CERtuS

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Cost Efficient Options and Financing Mechanisms for nearly Zero Energy Renovation of existing Buildings Stock

TECHNICAL GUIDE

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INTRODUCTION

PURPOSE OF THIS GUIDE

This Guide is intended to provide general information on how the municipalities of Southern Europe can achieve nZEB renovation under tight economic conditions. In addition, is wished-for give a working knowledge of how to engage stakeholders, (financing entities, ESCOs, third parties) and allow for capital investment, as to convey into the needs and expectations of Municipalities. The Guide is part of efforts within the IEE Promotion/ dissemination Project CERtuS of Integrated initiatives of EASME. It is concentrated on the Public Buildings stock and is primarily applied to renovation projects of Municipal buildings, mostly with a large footprint.

The publication is detailing design criteria and the possible technical options for realistic nZEB, the economic evaluation and the financial schemes for the Municipalities in order to give information to all decision makers about possibilities to renovate the public building stock in a more energy efficient one. Furthermore it is describing how to increase the market penetration of innovative and cost-efficient nZEB solutions optimizing sustainable financing, favorable for the Municipalities, through bankable renovations.

The Guide is divided into three main parts:

- Part A provides technical guidelines for nZEB renovation – Energy efficiency and use of renewable energy systems. This part is dealing with the design process of nZEB renovation projects. It is pointing out ways to reduce energy load, increase efficiency and utilize renewable energy sources in facilities of all types.
  CERtuS project team has developed this part A of the Guide to be used as criteria for the renovation design of municipal buildings. More specifically those technical guidelines provide design oriented information in order to assist the technical personnel of municipalities to increase the performance of their buildings, making informed choices to the key aspects of energy efficiency and renewable energy systems, considering the best practice of CERtuS examples.
  Whereas there is an extensive literature on the topic of energy efficiency in the building sector, the CERtuS team has seriously

reflected on the opportunity to propose a further version on this topic. The decision was taken with conviction, especially because the CERtuS approach provides a larger and still different purpose to the question of nZEB renovation as a whole, as it is including and taking into consideration further guidelines for complete the process. This part A of the guide cannot offer exhaustive details on the technical options; it provides some guidelines that will assist technical personnel of Municipalities and other involved to develop an overview of the building renovation options and technologies.

- The scope of Part B is to make easily accessible, all available useful information, concerning the main financing tools and schemes that can be used in the early stage of the building deep renovation projects.
  It is obvious that not all financial tools or schemes are appropriate for all projects and that financial efficiency of building' deep renovation projects depends highly on the characteristics of the financial tools and the construction project itself. Therefore, Part B offers the required information to set up the dedicated solution for each construction project, rather a common solution that fits to all projects. Furthermore, Part B provide this information with a systematic way, which is aligned with a simplified, but efficient methodological approach, introduced from the CERtuS Project. The proposed methodology aims to be a logical path that can be adapted and modified according to the needs and requirements of each deep buildings' energy renovation project and especially those focusing to nZEB.
  Detailed information on specific financial tools are available in Part B, sorted in the following main categories: (iu) Equity, (ii) Subsidized and Dedicated Funds, (iii) Grants and (iv) Fiscal and Other Incentives
  Concluding, Part B of the Guide provides comprehensive and practical information on available financial opportunities for supporting the deep energy retrofitting of existing municipality buildings in order to become nZEB.

- Part C of the Guide provides additional information on selecting energy service models. In particular, this part indicates the appropriate tools to allow individual municipalities to choose the type of contract/s that will be most suitable to meet their needs. In particular, in order to identify the most suitable type of EPC to be used for each energy renovation project, a working methodology has been developed. The first phase of the methodology permit to verify the existence of minimum conditions for which the proposed projects can be the subject of a partnership public- private through the instruments of the EPC contract and the Third-party financing (TPF), according to the standard market conditions. In the second phase, according to the Reference scenario shared and based on the characteristics of each project developed, it is identified the type of Contract EPC most suitable to be applied.

As previously alluded, the guide is addressed mainly to the key players in developing and delivering nZEB renovation schemes for public buildings of local and regional bodies. Still the guide aims to help the involved technical staff and employees of Municipalities to:

- ❖ Contribute in overcoming the lack of knowledge and experience which often leads to requests for very expensive expertise (consultants);
- ❖ Give holistic view about best practices and solutions and introduce a systematic approach and procedure on how to engage various stakeholders;
- ❖ Meet the needs and expectations of municipalities;
- ❖ Overcome the low level of confidence in EPC schemes;
- ❖ Contribute in overcoming the limited technical and financial capacity of municipalities to manage investments and project economy, providing technical, legal, economic and financial aspects;
- ❖ Help to work collaboratively and in partnership with Financing Institutions and ESCOs in order to have the greatest effect in drastically reducing building energy consumption and deliver nZEB economically.

The CERtuS Guide reflects current good practice in renovation options, financing of energy efficiency and nZEB renovation and selecting energy service models due within the framework of the project. Good practice in the context of this guide means to highlight an optimised application of currently available technologies and materials. However, this work must be seen as a work in process with much more to add and to learn, especially around the sustainable financing and energy service models.

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CERTUS PROJECT IN BRIEF

CERtuS is built on the consideration of the severe economic crisis of Southern European countries that has generated a profound negative effect on energy efficiency and the progress towards achieving 20-20-20 goals. The scarcity of economic resources and, in addition, the market uncertainty hinder the compliance to the latest Energy Efficiency Directive, demanding strict energy efficiency measures and rendering investments difficult for the public sector especially when it would be most necessary. Investments required to renovate public buildings and achieve nearly zero energy consumption have long payback times. So the interest of financing entities and ESCOs is small, especially when banks have limited resources. Many of the municipal buildings in Southern Europe require deep renovations to become nZEB and this should not be regarded as a threat but rather as an opportunity for the energy service and the financing sector.

The objective of the CERtuS project is to help stakeholders gain confidence in such investments and initiate the growth of this energy service sector.

Municipalities, energy service companies and financing entities in Italy, Greece, Spain and Portugal are involved in this project. The plan was to produce representative deep renovation projects that will act as models for replication. Twelve buildings in four municipalities have been selected. As none of the participated countries had, at the time of the submitted action, defined nZEB standards and levels, within CERtuS project has been fastened a shared definition of nZEB based from that proposed by the European Directive EPBD. Furthermore, the project has promised that deep renovation of the 12 case studies will yield 75 - 80% of energy performance improvement. The partners prepared the representative projects of deep renovation, with the ambition to act as model examples for the whole Southern Europe. Those case studies show how by various building renovation measures of energy efficiency and ZEB levels and targets can be achieved. The renovations are based on different solutions and scopes and represent the impact of different goals and/or needs regarding the selected and representative retrofit of Southern European public building stock.

The partners have adapted existing energy service models and procedures and worked out financing schemes suitable for the 12 projects. They also created materials, such as leaflets and maxi brochures, suitable to support an intensive communication plan.

We expect that our action will have a significant impact by triggering investments in renovations to achieve nZEB and the uptake of the ESCO market in Southern European member states.

OBJECTIVES OF CERtuS PROJECT

The objectives and future CERtuS effects and purposes for the upcoming years (2017-2020), are:

- To create conditions so that more municipalities, financing institutions and third party contractors develop projects of nZEB renovations. The goal is to create an avalanche effect. The CERtuS model projects will act as good examples to demonstrate the feasibility of such renovation projects.

- To stimulate the inflow of more private funds in nZEB renovation supporting the southern member states to fulfil obligations towards EPBD recast and EED Directives.

- To stimulate the development of even more financial schemes to accelerate the implementation of the EPBD recast and EED Directives in the southern European member states.

- To stimulate the uptake of ESCo´s market in southern European member states.

- To facilitate the implementation of the Energy Efficiency Directive.

The vision of CERtuS to develop and demonstrate, through its pilots, the feasibility of cost-effective and high-performance renovation of existing public building stock is based on a complex and, sometimes, gradual package of financial mechanisms combining market and public instruments. Financial institutions and other third party investors and ESCOs represent key stakeholders for sustainable energy projects.

PARTNERS OF CERtuS PROJECT

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PART A

TECHNICAL GUIDELINES FOR NZEB RENOVATION – ENERGY EFFICIENCY AND USE OF RENEWABLE ENERGY SYSTEMS

A.1 IMPLEMENTATION OF ENERGY EFFICIENCY AND INDOOR AIR QUALITY STRATEGIES

Background and General Knowledge

The European energy policy is currently implemented through the concept of nearly Zero Energy Building (nZEB) which has received increasing attention in the recent years. Buildings efficiency standards have been enhanced by (i) the recast of the Energy Performance of Buildings (EPBD, 2010/31/EU), (ii) the Energy Efficiency Directive (EED, 2012/27/EU), and the Renewable Energy Directive (2009/28/EC). More recently another important focus on cost-effectiveness of minimum energy performance requirements for buildings and building elements has been also introduced in order to identify the best balance in terms of investments costs in envelope and in energy building performances.

The EPBD recast, article 2.2 defines a nearly Zero Energy Building *as "a building that has a very high energy performance […] The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby".* This definition is open to be interpret by each Member State and does not provide any specification on energy performance calculation, which has to be adapted to the specific local conditions.

The energy efficiency improvement of the existing public building stock leads to a significant reduction of the energy demand. This can be done by using energy efficient appliances lighting, heating, cooling, controls etc., and by simultaneous energy production of renewable sources. As in every renovation projects, in order to reach nZEB standards, the starting point is the condition of the present target building. What is the actual energy consumption level before renovation, what is a realistic and planned new consumption level, what kind of measures are needed to reach the goal and what investments it will required? Time to recoup the funds expended in an investment (payback time) should also be considered, as the investments needed to achieve the planned energy consumption level can be too high compared with the achievable energy savings. The financing of investments is another very essential issue for a criterion of renovation design.

TECHNICAL GUIDELINES FOR nZEB RENOVATION – ENERGY EFFICIENCY AND USE OF RENEWABLE ENERGY SYSTEMS

It is generally recognised that people spend big part of their time indoors. Indoor environments are highly complex and building occupants / users may be exposed to a variety of contaminants, in the form of gases and particles, produced inside or outside the building. Other factors such as indoor temperatures, relative humidity, and ventilation levels can also affect the good indoor air quality. In energy-related renovations the indoor conditions should be increased into acceptable level. In some cases, when energy consumption is tried to be minimized, indoor conditions can be worsened. Healthy and safe indoor environment cannot be compromised in order to favour the reduction of energy consumption. Energy-related renovation is, mostly and mainly, a compromise between the technical solutions and available financial direct or indirect resources.

A key challenge for nZEB renovations solutions in Southern European countries is to ensure the environmental comfort without the use of significant energy for cooling. Furthermore, in those countries the energy efficiency improvements are based mainly on building damages or on impaired performance (poor or insufficient indoor environment) and lack of functionality, as well on the change of use. The repairs improving energy performance have been carried out mainly in that connection.

Design intentions of public building stock depend also in some cases on the unwillingness of designers and professionals to move away from traditional forms of renovation. This is also due to the lack of expertise and knowledge on technical solutions to achieve nZEB standards in renovation projects. In most cases, renovation measures are based on incomplete information, which can be replaced and supplemented by modelling the building. The trend is toward remote-controlled buildings in facility and energy management and there must be an opportunity to collect proper data from the buildings.

In energy renovation design process the first step is to define the actual condition of the building by performing an energy check. Optimally, the consumption figures from at least 3 previous years as well as building documents and information about structures and equipment should be available. This is not always possible due to missing data or documents that have not been updated. Most often we only know the total consumption of electricity but its distribution for the different uses (lighting, HVAC systems etc) cannot be measured or is unknown. The heating energy consumption, heat losses and their distribution for different elements (i.e.: windows, walls, etc.) can be evaluated using the existing data and calculation tools. It is also useful to estimate the optimum consumption under prevailing conditions – what can be achieved with the existing systems and what are the goals of building titleholder. Especially the documents (existing drawings, previous data, etc.) of relatively old buildings can be lost, inaccurate or can include incorrect and dated information. All the documents should be updated in renovation project matching the recent situation and should be converted also into electronic format. The documentation of the renovation project is an essential topic.

In energy-related design the goal must be defined and compared with the recent situation – what is the realistic saving potential and what measures dealing with building envelope and heating, cooling, ventilation and building automation system (if this exists) can be done. It is essential to determine the titleholder requirements. To meet these requirements, it is necessary to find various technical solutions to realize them and also calculate the investments needed and the payback time.

Often the renovation project must be phased for several years on, when it is important to take the right measures at the right time. Indeed, the renovation measures can be divided into period of longer time, if needed. Also the order of the renovation is very important – what must be done at the first stage and what later. This is critical especially in nZEB-buildings, when the financing resources are limited and the goal is to have optimal energy efficiency.

There are many factors affecting the performance and the energy efficiency of a building and those factors influence each other.. We can speak about “renovation debt” which means how much be invested so that the performance level of a building would be in a proper level, (about at least 70-80 % of the performance level of a new building). If there is no available funding to increase the performance level, the life cycle of a building will be shortened, and in the worst case the building must be demolished. That´s why the short- and long-time maintenance works must be planned very carefully.

Together with the technical solutions, the financial options will play a significant role, when planning energy-related renovation. The renovation project must be seen as a complex process, to be developed and managed using special tools, such as the Building Commissioning

(Cx)-procedure. The Building commissioning is a methodology, ensuring that the building meets the requirements and performs “as designed”. It is a systematized quality assessment of the building process/project which covers the whole life cycle of a building from pre-design to use stage. This can be verified by titleholders and by controlling in each stage of the project that the process is going to the right direction. It is also very important that the performance of the building can be monitored during the use stage. In renovation the instrumentation level - numbers of meters and replacing the sensor (if needed) must be improved, that there is data enough available for building titleholder, maintenance staff and for other stakeholders. The measured raw data must also be converted into useful information (analyse and reporting). A lot of data from a building can be collected, e.g. based on the building automation system to run the technical systems properly, but from facility and energy point of view there must be useful information available for stakeholder´s needs – raw data is not such an information before it has been analysed and processed.

The most important topic is a proper planning and project management. The renovation of an old building – especially when the goal is to meet much lower energy consumption levels – needs a good project management, different but complementary areas of expertise, well-organized and cooperative teamworks. The costs should be kept in the budget estimates (provided that the budget has been prepared realistically). The maintenance costs of a building may be even higher in longer run than investment costs (depending on the calculated life-cycle period). This means that the investments should be counted based on life-cycle evaluation.

Building renovation is the result of a process, with the aim of achieving a good indoor environment and optimizing energy consumption. All measures concerning building envelope as well as technical systems and equipment are serving to this goal. That is why there should be no compromise between indoor conditions and energy savings – the aim is to optimize the use of energy, always ensuring healthy and safe indoor environments. There are examples showing that that the minimization of the energy consumption (e.g. decreasing the running time of ventilation) can lead to problems in indoor air quality.

THE TECHNICAL STEPS OF AN ENERGY RELATED RENOVATION PROJECT CAN BE DIVIDED BY THE FOLLOWING WAY:

- **Energy Audit and Condition survey:**
  - Collection and analysis of available documents and other information
  - Execution of additional measurements that may be needed (air tightness test, thermography, air flow measurements etc.)
  - Renovation plans based on life-cycle evaluation and sensible payback times
  - Identifying interventions with the best cost/effectiveness ratio and final design
- **Realization of the energy-related renovation**
  - Building Commissioning tools in each stage of the project: performance as designed
- **Evaluation and verifying the results**
  - Establishment of performance indicators

A.1.1 BUILDING ENVELOPE: CONSIDERATIONS

The public sector manages a wide variety of buildings of different ages, sizes and uses. The envelope renovation of these buildings greatly depends on the construction technology as well as on the kind of use, such as representative buildings (frequently listed), offices, schools, libraries, cultural centres and other public service buildings. It sometimes happens that the same building hosts different functions. In addition, the envelope renovation is affected by the building location and climate, the building function and the specific local rules and laws. These assumptions lead us to reinforce the concept that each renovation design and work is in large part unique and unrepeatable, and that must be tackled case by case.

In many parts of Southern Europe, especially where the climate is particularly warm the level of public building insulation is not effective, or many buildings have been constructed without any insulation.

The majority of Southern European countries public building stock was built when there was not yet any legislation on the reduction of energy consumption. (i.e.: for Italy that date came on 1976, in Greece 1981, in

Portugal on 1990, in Spain on 1980). The energy performance of these buildings envelope has been neglected, as many of them are still leaky, have no insulation or exterior shade control, have single-glazed windows and absorbing roofs in hot climates.

It is precisely these buildings that needs the implementation of energy efficiency measures in order to reduce energy consumptions.

A.1.2 OPAQUE BUILDING ENVELOPE RENOVATION DESIGN

The building envelope is in most cases the most important source of heat losses, but the building must be considered as a holistic unit and also other systems effect on the performance of building envelope. Before choosing the renovation measures it is useful to have an overall review for the various options to reduce energy consumption and the role of building envelope in it.

The main steps for the reduction of energy consumption are:

- **TO IMPROVE THE PERFORMANCE OF BUILDING ENVELOPE:**
  - by additional insulation
  - tightening the envelope to avoid uncontrolled air flows and infiltration by increasing airtightness
  - by changing windows and using shading systems

Reducing thermal bridges and improving the performance of building envelope by insulation

Increasing the insulation level of the envelope represent mostly a key strategy to improve building performance as the additional insulation has the largest impact in reducing consumptions and on the thermal comfort. It is important to have a continuous and constant thickness boundary of insulation materials as lacks of continuity, gaps and/or voids could provide paths through which air can flow.

The additional insulation can be installed on the outside of the building walls or the inside. The third option is to fill the air cavity, if the air gap exists. In all cases the heat and mass transfer conditions will be changed. This is important especially when there is a possibility of water vapour condensation: when water infiltrates from indoor to outdoor it can condensate, if the indoor temperature is higher enough compared with the outdoor temperature. Condenation can also occur if there are air leak routes in the exterior wall and the outdoor temperature is higher than indoor temperature with high humidity (in case of cooling for instance).

The pros and cons of external walls insulation:

Additional external wall insulation is the most commonly used energy-related renovation measure dealing with solid external wall. In many European countries, installation of external additional insulation is productized and often supported by the financial system. Replacement of windows belongs to the same concept.

The costs of external additional insulation, including scaffolding and other auxiliary works must be compared with energy savings; in some cases, the pay-back time may be relatively long.

External additional insulation covers also thermal bridges of wall structures. The air-tightness of the envelope will increase, and the heat losses caused by infiltration will decrease. External insulation will thicken the wall structure, so the roofing must be able to operate properly, and there must be space enough for eaves. If the structures of external wall are flat, the installation can be carried out relatively easily. There are various technologies and solutions for installation. Generally the insulation layer and external board is coated by plaster, and the color of the plaster influences on the performance of the wall. According to the current practices, light colors absorb less heat and avoid micro-cracks which shorten the life of the wall.

Additional external insulation cannot be installed, if the building and it`s facades have remarkable historical value or if the building is listed, which means that the ‘aesthetical case’[1] of a building may not be changed. Depending on the original structures and the height of the building, some strengthening for insulation solutions may be used. Furthermore, depending on the national legislation, if the building is facing public pavement or road, the increase of the wall thickness on the exterior can be considered as an encroachment on public space.

[1]aesthetical case’ refers to the aesthetic value of the artwork

By using additional insulation, it is possible to reduce also the effects of thermal bridges due to the improvement of the air-tightness and achieve energy savings. The common practice is to halve the U-value but it is possible to reach lower U-values, too. The costs of external additional insulation, including scaffolding and other auxiliary works can be compared with energy savings; the pay-back time may be relatively long in some cases. In addition to the improvement of energy efficiency the additional insulation decreases risk for structural damages. In some cases, the repair of structural damages may be the most important reason for carring out these measures.

In conclusion, in an energy renovation project a systematic and comprehensive approach should be adopted even though the renovation works will take place in several stages.

PROS:

- **MINIMISING DISCONTINUITY OF INSULATION MEANS REDUCTION OF THERMAL BRIDGES, BETTER U-VALUE, BETTER AIRTIGHTNESS, NO CONDENSATION ON THE WALLS, MORE EVEN TEMPERATURE IN NDOOR ENVIRONMENT**
- **INCREMENT THE WALL'S ABILITY TO WITHSTAND THE VARIOUS CONSTITUENT ELEMENTS, IMPROVEMENT OF THE EXTERNAL ASPECT OF THE BUILDING**
- **PREVENTION OF THE DAMP DAMAGES, REDUCTION OF NOISE, AND NO IMPACT TO THE BUILDING USERS.**

CONS:

- **OUTLOOK OF FAÇADE MAY CHANGE, INSTALLATION PROBLEMS MAY OCCUR, ESPECIALLY IN TALL BUILDINGS, THICKNESS INCREASE, OFTEN NOT ALLOWED IN LISTED BUILDINGS.**

The pros and cons of internal insulation:

Internal additional insulation is also used relatively often, depending on the building type. The biggest difference compared with external insulation is that, the insulation layer has not continuity. It means that e.g. the junction of an outer wall and the floor (or the ceiling) forms a thermal bridge. If the heat flow through walls decrease, the heat losses through this junction relatively will increase, which may cause problems (draft, condensation etc.) especially if there are air leak routes.

The room size will be decreased if one outer wall is insulated. This reduction of floor area is not so significant but the occupant or user can experience it as such. Also the installations of heating system, like radiators and pipelines may cause a problem for insulation. The appearance reasons especially in historical buildings can preclude the use of internal insulation. Internal insulation is a cheaper solution compared with external insulation, so pay-back time could be shorter. The downsides are discontinuity, remaining of thermal bridges and uncertainty of possible air leak routes, if sealing works have not been done in the same connection. To optimize the thermal performance of the building envelope all the structural elements of outer walls that affect the performance must be taken into account. When internal insulation is installed, the temperatures of outer parts of the wall will decrease. This may cause some moisture problems in cold season because of slower drying. In case of external additional insulation, the wall temperatures will increase compared with the previous situation.

PROS:

- **RELATIVELY EASY TO INSTALL IN MOST CASES, NO IMPACT ON THE EXTERNAL APPEARANCE OF THE BUILDING**
- **NO ADDED SCAFFOLDING EXPENSES ASSOCIATED WITH INTERNAL INSULATION APPLICATION.**
- **PAYBACK TIME SHORTER IF COMPARED WITH EXTERNAL INSULATION.**

CONS:

- **FLOOR AREA WILL BE REDUCED**
- **THERMAL BRIDGES MAY REMAIN, (RISK OF COLD BRIDGING AT THE WALL-FLOOR JUNCTION IF THE INSULATIONBETWEEN THE FLOORS UNLESS IF THE INSULATION IS NOT RUNNING UNINTERRUPTED DOWN THE WALLS).**

The pros and cons of the air cavity insulation

The external walls may have also air gap, which are acting as ventilation space for the structures. In the case of renovation, the air gaps have often been filled using insulation materials. his technique improves the performance of the wall, and its size remains the same.. No changes in the appearance of the building. here is also a possibility that due to the decreased air exchange – depending on the structures – and the decreased outer wall temperatures can cause moisture problems can occur. The filling of air gap must be analysed very carefully case by case.

PROS: NO CHANGES IN WALL SIZE

CONS: MASS TRANSFER PROPERTIES CHANGES,DUE TO NARROW GAPS AND INSULATION LAYERS

The insulation materials

The most common insulation materials can be divided into mineral wools and plastic foams. Mineral wools include stone and glass wools. The most used plastic foams are EPS (expanded polystyrene foam), XPS (Extruded Polystyrene foam) and PUR (polyurethane). PUR has the lowest thermal conductivity, it means that to achieve the same U-value. PUR has the thinner insulation layer than the other materials.

The insulation materials are sold in plates or loose-fill products. In northern Europe, where the insulation practice and the better energy performance have a longer tradition because of the rigid climate conditions, also pulp wool (cellulose-based insulation material) has been used (loose-fill). Advanced insulation materials have been tested, such as transparent insulations and some new type of materials, but all these new products are in the development stage and frequently not commercially available. When selecting an insulation, the safety and fire regulations must be taken into account, because one task of the building envelope is fire safety.

Figure 1: Insulation products in Flax Fibres, made from organically grown plants, non-polluting and of low energy demand, totally recyclable, biodegradable and compostable, durable and lightweight. They are characterized by their high stiffness, for the ability to attenuate vibrations and for low density compared to other fibres. They are excellent thermal and acoustic insulation materials,, eco-friendly and with a low wear level. Flax Fibres can be used to insulate roofs, floors and to create ventilated roofs and ventilated coats.

Further information on: http://www.certus-project.eu download area_Catalogue

Insulation is based on a still air, i.e. insulation material contains pores filled with air. If air leakages are not blocked, mineral wool will lose part of its insulating properties.

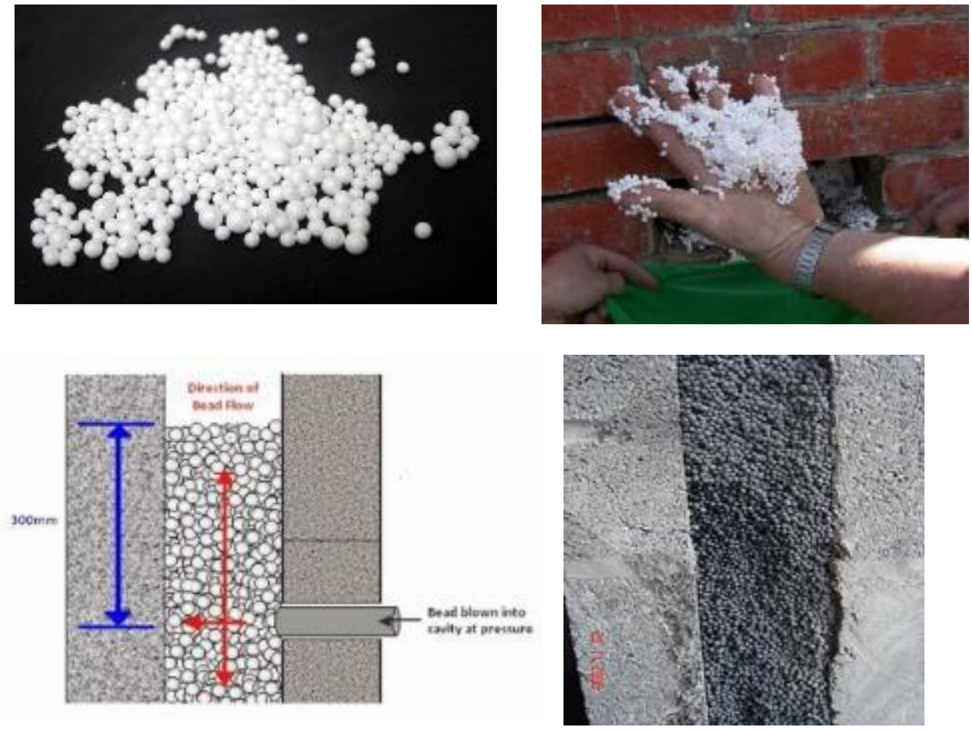


Figure 2: Polystyrene is a very common insulator, but used as beads you can easily fill the cavity of an existing facade improving its insulation. The polystyrene beads are injected into the cavity of a wall with a bonding agent through little holes made on one side of the facade . The beads and adhesive solidify to form an insulating barrier and this significantly reduces the amount of heat lost through the walls.

Further information on: http://www.certus-project.eu download area_Catalogue.

When renovating, it is important that the installation is made properly and that the uncontrolled air infiltration is avoided. In this connection the performance of the external wall must be verified; vapour barrier (if it is needed to be used) must be in a proper position and well installed, as well as the placement of wind shield. If the air and moisture are infiltrating the wall (wind, rain), they will cause damages in longer run and degrade the insulation.

Optimum thickness of the envelope external insulation

The optimum thickness of the envelope insulation depends on a large number of parameters, such as climate and micro-climate conditions of the location, exposure and orientation of the building as well the indoor heat loads. The optimum thickness of the envelope insulation can be calculated: within CERtuS renovation options the additional external insulation thicknesses have been investigated from the energetic and economic point of view. There are lots of different calculation tools available to evaluate the optimum thickness. This optimization details given in the following sub-chapter A.1.5

Opportunities to replace the additional insulation of facades

If the additional insulation of facades is not a viable choice, available, there are other opportunities to replace this option. These options can be evaluated by using energy efficiency calculations. Also in this case, there are various energy efficiency calculation tools available in the market. The aim is to reach the same level of energy savings by using other technical solutions.

