy savings. • Reduced equipment or process failure. • Estimated 12% to 18% cost savings over reactive maintenance program. • Extends the useful lifecycle of assets decreasing the need for capital replacements. • Enhances the efficiency of equipment keeping them running more efficiently and lowering power expenses. • Enhances the performance of assets by increasing uptime. • Enhances customer (internal or external) service because maintenance teams have less unplanned maintenance and can respond quicker to new problems. • Preventive maintenance can also help companies to provide customers (internal and external) with better customer service.
Weaknesses	• Catastrophic failures still likely to occur. • Labor intensive. • Includes performance of unneeded maintenance.
Opportunities	• Preventive maintenance doesn't just enhance the lifespan of regularly used equipment, it enables higher performance. • Contributes positively to the reputation of companies
Threats	• Potential for incidental damage to components in conducting unneeded maintenance

54 http://www1.eere.energy.gov/femp/pdfs/om_5.pdf

http://www.mintek.com/blog/eam-cmms/advantages-preventive-maintenance/

SWOT ANALYSIS	PREDICTIVE MAINTENANCE[55]
Strengths	• Increased component operational life/availability. • Allows for preemptive corrective actions. • Decrease in equipment or process downtime. • Decrease in costs for parts and labor. • Better product quality. • Improved worker and environmental safety. • Energy savings. • Estimated 8% to 12% cost savings over preventive maintenance program. • Return on investment: 10 times • Reduction in maintenance costs: 25% to 30% • Elimination of breakdowns: 70% to 75% • Reduction in downtime: 35% to 45% • Increase in production: 20% to 25%.
Weaknesses	• Increased investment in diagnostic equipment. • Increased investment in staff training. • Savings potential not readily seen by management. • Training of in-plant personnel to effectively utilize predictive maintenance technologies will require considerable funding. • Requires costly monitoring equipments.
Opportunities	• Improved worker morale.
Threats	• To initially start into the predictive maintenance world is not inexpensive.

55 http://www1.eere.energy.gov/femp/pdfs/om_5.pdf

SWOT ANALYSIS	RELIABILITY CENTERED MAINTENANCE[56]
Strengths	• Can be the most efficient maintenance program. • Lower costs by eliminating unnecessary maintenance or overhauls. • Minimize frequency of overhauls. • Reduced probability of sudden equipment failures. • Able to focus maintenance activities on critical components. • Increased component reliability. • Incorporates root cause analysis. • Efficient. • Increased system reliability. • Lowered costs due to no unnecessary maintenance. • Minimized overhauls. • Reduced sudden equipment failures. • Maintenance focused on critical components. • Incorporates root cause analysis.

Weaknesses	• Significant initial costs for:
	  ◦ Training
	  ◦ Equipment

Opportunities	• RCM methodology deals with some key issues not dealt with by other maintenance programs. • It recognizes that all equipment in a facility are not of equal importance to either the process or facility safety. • It recognizes that equipment design and operation differs and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others.
Threats	• Savings potential not readily seen by management.

56 http://www1.eere.energy.gov/femp/pdfs/om_5.pdf

7.2.2 Conclusions

As it is described above there are several maintenance strategies:

Reactive maintenance is basically the "run it till it breaks" maintenance mode. It has the lowest start up cost and less staff due to the reduced planning, in change, the equipment may work inefficiently, high costs may come up due to repairs or replacements and the unpredictability of when issues may occur will be very common.

Preventive maintenance is actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Predictive maintenance is measurements that detect the onset of system degradation (lower functional state), thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state.

Reliability Centered Maintenance emphasizes the use of Predictive Maintenance techniques in addition to traditional preventive measures. It recognizes that all equipment in a facility are not of equal importance to either the process or facility safety. Moreover, equipment design and operation differs and those differences will have a higher probability to undergo failures from different degradation mechanisms than others.

The principal motivation for commissioning or O&M systems is to really achieve systems that work properly to provide comfort to all the occupants of a building unobtrusively and at low cost. Inadequate maintenance of energy-using systems is a major cause of energy waste. Energy losses from steam, water and air leaks, uninsulated lines, maladjusted or inoperable controls, and other losses from poor maintenance are often considerable. Good maintenance practices can generate substantial energy savings and should be considered a resource.

The O&M Plan for the EcoShopping demo site will be assisted based on the developed sensor network and performance baselines. Key parameters for key equipment (HVAC, Lighting) will be designed. IAU will obtain data and provide user-friendly access (web) to the data in order to assist building operators to ensure proper equipment operation. For the best commissioning, algorithms will be design to analyze actively the building operating data received from BAM to determine possible equipment malfunctions. When inefficiencies of the system performance are identified, the system will ensure the control of building operators with alarm notifications.