Often the efficiency of ventilation by improving the heat recovery of the ventilation system, by optimizing the running time of ventilation, by adjusting the rate of air exchange (if the rate of ventilation is higher than needed). There may be also an opportunity to increase the insulation of attic. The insulation of attic using blown loose wools is a fairly inexpensive way.

Also, the change and/or coating of windows could come in question if additional external insulation is not possible. If external insulation is excluded, is possible to install internal additional insulation.

In many cases the replacement of additional insulation must be compensated by many separate operations. By anticipating concepts which will be developed in the next sub-chapters, but strictly connected with the topic, hereinafter are described some possibilities.

An option is to decrease the use of electricity, e.g. by changing lighting system to less energy consuming lamps (LEDs), or decreasing the electricity consumption by other means. The change of lighting elements also will decrease the heating load which must be taken into account (decreasing internal load compared with light bulbs. Also the use of distributed energy production, like adding solar water systems, solar panels for electricity production, utilizing wind energy and increasing the efficiency of cooling systems (if exists). Moreover, the set point adjustment of building automation and control systems can bring 5-10 % savings in the best cases. In all cases the tuning of the systems should be checked. The use of various separate solutions may generate results which meet the requirements. The aim is to reach the same consumption reduction that would occur with the additional insulation, by implementing alternative savong measureswith, if possible, the same payback time..

The strategy to be adopted is to optimize the performance of the building, the energy consumption and the indoor environment through proper metering and reporting systems.

A.1.3 Transparent building envelope

How transparent elements contribute to heat losses and solar gains.

Transparent insulation

The use of transparent elements can be considered an option in some special cases. If there are room spaces which need lot of daylight but also require reducing heat losses, measures on transparent elements can be an alternative.

The commercial use of transparent insulation elements is still in an early stage, although technical solutions fpr transparent insulation are available. Depending on the price, there are several targets for transparent insulations and in some special cases the use of transparent insulation may be considered.

Utility and ventilation purposes especially in Mediterranean climates

The essential topic is to have a proper rate of air exchange and indoor conditions. If the indoor temperature will be kept at the appropriate level, cooling is needed. The cooling load and power supply should be optimized: the need of cooling load is depending on heat losses through windows and walls, the reflectivity of windows, the rate of ventilation and the efficiency of ventilation (which means that the air exchange must cover the whole room area in question) The first topic is to optimize the need of cooling, the second issue is to have an efficient cooling system. In various countries there are requirements for indoor temperatures – many studies show that the work efficiency decreases if the room temperature exceeds a certain level.

The passive use to control the daylight is important, e.g. by coating the windows and also by shading. Active daylighting, anyway, decreases the need for electricity use.

The simultaneous cooling and heating demand must be prevented. This is a rather common finding of energy audits.

A.1.3.1 Windows

The change of windows is one of the most used renovation measures. In the old building stock, the U-value of windows may be very high and condition and performance can be very low. The U-value of old windows is much higher than the U-value of existing wall, and even after the renovation the thermal resistance of windows can be lower than the remaining part of the building envelope.

There are high-performance windows available in the market, which can also reduce the effect of solar radiation and the need of cooling load. The installation of external shading can be carried out together with the change of windows or can be realized separately. Also the lighting conditions are depending on windows, but in renovation the open area of windows do not significantly increase, if new window opening (e.g. on the roof) have not been designed. The reasons for the change of windows are below summarized:

- to improve the thermal performance of the building envelope and reduce heat losses through the windows
- to reduce cooling load by coatings
- to decrease air leak by better tightness

If no changes occurs in ventilation system, both natural and mechanical, the air supply must be ensured to be taken without draft and properly.

The change of windows must be planned carefully also if there are some limitations in changing the look of the facades. The option of the window change is repair and refurbishment (e.g. new sealants etc.). The payback time of investments must be evaluated case by case. The impact on indoor environment and thermal comfort must be taken into account, too.

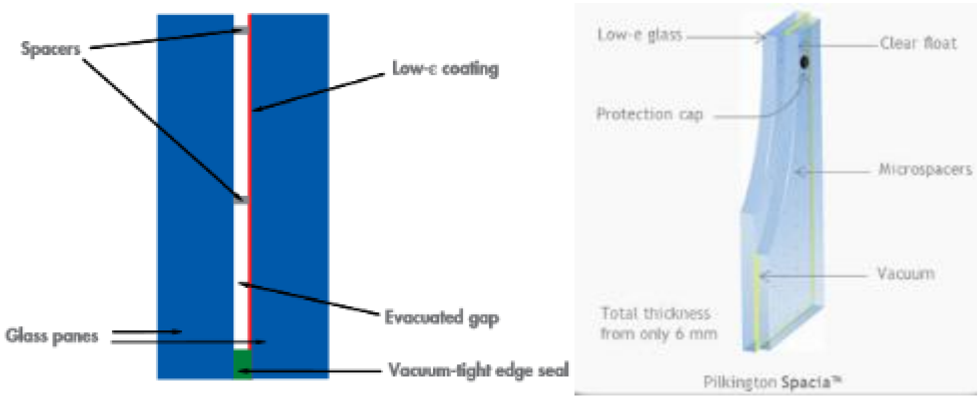


Figure 3: Vacuum glazing or Vacuum Insulated Glass (VIG) consists of an outer pane of low-emissivity glass and an inner pane of clear float, with a vacuum rather than air or another gas in between. The result is an excellent thermal performance from a unit only fractionally as thick as a standard one

The best condition to use this product is to change only the glazing of a well preserved wooden frame window because almost always it will not be necessary to modify the window frames which have good enough thermal behaviour. In other cases it will be necessary to change the whole window.

Further information on: http://www.certus-project.eu download area_Catalogue.

A.1.3.2 Better U-values and radiation shield

Air leak prevention

One major source of energy loss in a building is air leakage. Air leaks also makes the ventilation control more difficult, because they are uncontrollable. If the building has natural ventilation, the air supply must be properly managed mainly through air supply units located in the window frame (or in the walls). Windows must be tightened, so the air supply routes must be arranged. In mechanical ventilation with heat exchange the air supply can be heated by exhaust air; in mechanical exhaust and natural ventilation there is no heat exchange between supplied and exhaust air. A special attention should be paid to the quality of the supplied air, which may contain impurities.

Windows play a very important role in meeting energy saving targets during building renovation. Air leaks may cause feeling of draft and to avoid it, the most common reaction is to increase the room temperature, with the consequent increase in energy consumption

Serviceability and cleanability are other important factors to be considered when choosing new windows.

Description of window types and their effectiveness

Windows can be divided into different types depending on the number of panes: 1-, 2- or 3-pane windows. Two-pane window can be a thermal window, if there is a gas filling between the panes. The windows can be coated by reflective coating or filter-type coating. Also in the case of windows, the performance calculations should be carried out to select the most suitable window type. The other important thing, in addition to U-value, is how the windows are installed.

A.1.4 Verification of performance

When the building performance requirements have been set, there must be a procedure and tools to monitor and verify the performance during the implementation process and during the use stage. Otherwise there is no way to see the new performance level, to compare it with the previous figures and to evaluate savings.

There are systematic procedures for performance and quality control: the Building Commissioning (Cx) is a method for optimizing energy performance in building renovation projects. It ensures that building systems meet the design intent, operate and interact in the best way and run according to the owner‘s needs. Building Commissioning-procedure is a holistic quality assessment method covering the whole life-cycle of a building. The key issue is the metering level of a building. The renovation process can be compared with an industrial process, which is constantly monitored by various measurements, analyses and reports, with the aim to have the planned production.

It is necessary to provide the building by a requisite metering, also in aim to monitor energy consumption and indoor environment. Normally the instrumentation of Building Automation System (BAS) is for proper operation of building services and these installations will not serve the facility management needs as much as it could do.

The metering planning is one part of a successful energy-related renovation. In addition, some in-situ measurements and operations are needed for renovation design and also to verify the performance during implementation and use stages. The measurements and monitoring can be one part of BIM[2] (Building Information Model).

Air tightness test

The air tightness of the building envelope can be verified before and after renovation by air tightness test. It can be done concerning part of the building or the whole building. There are two main ways to undertake air-tightness test:: blower door(s)[3] or using the own ventilation system. The use of ventilation system has some limitations; it needs to have frequency-controlled fans to control the air flow or, at least multi-stage controlled fans.

The principle of air tightness test is to cause a pressure drop between outdoors and indoors by using the so called blower doors.

According to the standards, 50 Pa negative and positive pressure drops over the envelope must be caused, and measure the air flow which maintain the pressure drop. This average air flow at +50 Pa and -50 Pa pressure drop will be divided by the measured area (q50) of the building envelope or by the measured indoor volume (n50). The results, q50 or n50 (the value of both is marked 1/h, air changes per hour) presents the air tightness level. The method is standardized.(EN 1329). The air leak routes can be located and defined by thermography and by smoke tests. The use of thermography requires a sufficient temperature difference between indoor and outdoor.

When using the ventilation system of the building

Frequency controlled fans mean that the rotational speed and the efficiency can be changed stepless. The needed pressure drop can be organized by stopping the air supply fan/s (negative pressure drop over the envelope) or the exhaust fan/s (positive pressure drop over the envelope. By changing the pressure drop and measuring the air flow needed to maintain the pressure drop it is possible to create air flow curve and define the air tightness value at 50 Pa pressure difference.

[2] Building Information Model is a whole-time data of the building and construction process throughout the life cycle in a digital format.

[3] One system or more units.

Other tests

One of the most important tests is the building thermography. It is based on thermal radiation whose intensity is proportional to the surface temperature of the target. The thermal bridges and heat losses can be detected by thermography but, again, there must be a large enouph temperature difference when thermography can be used (10°C). Also the outdoor weather conditions must be stable enough before performing the thermography, especially sun radiation and heavy wind will cause limitations for outdoor thermography otherwise they may cause problems to carry out the measures. Building thermography is controlled by ISO- and EN-standards.

Thermography is normally carried out both inside the building and outside of the building. The operator must be qualified because the method itself – especially now when the prices of devices have gone down – seems to be deceptively simple but actually the scanning and the interpretation requires high expertise. Indoor (and also outdoor) thermography can be carried out by two stages: in normal operational conditions and in pressurized (outdoor) / depressurized

Following, some investigations concerned the north and the east side of the building Monte dei Pegni, located in the historic center of the City of Vittorio Veneto (TR), Italy. The building was an apartment building, but it has been planned to change to residential and offices use. The building had natural ventilation system and water circulation based radiator heating, partially fan coils.

The measurements showed that the exterior wall structures varied a lot also in case of the same buildings. Subsurface constructions, covered openings, thermal bridges, uneven structures etc. were found. Some of these findings have been taken account into renovation design.

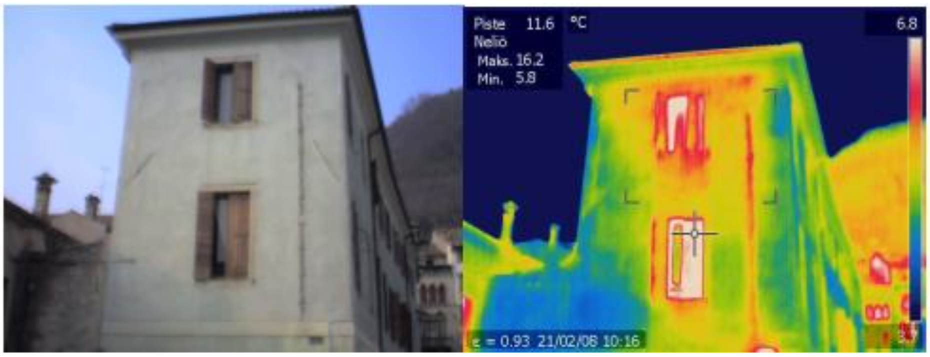


Figure 4: Thermal image applied to detect discontinuities beneath the surface, using an inclusive range among 3,7° and 6,8° for the thermographs staircase. It is possible to see a different superficial temperature of materials for that heated places internally. Every combination of masonry structure type to be investigated needs e specific IR calibration.

Figure 5: Moisture distribution and moisture growth detected by thermal scanning.

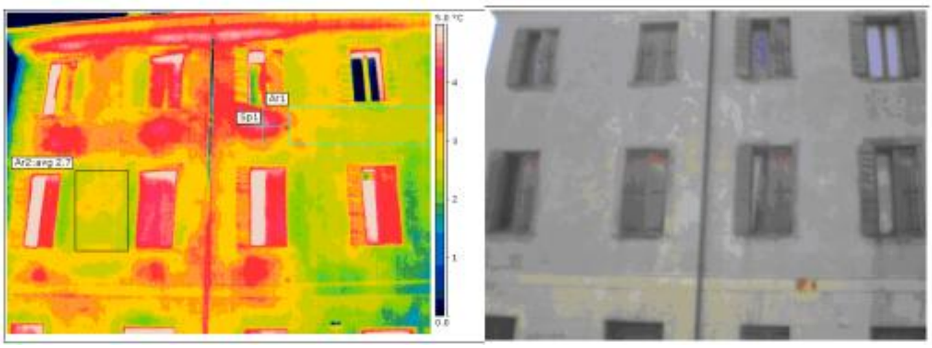


Figure 6: The upper part facade in the morning, before the sun. The radiators and also the intermediate floors, walls both pipelines are visible.

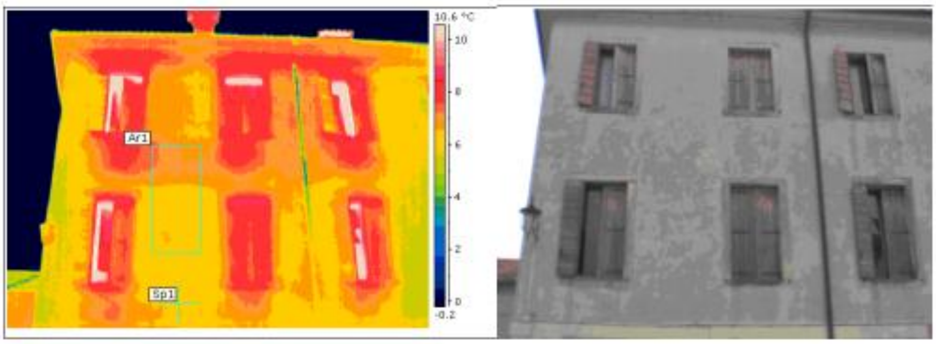


Figure 7: The same facade during sun radiation. The external heat source removes the structural details.

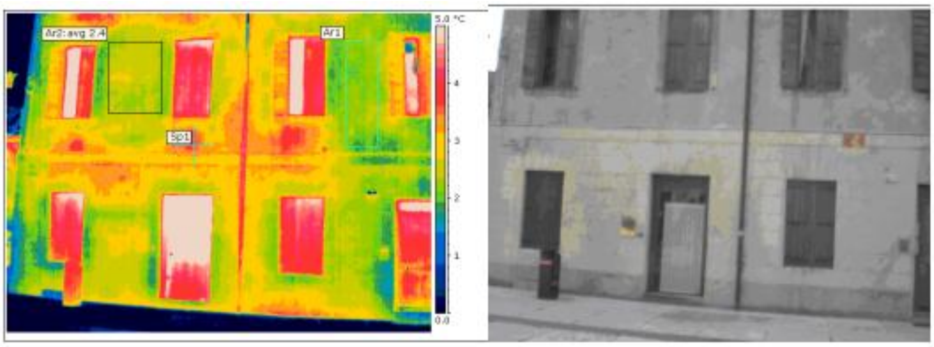


Figure 8: Lower part of the facade in the morning. An earlier door place can be seen between the window and the door.

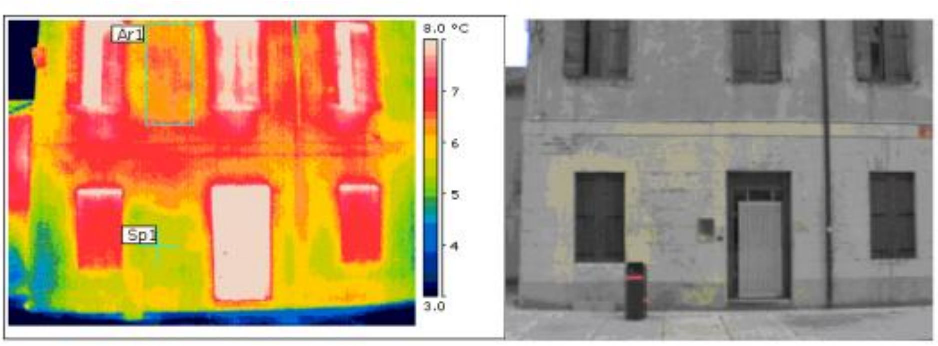


Figure 9: Lower part of the facade during sun radiation. The earlier opening in the wall cannot be seen.

There are also other tools to measure the performance of building envelope – a method is to use heat flux meters, by which is possible to determine the U-value of a wall, supported by thermography. The method gives an approximately value and it has restrictions too.

The thermal scanning must be done before the sun begins to effect on the surfaces. The measurements can be repeated during the heating up period and then during cooling down period – during heating and cooling delamination structures and different structural elements can be seen, depending on the differences of thermal capacities. Using dynamic thermography in changing conditions it is possible to detect delamination phenomena and in some case also moisture distribution in the structures.

Cx-Building Commissioning

The in-situ measures before and after renovation, the planning of additional instrumentation and monitoring, reporting development and other performance related actions can be part of systematic Cx (building commissioning procedure), which means that the building will meet the expected requirements – performs “as designed”. It is very important that the titleholder needs have been set by proper way and they will be monitored. The building titleholder can also set of Key Performance Indicators which describe the performance of the building. By monitoring these indicators, facility managers and the maintenance personnel can view how well the objectives of the renovation options are achieved. This also means that the instrumentation –metering- of the building will be designed and installed before the renovation (if some extension or additional meters are needed.

For commissioning of building envelope, the commissioner can utilize various checking lists, which are available in the Cx - literature. It is divided into commissioning of design intents and design details and then verification during the construction phase. It is quite usual, that the lack of building envelope performance problems are caused already by design errors – the details effecting on thermal performance of building envelope must be recognized and also must be brought to plans and worksite so that there is no misunderstanding. Also the verification of the performance of building envelope must be checked during the construction works paying attention to possible performance-debilitating topics (e.g. tightness, thermal bridges, insulation defects etc.)

Key performance indicators depend on the type and use of a building. If they are defined, it is easier to install the meters for monitoring or complete the existing instrumentation. Nowadays there is lot of opportunities for wireless sensors and data collection be relatively less-expensive techniques. It must be pointed out that increasing the measurements does not increase the information from the building; the raw data must be collected from the right points and, it is very important, to filter and process, convert and analyse the collected data. By that way the stakeholders can have good and proper on-line information about the performance of the building. This will set some demands for reporting. This is forgotten many times; there is no use of raw data if it is not processed for the customer`s needs. The question is “manage by information”. The monitoring process and the solutions to verify the performance, as well as the final results must be seen as a one essential topic of the energy renovation. The decreasing of energy consumption level without compromising the indoor environment must be a final goal of the renovation. Also the increasing technical conditions of the building (i.e.: by repairing damages etc. and by rising the indoor air quality and the thermal comfort to the new level) are very important results even the energy consumption figures and performance are not being fully in theoretically planned level.

A.1.5 Example of energy demand reduction on the opaque envelope: Alimos City Hall, Municipality of Alimos, Greece

The pilot building of Alimos City Hall is located close to the sea, in the South eastern part of Athens Metropolitan area. The building was built in1986. The aim of the renovation design is to achieve nearly zero energy consumption ensuring thermal and visual comfort as well as impeccable functional conditions.

The envelope of the investigated building is composed of double brick walls and reinforced concrete for the load bearing structure. Walls are insulated with 4 cm of extruded polystyrene placed between the two brick layers. Roof slab are insulated with 4 cm of extruded polystyrene. There is a mineral fiber suspending ceiling on each floor.

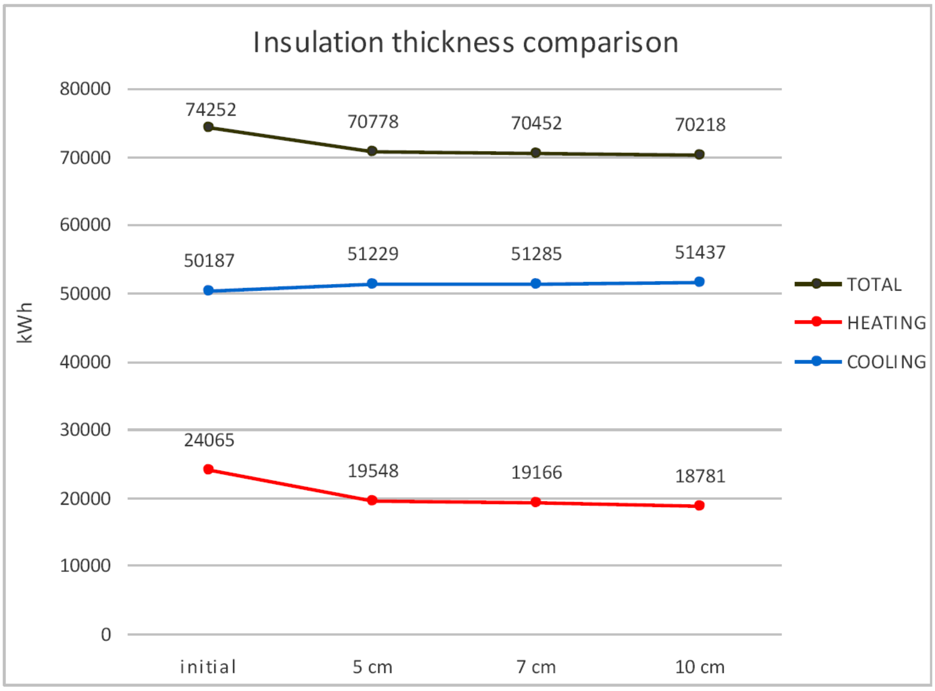
The building envelope is in good condition but it has significant thermal bridges that increase the current overall U-value of the opaque part, by about 30%. This is due to the type of wall construction (insulation in between the two brick layers) that makes the avoidance of thermal bridges difficult.

Therefore, the addition of external insulation was investigated as a means to improve the current conditions. Its impact on the year-round energy performance of the building was modelled by means of the simulation code. For modelling purposes, an insulating material with 0.032 W/mK thermal conductivity was considered.

Three different values of thickness, namely, 5 cm, 7 cm, and 10 cm were successively studied. As it can be seen below, by applying 5 cm of external insulation there is an annual decrease in heating of 4,517 kWh,. Any further increase of the insulation thickness does not significantly affect the energy consumption. Additionally, the installation of 10 cm would require not only an extra budget but extra structural works in order to be adequately supported. Thus, the most suitable option is the addition of 5 cm external insulation of 0.032 W/m^{2}K. Any other equivalent combination is equally suitable. The situation is clearly depicted in the below figures concerning the insulation thicknesses comparison for the three buildings.

Furthermore, the addition of investigated external insulation reduces the U-value of the walls from 0.526W/m^{2}K to 0.272 W/m^{2}K and the U-value of the roof from 0.451 W/m^{2}K to 0.250 W/m^{2}K.

	Before	Retrofit	After Retrofit	
	Heating	Cooling	Heating	Cooling
Consumption (kWh)	24,065	50,184	19,548	51,229
Savings (kWh)	-	-	↓ 4,517	↑ 1,045
Savings (%)	-	-	↓ 19%	↑ 2%



: ENERGY PERFORMANCE ACCORDING TO DIFFERENT WIDTH OF INSULATION

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(S.F, E.M, A.G)

A.2 THE USE OF ENERGY EFFICIENT HVAC-EQUIPMENT, LIGHTING SYSTEMS AND OTHER INNOVATIVE AND NEW TECHNOLOGIES FOR ENERGY EFFICIENCY

A.2.1.1 HVAC

HVAC (Heating, Ventilating, and Air Conditioning) is the technology of indoor and vehicular environmental comfort. Its three central functions (heating, ventilation, and air-conditioning) are interrelated, especially with the need to ensure thermal comfort and indoor air quality.

Heating

A heating system contains a boiler, furnace, or heat pump to heat water, steam, or air in a central location. Such heaters can use different types of fuel, including solid fuels, liquids, and gases. Another type of heat source is electricity, which was traditionally used to heat resistances, but also used in heat pumps that can extract heat from various sources, such as environmental air or from the ground.

Heat distribution can be made through water and steam or air. In the case of heated water and steam, piping is used to transport the heat to the rooms. Most modern hot water boiler heating systems have a circulator, which is a pump, to move hot water through the distribution system. The heat can be transferred to the surrounding air using radiators, hot water coils (hydro-air), or other heat exchangers. The heated water can also supply an auxiliary heat exchanger to supply hot water for bathing and washing.

Ventilation

Ventilation ensures the changing or replacing of air in any space to control temperature or to remove any combination of moisture, odour, smoke, heat, dust, airborne bacteria, or carbon dioxide, and to replenish oxygen. Such system is one of the most important factors for maintaining acceptable indoor air quality in buildings and it includes both the exchange of air with the outside, as well as circulation of air within the building.

Methods for ventilating a building may be divided into natural and mechanical or forced types:

- Natural ventilation - is the ventilation ensured with operable windows, louvers, or trickle vents when spaces are small and the architecture permits.
- Mechanical or forced ventilation - is provided by an air handler, fans or other mechanical systems and is used to control indoor air quality.

Air Conditioning

A central air conditioning system provides cooling and humidity control for all or part of a building. Air conditioned buildings often have sealed windows, because open windows would work against the system intended to maintain constant indoor air conditions. Outside, fresh air is generally drawn into the system by a vent into the indoor heat exchanger section, creating positive air pressure.

There are two main types of air conditioning systems:

- Split systems are fixedly installed and consist of at least two units. The outdoor unit contains a compressor and condenser. The indoor unit contains the evaporator and can have different shapes and it can be placed on the ceiling, wall, floor or in a canal.
- Multi-split systems combine two or more indoor units with an outdoor unit. The indoor units can be placed in different rooms.

A.2.1.2 Efficient Technologies

In Europe, HVAC systems represent about 40% of the energy consumption in commercial and residential buildings[4]. Developing energy efficient HVAC systems is essential, both to protect consumers from surging power costs and to protect the environment from the adverse impacts of greenhouse gas emissions caused by the use of energy-inefficient electrical appliances. Therefore, a wide range of

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[4] Constantinos A. Balaras, Gershon Grossman, Hans-Martin Henning, Carlos A. Infante Ferreira, Erich Podesser, Lei Wang, Edo Wiemken, Solar air conditioning in Europe—an overview, Renewable and Sustainable Energy Reviews, Volume 11, Issue 2, February 2007, Pages 299-314, ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2005.02.003.

different technologies and strategies for HVAC energy savings have been developed.

Figure 10 presents the main strategies to improve the performance of HVAC systems in order to reduce energy consumption. As can be seen, such technologies can be divided in Vapour Compression Systems (including Air-Cooled, Water Cooled and Ground-Coupled systems), Evaporation Cooling Systems and other configurations.

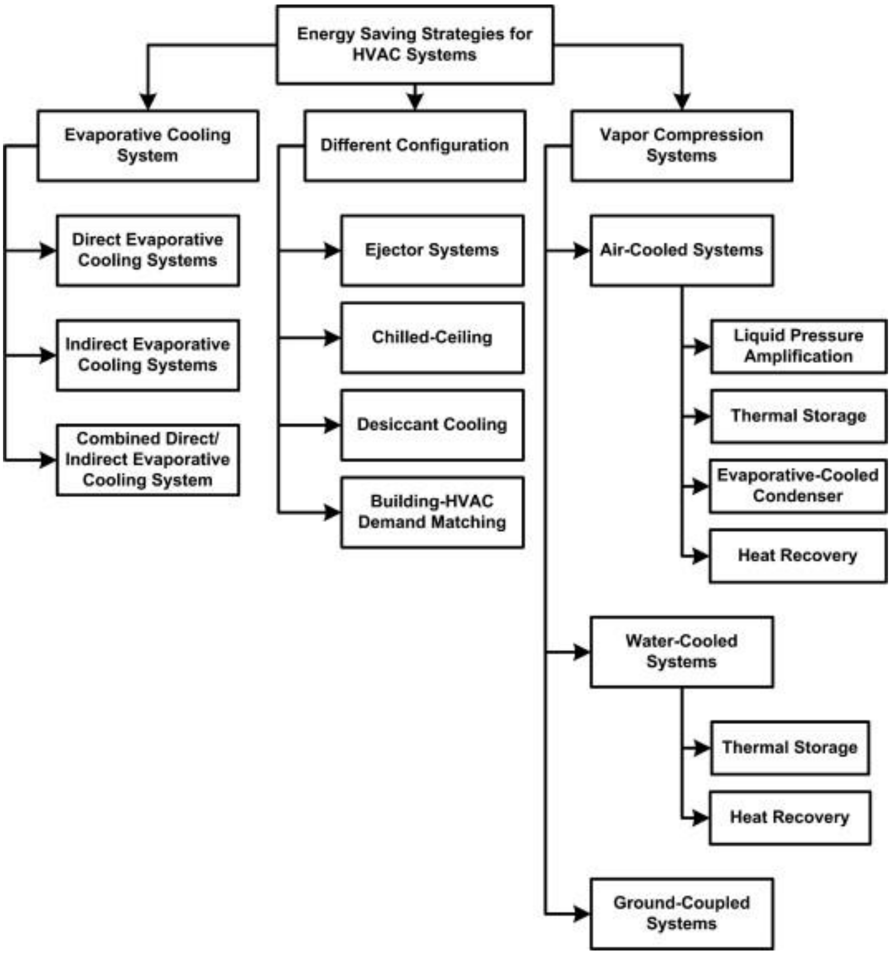
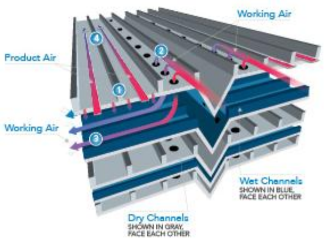


Figure 10: HVAC energy saving strategies5

[5] Vahid Vakiloroaya, Bijan Samali, Ahmad Fakhar, Kambiz Pishghadam, A review of different strategies for HVAC energy saving, Energy Conversion and Management, Volume 77, January 2014, Pages 738-754, ISSN 0196-8904, http://dx.doi.org/10.1016/j.enconman.2013.10.023.

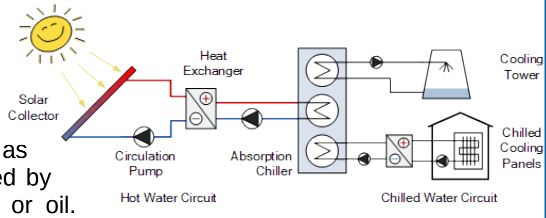
Some of the best available technologies for cooling, heating and simultaneously heating and cooling are briefly presented in Table 1, Table 2 and Table 3, respectively.

Evaporative Cooler Utilizing the Maisotsenko Cycle



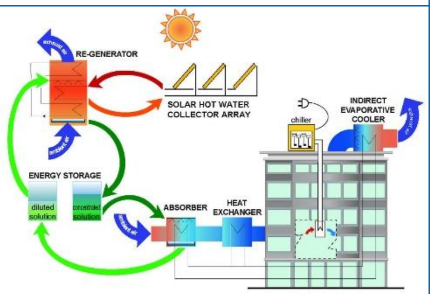
This cycle uses a novel geometry to maximize cooling efficiency and to achieve temperatures below wet bulb. The advantages of the Maisotsenko cycle against conventional evaporative cooling systems are the possibility of achieving lower temperatures (generally below the wet bulb temperature of the environment), greater efficiency, reduced water consumption and low pressure drops in the absence of porous medium.

Solar Cooling System



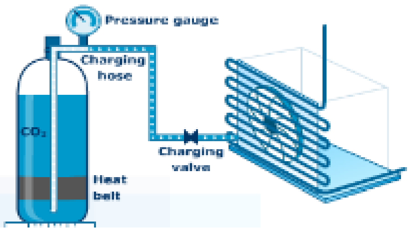
In such systems, solar collectors are specifically designed to provide pressurised hot water. The system uses either hot water or hot steam as an energy source, or can be powered by other fuels, such as gas, kerosene or oil. The chiller's flexibility has the advantage to allow continuous operation of the system even during non-sunny hours. The system generates chilled water, which circulates through the installed fan coil units. The advantages of this system are the reduction of space needs by nearly 30% and increasing on cooling efficiency by 20 % compared to typical solar cooling systems.

Open Absorption Cycle-Liquid Desiccant Cooling System



In this air conditioning system, the air is dehumidified and cooled by its direct contact with a liquid desiccant. In contrast to conventional air conditioning technologies, this system is heat driven. Because the heat required is of low temperature, the system can incorporate solar thermal collectors as heat source. The open cycle air conditioning with liquid desiccants is ideal for energy intensive buildings with high latent loads. The advantages of this system are the use of water as refrigerant, chemical storage of energy, reduction of CO_2 emissions, low operation costs, control of humidity and temperature e levels, free thermal energy. Such system works under any condition, but its effectiveness is directly linked with the presence of sunshine (when solar-driven).

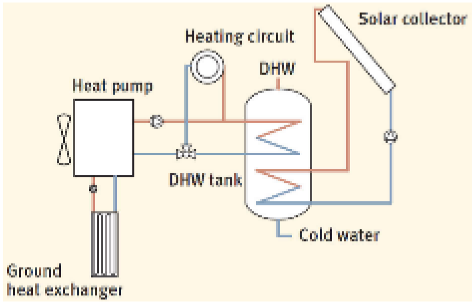
CO_2 Refrigeration Systems



Concerns with hydrochlorofluorocarbons (HCFC) and organofluorines (HFC) refrigerants have led to interest in other chemicals that can be used as refrigerants, one of which is carbon dioxide (CO_2). The existing systems can be modified so as to utilize CO_2 as refrigerant. CO_2 heat pumps can be integrated with hot water systems. The advantages of this system are the high volumetric capacity, low refrigerant cost (CO_2 costs 90% less than HFC), reduced carbon, possibility to reuse existing pumps and piping for the brine/glycol closed loop, reliable and proven systems, increased energy efficiency and simple and compact and factory manufactured system.

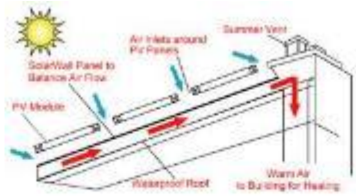
Table 1: Examples of efficient cooling technologies

Solar Heat Pump – Closed Absorption Cycle



The solar air conditioner / solar heater is powered by solar energy collected in the evacuated tube solar thermal panels. The thermal energy collected is then delivered to the solar powered chiller using a Propylene Glycol (or other heat transfer solution) and a simple system. The collected thermal energy is used as energy source for the closed absorption cycle of the chiller/heat pump. The advantages of this system are the low operation costs, absence of CFC refrigerants, reduced moving parts, good performance and absence of compressor.

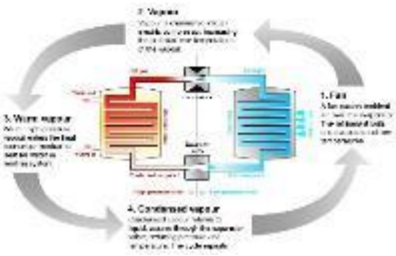
Combined Solar Power and heat Generation



PV/T is a hybrid system which provides up to 300% more energy (in the form of solar electricity + solar heat) than a conventional solar PV system. The heat energy captured from the PV modules is ducted into the building's HVAC system where it is used to displace the conventional heating load. The secondary benefit is to provide PV cooling by reducing the operating temperature of the PV modules, which improves the electrical performance. The advantages of this system are the higher life cycle cost savings when compared to a convention PV system, Huge reduction in greenhouse gas emissions, reduction of both electricity and heating costs and allows for the production of two types of solar energy from one footprint.

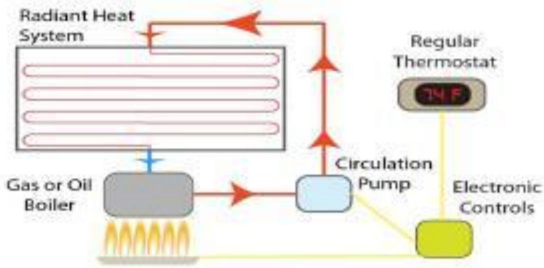
Table 2: Examples of efficient heating technologies

Air to Water Heat Pumps



Air source heat pumps absorb heat from the outside air. This heat can then be used to heat radiators, underfloor heating systems, or warm air convectors and hot water in your home. Heat from the air is absorbed at low temperature into a fluid. This fluid then passes through a compressor where its temperature is increased, and transfers its higher temperature heat to the heating and hot water circuits of the building. An air-to-water system distributes heat via the wet central heating system. The advantages of this system are the reduced heating bills and maintenance costs, reduction of carbon footprint, simple to integrate into most heating systems and can be seen as an energy efficient alternative to oil, LPG and electric systems.

Hydronic Radiant Systems



Modern radiant heating systems can be implemented with heated floors, to take advantage of convective air heating, as well as mean radiant temperature. Because hot air rises, a warmed floor will heat air that will rise and distribute itself through the space. Radiant cooling systems are generally chilled ceiling beams or panels, to take advantage of convective air cooling as well as mean radiant temperature. Because cool air sinks, a chilled ceiling beam will cool air that will sink and distribute itself through the space. The main advantage of this system is the higher efficient when compared with baseboard heating and usually also more efficient than forced-air heating because it eliminates duct losses. Others advantages are the wide variety of energy sources to heat the liquid, the option to storage in thermal mass and absence of distribution of allergens.

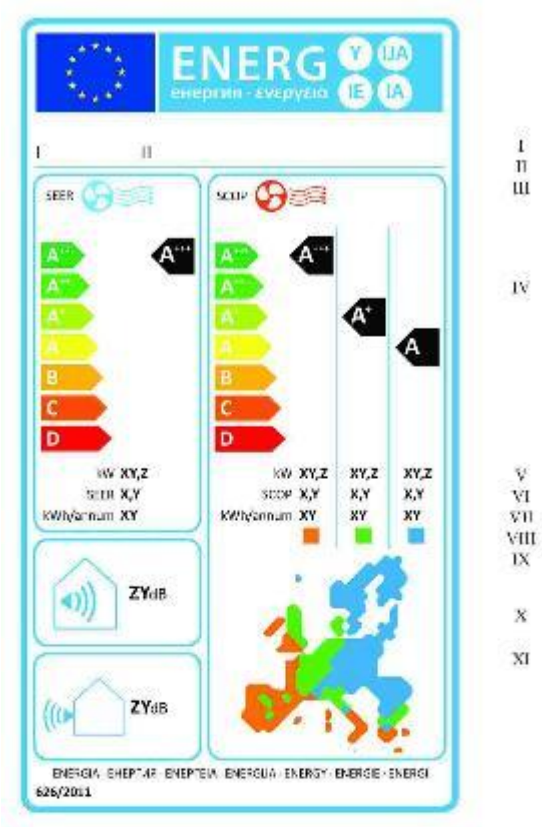
Geothermal Heat Pumps

Geothermal heat pumps (GHPs), sometimes referred to as GeoExchange, earth-coupled, ground-source, or water-source heat pumps use the constant temperature of the earth as the exchange medium, instead of the outside air temperature. What has boosted the usage of GHP during the recent years is the need of reducing energy cost. For this reason, new techniques of increasing the GHP EER were found. These systems reach fairly high efficiencies (300% to 600%) on the coldest winter nights, compared to 175% to 250% for air-source heat pumps on cool days. Therefore, its main advantage is the high efficiency and simultaneously it uses a clean, reliable, and renewable source of energy.

Table 3: Examples of efficient heating/cooling technologies

A.2.1.3 Energy Labelling

Air conditioners meet different requirements regarding cooling and heating efficiency, based on the Labelling Regulation No. 626/2011[6]. The Energy Label (Figure 11) defines classes from A+++ to G. Split models with lower efficiency than class B (cooling)/ A (heating) are no longer permitted on the market since January 2014.



I. Supplier's name or trade mark;
II. Supplier's model identifier;
III. 'SEER' and 'SCOP' for cooling and heating;

IV. Energy efficiency class;

V. For cooling mode: design load in kW;
VI. For heating mode: design load in kW;
VII. For cooling mode: SEER value;
VIII. For heating mode: SCOP value;
IX. Annual energy consumption in kWh per year;
X. Sound power levels in dB(A);
XI European map with a display of three indicative heating seasons and corresponding colour squares.

Figure 11: Labelling for reversible air conditioners D

The labelling class is defined based on the cooling function efficiency and the heating function efficiency, according with Table 4. The Seasonal Energy Efficiency Ratio (SEER) indicates the energy efficiency of the cooling function. It is calculated based on several part load measurements according to the Energy Labelling regulation and the higher the SEER, the more efficient is the product. The Seasonal Coefficient of Performance (SCOP) indicates the energy efficiency of the

[6] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:178:0001:0072:EN:PDF

heating function. It is calculated analogically to the SEER and the higher the SCOP, the more efficient a product.

Energy Efficiency Class	SEER	SCOP
A+++	SEER ≥ 8,50	SCOP ≥ 5,10
A++	6,10 ≤ SEER < 8,50	4,60 ≤ SCOP < 5,10
A+	5,60 ≤ SEER < 6,10	4,00 ≤ SCOP < 4,60
A	5,10 ≤ SEER < 5,60	3,40 ≤ SCOP < 4,00
B	4,60 ≤ SEER < 5,10	3,10 ≤ SCOP < 3,40
C	4,10 ≤ SEER < 4,60	2,80 ≤ SCOP < 3,10
D	3,60 ≤ SEER < 4,10	2,50 ≤ SCOP < 2,80
E	3,10 ≤ SEER < 3,60	2,20 ≤ SCOP < 2,50
F	2,60 ≤ SEER < 3,10	1,90 ≤ SCOP < 2,20
G	SEER < 2,60	SCOP < 1,90

Table 4: Energy efficiency classes for air conditioners, except double ducts and single ducts

A.2.1.4 Example of HVAC Renovation

"Kapitain Etxea" Building – Errenteria (Spain)

Nowadays, the building has forced air ventilation in the main room of the second floor, but the rest of the building does not have any climate control or forced ventilation. This forced ventilation is carried out by means of double aspiration electric centrifugal fans (with a total power of 6.5 kW), complemented with a heat recovery device that extracts heat from the heating system in order to warm the air that is being moved.

The heating system is designed to heat all the rooms of the building and is formed by 2 string system heat radiators that are warmed by hot water. The supply system is a natural gas-fired boiler placed in the City Hall, another municipal building placed at 350 m. This boiler (with a COP of 0.88 and total installed power of 232.6 kW) produces hot water depending on the needs of the City Hall and Kapitain Etxea. The hot water is distributed to the building by underground uninsulated pipes buried in the street. Once the pipes are inside the building, the net is ramified in collectors to reach the different heat radiators.

The boiler, placed in the City Hall, is controlled by an outdoor temperature sensor. This system is not very effective in terms of energy efficiency. The main control for the building under study depends on conditions in another building. Inside Kapitain Etxea, all the radiators are manually managed by valves that control the flow of hot water.

Existing elements related to HVAC systems will be replaced to avoid the use of heat radiators and the use of underfloor heating in the existing timber structure. With these conditions, the option of an Air Handled Unit (AHU) that comprehends all the HVAC systems was decided upon. This solution has advantages and disadvantages, the Air ducts will be larger and the AHU will have a bigger physical geometry. Nevertheless, only one system is necessary which is an advantage in this kind of buildings, where there is a lack of space. Nowadays, the presence of exposed air ducts in the occupied space is visually accepted if designed well and properly installed. Moreover, the maintenance will be easier due to the existence of a single system. The idea is to install an AHU with heat recovery at the exhaust side and by means of this device the efficiency of the system is enhanced. The two streams of air are passed through the core of the heat exchanger, where heat from the exhaupublicst air is passed to the cooler incoming air. Hence, fresh air supplied to the building has already been pre-heated reducing the energy necessary to achieve the established conditions. The incoming air is then distributed evenly to all rooms and spaces by the duct work. A general scheme of the proposed system is represented in Figure 12.

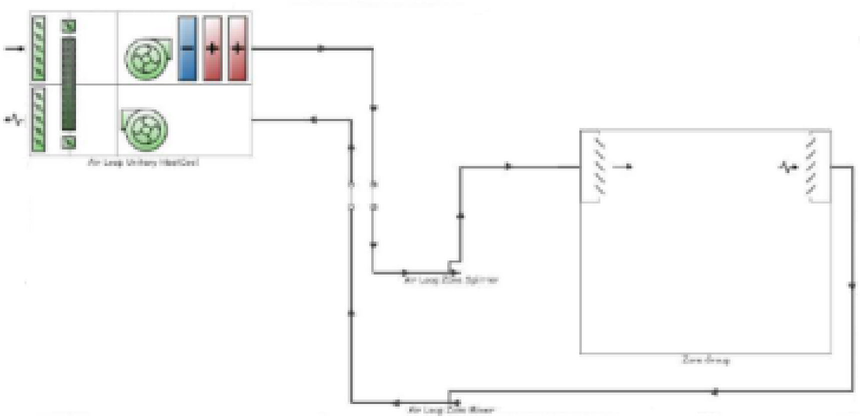


Figure 12: General Scheme of the Proposed HVAC System

The loads for the different zones are calculated with the software EnergyPlus considering the renovation of the building envelope accorded with the Municipality. Hence, the HVAC system will be designed in line with the energy demand reduction that will be achieved by means of these actions, requiring a total heating load of 23.47 kW and a total cooling load of 12.55 kW. According to these loads the systems was selected and modelled in the software.

Once the new HVAC system is defined it is possible to assess the total energy consumption of the renovated building (energy demand reduction + implementation of new HVAC system) considering the same parameters for the simulations. Table 5 reflects the final energy consumption of Kapitain Etxea once all the insulation measures and the new HVAC system are implemented, achieving 63.7% of savings on the final energy consumption.

	Baseline (kWh)	**Renovation (kWh)**
Pumps/Fans	287.68	3,058.28
Heating	54,383.13	13,929.11
Cooling	642.41	3,108.63
Total	**55,313.22**	**20,096.02**
Savings (kWh)		**35217.2**
Savings (%)		**63.7%**

Table 5: Energy consumption and savings of Kapitain Etxea HVAC system

A.2.2 LIGHTING

Besides affecting the physical and emotional well-being of the building occupants, a building's interior lighting system is both a major source of internal heat and a dominant consumer of electrical energy, being the EU-27 office lighting consumption the biggest share of total electricity consumption in the tertiary sector with 21.57%[7]. Specifying a high quality energy efficient lighting system, that utilizes both natural and electric sources, as well as lighting controls can provide a comfortable yet

[7] P. Van Tichelen, B. Jansen, T. Geerken, M. Vanden Bosch, V. Van Hoof, L., Vanhooydonck, A. Vercalsteren: Preparatory Studies for Eco-design Requirements of EuPs, Project Report, Lot 8: Office lighting, July 2007

visually interesting environment for the occupants of a space. Recently developed energy efficient lighting equipment can be used to help cut lighting operational costs while enhancing lighting quality, reducing environmental impacts, and promoting health and work productivity[8].

A.2.2.1 Lamps

Halogen light bulbs, fluorescent, and LEDs have their own advantages and disadvantages and they could be a good option for different applications.

Halogen Lamps

Halogen lamps are, basically, advanced incandescent lamps, since its technology is also based on a heated filament that emits light. However, they contain a halogen gas inside under high pressure that allows a higher temperature. Also, by reacting with the vapours of the filament, its durability and hence the lamp lifetime is extended. Halogen lamps are the least efficient lighting technology available in the European market. Even though its (massive) use is not recommended, there are several types of halogen lamps used in public buildings.

- Bulb | used in direct retrofit of incandescent lamps;
- Spot | for high-voltage (GU10) and low-voltage (GU5.3) application;
- Linear | typically used in uplighters, usually with higher power.

Table 6 presents some specific characteristics and lamp types of halogen lamps.

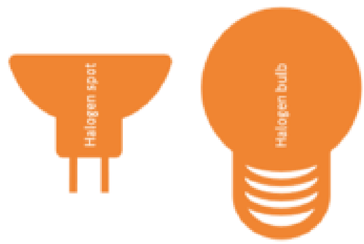
Specific Characteristics	
Colour Temperature Only warm ("yellow colour")	
Colour Rendering Index Maximum (100)	
Energy Efficiency At best can only be Class B	

Table 6: Specific characteristics and lamp types of halogen lamps

8 https://www.wbdg.org/resources/efficientlighting.php

Table 7 presents the main advantages and disadvantages of halogen lamps.

Advantages	Disadvantages
• Bright light • Excellent colour rendering • No warm-up time until maximum flux is reached • Dimmable lamps (from 0 to 100% of the lighting flux)	• Poor efficiency, hence high consumption (2 to 4 times higher than other technologies) • Small lifetime (normally between 2.000 to 3.000 hours) • High lamp surface temperature • Despite its smaller initial price, it will have a high cost throughout the lifetime

Table 7: Advantages and disadvantages of halogen lamps

Fluorescent Lamps

Two different families of fluorescent lamps can be defined: linear and compact. Linear Fluorescent Lamps (LFL) have a tubular format and an external ballast (device used to control the lamp). Compact Fluorescents are not linear and can either have an external ballast and be pin-based, or they an integrated ballast and an Edison socket. In this case they are called Compact Fluorescent Lamp (CFL).

All types emit light according to the same principle. They have mercury inside and a fluorescent layer, with several types of phosphorous, on the inner side of the envelope. When a voltage is applied, the mercury vaporizes and emits ultraviolet radiation that will become white light as soon as it goes through the fluorescent layer. The lamp colour temperature will depend on the layer’s composition. Linear Fluorescent Lamps are largely used in the service buildings. Given their indirect light distribution and high luminous flux, they are built in the ceilings, thus properly lighting a wide open area.

According to the tube´s diameter they can be:

- T5 | 16 mm (most efficient);
- T8 | 26 mm;
- T10 | 33,5 mm (least efficient of last three);
- T12 | 38 mm (was banned from the market due its inefficiency)

Table 8 presents some specific characteristics and lamp types of linear fluorescent lamps.

Specific Characteristics	
Colour Temperature Mostly cold ("blue-white")	
Ballast Always external to the lamp	
Light dispersion Very wide	
Luminous Flux Normally high lumen values	

Table 8: Specific characteristics and lamp types of linear fluorescent lamps

Compact Fluorescent Lamps (CFLs) are a great solution when the objective is to achieve high efficiency at low cost, with a low lumen output, thus being applied where modest levels of lighting are acceptable. The electronic ballast is already incorporated in the lamp, making it a quick retrofit solution.

There are four common shapes of CFLs:

- Bulb;
- Stick;
- Spiral;
- Candle.

There is also a CFL with a reflector (PAR type) to concentrate the light flux, thus having a less diffuse light distribution. However, nowadays, with LEDs, this type of lamp is becoming obsolete as it is less efficient.

Table 9 presents some specific characteristics and lamp types of compact fluorescent lamps.

Specific Characteristics	
Colour Temperature Can go from yellow to blue	
Ballast Integrated in the lamp	
Socket E family (e.g. E14, E27)	
Dimension Smaller lamps	

Table 9: Specific characteristics and lamp types of compact fluorescent lamps

Other Fluorescent Lamps are mainly used in office buildings. However, they are far less used than any other fluorescent lamps. These lamps are sold without the ballast in two separate pieces. This way, maintenance costs are reduced, since the ballast lifetime is up to five times higher than the lamp itself. This type of fluorescent lamp has the following shapes:

- Stick;
- Circular | the T9 (29 mm) is the most common example;
- Square.

Table 10 presents some specific characteristics and lamp types of other fluorescent lamps.

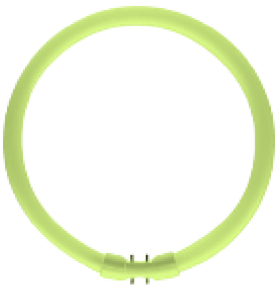
Specific Characteristics	
Socket Pin based (normally 2 or 4)	
Ballast Always external to the lamp	
Retrofit Does not allow halogen lamps to replace it	
Socket Pin based (normally 2 or 4)	

Table 10: Specific characteristics and lamp types of other fluorescent lamps

Table 7 presents the main advantages and disadvantages of fluorescent lamps.

Advantages	Disadvantages
• Greater lifetime than halogen lamps • Energy efficiency class A • Economic lamp at a cheaper price than LEDs	• Contains mercury • Needs a warm-up time to get full brightness • Does not start immediately • Not the best colour rendering index (CRI) • Not the best technology for dimming purposes

Table 11: Advantages and disadvantages of fluorescent lamps

LED Lamps

A Light Emiting Diode (LED), also referred to as SSL (Solid State Lighting), is an electronic device (chip) that produces light when an electrical current is passed through it (diode). A diode is a semi-conductor that will, once excited, allows electrons to move thus emitting UV radiation, which, in turn, will become visible light passing through the LED coating. LEDs are the most efficient lighting technology on the market. LEDs can also be integrated in luminaires and one particular design is the LED flat panel to be built in the ceiling.

Types of LED lamps:

- Bulb | For retrofit purposes of CFLs and halogen light bulbs;
- Spot | where its directionality property is best applied;
- Tube | for lighting wide open areas, replacing LFLs;
- Strip | taking advantage of LED´s flexibility for aesthetic purposes.

Table 12 presents some specific characteristics and lamp types of other LED lamps.

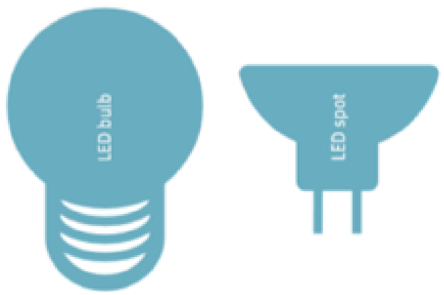
Specific Characteristics	
Colour Can have any and can be changed using controls	
Colour Temperature All, from warm to cold	
Light output Directional with several available beam angles	
Dimming Possible, but must pay attention to its driver	
Colour Rendering Index Can be higher than 90	

Table 12: Specific characteristics and lamp types of LED lamps

Table 13 presents the main advantages and disadvantages of LED lamps.

Advantages	Disadvantages
• Only technology that can, at least, have efficiency Class A+ • LEDs have, by far, the longest lifetime of all lighting technologies • Lowest cost of ownership (cheaper than any other technology during the lifetime) • Extremely flexible technology for aesthetic and controlling purposes • Low temperature when functioning avoids any possibility of burning at touch • Regarding CFLs, LEDs withstand many more switching cycles and light up immediately	• Its initial cost is higher than other technologies (but the prices have been quickly decreasing). • LEDs are temperature sensitive. Efficacy and lifetime is strongly reduced if lamps are overheated

Table 13: Advantages and disadvantages of LED lamps

A.2.2.2 Lamps Control

Ballasts

A ballast has two main functions: it starts the lamp and it controls lamp operation. However, depending on their characteristics they can also: transform the voltage, dimming the lamp and correct power factor.

All fluorescent lamps need a ballast to work and there are two types of ballasts:

- Magnetic ballasts are the older technology, with a core of steel plates wrapped in copper windings. Joule losses that occur on copper, and hysteresis losses in the nucleolus, reduce lamp input power between 5 and 25%. This value will depend on ballast dimension and construction. The most efficient magnetic ballasts are the low losses ones. These are also known as hybrid ballasts.

- Electronic ballasts use solid-state technology to operate at much higher frequency (thousands of Hz) resulting in energy conservation through lower power loss and higher lamp efficacy for fluorescent lights. Additionally, these ballasts can also improve the power factor.

Table 14 presents the classes of efficiency for ballasts.

Class A1	Dimmable electronic ballasts
Class A2	Electronic ballasts with reduced losses
Class A3	Electronic ballasts
Class B1	Magnetic ballasts with very low losses
Class B2	Magnetic ballasts with low losses

Table 14: Ballasts Classes of Efficiency

LED drivers

LED drivers are low-voltage devices that convert the line-voltage power to the low-voltage needed for the LEDs, coming in either constant current or constant voltage, depending on the LED load. LED drivers bring additional benefits, such as operational flexibility, efficiency, reliability, controllability and intelligence to the system.