7.3 Operation and Maintenance Plan in WP6

7.3.1 O&M Plan

The O&M Plan for the retrofitting of the shopping mall in Sopron will take into account the 3rd and 4th options explained above: PREDICTIVE MAINTENANCE and RELIABILITY CENTERED MAINTENANCE. The aim of the methodology followed will be the development of the solution to automatically:

1) Identify failures and inefficient system performance in operation of HVAC equipment and systems
2) Foresee the possible problem and alert the building operator to perform advance maintenance

Some of the advantages implementing the maintenance procedure will be:

1) System falts will be fixed sooner
2) Decrease the time of operating in failure or in inefficient modes
3) Maximization of the reduction in energy consumption
4) Interruption will be avoided or shortened
5) Building security monitoring for aggression detection could also be integrated into the system.

The Maintenance plan to be developed will take into account the posible improvement of the system with the automatic maintenance potenciality.

The developed Web based platform that obtains data from sensor and the Intelligent Automation Management can provide user-friendly access to the data, and also assist building operators to ensure proper equipment operation by:

1) Easily-viewable graphic displays
2) Plotting of data trends
3) Comparison of actual and modeled building operations
4) Analysis of building operating data received from a Intilligent Automation Unit to determine possible equipment malfunctions.

Alarms will be generated and shown in the web (or sent by email) when abnormal values of the system are encountered.

Strong and weak points, savings potential and approximate commercial value will be studied during the research period. This technology will be tested and improved to obtain a competitive O&M procedure, lower costs by eliminating unnecessary maintenance or overhauls, increased component operational life, improve the quality of processes and the environmental safety, and taking into account always the maximization of energy savings.

8. CONCLUSIONS

This deliverable has set a path to evaluate and compare the different technologies and solutions that can be implemented in a retrofitting project of a shopping centre. Although not all the studied alternatives are available on the market or they are not suitable enough for all kind of shopping centers (different circumstance need to be taken into account, for example, the surroundings and climates), the assessment and study of these alternatives, including the new and emerging retrofit solutions could help designers and building owner in their decision process, offering them a database or guideline, with detailed analysis in strengths, weaknesses, opportunities and threats of the potential solutions and some technical datas.

In the conclusions of each section, it has been summarized the SWOT analysis of the related technologies, and at the end of each summary we have focused on the solution that the EcoShopping partners are taking into account in the development stages. As a predeep research activity, this study enables our partners to review the risk and weak points of each technology and solution, allows us to have a holistic view by trying to integrate different solutions as a whole. Nevertheless, this study will serve as a database of backup alternatives when any serious problems raise with the listed solutions in any WPs, such as the unsolvable technical difficulties, unexpected cost and unavalibility of any component etc, the whole consortium then may respone inmediately by turning into this listed alternatives for further investigation avoiding unnecesarry time lost and cost.

In some cases, the technologies to be researched and implemented maybe not the best option (technically, environmentaly and/or economically), but the building as a whole can not be split up ignoring the links between its subsystems, instead, a systemic vision is fundamental when designing a solution for a building. The integration of different technologies by maximizing the advantage of different technologies and solutions is clear, we cannot focus only on reducing the energy consumption, without taking steps on the insulation, neither just use the capillary tube system with the old high tempreture tube, the use of RE powerd heat pump should offer a proper tempreture for the radiant system by maximizing its efficiency, while the Intelligent Automation technologies could optimize the system control, maximize the benefits from free (free in emission and cost) energies and harness the Building Thermal Mass for reducing the energy consumption, nevertherless, the O&M could reduce the system risk and cost, maintaining it in a heath status.

The viability and feasibility of diffrent retrofitting technologies are elemental for a project, while the systemic integration of them could be vital. This will be further studied in the evaluation phase and replicability analysis.

9. ACRONYMS AND TERMS

SWOT: Strengths, Weaknesses, Opportunities and Threats

HVAC: Heating, Ventilation, and Air Conditioning

ROI: Return Of Investment

R&D: Research and Development

WP: Work Package

VIP: Vacuum Insulating Panels

VOCs: Volatile organic compounds

CFC: Chlorofluorocarbon

UV: Ultraviolet

CFL: Compact Fluorescent Lamp

LED: Light-Emitting Diode

OLED: Organic Light-Emitting Diode

PMMA: Poly(methyl methacrylate)

NLIS: Natural Light Illumination System

DHW: Domestic hot water

PV: Photovoltaic

GHP: Ground Source Heat Pump

DC: Direct Current

CHP: Combined Heat and Power

IC: Internal combustion

COP: Coefficient Of Performance

CFCs: Chlorofluorocarbons

ARS: Adsorption Refrigeration Systems

RCC: Reverse Cycle Chiller

GMCE: Giant Magneto-Caloric Effect

PP: Polypropylene

PE: Polyethylene

PUR: Polyurethane

BMS: Building Management System

VSD: Variable Speed Drive

TVOC: Total Volatile Organic Ccompounds

PM: Particulate Matter

RH: Relative Humidity

IAQ: Indoor Air Quality

HGBP: Hot Gas Bypass

IAU: Intelligent Automation Unit

BAM: Building Automation Management