The selection of the most appropriate topology to drive LEDs depends on the application requirements (e.g., operation environment conditions, system input voltage, number of LEDs, etc.), standards and specifications. Electronic drivers are important components in most LED-based systems, since relatively small improvements on the driver efficiency often result in big improvements in the system's efficiency.

A.2.2.3 Lamp Characteristic and Labelling

The power consumption of a lamp (in Watt) is not the only factor to the selection of a lamp. There are other important factors such as.

- CRI - The Colour Rendering Index is the ability of a light source to represent the various colours of lighted objects in a room.
- Bright - Lumens (lm) indicate how much light is made available by the lamp.
- Lifetime - Minimum operation time of a lamp measured as the time when at least 50% of those lamps still provide at least 70% of the initial lighting.
- Colour Temperature - 2600 - 3200 Kelvin is warm white (good for relaxation), 3200 - 4000 Kelvin is neutral white (best colour for working conditions), 4000 - 5000 Kelvin is cold white (provides the highest energy efficiency).
- Efficiency - The luminous efficiency of a light source is typically given as the rated lamp lumens divided by the nominal wattage of the lamp, abbreviated lm/W.

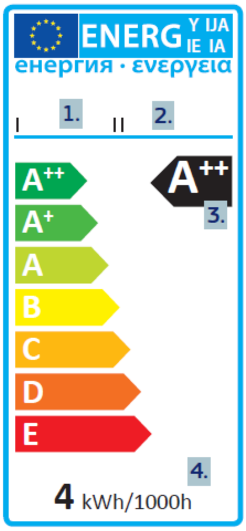
Table 15 presents the quality criteria for the characteristics of the main types of lamps.

QUALITY CRITERIA	CFL Bulb	Fluorescent Linear	Halogen Spot	LED Bulb	LED Spot
					
Efficiency Class	A	A	C	A+	A
Colour Temp. (K)	Warm / Neutral / Cold	Warm / Neutral	Warm	Warm / Neutral / Cold	Warm / Neutral / Cold
Colour Rendering	> 80	> 80	100	> 90	> 80
Lamp Lifetime (h)	> 12.000	> 20.000	> 2.000	> 25.000	> 25.000
Switching Cycles	> 12.000 (500.000)*	> 20.000	-	> 25.000	> 25.000

* for applications with frequent switching

Table 15: Quality criteria for lamps9

Lighting products are subject to EU energy labelling and ecodesign requirements, based on the Labelling Regulation No. 874/2012[10]. The Energy Label (Figure 13) defines classes from A++ to E.



1. The company that made or placed the lamp on the market

2. The lamp model

3. How energy efficient the lamp is

4. Energy consumption during 1 000 hours (typical energy consumption in a year)

Figure 13: Labelling for lamps

[9] http://www.premiumlight.eu/

[10] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0874

Additionally, a lamp's package also has other important characteristics, as presented in Figure 14

1. Energy label

2. Average lifetime of the lamp in hours

3. Colour of the light

4. CRI

5. Whether it is dimmable or not (if not, a cross appears over the symbol)

6. How many times the light can be switched on and off before it burns out

7. Bright in lumens

Figure 14: Lamp's package

A.2.2.4 Luminaires

A luminaire is a complete electric light fixture, including the lamp(s), mechanism for inserting or holding the lamp(s), wiring, socket, control systems (e.g. ballast) and reflector(s) to diffuse the light. The function of a luminaire is to direct light to desired locations, creating the required visual environment without causing glare or discomfort. Choosing luminaires that efficiently provide appropriate luminance patterns for the application is an important part of energy efficient lighting design.

There are many types of luminaires, opaque or translucent, and they can vary a lot concerning the type of light source. Figure 15 presents some examples of luminaires types.

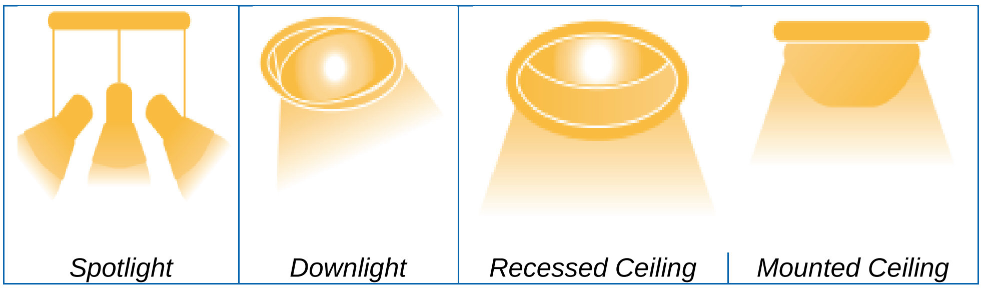
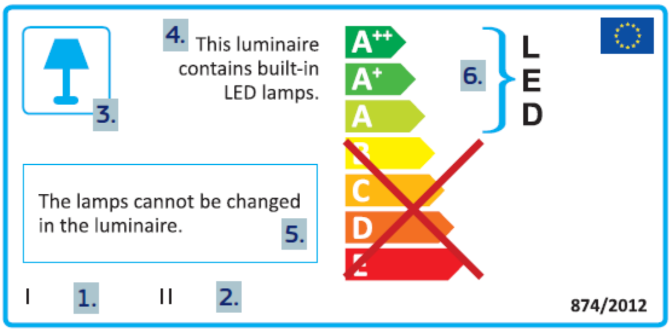


Figure 15: Examples of luminaires types

The following criteria should be considered for procurement of luminaires:

- high luminaire operating efficiency level (> 80%);
- optimal lamp reflector;
- highest direct ratio possible.

Lighting products are subject to EU energy labelling and ecodesign requirements, based on the Labelling Regulation No. 874/2012[11]. The Energy Label (Figure 13) defines classes from A++ to E.



1. Company
2. Luminaire's model
3. Luminaire type or
4. Compatible lamps
5. Indicates if it contains a lamp and if they are replaceable or not
6. Efficiency class of the compatible lamps

Figure 16: Labelling for luminaires

A.2.2.5 Example of Lighting Renovation

Municipal House of Culture – Coimbra (Portugal)

Nowadays, the lighting of the building is mainly ensured by T8 fluorescent lamps with ferromagnetic ballasts. The exception is just one circulation area where T5 lamps with electronic ballasts are already used. Some rooms with double height ceiling use incandescent and halogen lamps and the bathrooms had incandescent lamps. However, some lamps were already replaced by CFL and one bathroom, recently renovated, already have LED lamps. Table 16 presents the quantities and power of the actual lamps

[11] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0874

Lamp Type	Quantity n	Power (W)
Fluorescent Linear T8 F60	9	211
Fluorescent Linear T8 F120	803	37,580
Fluorescent Linear T8 F150	312	21,091
Fluorescent Linear T5 F60	8	136
Incandescent	23	1,380
Halogen Projector	24	7,200
Halogen Spot	5	250
Compact Fluorescent	70	1,260
LED Spot	12	66
Total	**1,266**	**69,174**

Table 16: Types and quantities of the actual lamps

The retrofit of the lighting system was done by replacing all lamps by LEDs. In such scenario, 1,254 lamps have to be replaced. Table 17 show the new distribution of lamps. As can be seen, the total power decreases to 27,095 W (reduction of 61%).

Lamp Type	Quantity n	Power (W)
LED Linear F150	312	7,488.0
LED Linear F120	803	16,060.0
LED Linear F60	17	170.0
LED Bulb	93	883.5
LED Projector	24	2,400.0
LED Spot	17	93.5
Total	**1,266**	**27,095**

Table 17: Types and quantities of lamps considered in the renovation

Table 18 presents the yearly consumption with lighting, as well as the percentage of achievable savings. Such energy consumptions were simulated considering the actual usage profile for each lamp type and room of the building. As can be seen, the renovation ensures 61% of energy savings.

	Baseline	Renovation
Lighting (kWh)	166,930	65,773
Savings (kWh)	-	101,157
Savings (%	-	60.6%

Table 18: Yearly consumption with lighting

A.2.2.6 Monitoring and Control

Building Energy Management Systems (BEMS) are computer-based systems that help to manage, control and monitor heating, ventilation, air conditioning (HVAC Control), lighting and the energy consumption of devices used by the building. BEMS provides the essential instrumentation and control to analyse and monitor performance, allowing the facilities manager to adjust and optimise HVAC and illumination controls for optimum occupancy comfort and building efficiency.

The components of a BEMS are (1) outstations (Inputs, Outputs, Microprocessor, Memory, RAM, Eprom with Configurable Strategy, Modules, Time-clock, Power Supply, Local RS232 port for Supervisor; (2) BEMS network and communications hardware and (3) Computer with supervisory and control software. Figure 17 presents an example of a BEMS.

Such systems present as advantages the reduction of operational and energy costs, increase of productivity and fast and accurate decisions on energy strategy. However, they have high initial costs for design and installation and if the system settings and parameters are not properly monitored and maintained the building performance will begin to suffer, resulting in higher building operation costs and reduced occupant comfort.

Considering building automation, monitoring and control systems are used for:

- Ventilation, heating and cooling - A properly designed monitoring and control system should be capable of maintaining present environmental conditions in the building.
- Feeding - Boilers feeding control system requires some way of knowing when to turn feeders on and off. Feed monitoring systems are available to measure the amount of feed consumed by broilers.
- Lighting - A monitoring and control system should provide scheduling of lights that is easy to use. A system than can pre-program lighting schedules over the life of the flock is very useful for management. It is also important to provide the desired intensity of light.

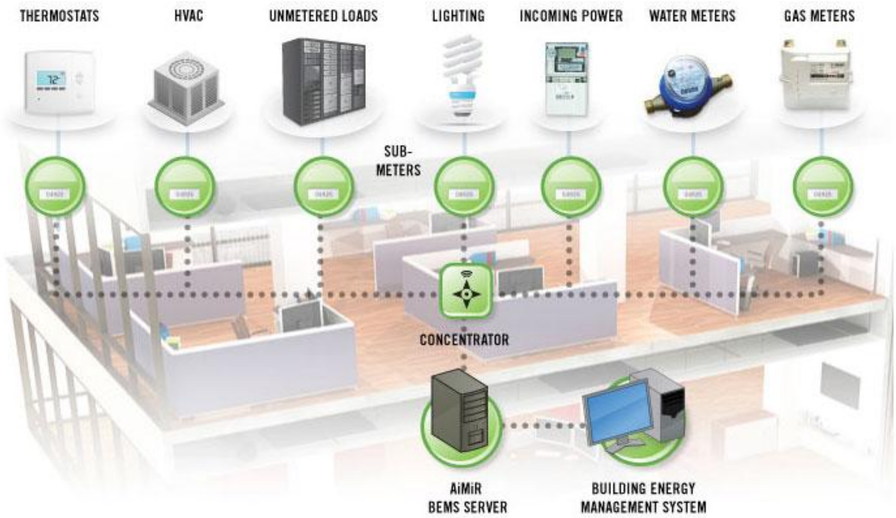


Figure 17: Building Energy Management System12

A.2.2.7 HVAC Control

The capacity of the HVAC system is typically designed for the extreme conditions. Most operation is part load/off design as variables such as solar loads, occupancy, ambient temperatures, equipment and lighting loads, etc. keep on changing throughout the day. Deviation from design shall result in drastic swings or imbalance since design capacity is greater than the actual load in most operating scenarios. Without control system, the system will become unstable and HVAC would overheat or

[12] http://www.nuritelecom.com/products/aimir-building-energy-management-system-bems.html

overcool space. Therefore, the control system is needed to regulate the operation of a heating and/or air conditioning system. Usually, a sensing device is used to compare the actual state (e.g. temperature) with a target state. Then, the control system draws a conclusion what action has to be taken (e.g. start the blower).

The most common used sensors are temperature, occupancy, pressure, humidity and carbon dioxide sensors.

Temperature Sensors

One of the most common properties measured in the HVAC control is temperature. The principle of measurement involves the thermal expansion of metal or gas and a calibrated change in electrical characteristics. The use of temperature sensors in different rooms enables the control of the required heating/cooling appliances temperature.

Occupancy Sensors

As part of an HVAC energy management system, occupancy sensors enable the management system to automatically control HVAC operation based on room occupancy. If the room is physically occupied, then the system will allow occupants to control the climate. Once a room is vacant, the system will automatically set back the HVAC equipment to reduce energy consumption.

Pressure Sensors

The ability to monitor volumetric flow rates and pressures in lines and rooms is decisive when it comes to operating HVAC systems efficiently and economically. Pressure sensors are a central element for controlling the systems. To ensure compliance with strict legal requirements and to minimize energy costs, ever-decreasing measuring ranges as well as greater measuring sensitivities, accuracies, and long-term stabilities of the sensors are required.

Humidity Sensors

A humidity sensor measures and regularly reports the relative humidity in the air. They are used to control and provide a good humidity level air for each use of building or room. An adequate air quality is needed for each building or room and relative humidity is a very important factor for the comfort and some kind of object conservation. Ventilation rates can be measured and controlled to a specific (l/s)/person based on actual occupancy and use of the building or room. Building codes require that a minimum amount of fresh air be provided to ensure adequate air quality, but this way less air must be conditioned, resulting lower energy consumption and costs for the appropriate ventilation.

Carbon Dioxide Sensors

Measuring carbon dioxide is important in monitoring indoor air quality. Demand-controlled ventilation (DCV) using carbon dioxide (CO_2) sensing is a combination of two technologies: CO_2 sensors that monitor CO_2 levels in the air inside a building, and an air-handling system that uses data from the sensors to regulate the amount of ventilation air admitted.

A.2.2.8 Lighting Control

Lighting sensors help to achieve a high quality energy efficient lighting system. When electric lighting controls are used properly, energy will be saved and the life of lamps and ballasts can be extended.

Lighting controls will help to reduce energy by:

- Reducing the amount of power used during the peak demand period by automatically dimming lights or turning them off when not needed;
- Reducing the number of hours per year that the lights are on;
- Allowing occupants to use controls to lower light levels and save energy.

The ability of a lighting control system to match the lighting in use to the numbers of staff present is a very valuable input.

Occupancy detectors

Often referred to as ‘presence‘ or ‘occupancy’ detection the current sensors on the market rely on one of three methods of movement detection:

- Passive Infra Red (PIR) - works based on heat movement detection. The device has a pyroelectric sensor calibrated to detect infrared radiation radiated by human body movement.

Based on the detection, the sensor operates and turns on the lighting systems connected to it.

- Ultrasonic - similar to a radar. An ultrasonic sensor sends high frequency sound waves in one area and checks for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy and the lighting load connected is turned on. If the reflected pattern is the same for a preset time then the sensor assumes there is no occupancy and the load is switched off.
- Microwave – Similar to the ultrasonic detector. A microwave sensor sends high frequency microwaves in an area and checks for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy. A microwave sensor has high sensitivity as well as detection range compared to other types of sensors.

Daylight detectors

Daylight controls are photoelectric devices provides efficient light control and optimum energy savings by reducing lighting levels based on available daylight. Smooth and continuous dimming is the preferred strategy for automated daylight controls. Its use in rooms and spaces with an optimum presence of natural daylighting can reduce the consume of artificial light. It can be combined with elements that provide or spread natural light into inner spaces, such as reflectors, sunpipes or light shelves.

Time Control detectors

Time clocks are devices that can be programmed to turn the lights on or off at designated times. These are a useful alternative to photoelectric sensors in applications with very predictable usage.

Dimmers

Dimmers are devices used to lower the brightness of a light. By changing the voltage waveform applied to the lamp, it is possible to lower the intensity of the light output. Dimmers are used to control the light output from resistive incandescent, halogen, CFLs and LEDs. In the professional lighting industry, changes in intensity are called “fades” and can be “fade up” or “fade down”. Dimmers with direct manual control had a limit on the speed they could be varied at, but this issue has been largely eliminated with modern digital units (although very fast changes in brightness may still be avoided for other reasons like lamp life).

Modern dimmers are built from semiconductors instead of variable resistors, because they have higher efficiency. A variable resistor would dissipate power as heat and acts as a voltage divider. Since semiconductor or solid-state dimmers switch between a low resistance "on" state and a high resistance "off" state, they dissipate very little power compared with the controlled load.

Light sensors reduce energy consumption by reducing artificial light when there is adequate and suitable natural light, especially when no one is spotted to be in the area. Figure 18 presents the potential savings that different light sensors controls, working together, can achieve in a service building.

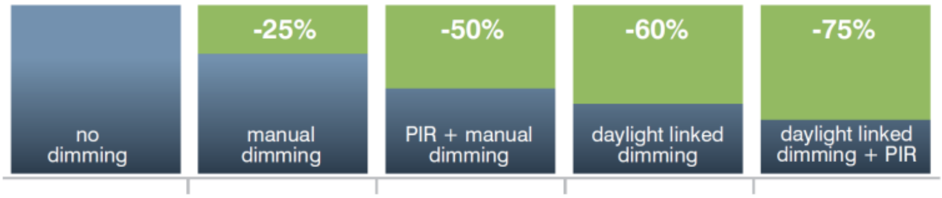


Figure 18: Potential savings of different dimming options

A.2.2.9 Example of Control Renovation

City Hall – Alimos (Greece)

In order to optimize the performance of the building's mechanical and electrical equipment such as, lighting, ventilation and HVAC system, an BEMS will be installed in the building. The BEMS consists of one Touch Controller (LCD touch screen), power meters, electrical wiring equipment and a software. The equipment which is connected to the BEMS is presented in Table 19.

Equipment	Units	Signal
VRV Heat Pump	3	digital
VRV Cassettes	44	digital
HRV Units	2	digital
Air Dampers	10	analogue

Lux Sensors	16	analogue
CO_2 Sensors	2	analogue
Anemometer	1	analogue
Ambient Sensor	1	analogue
Power Meters	6	pulse tone
On/Off Switches	50	analogue

Table 19: equipment connected with the BEMS

The BEMS will control, monitor and record data such as air temperatures, hours of operation and power consumption, of each VRV cassette separately. It will also control, monitor and record the lighting energy consumption of each floor separately and the operation of each Lux sensor. All windows and doors will have an on/off touch connected with each VRV cassette operation. If a window is open, it will stop the operation of the corresponding VRV. The opening and closing of the openings will be recorded by the BEMS. The BEMS layout is presented on Figure 19.

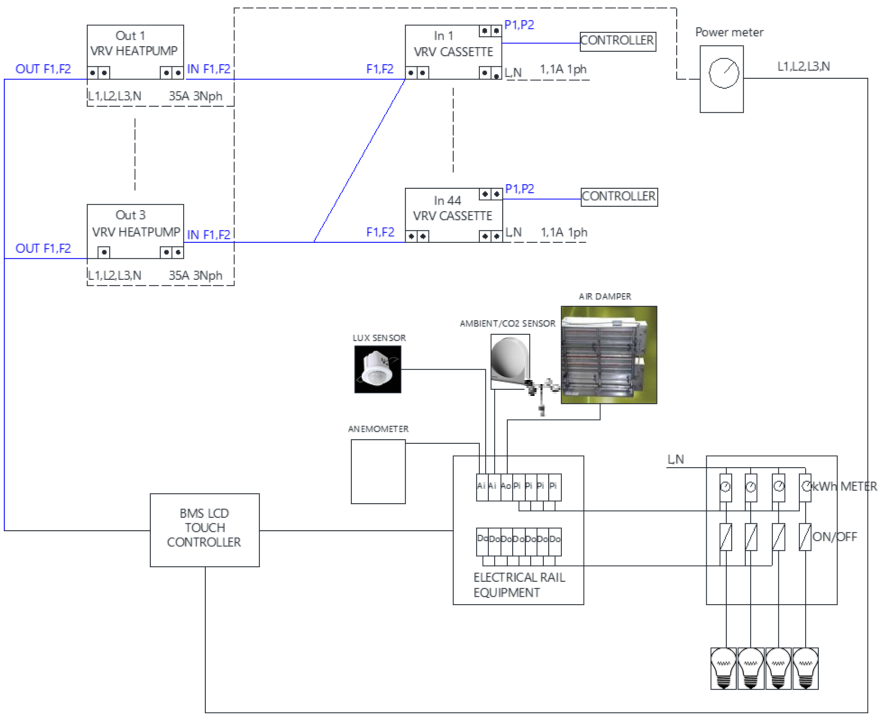


Figure 19: BEMS Layout

Table 20 presents the achievable savings, with the BEMS integration. The use of the BEMS ensures the standard internal condition such as air temperature and lighting levels and prevents the excess use of energy.

	Baseline (kWh)	Renovation (kWh)
Heating	24,065	12,273
Cooling	50,184	35,131
Lighting	37,713	32.999
Total	**111,962**	**80,403**
Savings (kWh)		**31,599**
Savings (%)		**28.2%**

Table 20: Energy Consumption and savings with the use of BEMS

In total the energy savings are up to 28%. The figure is higher than the usual savings obtained with the use of BEMS, since the internal conditions are fully controlled with little deviations from the set point. An additional benefit is that system's capacity to detect automatically the energy intensive units and produce energy saving scenarios with no need of human intervention. Finally, further cost reduction is achievable due to the lower cost of the maintenance of the VRV systems as BEMS displays the units with the lower refrigerant and prevents permanent damages on the HVAC.

A.2.3 REFERENCES

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A.3 THE RENEWABLE ENERGY SOURCES INTEGRATION

A.3.1 INTRODUCTION

Renewable Energy Sources (RES) are forms of energy which resulted from various natural processes, such as wind, geothermal, water circulation and others. Specifically, according to Renewable Energy Directive 2009/28/EC of the European Parliament, as energy from renewable non-fossil sources considered that generated from wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases (European Union, 2009). In any case, RES have been studied as a solution to the expected depletion of (non-renewable) reserves of fossil fuels. Lately, the EU and many individual states adopted new policies for the use of RES such as 20% target for the overall share of energy from renewable sources in built environment and a 10% target for energy from renewable sources in transport.

There is also the Energy Performance of Buildings Directive 2010/31/EU of the European Parliament which set the following targets. All new buildings must be nearly zero energy buildings by 31 December 2020 and regarding the public buildings by 31 December 2018. Also, the Energy Efficiency Directive 2012/27/EU set the 3% target for public buildings renovation in order to meet at least the minimum energy performance requirements. These directives show the trend during the next years regarding the energy performance of the public buildings. Undoubtedly, in the effort of transforming public buildings to nZEB the integration of RES will play an important role.

For these reasons, under CERtuS project a detailed investigation regarding the maturity, the performance, the integration ability and the cost of various RES systems was undertaken. The description of the preponderant RES systems, as well as the applicability and limitations of them are listed in this guide. There is an extensive reference to the PV systems due to their widespread use especially in Mediterranean countries which have high solar radiation. Finally, several examples and sizing rule of thumb are also described in order to give more specific information on the examined RES systems.

A.3.2 PHOTOVOLTAICS

A.3.2.1 Operation

A photovoltaic (PV) system converts solar radiation into electricity. It uses the most available and clean source of energy on the planet for producing electricity. PVs are ideal for producing electricity in an urban environment because they can be easily placed on building roofs. Moreover, they are noiseless, safe to use and they can fit any size or roof as their size can be small or big without any impact on their performance.

They comprise a photovoltaic array, to be installed on the building roof, and an electronic device, called inverter, which is used to convert the solar electricity and feed the electricity grid. Photovoltaic arrays consist of photovoltaic panels (or modules) which are electrically connected to form the array. Suitable inverters are selected to match the electrical characteristics of the photovoltaic array.

The above described systems do not store the electric energy. The produced electricity has to be directly consumed or be injected into the electricity grid. If the consumer wants to be independent from the electricity grid, the photovoltaic system has to include energy storage devices, such as batteries.

PVs will be the renewable power source to be installed in most public buildings in the upcoming decades. Due to high solar radiation in Mediterranean countries, they can produce electricity at lower cost than most other power sources, including nuclear. In some cases, they will be combined with energy storage so as to match the power profile of the produced electricity with the power profile of the electricity consumption of the building. However, this will depend on country specific electricity cost structures and restrictions for the connection of photovoltaics to the grid.

A.3.2.2 Types of Solar cells

Solar cells consist of a semiconductor material which converts the sunenergy (sunlight) directly into electricity. The PV panels are made of several individual solar cells. Each one has a positive and negative semiconductor layer, creating an electric field which is used to convert the solar energy into electricity. Sunlight is energy in the form of photons and when it strikes the surface of a solar cell a large amount of photons is absorbed by the solar cell, freeing up electrons in the semiconductor material and creating electric current. This phenomenon is called “photovoltaic effect”.

Solar cells convert only a percentage of solar energy into electricity. The value of this rate depends on the type of the solar sell. Today, the majority of market available photovoltaic modules have solar cells with efficiencies ranging from 14% to 18%.

Solar cell efficiency should not be the criterion for selecting a photovoltaic module for applications on public buildings. If the roof is limited, photovoltaic modules with higher efficiency are installed in order to fit more power on the roof.

The most used material for manufacturing PV solar cells is crystalline silicon (c-Si) which constitutes the raw material for 90% on the PV market. Solar cells made of single-crystal silicon are called monocrystalline and have efficiencies close to 19%. The polycrystalline cells made of multi-crystal silicon and have efficiencies close to 16%. The latter one is the most used material, since its efficiency is only a little lower than the single crystal cell efficiency but its cost is lower.

Different materials and manufacturing processes have been tried in order to decrease the manufacturing cost of solar cells. Many types of cells have been available in the market in the past. Most of them are not cost competitive today and they are not produced anymore. Among those which survive and still be commercially successful are the cadmium telluride (CdTe) cells which are the most commonly used thin-film and the amorphous silicon (α-Si) cells. Thin-film solar cells use less material (layers of semiconductor materials only a few micrometres thick) and have faster manufacturing processes. The disadvantage of these cells is their relatively low efficiency, which make them undesirable when space is an issue.

Below are the types of the most commonly used solar cells in building applications.

TYPE		Efficiency	Area per kWp
Thin Film		CdTe: 6-11% CIGS: 12-14% a-Si: 4.5-9%	9-25 m^2
Polycrystalline		11-16%	7-9 m^2
Monocrystalline		11-19%	5,5-9 m^2

A.3.2.3 Energy Performance

The optimum solution regarding the design of a building photovoltaic system depends on existing regulations and incentives, installation restrictions or aesthetics. The following cases describe 3 different typical examples.

1. When feed in tariffs (FIT) were available in Europe, photovoltaics on rooftops were a highly efficient investment and building owners were trying to use as much space available on the roof. In these cases, the objective was to have a system as large as possible and to inject all the generated energy into the grid.

2. Today, in many European countries there is net-metering or net-billing13. In these countries, the electricity produced in excess of the building consumption is fed to the utility grid for free or with a very low price. In these cases, users want to have a PV system that does not produce more electricity than the building consumption.
3. Many renowned architects have used photovoltaics to demonstrate the low impact of the building to the environment and to demonstrate the aesthetic integration of photovoltaics. In most of these cases the high energy production and cost effectiveness is not the main objective.

Today, net-metering regulations prevail in most European countries. Therefore, PV are sized to satisfy the building demand and not to exceed it. PV system energy performance and load profile have to be estimated in these cases. Design factors include the load size, the operation period (all year, summer only etc.) and the location of the system (solar radiation).

The electricity production from a PV system can be accurately predicted in most locations and specifically for Mediterranean countries varies from 1,250 to 1,650 kW/kWp. Below is a European map showing: a) The yearly sum of solar electricity generated by an optimal inclined 1 kWp PV system b) The yearly sum of global irradiation incident on optimal inclined south oriented PV modules. [source: Photovoltaic Geographical Information System14 (PVGIS),It can be used to predict the performance of a photovoltaic system.

[13] It is a method of offsetting the energy production and consumption via the network from a PV system. The Net-metering systems belong to the interconnected photovoltaics as require a connection to the utility grid. The energy is offset annually by power consumption in kWh. Any excess energy at the end of the year is going into the grid without any compensation. The correct sizing of the PV system in order to produce, as much energy as it consumes for a year, minimizes the cost of energy consumed from the utility grid.

[14] Photovoltaic Geographical Information System[14] (PVGIS : http://re.jrc.ec.europa.eu/pvgis

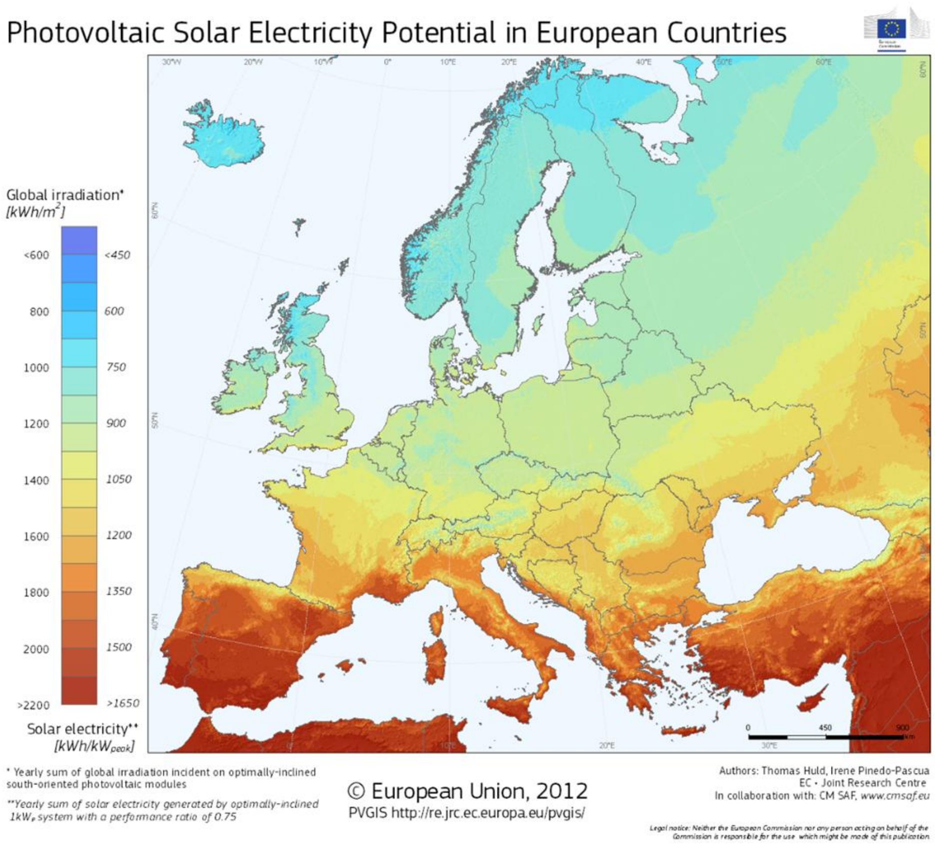


Figure 20: photovoltaic solar electricity potential in European countries

A.3.2.4 Different ways of integrating photovoltaics into buildings

Technical and aesthetic characteristics of the PV module must be considered in order to arrive at a satisfactory integration of PV into the building. A PV system can be integrated at the building's sloped or flat roof, into the building envelope or as a shading device. Crystal silicon solar cells need an area of 15 m^2/kWp in a flat roof and 7-10 m^2/kWp for a sloped roof (Friedrich Sick, 2007). Regarding the flat roof, more space is needed in order to avoid shadows, but it always depends on the latitude.

The various module types such as monocrystalline, polycrystalline and thin film have differing aesthetic considerations. This fact has to be taken into account mainly when PV modules are part of the building skin and are integrated on the façade of the building, the correct type of module has to be chosen in order to match with the aesthetic of the building. This factor is even more important when PV systems must be integrated at listed buildings.

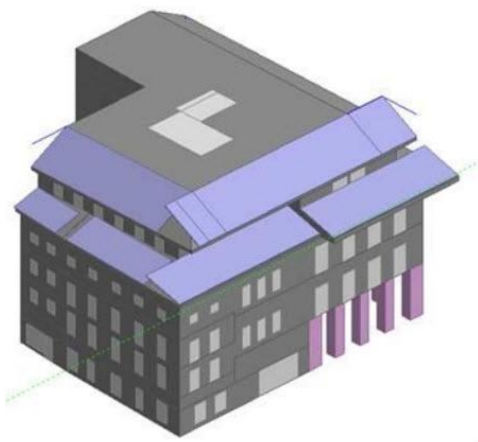
An example from CERtuS project is the Coimbra's City Hall building which is part of the property "University of Coimbra — Alta and Sofia" inscribed on the World Heritage List of UNESCO. As several restrictions are applied regarding the building's renovation, the use of PV tiles made from thin film is essential, as they do not cause high visual impact following the roof's inclination. The buildings' roofs where the PV system will be installed is presented below.

Cell Type	**Thin film**
PV Power	126,1 kWp
Area per kWp	16,7 m^2
Roof Type	Sloped 25^o
PV angle from horizontal	25 ^{o}
Orientation	South-North-East-West
PV Generation	143,311 kWh/year
Annual Performance	1,136 kWh/ kWp

Figure 21: Coimbra City Hall with highlighted roof area for PV

Figure 22: Example of Solar tiles

Other examples of PV integration at CERtuS buildings, include the installation of monocrystalline panels on the sloped roof of the City Hall of Errenteria and the installation of polycrystalline panels on the flat roof of Alimos Environmental Office building.



Cell Type	**Polycrystalline**
PV Power	26,7 kWp
Area per kWp	13,4 m2
Roof Type	Flat
PV angle from horizontal	28°
Orientation	South
PV Generation	37,300 kWh/year
Annual Performance	1,397 kWh/ kWp

Figure 23: Errenteria's City hall sloped roof

Cell Type	**Polycrystalline**
PV Power	26,7 kWp
Area per kWp	13,4 m2
Roof Type	Flat
PV angle from horizontal	28°
Orientation	South
PV Generation	37,300 kWh/year
Annual Performance	1,397 kWh/ kWp

Figure 24: Alimos Environmental Office with PV panels installed in flat roof

When integrating photovoltaics into buildings, the PV elements become part of the building, a collaboration between engineers and architects is essential from the aesthetic and technical perspective. Some general recommendations for buildings PV integration are given below.

- The visible parts of PVs such as surface texture and colour should be compatible with the other building skin materials and other façade elements in order to minimize visual impact
- The position and dimension of the PV modules have to be coherent with the architectural alignment of the building
- It is important to avoid shades by site obstructions, such as nearby buildings or trees, the system must be completely unshaded during the whole year for best performance
- It must be considered the impact that the climate and environment have on the PV performance as in cold and clear days the power production is maximised, while at hot and overcast days the PV system's output is reduced

- PVs in dusty environment and tilted angle close to horizontal must have easy access as they require washing to limit the efficiency losses

A.3.2.5 Types of Photovoltaic systems

Off-Grid PV Systems

PV systems are very effective at remote sites especially in locations with no access to the utility grid. These systems require extra components such as a solar charge controller and a battery bank covering the entire energy needs of the building.

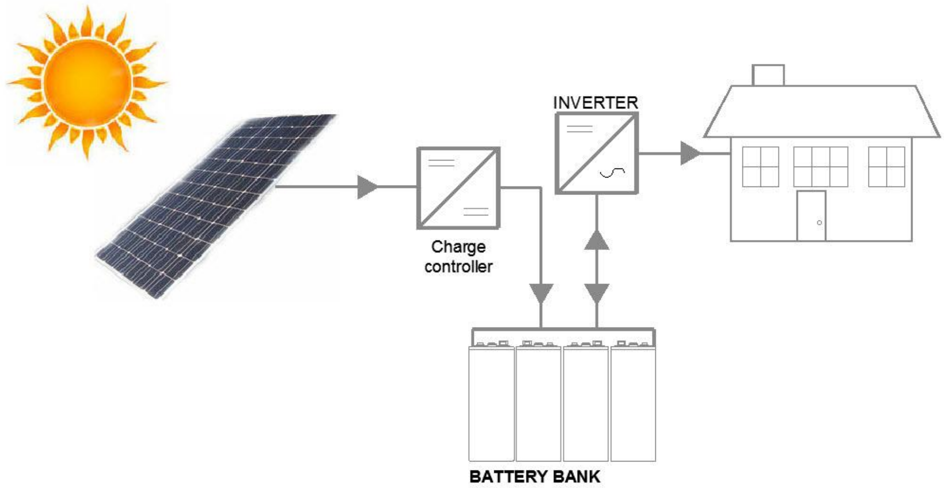


Figure 25: off-grid PV systems

On-Grid PV systems

PV systems may be connected to an electric distribution system (grid-connected). These systems require an inverter to transform the PV-generated DC electricity to the grid AC electricity. When the connection to the grid is according to net-metering, a two-way meter is used in order to offset the produced and consumed energy.

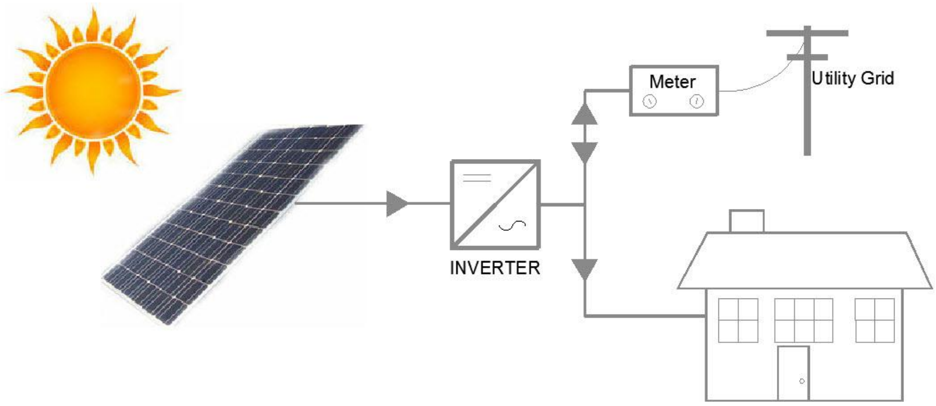


Figure 26: on-grid PV systems

On-Grid with Storage PV systems

These systems use the utility grid as backup for electrical power and the battery bank for storage. Excess electricity produced from the PV system is not fed into the grid but it is stored at the battery bank and it can be used when there is no sunlight, maximising the rate of self-consumption. When these systems operate according to net-metering, the financial benefits are increased as less energy throughout the day has been consumed using the grid connection. The utility grid should only be used as the last energy resource.

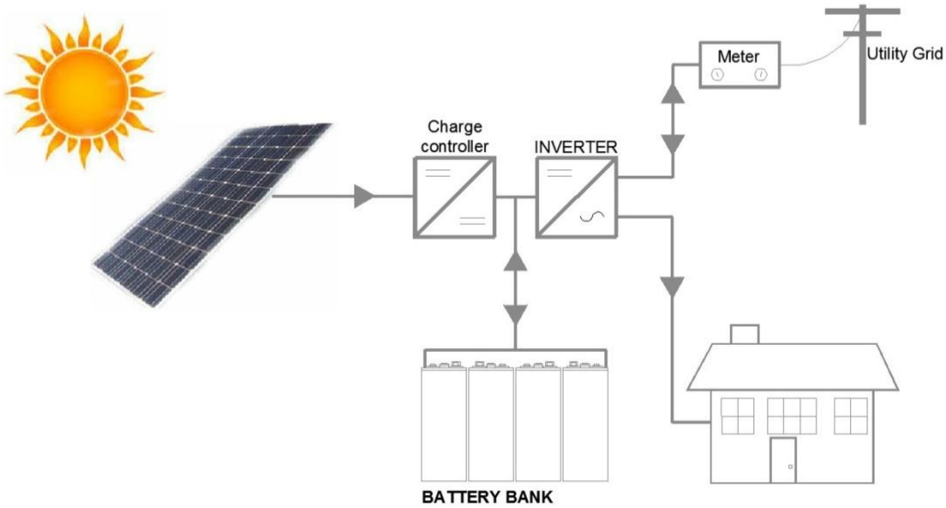


Figure 27: On-Grid with Storage PV systems

A.3.2.6 Applicability and Cost

Nowadays, the tariffs intend to promote the self-consumption of electricity, to avoid consumption from the electrical grid. When the energy is injected into the electrical grid the tariff is very low and reduces the cost-effectiveness of the generation facility. For this reason, the application of PV in public buildings (city halls, schools, etc.) is the most preferred one as these buildings operate during the daytime when the system produces energy. In addition, the energy needs from others technologies (e.g. VRF, AC, etc.), which are very efficient and at the same time they are widespread in the market, can be combined with PV. This fact makes this system the most cost efficient one as the cost for purchase, installation and maintenance is not high.

A.3.2.7 Limitations

PV present some limitations, such as:

- Produce energy only during daytime and have low performance on cloudy or rainy weather and at very high air temperatures
- Installation area must have sufficient free space, be free of shadows and have south orientation
- PV panels should be oriented to South (in the North hemisphere) and inclined with an angle that is slightly lower to the latitude of the location where it is installed.
- The optimum inclination (relative to the horizontal plane) for maximizing the performance of the photovoltaic during the whole year, is relative to the horizontal plane depending on the latitude of the geographical location. When the integration of PVs is on existing buildings is not always possible to install them with the optimum inclination.
- Even though PVs are widely used, their installation on buildings still requires special attention with respect to aesthetic integration in order to avoid visual impact.
- Integration in vertical facades will result in the reduction of the system efficiency producing much lower output (kWh) especially in southern countries.

A.3.3 SOLAR THERMAL

Nowadays, Solar Heating and Cooling (SHC) do not have much contribution to world energy demand. However, the SHC roadmap envisages that if concerted action is taken by governments and industry, solar energy could annually produce more than 16% of total final energy use for low temperature heat and more than 17% of total final energy use for cooling (INTERNATIONAL ENERGY AGENCY (IEA), 2012).

A.3.3.1 Operation

Solar water heating systems are appropriate for covering buildings' need for domestic hot water, space heating and space cooling. Their operation based on the conversion of sunlight into usable energy form to heat up water by using solar thermal collectors.

The operation of this system during winter in order to cover the needs for heating is quite simple. The hot water which is produced from the collectors and is concentrated in the storage tank goes directly to the building. Then, it is used accordingly by the terminal units (fan coils, underfloor system, etc.) to heat up the spaces.

The operation of this system during summer, when cooling is needed, is different and more complex. The absorption chiller which is the most common system for solar cooling, use solar collectors to heat up water and a thermal-chemical absorption process to produce cold water without using electricity (Solar Energy Industries Association, 2016). The cold water is then led to the terminal units (fan coils, underfloor system, etc.) in order to cool the spaces. Each room can have a different temperature depending on the users' requirements.

It is also important to mention that from numerous solar-powered air conditioning projects with absorption systems was pointed out that the single-effect absorption systems[15] are limited in COP to about 0.7, and so they require large collector area to supply the solar heat needed for their operation (SOLAIR, 2009). There are also available on the market

[15] They have only one heating level of the working fluid (dilute solution).

the double-effect systems[16], with COP to about 1.0 - 1.2 and the triple-effect systems[17], with COP of about 1.7.

There are also the “combi-systems” which are solar heating systems for combined domestic hot water and space heating. These systems have the same type of solar collectors with the above described systems but they have a larger collector area and usually larger storage to meet the space heating needs and water heating demand. This system has potentials for widely used in countries that high level of sunshine, as for example in the Mediterranean countries.

A.3.3.2 Applicability and Cost

These systems can be integrated both in existing and new buildings and can be combined with terminal units such as radiant floor, fan coil, etc. They can be used even with conventional radiators but only for heating. The most used collectors for space heating and cooling are the *Flat Collectors,* but the *Evacuated Tube Collectors* are suitable for these systems too.

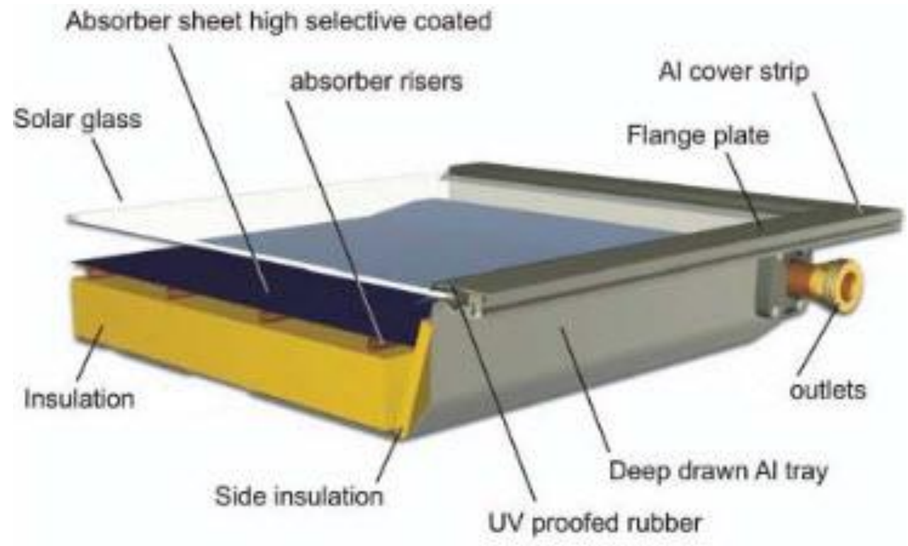


Figure 28: Parts of flat collectors

[16] They have two stages of vapour generation to separate the refrigerant from the absorbent. The heat transfer occurs at a higher temperature compared to the single-effect cycle.

[17] Each unit of heat is used in three different desorber to generate vapour.

According to the water inlet temperature, solar collectors can be efficient and suitable for the radiant floor's requirements. More specific for the underfloor heating systems, the temperature of the circulated water (heating mode) needs to be around 45 ^{o}C, which is significantly lower than the one for radiators. As well, the temperature of circulated water for radiant floor or chilled ceiling (cooling mode) has to be around 18 ^{o}C. The under floor heating is more efficient when it is always ON as its response is very slow, for these reason is more suitable for buildings which need heating or cooling the whole day. Regarding other terminal units, the absorption chiller has to cool down the water (cooling mode) at around 16 ^{o}C and 7 ^{o}C when the solar thermal system combined with supply air system and fan coils respectively. (TRANS-SOLAR, 2010)

Concerning the sizing of the system, in hot and sunny climates, the required collector area (rule of thumb) is approximately 2 m^2 per kW of cooling capacity and 4 m^2 per kW heating capacity (excluding storage). The needed area to install the required collectors is quite large, but this area could be reduced by employing systems with improved COP. These systems may be adapted to and employed in a solar-powered installation, with high temperature solar collectors (such as evacuated tube collectors).

Regarding the cost of the solar thermal systems, the cost of the equipment is still high so the fixed costs of these systems is much higher than conventional systems. On the other hand, the life-cycle cost of a solar water heater system is lower than this one of a conventional heating system and the operating costs is lower compared to the costs of buying fossil fuels (TRANS-SOLAR, 2010). Also, it is important to mention that solar water heating system are more cost effective the southern they are installed.

A.3.3.3 Limitations

The visual impact caused by these systems is the main problem (especially when the storage tank is coupled with the collectors). In buildings inside historic district the visual impact can also be an issue.

Solar heating and cooling is difficult to be integrated due to the limited sunlit space available for such installation within the dense built environment. Even though the building has the required space for this installation, this system is not the optimum choice as it has very low performance and covers only a part of the annual cooling-heating load of the building. For this reason, this system has to be combined with other systems in order to be secured the thermal comfort inside a building. More specific for the building of environmental services office in Alimos (case study of CERtuS), was investigated the option of using solar heating and cooling system. This building has an available roof of about 300 m^2 and total need for heating and cooling loads of 35,300 kWh. Even though the proposed system could cover only 30% of the total loads for heating and cooling.

Furthermore, innovative technologies that could contribute in achieving nZEB levels are still new on the market and costly. An example of this situation is the high price of solar water heating system due to low market penetration. This system is expected to enter the market between 2015 and 2020.

A.3.4 Geothermal Energy

Geothermal energy is stored thermal energy beneath the earth's surface (underground, underground water, steam or hot air) with temperatures of 25 - 350 °C. As this is an inexhaustible and clean energy source utilized in power generation, agricultural and industrial applications, greenhouses, aquaculture, desalination of sea water, thermal baths and more.

Regarding the use of thermal energy in buildings, the term refers to the thermal energy from the ground with a temperature below 25 °C which results from the storage of incident solar radiation. In this case the exploitation depth is typically less than 150 m (shallow geothermal), and is mostly used to produce cooling and heating and hot water in domestic and other premises by using ground source heat pump. The shallow geothermal advantage is that it is available everywhere and is quite easy to exploit.

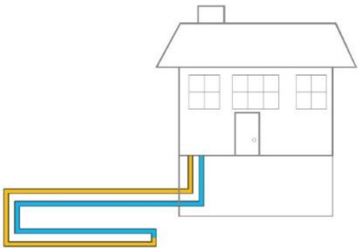
A.3.4.1 Operation

A ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground. This system can be used to provide home heating and domestic hot water heating. They can also provide cooling. Depending on latitude, the temperature beneath the upper 6 meters of ground maintains a nearly constant temperature around 18 °C. These systems use a heat pump to force the transfer of heat from the ground. GSHP's are mainly combined with low temperature distribution systems such as underfloor heating, the lower the temperature required by the distribution system in the building the more efficient the system will be.

A.3.4.2 Geothermal Systems Integration

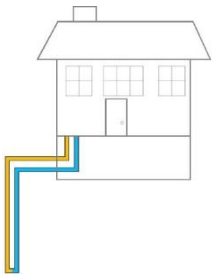
There are several types of geothermal systems. Three of these (horizontal, vertical, and pond/lake) are closed-loop systems and the fourth type is the water open-loop option. Their choice depends on the conditions available (climate, soil conditions, available land, and installation costs). All of these systems can be used both for residential and commercial building applications.

Horizontal – Closed Loop System



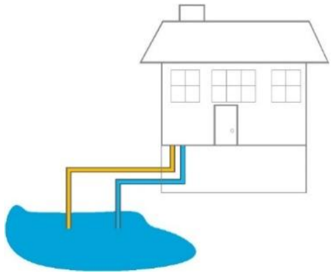
This system is suitable for constructions where adequate land is available around it. It needs trenches at least 1.2 meters deep. There are two common layouts, the first one uses two pipes, one buried at 1.8 meters and the other at 1.2 meters, and the second one uses two pipes placed side-by-side at 1.5 meters deep in the ground in a 0.6 meters wide trench. The Slinky™ method which uses looped pipe allows more pipes in a shorter trench. This fact reduces the installation costs and makes horizontal installation possible in smaller available areas. (ENERGY.GOV, 2016)

Vertical – Closed Loop System



This system is used mainly when the soil is too shallow for trenching and when the needs of a building are too high to be covered with horizontal loops. For a vertical system, holes (diameter around 10 cm) are drilled about 6 meters apart and 50 to 150 meters deep. These holes enclose two pipes which are connected at the bottom with a U-bend to create a loop. The vertical loops are connected with horizontal pipe which in turn is connected to the heat pump in the building. (ENERGY.GOV, 2016)

Water – Open Loop System



This system is used mainly when a well or surface body water exists. The water used as heat exchange fluid and circulates directly through the GHP system. After the end of the circulation the water returns to the ground. This system is suitable only if there is sufficient supply of relatively clean water, and all local codes and regulations regarding groundwater discharge are satisfied. (ENERGY.GOV, 2016)

A.3.4.3 Applicability and Cost

The most important factor regarding the applicability of the system is to locate areas which prove to have temperature differentials that could justify GSHP implementation.

Geothermal heat pumps can be combined with low temperature heating and cooling systems (underfloor heating, fan coils, duct air, etc.) but also with conventional radiators. The combination with conventional radiators need the less possible interventions inside the building but is not very efficient.

A well performed combination for public buildings is the use of GSHP with VRF. This system combines the advantages of both technologies into one system, making it one of the most efficient HVAC systems available for many applications especially for buildings which host public services. By using ground water loops, multi-speed fans and variable speed compressors, ground-source VRF heat pump systems achieve higher savings than GSHP or VRF on their own.

For buildings with 24 or nearly 24 hour operation, another option is the use of GSHP with underfloor heating because GSHP is more efficient if combined with a large warm water circuit (like underfloor heating) rather than a small high temperature circuit (like conventional radiators). The efficiency of a heat pump when supplying a distribution system at 35°C will be approximately 25% higher than if it had to supply a distribution system at 45°C (Ground Source Heat Pump Association, 2007). Also, to maximize the efficiency of a heat pump when providing heating, it is important not only to have a low temperature distribution system in the building, but a large radiant surface too. More specific, a GSHP under these circumstances can achieve a COP around 4. Additionally, GSHPs are emission free at the site of use and need no flue or chimney.

As it was mentioned, the underfloor heating is not the optimum choice for public buildings which operate 8-10 hours per day. This system is more efficient when it is always ON as its response is very slow and energy consuming, therefore it is more suitable for buildings which need heating the whole day. For this reason, the best choice for buildings like schools and city hall is a GSHP combined with VRF system.

Regarding the sizing of the system for space heating, the general rule of thumb is that for every 1 kW required, there is a requirement for 10 m of horizontal piping. For vertical bore-hole piping, every 100 meters delivers around 3 to 5 kWp of heat capacity, depending on the type of soil or rock and the ground temperature. Under the GROUND-MED project a study for Regional Administration building in Coimbra, Portugal was undertaken in order to install GSHP. The conditioned area of the building was 586 m^2 and the heating and cooling power demand was 34 kW and 48 kW respectively. In order the building's needs to be satisfied, seven vertical boreholes up to a depth of 125 m were drilled (A. Almeida, J. Fong, A. Quintino, A. Carvalho, 2014).

The maintenance cost is not too high as there is no need for safety checks for GSHP and regular maintenance requirements are very low. The maintenance procedure includes pre-heating season checks of the water pump, external pipes and fittings and electronics. Also, the life expectancy is very long, typically 20-25 years for the heat pump and over 50 years for the ground coil (Ground Source Heat Pump Association, 2007).

A.3.4.4 Limitations

Even though the geothermal heat pumps are very efficient there are few limitations which prevent their widespread use. The main constrains are the following:

- Most of the buildings may have problems concerning the surrounding areas making the installations of such systems not viable.
- The geothermal heat pump, although very efficient, is difficult to be installed in a dense built environment because of lack of space to accommodate the drilling rig.

- Creating passage for these pipes and other components makes the installation in historic areas/buildings rather difficult.
- The main constraints are still the initial investment in the system and the associated costs (e.g. the need to perform the necessary geological surveys).

A.3.5 BIOMASS

The term biomass mean any material derived from living organisms (such as wood and other forest products, crop residues, animal wastes, waste from food industries, etc.) and can be used as fuel for energy production. Burning biomass releases as much CO_2 as it was absorbed during the plants' life so it has no impact on the environment. Biomass can be used to produce heat or electricity through the corresponding procedures, but at building integration scale only the first use is described.

Figure 29. Types of biomass

A.3.5.1 Operation

The most common biomass-based systems for buildings such as city halls, schools, etc, are the biomass boilers. This kind of boilers work in a very similar way to conventional oil or gas boilers, combusting the fuel to produce heat that is then used to heat water. The boilers using wood chips are high-tech devices with automatic fuel feeding. They are operating at high temperatures and their efficiency is greater than 90% (similar to efficiency of oil-based boiler).

The use of biomass for the building heating has no major legal restrictions. Regarding the fuels, they have to be certified and the heating systems have to satisfy all the provisions of law in order to ensure the proper operation.

The increasing interest in biomass energy and biofuels has been the result of the following associated benefits (Biomass Energy Center , 2011):

- "carbon free" fuel as the carbon emissions are negligible compared to fossil fuels
- can be sourced locally contributing to security of supply
- support the rural economy
- the establishment of local networks of production and usage, this fact minimise the transportation costs
- the use of biomass fuel provides an economic incentive to manage woodland which improves biodiversity
- current biomass combustion systems are modern with high quality, offering high combustion efficiency comparable with the conventional boilers
- biomass residues, co-products and waste are not toxic

A.3.5.2 Applicability and Cost

For the buildings with central heating system based on oil-burning boiler the use of biomass needs the less possible changes on the heating system. For this reason, the use of pellet is the most feasible one. In this case the integration of the boiler is not challenging as it can replace the conventional one. Also, the biomass-burning boiler can be combined efficiently with other systems such as water-to-air Air Handling Units (AHUs) in order to cover the heating loads. The difficult part of the integration is the large space which is needed for the installation of the automatic feeding system and pellet storage. More specific, for annual heating energy demand 140 MWh the recommended system size is 100 kW. In order for these needs to be satisfied the volume of the required wood pellets at 10% moisture content (MC) is 44 m^3 (with density 670 kg/m^3) (Biomass Energy Center , 2011).

The maintenance cost is not high as the system needs 4 times a year hob cleaning and 1 time per year chimney, exchange surfaces and fan cleaning.

In conclusion, the biomass-burning boiler is a technologically mature system, which can be easily integrated and with high COP. Once there is adequate space for automatic feeding system and pellet storage it is a reliable solution. For this reason, in two of the CERtuS buildings, Lekuona in Errenteria and Municipal Library in Alimos, biomass-burning boiler will be installed. Specifically, in order to cover the heating needs for Lekuona, a 201 kW boiler combined with AHUs is proposed. Furthermore, for the Municipal Library, the proposal foresees a 75 kW boiler combined with radiators.

A.3.5.3 Limitations

As it was mentioned the conversion of conventional boiler to biomass one is the easiest way to integrate RES in building. However, there are few limitations which are:

- It needs to be feed of fuel even if it has automatic feeding system.
- It is important to mention that solid fuels have ash content at least 1%, this means that for each ton of pellet which is burnt 10 kg remains in the form of ash in the boiler. For this reason, in order to ensure an efficient operation, the system has to be cleaned regularly.
- Require an adequate storage space for the fuel, since each ton of pellet needs almost 1.5 m^3 of storage space.
- Biomass boiler has integration potential but its use would require extra equipment in the building just for heating.

A.3.6 Wind Turbines

Wind energy is the energy that results from the conversion of the kinetic energy of wind into electrical energy using a wind turbine.

A.3.6.1 Operation

The size of the system depends on building's energy needs and the annual average wind speed of the site. In a typical residential application, wind turbine of 4-10 kW can meet the energy needs. A well performed small wind turbines usually has efficiency of 30-35%.

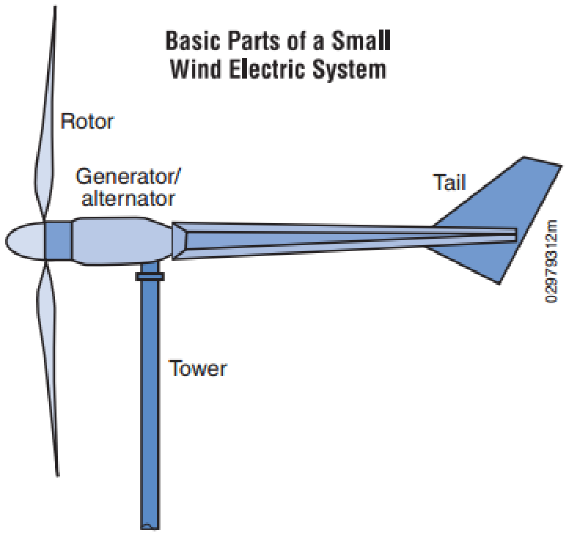


Figure 30: basic parts of small horizontal axis turbine (U.S. Department of Energy, 2016)

Wind turbines are divided into two main types: vertical axis turbines and horizontal axis turbines. On the world market the horizontal axis wind turbines have gained market share in about 90%. It is also important to mention that the noise level of most modern small turbines is about 52-55 decibels.

Apart of the wind potential of the site another main factor which affects the wind turbines performance is the size of the blades. The larger the blades, the greater its energy production. Doubling the length of the blades, increases four times the power for constant speed. Also, doubling the wind speed, increases eight times the produced energy for constant size. Most manufacturers' specifications refer to wind speed of 12 m/s but common wind speed varies from 5 to 6 m/s. However, wind at roof top levels is rarely this high for any extended period of time, especially in an urban environment.

A.3.6.2 Wind Turbine Integration

Wind turbines do not start reaching a steady energy producing level until they are about 9 metres higher than the highest tree or building in the area and at least 90 meters away from any obstructions. This would necessitate a pole mounted turbine on at least 4000 m^2 of free land, which is almost impossible to achieve in a city. (U.S. Department of Energy, 2007)

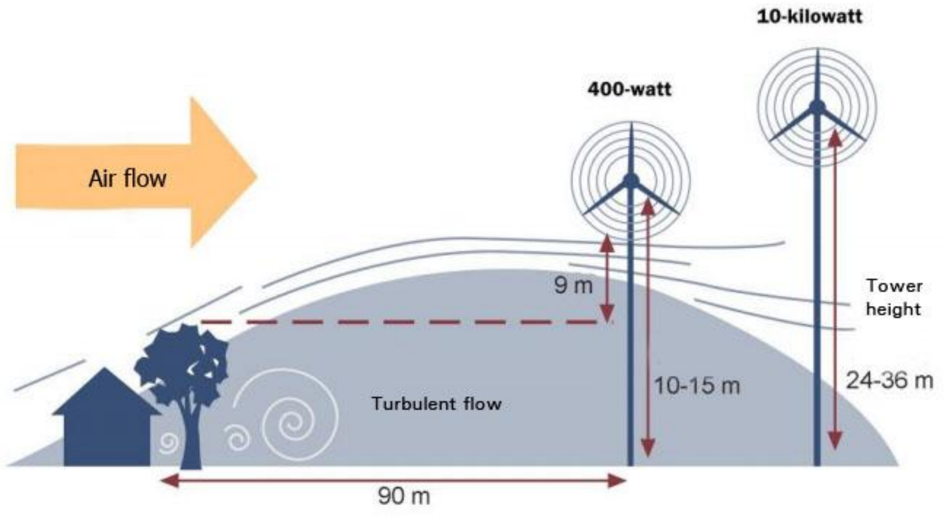


Figure 31: parameters for small wind turbine installation (U.S. Department of Energy, 2016)

Horizontal Axis Turbines

Horizontal axis means the rotating axis of the wind turbine is parallel with the ground. The main advantage of horizontal wind is that it has better performance compared to other type of wind turbines. The disadvantage of horizontal axis is that it is heavier system, it does not perform well in turbulent winds and it causes high visual impact on the surroundings buildings.

Vertical Axis Turbines

Vertical axis means the rotating axis of the wind turbine is vertical with the ground. Vertical axis turbines are primarily used in small wind projects where the energy needs are not very high and at the same time the wind direction is highly variable.

Applicability and Cost

In wind farm applications, horizontal axis wind turbines are almost the only ones used. However, regarding the small and residential wind turbines applications, vertical axis turbines have share of the market.

Prerequisite for any next step is to measure the wind potential at least for six months at exact position and height of the wind turbine. In order the installation to be economically feasible it is required a medium level wind 5 m/s (rule of thumb). This is difficult, but not impossible within the urban environment.

It also important to mention that the vertical axis wind turbines are the optimum choice where the turbines cannot be extended too much above the building and so they cannot take advantage from steady wind.

Regarding the size of the system, turbines used in residential applications can range in size from 400 watts to 20 kW (100 kW for very large loads). More specific a 1.5 kW wind turbine will meet the needs of a building requiring 300 kWh per month in a location with a 6.26 m/s annual average wind speed. (U.S. Department of Energy, 2016)

Although small wind turbines are very durable machines, they do require some annual maintenance which is not expensive. After 10 years, the blades or bearings may need replacement, but if the installation and maintenance is the required one, the turbine should last up to 20 years or longer (U.S. Department of Energy, 2016).

A.3.6.3 Limitations

In general, mounting turbines on rooftops is not recommended. All wind turbines vibrate and this vibration is transmitted to the construction on which they are mounted. This can lead not only to noise but to structural problems too. Also, the vibration can cause excessive turbulence that can shorten the life of the turbine (U.S. Department of Energy, 2007).

Furthermore, there are the following constrains:

- Visual impact specially in historic areas;
- Moving shadows cast by the blades on windows can affect visual comfort inside neighbouring buildings;
- To make wind power cost-effective, turbines need access to strong and sustained winds, which are not available on rooftops.

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(E.G, B.N)

A.4 HISTORIC BUILDINGS DEEP RESTORATION

Background and General Knowledge

50 million buildings throughout Europe are 50 years old or more and, although a small share is officially listed, many of them present some historic, architectural, artistic and social value. Historic buildings are often left apart from sustainable and technological development because of their complex legislative framework, which also led to their exclusion from national obligations towards the reduction of energy consumption and CO_2 emissions. Consequently, energy related interventions, and, even more the application of the nZEB concept on historic buildings can be very difficult. However, their potential for energy savings is significant and the implementation of energy related techniques adapted to their specific characteristics it is not impossible.

The objective of retrofitting historic buildings should be focused on the following aspects:

- Improving comfort and indoor environmental quality
- Improving durability of the building as a conservation measure by improving its thermal performances thus ensuring its use and maintenance
- Reducing energy consumption and CO_2 emissions

Historic buildings were built to respond to specific climatic conditions while securing the optimal environment for living. Nevertheless, comfort levels as well as climate have changed over time. In order to ensure liveability of these buildings and adapt them to modern lifestyle, sustainability is a key issue, which should be tackled by introducing solutions and interventions able to respect and maintain their values. Therefore, the actual knowledge of the historic building and its energy behaviour is essential for the preservation of its values before making any intervention in order to avoid invasive operations. At the same time it is very difficult to acquire an appropriate level of knowledge when operating on historic constructions; in fact, often it is not possible to determine the thermal and physical behaviour of materials and their current and/or potential performance. Conversely than in modern and contemporary buildings, the thermal behaviour of the historic ones comes from thermal inertia of the walls, of which, very often, the stratigraphy and construction techniques are unknown. Moreover, historic buildings are often not heated or equipped with heating systems, able to guarantee a constant comfort of indoor air quality.

Nowadays the evaluation and modelling of the energy behaviour of the historic buildings is carried out with the same tools and methods used for contemporary constructions, which do not take into consideration problems and specificities of historic buildings. The majority of available tools are designed for contemporary constructions, whose materials characteristics and technological systems are well known. These evaluation systems are also adopted for historic buildings, even if they present considerable differences in morphology, technology and materials compared to modern ones, showing several limitations of application and suitability of results. Very often these kind of evaluations induce to radical interventions or replacement of building elements (i.e. windows frames) without any real benefit from the overall energy efficiency point of view and exacerbating the breathability of the structure.

An overview of the problematic of the historic buildings (not only from an energy point of view) helps to calibrate the possible solutions and alternatives of the intervention, considering also the future management of them. The choice of intervention can be related to the following topics:

- the building envelope;
- the building equipment;
- lighting, including the use of both artificial light sources, as well as natural illumination;
- passive solutions;
- introduction of systems for the production of renewable energy.

Building envelope

Historic buildings are working in a very different way with respect to the modern and contemporary ones and they are, oftentimes, thermally less efficient than those built according to recent and current building codes. The walls of the ancient buildings have a high degree of thermal inertia, ensuring constant thermal and lenses exchanges with the external environment, according to the daily and seasonal temperature range. Furthermore, thermal losses -through the vertical envelope- are not very common, except at certain points in which there is a reduced thickness or a discontinuity of the masonry. Intervening by insulating the envelope (through outer coat) to those types of buildings is often harmful and useless. The risk is to cause condensation phenomena, decreasing the permeability of the different layers, by altering the porosity of existing materials. Moreover, the interaction between 'new' and 'old' parts should be carefully assessed, not only from the aesthetic point of view, but mostly by the chemical, physical and mechanical compatibility, to avoid further deterioration. For this reason the thermal insulation must comply with the permeability and breathability of the existing wall system, or must be balanced by alternative measures for the dissipation of moisture in excess, such as an increase of natural ventilation, which increases the thermal dispersions.

Among the insulating materials available on the market, the ones which are usually particularly suitable for historic buildings are the natural fibrous materials, both organic and inorganic, able to reduce heat transmission by convection and radiation. Furthermore, their structure makes them breathable and hygroscopic, thus compatible with the thermo-hygrometric characteristics of traditional masonry. Concerning inner insulation, the reduction of useful surface should be considered. In this case, materials with high performances and reduced thickness should be preferred, such as radiant barriers or vacuum insulation.

Figure 32: Vacuum insulated panel

Figure 33: Radiant barriers

A deeper comparison between ancient and modern building indicates that modern and recent constructions (mainly of the tertiary sector) are commonly designed and conceived as sealed units, with low or non-existent natural ventilation, which frequently requires for mechanical ventilation systems. Historic buildings have, instead, a natural envelope 'breathability', depending on the porosity of materials, construction systems and natural ventilation of the whole structure. Traditional and historic buildings are built with materials having a high degree of vapour permeability, which, in the presence of high relative humidity values, respond differently than the hard and waterproof materials used in modern constructions. It is important to recall that the presence of moisture in historic walls constitutes a further risk both from a mechanical and deterioration point of view.

Roofs represent the portion of the envelope which is more subject to chemical, mechanical and physical stress due to atmospheric agents. Where possible, interventions should be focussed on the improvement of the passive systems of the buildings, such as the realization of skylights, ventilation chimneys or the integration of active systems for energy production.

In the energy balance of the envelope, windows and frames represent a critical point of the design project due to its characteristics (heat loss through glazing and joints/seals) and its functional characteristics (air exchange and ventilation). It is important to consider that interventions on windows alter the original aspect of the building but, at the same time, managing the relationship between new and old parts is a priority. This should be especially considered on buildings with high thermal mass, as its energetic behaviour can change due to introduction of new elements that regulate ventilation.

Traditional glasses generally don't have good properties of heat transmission resistance. Its replacement by glazing with higher heat resistance improve the envelope performances by reducing energy losses.

Building equipment

The improvement of energy efficiency of a building should foresee intervention on the equipment, especially regarding the production of thermal energy, necessary for heating and hot water. There are many solutions available on the market and modern boilers have very high performances compared to traditional ones.

The inclusion on the equipment should comply with standards calibrated on the historic buildings and not yield to the temptation to the automation at any cost. Should be preferred the quality and simplicity, both in the insertion of the equipment, as well during management and maintenance. These phases should be very smooth and never entail destructive operations.

In the design and management of air conditioning systems, it is advisable to diversify the heating / cooling systems for the different parts of the building, according to the specific characteristics, orientation, total structural mass, provision of the structural elements and the use of the different areas. The installation of new air-conditioning systems helps to maintain optimal conditions for the preservation of the historic buildings. It is necessary to carefully evaluate all the variations induced from the ignition of the systems which may affect the thermo-hygrometric values of the building areas. The systems should be brought to full operation in a long time, checking regularly the humidity values within the different areas of the building.

Improving the energy efficiency and the amount of energy used for the building air conditioning, depends on a number of factors related to the indoor and outdoor climate conditions: (i) the 'passive solutions' of the building (technological and constructive characteristics which take advantage of the outdoor climate), (ii) the 'active' solutions of the building (equipment that can control and modify indoor climatic conditions) and (iii) the type of systems for energy generation.

Lighting

In reference to the guiding principles of restoration, also in this case, the compatibility between old and new should be sought. This results in the search of old plants and pipes and their adaptation, considering the possibility of a partial re-use and the selection of tailored solutions and materials which are minimally invasive and compatible with the old structures. On an aesthetic level, it implies the specific choices regarding the visual and spatial impact. Reversibility should also be taken into account, thus it is preferable to select exposed system or existing cavities, rather than the creation of walls ducts. These criteria are pushing industries and professionals to analyse and propose new solutions and products in response to this specific market demand.

Passive strategies

Traditional buildings can hardly comply with the current requirements for thermal comfort in buildings. However, they employ a range of passive strategies of climate control that can be utilized in combination with active systems in order to reduce the energy demand. While retrofitting for energy efficiency, people often forget to take into consideration how their building worked when it was constructed. A common scenario is choosing a type of insulation to increase airtightness to prevent the heat loss, resulting in a decrease of natural ventilation, increase of moisture content in the structure which often leads to the appearance of mould.

Even if impact should be evaluated on each individual building, enhancing the passive principles and educating users can add to significant savings in energy use. Using shading devices, proper ventilation of spaces and nurturing vegetation in surrounding areas, save heat in cold season and provide coolness during warm season.

Renewable energies

One of the major barriers in the implementation of solar energy in historic buildings is the impact on the appearance of the volume, the materials and the surfaces of the structure. The importance of planning interventions which are based on the reversibility and on the non-invasive use of technologies has to be therefore considered, taking into account the heritage significance of the building. Solutions should be addressed in each case, according to the possible available technologies.

The most common system of Renewable Energies is still represented by the photovoltaic (PV). Concerning photovoltaic it has to be considered that through a continuous surface of panels better performances are achieved with respect to the use of small elements. Performance depends on the size of surface, orientation as well as gradient of the panels. In historic buildings, the implementation of PV panels on the roof, while respecting orientation and gradient, presents difficulties to achieve optimal benefits from an energy point of view. In order to obtain optimal cost-benefit ratio, it is usually recommended, especially if buildings are located in historic centres, to allocate the production systems in an exterior area, on parking or industrial spaces. The most used systems is the inclusion of PV panels of different sizes on architectural elements. Nevertheless, there are other PV elements available on the market, which are usually smaller than traditional panels and integrated in constructive elements. These can be more suitable for historic buildings, such as PV tiles, the PV film that can be applied on windows or glass plates integrating PV cells.

Same considerations apply to the use of solar thermal systems. In historic buildings it is usually recommended to adopt system with internal tank. The installation of panels should be analysed in order not to modify the architectural perception of the building and solutions with chromatic mimicry should be preferred.

Examples of the use of heat pumps, biomass and geothermal are in historic buildings or centres are still less known. Passive systems and strategies are usually preferred, such as buffer spaces, light pipes or ventilation pipes.

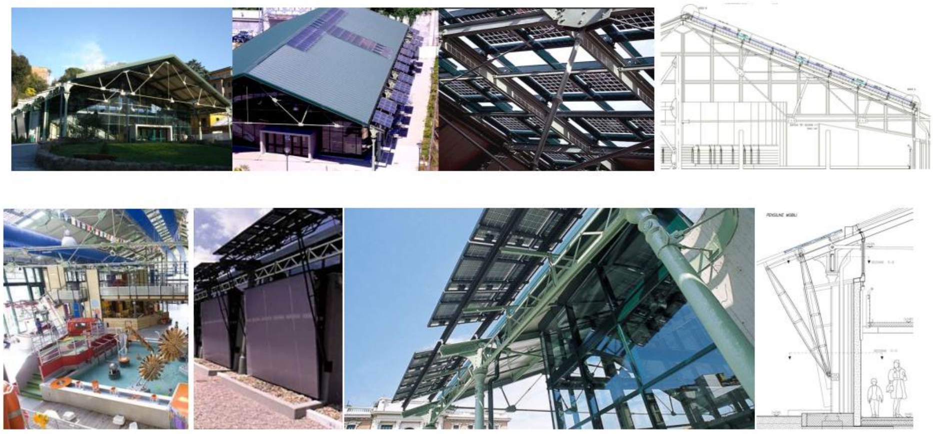

Figure 34: Rome, Italy. The building of Childrens museum, Museo dei Bambini, is a set of historic building arose between 1870 and 1920. The buildings and spaces have been restaurated and adapted to the exhibition function. The PV has been integrated in two steps:

The first PV system of 15.2 kWp was installed in 2001 on the skylight on the south side of a pavilion. It has 12 mobile shelters that allow a variation of the façade shading according to the seasons. The panels installed are in total 180 of which 72 on the skylight and 108 on the side shelters. This system produces the energy required to operate all of the museum computer, many games and exhibits and has been installed with the support of INNOPEX project (THERMIE- Energy)

The second PV system of 18 kWp, installed in 2007, is located in the area of parking lot. It is an installation of shelter for cars with 100 solar panels and produces the energy necessary for the consumption of the Administrative offices, the shop and the ticket office and has been installed through the incentive of the Italian "Conto Energia".

Sources: https://www.mdbr.it/visita-il-museo/il-museo/
http://ptp.irb.hr/upload/mape/kuca/01_Jens_Ole_Hansen_INNOPEX_Innovative_architectural_integrati.pdf

Figure 35: Paris, France. Designed originally as a machine, the building of the Compagnie Parisienne Distribution Electricite, completed in 1929 extends its vocation through a photovoltaic equipment (2007), a device unpublished in Paris and still very marginal in France. The electrical production tool therefore still remains in an experimental form.

Compagnie Parisienne Distribution Electricite, Paris, France Source: https://commons.wikimedia.org/wiki/File:Compagnie_Parisienne_Distribution_Electricite.jpg

Figure 36:"Sala Nervi", Vatican City, Rome Italy. An interesting example of RES application in sensitive contexts is represented from the courtroom of Pope Paul VI (Sala Nervi), as it plugs into a work of one of the most important actors of the Italian modern architecture.

The project (2007) involved the replacement of the facing south tiles with photovoltaic panels, while the northern part of the roof replaced with high-tech material, whose peculiarity is to reflect part of the solar radiation, thereby increasing the productivity of the system .In 2008 comes into operation 2,400 photovoltaic panels installed on the roof,able to cover at least a quarter of the energy needs of the courtroom Nervi and the neighboring buildings. This is the first photovoltaic system of Vatican City and can rely on 221.59 kW, able to annually generate about 315,000 kWh/a, reducing the consumption of 70 TOE and saving the emission of a quantity exceeding 200 tons of CO_2.

Source: http://www.architetto.info/news/energia/il-fotovoltaico-installato-a-citta-del-vaticano/

One of the major barriers concerning historic buildings is often associated to financial mechanisms, as the use of specific or limited solutions make the interventions more expensive compared to newer buildings. It is therefore necessary to approach historic buildings considering a wider and holistic perspective. Many of these buildings are located in historic centers and constitute the core of a community structure. The sustainability and efficacy of interventions might be improved if several buildings are tackled together at the same time, relieving historic buildings from any pressure to implement inappropriate and heterogeneous retrofitting measures which could damage their value.

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(A.G, E.M, S.F)

A.5 DEEP RENOVATION STRATEGY AND CO-BENEFITS OF ENERGY RELATED BUILDING RENOVATIONS

Deep renovation - Planning and designing strategy

High performance buildings have to be optimized in many different areas starting with the building design (architecture) which certainly can be influenced less strongly during the renovation of an existing building. Next step is looking at the thermal quality of the building envelope and detailed solutions for avoiding thermal bridges and ensuring airtightness to the choice and quality of the building services systems for heating, cooling (if needed), ventilation, lighting and building automation. Energy efficient public buildings equipment has to be chosen and energy has to be generated from renewable energy sources to compensate for the energy use.

It is essential to consider sustainability and energy efficiency at the very start, to establish the key targets. Ambitions and intentions should be stated in the building programme, containing a finite number of clear and manageable high level objectives. Objectives regarding building suitability, energy demand and building materials should be emphasised and put into specific terms. If goals are not set at an early stage, they tend to either be forgotten or be left out due to pressures from budget or work schedule.

The professional knowledge of architects and engineers is to be combined in the design phase, estimating how different building structures and envelope designs influence the indoor climate and energy use for heating, cooling, ventilation and lighting. Climatic analysis will reveal the potential for utilising available solar, light and wind resources. Concepts should be tested by means of sketch models to assess the design and adjust it to the situation, before gradually developing the final design.

Previously, environmental simulation of building performance was only done by engineers at the end of the design process. Any weak points in the performance of the design could then be ‘fixed’ by adding heating, cooling, shades, vents, fans, panels, etc. However, at the end of the design process it is too late to incorporate various passive techniques, which should be considered in the early, most conceptual stages of the building design process.

Essentially, an interdisciplinary planning process is based on the idea of optimised team work, which should start in the pre-project stage to make a clear definition of goals. Furthermore, there should be a qualified design process management, and tools for analyses and assessments should be applied, taking into account a variety of options from the very start. The knowledge of different specialists should be introduced at an early stage.

Cx (Building Commissioning) procedure can combine all the objectives introduced in the previous chapters. It is important that the design intent is clearly set and the performance goals – the various factors which effect on the performance in various stages of the building project - will be checked during each step of the project. New concepts and new technology applications are challenging for building owners, architects and consultants. If the design team lacks knowledge of environmental issues or if the performance goals are especially challenging, an external process facilitator should be added to the team. The facilitator will have the task to raise performance issues throughout the process and bring specialised knowledge to the design team. The facilitator can be a Commissioning Agent.

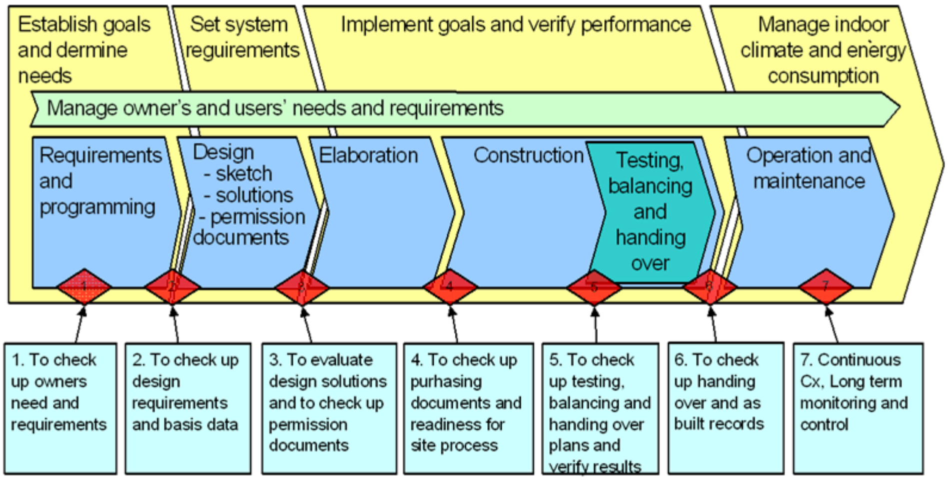


Figure 37: The commissioning procedure

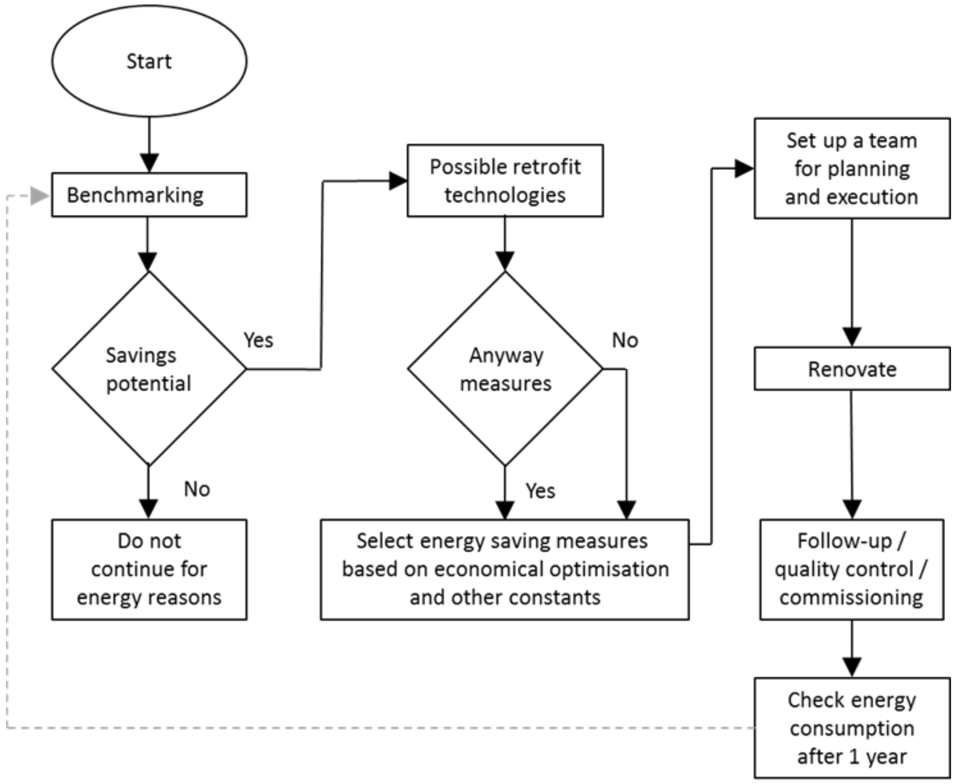


Figure 38: Energy renovation process

In aiming to reduce the energy consumption, a five step strategy is recommendable:

1. Reducing heat losses and cooling demand
2. Reducing electricity consumption
3. Utilising passive solar gain
4. Controlling and displaying energy use
5. Selecting energy sources, preferably renewables to a large extent.

In other words: the starting point is application of energy efficient measures to reduce energy demand, and then supply the remaining demand utilising renewable energy sources.

Designers should repeatedly estimate how different plan lay-out, structure and envelope design influence the indoor climate and energy use. A major challenge is handling goal conflicts. Measures must be balanced to reach several goals, e.g.:

- Exploitation of daylight will benefit users' contentment and well-being. At the same time exploitation of daylight will reduce the consumption of electric power for artificial lighting. On the other hand, an extended use of glazing may cause a higher demand for heating and possibly cooling energy.
- Air quality and comfort temperature will benefit users' contentment and well-being. A high performance ventilation system is thus required. On the other hand, energy consumption for the system should be kept as low as possible.
- Adequate acoustics will benefit users' contentment and well-being. The desired reverberation time will vary according to functions, and it may be contradictory considerations to take into account regarding multi-functional space. The placement of absorbers must be considered in relation to the benefit of thermal mass stabilising internal temperatures.

Different solutions have different strengths and weaknesses, and the project team has to optimise the solution as a whole, and not on a component-by-component basis. From the assessment of different solutions the project team identifies parameters that make a difference, and gain an increasing awareness of the environmental impacts of the design. The success criteria should be related to achieving the objectives and intentions stated in the program.

Co-benefits of energy related building renovation

Reducing energy demand and providing good indoor climate is fundamental when retrofitting public buildings. For any building renovation project a holistic point of view should be taken. This includes considering which part of the renovation should to be carried out for other reasons than energy savings, wear and tear (deterioration) as the most likely reason. The need for renovation anyway greatly influences the costs which should be assigned to the energy-related retrofit and thus the Net Present Value and simple financial payback of the investments. Therefore one of the first activities in any renovation project is to identify anyway measures.

Secondly, as early in the renovation process as possible, co-benefits such as a significant improvement of the indoor should be identified and kept in focus to make sure that these co-benefits are becoming results of the renovation. It may even be possible to assign an economic value to them.

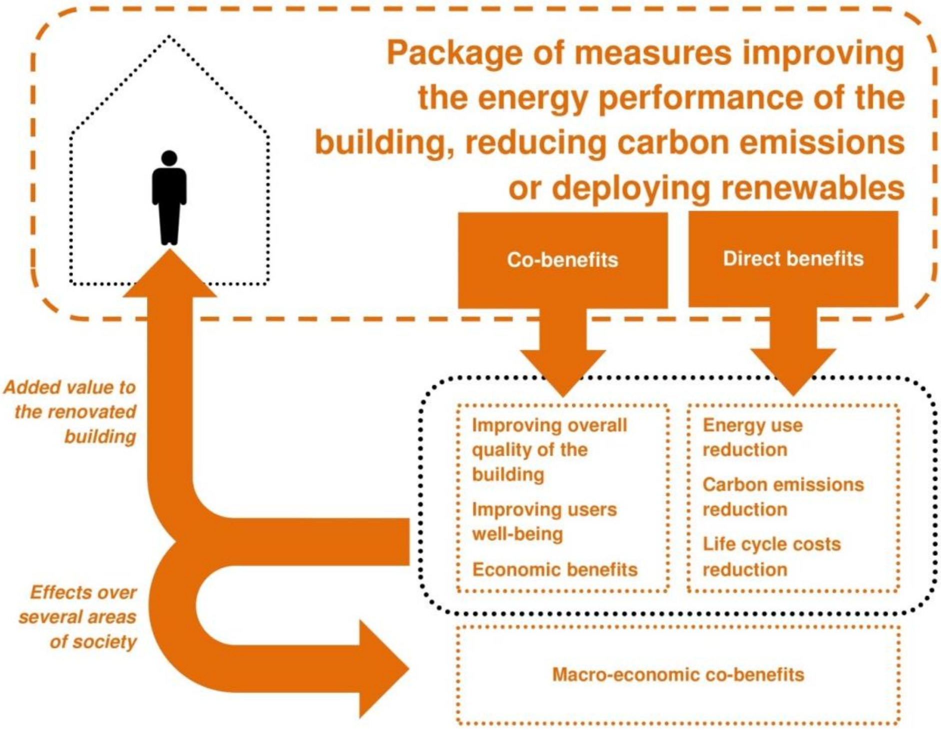


Figure 39. Direct benefits and co-benefits from cost effective energy and carbon emissions related building renovation[18]

Several terms are used in the literature for side-effects that arise from building renovation such as co-benefits, non-energy benefits (NEBs) and multiple benefits. The term co-benefits is used here to include all effects of energy related renovation measures besides reduction of energy, CO_2 emissions and costs. These co-benefits can have a significantly value and are most often disregarded and that is why the full value of renovation work is often underestimated.

[18] *Co-benefits of energy related building renovation, Annex 56, Marco Ferreira, University of Minho – Civil Engineering Department, Guimarães, Portugal et al.)*

These benefits can be felt at the building level (like increased user comfort, fewer problems with building physics, improved aesthetics, see Table 1), but also at the societal or macroeconomic level (like health benefits, job creation, energy security, impact on climate change, see Table 2).[19]

Table 21Typology of private benefits of cost effective energy related renovation measures

Category	Co-benefit	Description
	Building physics	Less condensation, humidity and mould problems
	Ease of use and control by user	Ease of use and control of the renovated building by the users (automatic thermostat controls, easier filter changes, faster hot water delivery, etc.)
	Aesthetics and architectural integration	Aesthetic improvement of the renovated building (often depending on the building identity) as one of the main reasons for building renovation
	Useful building areas	Increase of the useful area (taking advantage of the balconies by glazing or enlarging the existing ones) or decrease of useful area (like the case of applying interior insulation or new BITS). This can also occur as a result of removal of cold surfaces, making it more comfortable to be nearer to windows.
	Safety (intrusion and accidents)	Replacement of building elements with new elements at the latest standards, providing fewer risks such as accidents, fire or intrusion.
	Reduced exposure to energy price fluctuations	Reduced exposure to energy price fluctuations gives the user a feeling of control and increased certainty to be able to maintain the desired level of comfort.
	Thermal comfort	Higher thermal comfort due to better control of room temperatures, higher radiant temperature, lesser temperature differences, air drafts and air humidity.
	Natural lighting and contact with the outside	More day lighting, involving visual contact with the outside living environment (improved mood, morale, lower fatigue, reduced eyestrain).
	Indoor Air quality	Better indoor air quality (less gases, particulates, microbial contaminants that can induce adverse health conditions) better health and higher comfort
	Internal and external noise	Insulation against outside noise but increased risk of higher level of annoyance due to internal noise after the reduction of external noise level
	Pride, prestige, reputation	Enhanced pride and prestige, an improved sense of environmental responsibility or enhanced peace of mind due to energy related measures

19 Co-benefits of energy related building renovation, Annex 56, Marco Ferreira, University of Minho – Civil Engineering Department, Guimarães, Portugal et al.

Category	Co-benefit	Description
	Ease of installation and reduced annoyance	Ease of installation can be used as a parameter to find the package of measures that aggregates the maximum of benefits

Table 22 Typology of macroeconomic benefits of cost effective energy related renovation measures

Category	Subcategory	Description
Environmental	Reduction of air pollution	Outdoor air pollution is reduced through reduced fossil fuel burning and the minimization of the heat island effect in warm periods. Less air pollution has positive impacts on environment, health impacts and building damages.
	Construction and demolition waste reduction	Building renovation leads to reduction, reuse and recycling of waste, especially if compared to the replacement of existing buildings by new ones.
Economic	Lower energy prices	Decrease in energy prices due to reduced energy demand
	New business opportunities	New market niches for new companies (like ESCOs[20]) possible resulting in higher GDP[21] growth when there is a net effect between the new companies and those that are pushed out of the market.
	Job creation	Reduced unemployment by labour intensive energy efficiency measures
	Rate subsidies avoided	Decrease of the amount of subsidized energy sold (in many countries energy for the population in heavily subsidized).
	Improved productivity	GDP/income/profit generated as a consequence of new business opportunities and job creation
Social	Improved social welfare, less fuel poverty	Reduced expenditures on fuel and electricity; less affected persons by low energy service level, less exposure to energy price fluctuations
	Increased comfort	Normalizing humidity and temperature indicators; less air drafts, more air purity; reduced heat stress through reduced heat islands.
	Reduced mortality and morbidity	Reduced mortality due to less indoor and outdoor air pollution and reduced thermal stress in buildings. Reduced morbidity due to better lighting and mould

[20] An energy service company or energy savings company (ESCO or ESCo) is a commercial or non-profit business providing a broad range of energy solutions including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure outsourcin, g, power generation and energy supply, and risk management.

[21] Gross domestic product (GDP) is a measure of the size of an economy.

Category	Subcategory	Description
		abatement.
	Reduced physiological effects	Learning and productivity benefits due to better concentration, savings/higher productivity due to avoided “sick building syndrome”[22].
	Energy security	Reduced dependence on imported energy.

Cost optimal packages of renovation measures only considering investment and operational costs are often not sufficiently ambitious regarding the building energy performance. It is relevant to identify and evaluate all the effects that arise from different renovation measures. These benefits are often difficult and nearly impossible to quantify and measure accurately, which makes it much more difficult to add their contribution into a traditional cost-benefit analysis. Some of the co-benefits occur as a consequence of reduction of energy consumption, CO_2 emissions and costs respectively while others occur as a side effect of the renovation measures (e.g. less noise significant integration efforts). Depending on the climate severity, period/quality of construction and many other factors the buildings behave differently, create different baselines and require different intervention strategies.

(K.T.)

A.5.1 References

Marco Ferreira, et al, .*Co-benefits of energy related building renovation,* Annex 56.

[22] The term "sick building syndrome" is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified.

A.6 CONCLUDING REMARKS

This Guiding principle for nZEB renovation – Energy Efficiency and use of Renewable Energy Systems has provided to identify the factors affecting the performance of the building which depend on:

- the performance of the building envelope
- the performance of heating system
- the performance of cooling system
- the functioning of ventilation and air conditioning system
- the functioning of BAS (building automation system)
- the location of the building, surroundings and microclimate around it (e.g. weather effects, traffic etc)
- the internal loads
- the use and users of the building

The total performance depends on how well these systems are integrated to operate together. For example, in the case of renewables it is very essential that the various parts of distributed energy sources work together by optimum way; also the compatibility and simultaneous use of various systems must be ensured – too often the integration will be disregarded and the intended benefits will not be achieved. The performance of renovated building is unfortunately tested only during the testing and balancing (TAB) period just when the implementation works are completed or even when a part of a building is under renovation. This checking period is often planned too short. Some failures will occur just after the renovation during the use stage, when repairs are too expensive to realize. That is why must be pointed out the significance of good planning and careful measures during the project also after the renovation works; this requires a good and competent management. Also the financial instruments must be under control. The essential topic is that the building owner and various stakeholders will have a holistic view for the renovation process and the goal and design intent are clearly defined.

Generally, the renovations are carried out also based on other reasons than only energy-related topics. If there are structural damages, the change of use or indoor environment reasons demands renovation, it is possible to combine energy-efficiency related repairs with other measures. Energy renovations are mostly supported by various incentives and financial instruments. It is extremely important that renovation process is well planned and organized.

- **TO IMPROVE THE PERFORMANCE OF BUILDING ENVELOPE:**
  - by additional insulation
  - tightening the envelope to avoid uncontrolled air flows and infiltration by increasing airtightness
  - by changing windows and using shading systems

- **TO DECREASE THE USE OF ELECTRICITY**
  - By changing lighting systems to more energy efficient lighting (e.g. LEDs)
  - By improving the efficiency of devices (e.g. using devices with low stand-by consumption)
  - By efficient use of daylighting
  - By using the various control options (occupancy sensors, smart lighting etc.)
  - By submetering for recognize the consumption distribution

- **TO USE THE POSSIBILITIES OF ICT-TECHNOLOGY:**
  - By additional wireless sensors,
  - By improving monitoring and control
  - By effective use of Building automation system (BAS) and
  - By Building Energy Management System (BEMS)

- **TO SELECT THE RENEWABLES SOURCES ACCORDING TO THE AVAILABLE NATURAL RESOURCES AND OPPORTUNITIES**

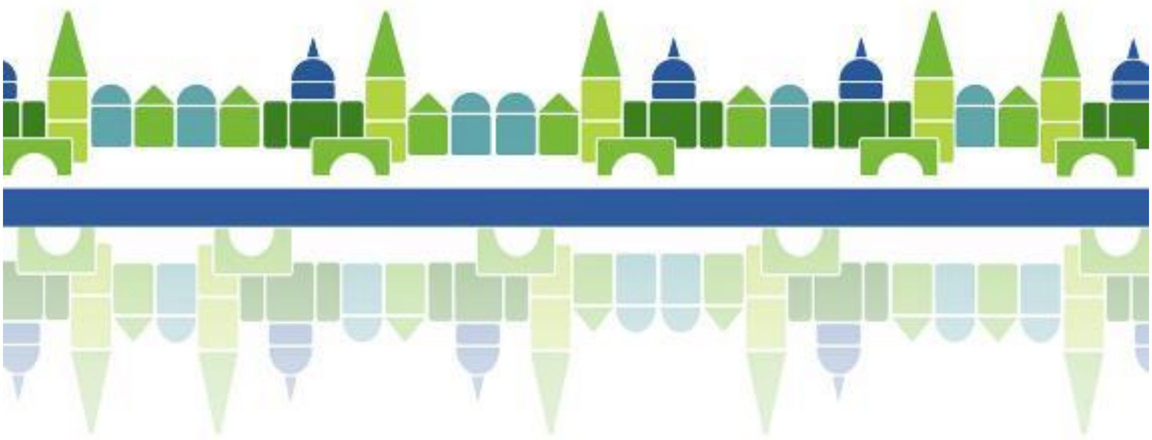
It must point out, as, above-mentioned, that the renovation measures can be divided into a longer period, if needed. Even the order of the renovation is very important – what must be done at the first stage and what later. The performance of building is depending on many interrelated factors. If the renovation measures are not properly allocated, there will be a possibility to cause more damages than saving energy –one example is that by tightening only building envelope in case of natural ventilation may cause indoor quality problems.

The single renovation and repair measures can not be differed from each other, because they are effecting (in most cases) on each other. If the effects of the measures are in conflict with each other, the objectives can not be attained. This can happen .e.g if the buidling has natural ventilation and by tightening (e.g. when the windows have been changed) can lead to deterioration of operating conditions.

(S.F)

PART B

A GUIDE FOR FINANCING OF NZEB RENOVATION PROJECTS



PREMISES

The guide intends to provide comprehensive and practical information on available financial opportunities for supporting the deep energy retrofitting of existing municipality buildings in order to become nZEB.

It is obvious that not all solutions are appropriate for all projects and that financial efficiency of the project depends highly on the characteristics of the financial tools and the construction. Therefore, following are given main financial tools and their characteristics.

It must be underlined that the analysis does not intend to be exhaustive and it is referred to the development period of the CERtuS' project.

In order to check the availability of the resources it is possible to think about the following relevant questions:

- Who are the subjects that manage the resources? What are the ways to contact them?
- What are the procedures to ask for the activation of a specific resources? Is the procedure simple or not? It is necessary to ask for a technical assistance?
- When will the project be realized? Is the instrument or resource available during the project's development period?
- Who are the beneficiaries? Could they guarantee a payment for the intervention and its benefit – energy savings?
- What are the main features of the project in order to ask for its candidature?
- What are the eligible investments? And what are the percentage to finance?
- What are the documents to produce in order to ask for the instrument/resources?
- What are the rules for the use and the project reporting? Are they compliant with internal rules for procedures, budgeting and reports?

Following are given detailed information on specific financial tools:

- Equity
  - Real Estate and Infrastructure funds

    - Energy Efficiency Investment Funds
    - Crowd funding
- Subsidized and Dedicated Funds
    - Main European Subsidized Funds
- Grants
    - Main European Grant Funds
    - Main national and regional Grant Funds
- Fiscal and Other Incentives
    - Tax Incentives
    - Feed-in tariffs
    - Net metering
    - White Certificates
    - On-Bill Repayment Mechanism

B.1 EQUITY

B.1.1 GENERAL DESCRIPTION

Equity can be provided with a wide array of potential expectations, depending on the money source and the management authorities. So, for example equity can be provided from a public authority or a private fund and the scope of the fund could be the investment in energy efficiency construction projects or in general in real estate or projects in other sectors. Considering the energy efficiency sector, the expectations of any potential equity investor for implementing a deep energy renovation in public buildings are presented in the table below.

Origin	Scope	Potential expectations
Public fund	Improvement of energy efficiency	Achieve 3% of building stock renovated each year (for EU)
	Renovation to nZEB	All new or renovated buildings should be nZEB
Single investor	The building's renovation, that could include a deep energy retrofitting	To increase the value of the building and increase its market attractiveness
Private fund	The investment in real estate, that could include a deep energy retrofitting	To increase the value of the building and increase its market attractiveness

B.1.2 BRIEF DESCRIPTION OF MAIN FORMS OF EQUITY

Equity can be provided to a project through a managing body, which could raise the money either from few big investors or from a very big number of smaller investors. Usually there is a minimum and possible a maximum amount of money that investors can contribute to the fund. Investors could be individuals, private or public companies or even organizations.

The main financing schemes that could provide equity for buildings' energy efficiency are:

- Real estate and infrastructure funds
- Energy efficiency investment funds

- Crowd funding

B.1.2.1 Real Estate and Infrastructure Funds

According to the Energy Efficiency Financial Institution Group (EEFIG), "*real Estate and Infrastructure funds provide a large amount of energy efficiency investment in the building sector. This investment takes place during a fund's investment life cycle and they are part of conventional real estate investments*"[23]. So, real estate investment funds are key stakeholders and are able to scale up financing of energy efficiency measures in buildings, through increased equity investments and increased fund activity. Also, a recent study[24] indicates that "the emergence of new dedicated Sustainable Real Estate Funds whose strict application of socially responsible investment criteria and potential focus on best-in class energy performance buildings can support market transformation." But according to the same study, their size tends to be small and they tend to focus on new buildings.

On the other hand, real estate companies seem to have an increased interest for buildings with relatively better sustainability credentials, as they tend to enjoy increased market value to both tenants and investors[25]. According to a study of Deloitte Center for Financial Services analysis regarding the retrofitting of existing office buildings with sustainable measures, including energy and water efficiency and waste reduction, reveals a higher internal rate of return (IRR) of the investment of approximately 155 basis points (bps) on average, on the overall building investment[26].

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[23]"Energy Efficiency – the first fuel for the EU Economy: How to drive new finance for energy efficiency investments", page 98, Energy Efficiency Financial Institution Group (EEFIG)
[24]https://ec.europa.eu/energy/en/news/new-report-boosting-finance-energy-efficiency-investments-buildings-industry-and-smes
[25]"2015 Commercial Real Estate Outlook Enhance Technology, Enable Innovation", Deloitte.
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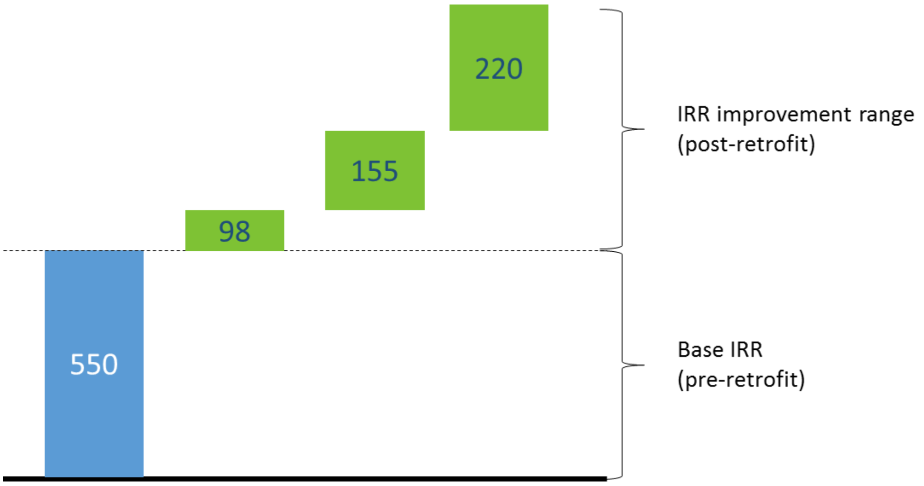

Figure 40. IRR improvement post-retrofit in basis points (Reproduction from "Simulation results from an analysis performed from Deloitte Center for Financial Services")

Finally, over of 70% of real estate fund managers are integrating environmental management systems into their portfolio management and these investors lead the drive to reflect energy performance in the valuation of commercial buildings[4].

B.1.2.2 Energy Efficiency Investment Funds

Energy efficiency investment funds have as main scope the investment in energy efficiency projects targeting both buildings and industry, seeking a return based, at least partly, on savings achieved. According to EEFIG' report, such funds target Socially Responsible Investment (SRI) investors and public financial institutions for their own fund-raising[4].

Energy Efficiency Investment Funds usually have expectations of high returns and therefore fill comfort with projects having short or medium payback periods. Consequently, although Energy efficiency investment funds may consider investing in the deep energy retrofitting of municipal buildings; it seems that it will be difficult for them to constitute the main investor body.

Some of the most well-known public and private Energy Efficiency Investment Funds in Europe are:

- **European Energy Efficiency Fund** (http://www.eeef.eu/)
- **Fondo Italiano per l'Efficienza Energetica** (http://www.fitef.com/)

- **Global Energy Efficiency and Renewable EnergyFund** (http://geeref.com/)
- **Sustainable Development Capital Limited** (http://www.ggf.lu)
- **Sustainable Development Capital LLP** (http://www.sdcl-ib.com)
- **SUSI partners** (http://www.susi-partners.ch)
- **The London Energy Efficiency Fund** (http://www.leef.co.uk/)
- **UK Energy Efficiency Investments Fund** (www.sdcl-ee.com)

B.1.2.3 Crowd funding

Crowdfunding is the practice of funding a project by raising contributions from a large number of investors[27]. It is a form of alternative finance, which has emerged outside of the traditional financial system.

The crowd funding model[28] is based on three types of actors: the project developer who proposes the idea or project to be funded; investors who support the idea; and “the platform” that brings the parties together to launch the idea.

In 2013, the crowd funding industry raised over $6.1 billion worldwide, reached $16.2 billion in 2014 and doubled once again in 2015 on its way to raising $34.4 billion.

Types of crowd funding

1. Rewards Crowdfunding: entrepreneurs pre-sell a product or service to launch a business concept without incurring debt or sacrifice equity / shares
2. Equity Crowdfunding: the investors receive shares of a company, usually in early stages, in exchange for the money pledged
3. Investment Crowdfunding: investors are given the chance to earn back a conventional fixed interest rate
4. Charitable projects: supporters - participants pledge a participation to support a local initiative or charitable project with non-monetary payoffs

Rewards-based crowd funding has been used for a wide range of purposes, including music and films promotion, free software development, inventions development, scientific research and civic

[27]http://cdn2.hubspot.net/hub/343005/file-2612198431-pdf/2015-Whitepaper_files-Retail/PENSCO_2015CrowdfundingReport_0315.pdf
[28]https://en.wikipedia.org/wiki/Equity_crowdfunding

projects, but not yet for real estate projects. The other three types have been used already for financing real estate projects.

Crowd funding and real estate projects

The most commonly used types are equity and investment crowd funding. In both cases, the crowdfunding company is doing the due diligence and evaluation of the building projects, while each company may have specific investment criteria. For example, some companies are focused on investments in a specific geographic area, in a specific type (use of) buildings or in investments with a minimum acceptable financial performance. Crowdfunding companies also require a minimum investment, that could be as low as €10, although usually it is greater of €1.000.

As long as a project satisfies the predefined investment criteria of the platform, then a financing call is initiated (launch of crowdfunding), either for the public or exclusively for the platform's members. Investors' contributions (equity and investment crowdfunding) are secured by a registered first legal charge against the property or land.

The crowdfunding company is charging the borrower a one-off fee and the investor an annual fee - until the exit of the investment - for managing the project.

Crowd funding for real estate projects is not a wide spread financing technique in South European Member States participating in the project. It should be noticed that most real estate projects, financed with crowd funding have been recorded in Italy and following Italy in Spain. In Portugal and Greece the financing of any real estate project with crowdfunding has not been recorded. Especially in Greece, only one platform is up and running, officially launched in February 2016 and up to now (September 2016) finances only with the charity - donation model[29].

B.1.3 ADVANTAGES, DISADVANTAGES AND OTHER CONSIDERATIONS

The provision of equity in the project financing structure is a critical parameter that indicates the interest of investors and the competitiveness of the project in market conditions. Usually, projects are

[29] https://www.nbg.gr/act4greece/act4greece-2/

financed through debt and equity, witha maximum 60/40 debt to equity ratio, even this is not always the case. Debt and equity are supposed to be paid back from the cash flow generated by the project[30]. In the case of energy conservation, the cash flow is generated from the reduction of the running cost, mainly due to the significantly lower buildings' energy consumption.

It is important to notice that equity financing is distinct from debt financing, as with equity financing investors are taking a percentage of the enterprise, usually in the form of shares for a certain time period (exit point) or indefinite time. A simplified but typical financing structure of a construction project[31] could be seen in the following figure[32].

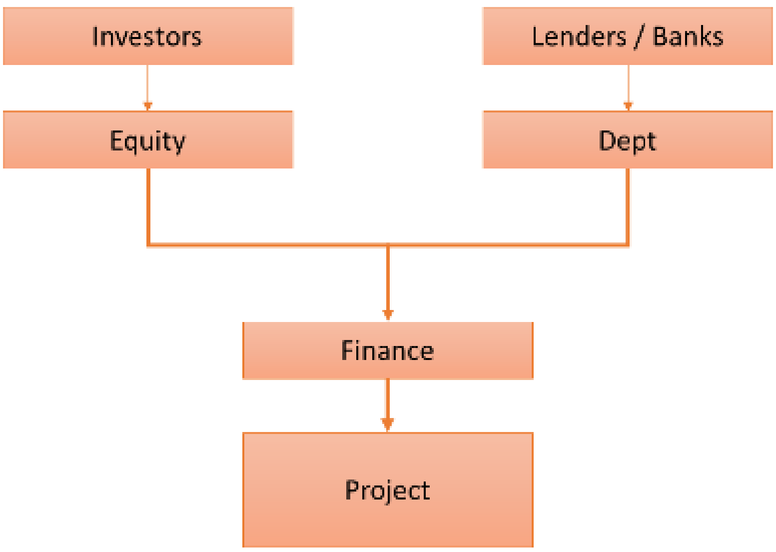

Figure 41. Simplified but typical financing structure of construction project

The disadvantages of project financing with equity are consequences of the fact investors become shareholders of the project and therefore:

- investors could participate to the management,
- they expect a rather high economic performance,

[30]"Key Differences Between Project Finance and Venture Finance", In[3] Finance (http://www.in3finance.com/project-vs-venture-finance-for-startups)
[31] "Project Finance", Fred Moavenzadeh, MIT OpenCourseWare (http://ocw.mit.edu/index.htm)
[32]Public-Private-Partnership in Infrastructure Resource Center (http://ppp.worldbank.org/public-private-partnership/about-pppirc)

- they are interested in big projects,
- the project financing scheme requires the setup of a SPV (Special Purpose Vehicle) which could be more complicated and have higher operational expenses compared with lending.

On the other hand, project financing with equity is a very efficient way for financing and managing, especially construction projects, as it is focuses on the achievement of a positive cash flow that ensures the repayment of the lenders and investors. Some very strong advantages of this type of financing are:

- it provides the appropriate cash that could contribute in making the project bankable,
- it requires the execution of a detailed and thorough due diligence that protects the project and the investors,
- it requires a sound business plan, which could be useful in terms of planning and especially of risk management,
- it is a clear indicator that the project is interesting for the market and that it could attract more investors.

In the case of crowdfunding, the fact that the business plan should be more or less public could be an additional disadvantage, as it will be known to the competitors, but the big number of small investors could be positive for management, as none of them could be a principal shareholder and therefore involved in the management.

B.2 SUBSIDISED AND DEDICATED FUNDS

B.2.1 GENERAL DESCRIPTION

Subsidised and dedicated funds are financial instruments created to finance projects with positive financial returns but lower than "market standards", in terms of:

- Financial returns (lower than market requirements);
- Payback periods (longer than market requirements);
- Security package (non-coherent with market requirements);
- Project sponsor financial standards (lower than market requirements).

In order to **fill the market gap** and at the same time reduce the investment of grant resources, some innovative financial instruments were created, supporting projects to enhance their "financial quality" and therefore making them market attractive.

Subsidized Funds are usually:

- Created and financed by Public Institutions (European, National, Local Entities) and/or by Philanthropic Entities (e.g. Foundations, Charities, NGOs, etc.) in order to reach social and environmental targets;
- Managed by specialized entities (e.g. banks, Private Equity Funds, development banks, etc.) that in some cases co-finance the funds they manage.

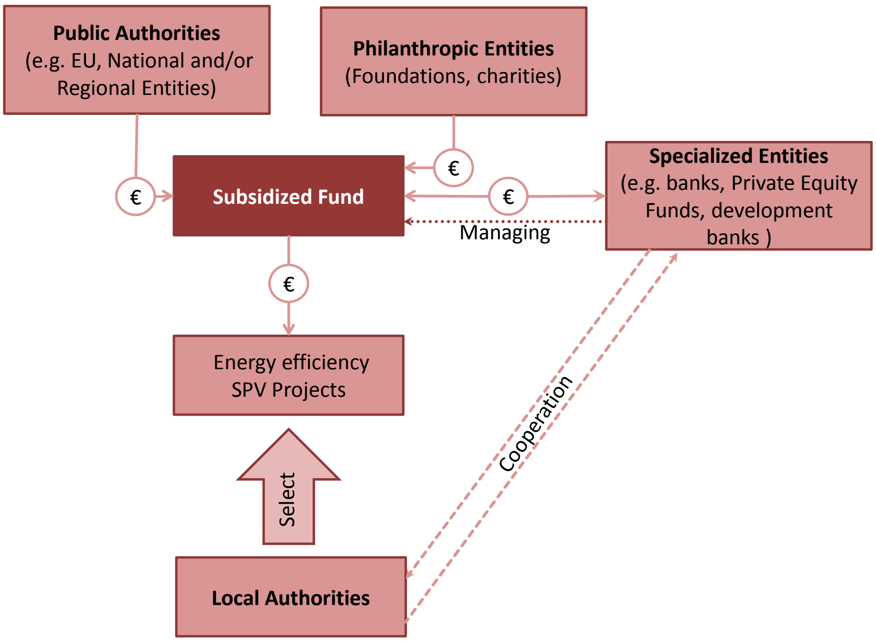

Figure 42. Subsidized Fund process

It's not possible to find a homogenous definition of Subsidized Funds, because of their large differences explained in the following points; with a relative high level of generalization, it will be tried to define their main characteristics.

Targets – Subsidized Funds in several cases play a pivotal role in the financial structuring of energy efficiency initiatives, because they fill the gap between grant and market finance and therefore allow initiatives to be financed. Therefore, typical aims of Subsidized Funds are:

- to reduce the use of grant financing, by means of revolving instruments (e.g. guarantees, lending, equity) that with positive financial returns expectation but lower than market instruments;
- to increase the cooperation between public and private institutions, with a knowledge sharing between the two parts;
- to attract private co-financing resources (fund managers may co-finance projects with their own resources).

Financers/Investors – Subsidized Funds are mainly backed by public and/or philanthropic entities, such as: EU Funds Managing Authorities (e.g. ERDF, ESF, EARDF, etc.), National Development Agencies, International Development Institutions, Foundations, etc.

These entities typically:

- Operate on the basis of investment plans to promote social/environmental conditions in a certain territory (e.g. Operational Programs, Development Plans, etc.);
- Finance several target projects and final recipients (e.g. promoting energy efficiency in public buildings via Public Partnership procedures financing ESCOs);
- Use the majority of their resources (e.g. ERDF, ESF, LIFE, etc.) as grant financing and some of the remaining as Subsidized Funds (e.g. soft lending, subsidized equity, etc.) via intermediaries (e.g. banks, guarantees insurers, Private Equity Funds, etc.).

Fund Managers – Subsidized Funds usually need professional fund managers (e.g. banks, Private Equity Funds, Financial Institutions, etc.) to be operative. This is due to:

- Legal constraints, in many Countries public entities (e.g. Managing Authorities) cannot operate as lenders and/or equity investor;
- Technical constraints, public entities involved in grant financing usually don't have experience in selecting and structuring financially viable projects and investment contracts;
- Risk management, public entities can share/transfer project risks to fund managers that are usually more capable of managing it.

Financial Products – as anticipated in previous paragraphs, "Subsidized Funds" utilize a wide range of financial products, briefly listed below:

- Equity (risk capital) is the most risky financial product because it is the "last financial source" to be repaid and therefore it is a very scarce asset class, especially in the energy efficiency sectors featured by low expected returns and many small undercapitalized ESCOs;
- Mezzanine financing is a hybrid form of financing (e.g. shareholder loans, convertible bonds, etc.). In energy efficiency initiatives it is supplied by equity investors, in order to mitigate the risk of their investment;
- Project loans, usually Subsidized Funds have softer requirements than banks in terms or: interest rate, duration and security packages;

- Guarantees and counter guarantees, these instruments (described in details in the next paragraphs) reduce the risk of the initiatives guaranteeing the financial sector;
- Other financial products that can be more close to grant financing are crowdfunding (that in certain case envisage a return for grantor), grant covering interests of market loans, etc.

Final beneficiaries and project selection procedures – as reported in previous paragraphs, public entities backing "Subsidized Funds" operate on the basis of investment plans to promote social/environmental conditions. These plans usually have rigid and structured procedures for the selection of projects and final recipients (e.g. public call for tenders, open candidatures, etc.). Even though it could be not possible to remove all project selection criteria for "Subsidized Funds", peculiar features of these instruments could be considered, such as:

- Project financial sustainability
- Project pay-back time
- Counterpart risk

Monitoring and control procedures – as written in the previous paragraph, public entities backing "Subsidized Funds" have rigid and structured monitoring and control procedures, which have to be adapted to the needs of Subsidized Funds.

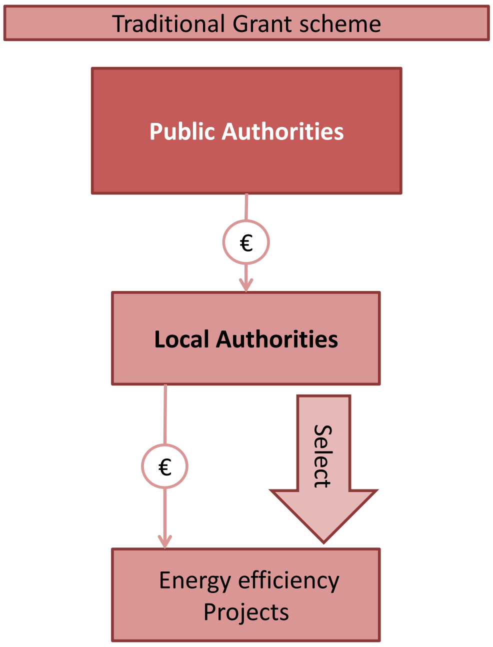

Figure 43. Traditional Grant Scheme

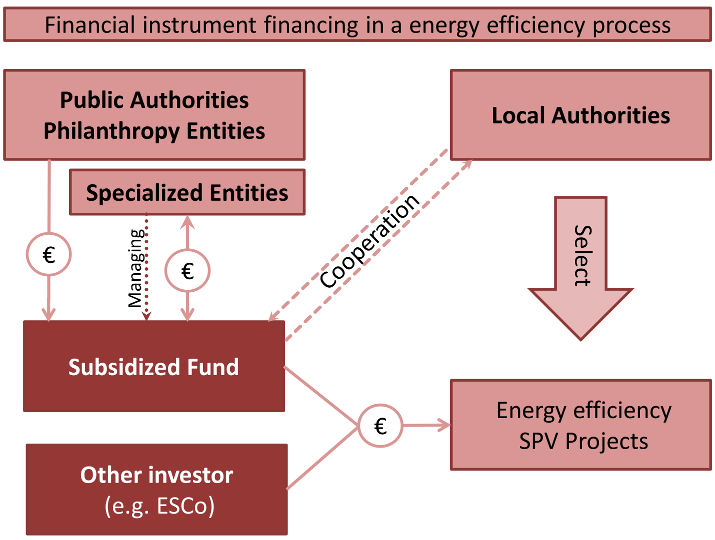

Figure 44. Example of an Energy Efficiency financing process

B.2.2 Main European Subsidized Funds

The main European Subsidized Funds and their characteristics are given in the following table.

Name of fund	Promoter	Beneficiary	Country of availability	Budget	Investment size		Suitability for nZeb
Private Finance For Energy Efficiency (PF4EE)	EIB, LIFE	Local authorities, SMEs, ESCOs, Utilities	ES, CZ, FR	€ 480 mln	< €5 mln		high
ESIF Financial Instruments (Former JESSICA)	EIB	Public authorities	Depends on operational program	Depends on operational program	Depends on operational program		high
EIB Intermediated Loans	EIB	Public and private sector	EU				medium
European Fund for Strategic Investments (EFSI)	EIB	Public and private sector	EU 28	€ 16 mln as guarantee € 5 bln as capital to co-invest	No restrictions		low

Table 23. Main European energy efficiency subsided funds available

B.2.2.1 Private Finance For Energy Efficiency (PF4EE)

Private Finance for Energy Efficiency (PF4EE) instrument is a joint agreement between the EIB and the European Commission which aims to address the limited access to adequate and affordable commercial financing for energy efficiency investments.

The instrument targets projects which support the implementation of National Energy Efficiency Action Plans or other energy efficiency programs of EU Member States.

The PF4EE instrument's two core objectives are:

- to make energy efficiency lending a more sustainable activity within European financial institutions, considering the energy efficiency sector as a distinct market segment
- to increase the availability of debt financing to eligible energy efficiency investments

The instrument is managed by the EIB and funded by the Programme for the Environment and Climate Action (LIFE programme). The LIFE Programme committed EUR 80m to fund the credit risk protection and expert support services. The EIB will leverage this amount, making a minimum of EUR 480m available in long term financing.

The instrument, where it is activated, is implemented by a **Financial Intermediary**. The Financial Intermediary is a financial institution who has been selected to participate in the implementation of PF4EE Instrument in accordance with the terms of the "Request for Proposals"[33] and with which EIB has entered into one or more legally binding agreements.

Final recipients benefitting from the PF4EE Instrument should be defined in the context of the relevant Participating Countries' NEEAP. They may include persons, home-owners' associations, enterprises, public institutions/bodies and any other entities undertaking Elegible EE Investments[34].

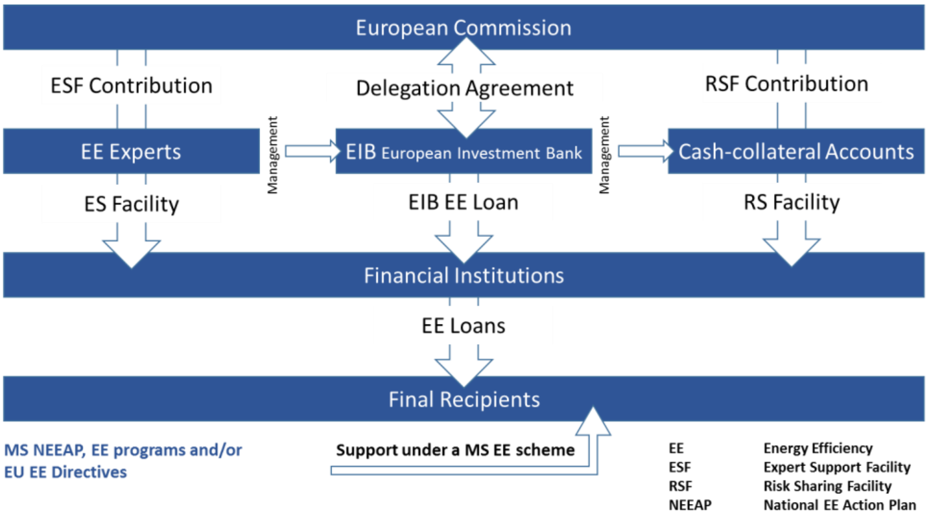

Figure 45. PF4EE function35

[33] "Request for proposals in order to become a Financial Intermediary under the PF4EE" - http://www.eib.org/attachments/documents/pf4ee_request_for_proposals_en.pdf

[34]See pag. 24 of the document "Request for proposals in order to become a Financial Intermediary under the PF4EE"

[35]Source: European Investment Bank

The PF4EE instrument will provide:

- a portfolio-based credit risk protection provided by means of cash-collateral (Risk Sharing Facility - RSF)
- long-term financing from the EIB (EIB Loan for Energy Efficiency) at competitive rates
- expert support services for the Financial Intermediaries (Expert Support Facility - ESF)

As of 31 December 2015, the instrument supported three financial intermediaries with Risk Sharing Facilities and Expert Support Facilities for a total amount of €14 mln.

PF4EE is now available only in Spain, Czech Republic and France.

The Spain experience[36] regarding energy efficiency in the hotel sector showed how this instrument combines three elements:

– The first is an EIB loan to improve the funding conditions of the energy efficiency investments financed by Santander.
– The second component partially covers potential losses by that Santander may incur as a result of the abovementioned energy efficiency loans.
– The third element will strengthen the lending capacity to energy efficiency investments of Santander by passing on technical and financial experience gained from similar schemes elsewhere in Europe.

[36] The European Investment Bank and Banco Santander signed an agreement worth EUR 50 million under the Private Finance for Energy Efficiency initiative, a new European scheme to increase and improve financing conditions to private sector investments in reducing energy use in Spain. http://www.eib.org/infocentre/press/releases/all/2015/2015-300-eib-banco-santander-agreement-to-finance-investments-in-energy-efficiency-in-the-hotel-sector.htm

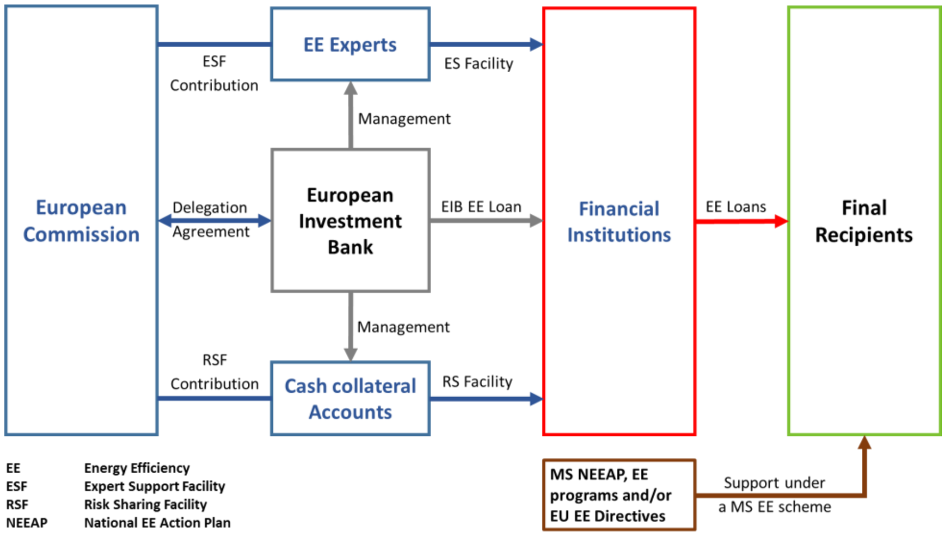

Figure 46. PF4EE function[37]

If a Municipality or a Final Recipient would consider this Programme, it should verify that:

- Is the PF4EE activated?
- Who is the Financial Intermediaries for the implementation of the instrument?
- Is the Project to candidate eligible?
- What are the steps defined by the Financial Intermediaries to start a selection procedure?

TYPE	BENEFICIARIES	COUNTRIES[38]	BUDGET
Favourable loans and guarantees	Local authorities, SMEs, ESCOs, Utilities	ES, CZ, FR	€ 480 mln

Table 24. Main characteristics of PF4EE

[37]"Request for proposals in order to become a Financial Intermediary under the PF4EE" – document published on 19/01/2015

[38]It is possible to activate the PF4EE in every Participating Country (Member State of European Union)

B.2.2.2 European Structural And Investment Funds (ESIF) – Former Jessica

Financial Instruments (FIs) transform EU resources under the European Structural and Investment Funds (ESIF) into financial products such as loans, guarantees, equity and other risk-bearing mechanisms. These are then used to support economically viable projects which promote EU policy objectives.FIs aim to put EU funds to good and efficient use, ensuring that grants are complemented by other financial products so that EU funding can be used time and time again in a revolving effect. FIs can be combined with technical support or guarantee/interest rate subsidies.

An example of the type of Financial Instrument that could be developed is the Urban Development Fund (UDF). The UDF can invest in public-private partnerships and other integrated projects for sustainable urban development. In the 2007-2013 programming period, many projects were financed by UDFs under the JESSICA program. The main benefits of JESSICA were the achievement of:

- Making Structural Fund support more efficient and effective by using "non-grant" financial instruments, thus creating stronger incentives for successful project implementation;
- Mobilising additional financial resources for public-private partnerships and other urban development projects with a focus on sustainability/recyclability;
- Using financial and managerial expertise from international financial institutions such as the EIB;
- Encouraging the development of the projects through the support of the financial institution dedicated to the implementation of the instrument.

TYPE	BENEFICIARIES	COUNTRIES	BUDGET
Mainly loans but also semi-equity and guarantees	Mainly Public Authorities	Depends on operational program	Depends on operational program

Table 25. Main characteristics of ESIF

B.2.2.3 European Investment Bank (EIB): Intermediated Loans

Intermediated loans are provided by the European Investment Bank to local banks. These loans can only be provided for certain purposes. Improving environmental sustainability of SMEs is one of these conditions, which includes supporting competitive and secure energy supply. Generally, all intermediated loans must further at least to one of the following public policy goals:

- Increase in growth and employment potential – including SME and Mid-Cap support
- Economic and social cohesion by addressing economic and social imbalances, promoting the knowledge economy/skills and innovation and linking regional and national transport infrastructure
- Environmental sustainability - including supporting competitive and secure energy supply
- Action for climate-resilient growth

The final beneficiaries can be:

- Small-and-medium-sized businesses
- Mid-Cap businesses
- Large businesses
- Local authorities
- National administrations
- Public sector bodies

The intermediary must transfer a financial advantage reflecting the impact of EIB funding, while loan conditions can be flexible in terms of the size, duration, structure etc.

TYPE	BENEFICIARIES	COUNTRIES	BUDGET
Favourable loans	Municipalities	EU Members	Ongoing

Table 26. Main characteristics of Intermediated Loansof European Investment Bank (EIB)

B.2.2.4 European Fund For Strategic Investment (EFSI)

EFSI is an initiative launched jointly by the EIB Group - European Investment Bank and the European Commission - to help overcoming the current investment gap in the EU by mobilising private financing for strategic investments.

EFSI is a EUR 16 billion guarantee from the EU budget, complemented by a EUR 5 billion allocation of the EIB's own capital.

With EFSI support, the EIB Group provides funding to economically viable projects where it adds value, including projects with a higher risk profile than ordinary EIB activities. It focus on sectors of key importance where the EIB Group has proven expertise and the capacity to deliver a positive impact on the European economy, including:

- Strategic infrastructure including digital, transport and energy
- Education, research, development and innovation
- Expansion of renewable energy and resource efficiency
- Support for smaller businesses and midcap companies

As of 16 June 2016, EFSI approved 266 transactions for a total €17,7 bln, of which 22% in Energy sector.

TYPE	BENEFICIARIES	COUNTRIES	BUDGET
Favourable loans and guarantees	Public and private sector	EU 28	€ 16 bln as guarantee € 5 bln as capital

Table 27. Main characteristics of European Fund For Strategic Investment (EFSI)

B.2.3 ADVANTAGES, DISADVANTAGES AND OTHER CONSIDERATIONS ABOUT THIS KIND OF FINANCIAL INSTRUMENT

nZEB projects usually show long pay-back times and low financial sustainability. In addition, Municipalities are often unable to provide the project with the amount of finance required and ESCOs are not interested in such projects if these don't offer a proper return on investment. Thus, the availability of subsidized funds could help Municipalities or ESCOs to reduce the cost of capital and improve the sustainability of the project.

Subsidised funds, delivered in the form of low or zero interest loans are very useful financial instruments for nZEB projects. As shown in CERtuS project, most of nZEB projects may need financial aid in order to become attractive for ESCos and to activate private investments.

European and National/Regional institutions are aware of this and thus offer the market proper financial instruments. In fact, many projects in the energy efficiency sector were financed by the JESSICA program with low interest rate loans. JESSICA, joint with co-financing and investment from the private sector, is an adequate instrument to increase the feasibility of nZEB projects. In addition, as a difference from grants, the revolving nature of the instruments allows the financer to recover financial resources invested and reinvest them in new projects.

In the end, subsidized funds are useful because:

- They provide the Municipalities with liquidity to make investments;
- They help ESCOs to reduce the cost of capital, thus reducing pay-back time and increasing return on investment;
- They may activate co-funding and private investments;
- Their revolving nature allow promoters to reinvest the financial resources in new projects.
- Provided that the right conditions are present, these mechanisms are not particularly difficult to administer.

On the other side, subsidized funds may bear some disadvantage, because:

- They may be not sufficient to ensure financial sustainability to projects;
- Energy savings may not always be considered as a cash flow by some financial intermediaries
- Projects may comply with strict features to be eligible for subsidized funds.

B.3 GRANTS

B.3.1 GENERAL DESCRIPTION

Grants[39] are a type of financial aid that does not have to be repaid. Generally, Grants are provided to projects that are not marketable, which means they can't be financed under normal market conditions, for example using a bank loan.

The common procedure is that a grant administrator provides a request of proposals with the specific targets of the call and requirements of the funder(s). The potential beneficiaries set up a proposal that is expected to fit into the requirements of the call (request of proposals). Following that, the grant administrator assesses and evaluates the proposals in order to choose those, if any, that satisfy its expectations and desires.

The grant administrator for financing the energy retrofitting of existing buildings in order to become nZEB is usually the general government, various managing authorities representing the European Union or other organizations. Municipalities could be beneficiaries of grants for nZEB retrofitting.

B.3.2 MAIN EUROPEAN GRANT FUNDS

The main European Grant Funds available in the market that could be used to finance the construction, renovation, design studies and even the communication activities are given in the table below. A brief description of the main Grant funds is given in the next paragraph.

[39] Definition of Grants: "direct contributions, by way of donation, from the budget in order to finance either an action intended to help achieve an objective part of the EU policy or the functioning of a body which pursues an aim of general European interest or has an objective forming part of a EU policy"
Glossary of the European Commission on financial programming and budget,
http://ec.europa.eu/budget/explained/glossary/glossary_en.cfm#g

Name of fund	Promoter	Manager	Country of availability	Budget	Suitability for nZeb
ELENA (technical assistance)	EE	EIB	ES, GR, IT, PT, (*)[40]		Low (technical assistance)
IEE	EE		ES, GR, IT, PT,		Medium
INTERREG (2014 -2020)	EE	ERDF	ES, GR, IT, PT,	m€359	Medium
HORIZON 2020 (capacity building)	EE	EASME	ES, GR, IT, PT,	m€70	Low
Urbact III (communication)	EE	ERDF Member Partners States City and region members	ES, GR, IT, PT,	m€96.3	Low
UIA	EE		ES, GR, IT, PT,	m€372	Strong
LIFE+	EE		ES, GR, IT, PT, (*)[41]	m€3,460	Low
The EEA Grants and Norway Grants	Iceland, Liechtenstein and Norway	EEA	ES, GR, PT	m€856	Medium

B.3.3 Brief Description of Main European Grant Funds

B.3.3.1 European Local Energy Assistance (ELENA)

ELENA[42] (European Local Energy Assistance) covers up to 90% of the technical support cost needed to prepare, implement and finance the investment program. This could include feasibility and market studies, program structuring, energy audits and tendering procedure preparation, but not the construction cost. With solid business and technical plans in

[40] (*) EU Member state, Norway, Iceland, Liechtenstein, Croatia and FYR Macedonia
[41] (*) EU Member state, Norway, Iceland, Liechtenstein, Croatia and FYR Macedonia
[42] http://www.eib.org/attachments/thematic/elena_en.pdf

place, this will also help attract funding from private banks and other sources, including the EIB.

So whether it is the retrofitting of public and private buildings, sustainable buildings, energy-efficient district heating and cooling networks, environmentally-friendly transport etc, ELENA helps local authorities get their projects on the track.

B.3.3.2 Horizon 2020

Horizon 2020[43] is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. One of the challenges which Horizon 2020 will address is “Secure, Clean and Efficient energy”.

Horizon 2020 provide financing support to activities related to energy-efficient buildings, industry, heating and cooling, SMEs and energy-related products and services, as well as for improving the attractiveness of energy-efficiency investments.

B.3.3.3 Intelligent Energy Europe (IEE)

Intelligent Energy Europe programmes[44] are not any more available, even there are still (September 2016) some projects on going[45], such as CERtuS. IEE programmes aimed at helping organisations willing to improve energy sustainability, either by providing financing for studies or/and demonstration activities. Launched in 2003 by the European Commission, the programme was part of a broad push to create an energy-intelligent future. It supported EU energy efficiency and renewable energy policies, with a view to reaching the EU 2020 targets (20% cut in greenhouse gas emissions, 20% improvement in energy efficiency and 20% of renewables in EU energy consumption). Municipalities were potential beneficiaries.

The EU's Horizon 2020 programme now supports the research, demonstration and market up-take of energy-efficient technologies.

[43] http://ec.europa.eu/newsroom/horizon2020/document.cfm?doc_id=4752
[44] http://ec.europa.eu/energy/intelligent/
[45] http://ec.europa.eu/easme/en/intelligent-energy-europe

B.3.3.4 Interreg (2014 -2020)

The INTERREG EUROPE Programme is an EU programme that helps regions across Europe to work together, sharing their knowledge and experience[46].

INTERREG aims to the support of the overall economic development and to the reduction of differences between regions in terms of wealth, income and opportunities. Concretely, the programme focuses on improving regional and local policies in two areas:

- Innovation and the knowledge economy
- Environment and risk prevention

B.3.3.5 LIFE+ Programme

"LIFE is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. Since 1992, LIFE has co-financed some 4306 projects. For the 2014-2020 funding period, LIFE will contribute approximately €3.4 billion to the protection of the environment and climate[47]".

The LIFE programme covers three priority areas: environment and resource efficiency; nature and biodiversity; and environmental governance and information. The programme also supports jointly funded integrated projects, which will operate on a large territorial scale. These projects aim to implement environmental and climate policy and to better integrate such policy aims into other policy areas.

B.3.3.6 Urbact

URBACT's mission is to enable cities to work together and develop integrated solutions to common urban challenges, by networking, learning from one another's experiences, drawing lessons and identifying good practices to improve urban policies. It is an instrument of the Cohesion Policy, co-financed by the European Regional Development Fund, the 28 Member States, Norway & Switzerland.

Even the Programme is not appropriate for financing the retrofitting of the building itself, it can be used to finance relevant actions.

[46] http://www.interreg4c.eu/fileadmin/User_Upload/PDFs/INTERREG_EUROPE_01.pdf
[47] http://ec.europa.eu/environment/life/about/index.htm#life2014

B.3.3.7 Urban Innovative Actions (UIA)

"Urban Innovative Actions (UIA) is an Initiative of the European Commission that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Based on article 8 of ERDF, the Initiative has a total ERDF budget of EUR 372 million for 2014-2020.

The main objective of UIA is to provide urban areas throughout Europe with resources to test innovative solutions to the main urban challenges, and see how these work in practice and respond to the complexity of real life[48]*".*

B.3.3.8 The EEA Grants and Norway Grants

The EEA Grants and Norway Grants represent the contribution of Iceland, Liechtenstein and Norway to reducing economic and social disparities and to strengthening bilateral relations with 16 EU countries in Central and Southern Europe and the Baltics. "Each beneficiary country agrees on a set of programmes with the donor countries, based on national needs and priorities and the scope for cooperation with the donor countries. All programmes must adhere to standards relating to human rights, good governance, sustainable development and gender equality[49]". **Italy is not among the beneficiary countries**[50].

[48] http://www.uia-initiative.eu/en/about-us/what-urban-innovative-actions
[49] http://eeagrants.org/Who-we-are
[50] http://eeagrants.org/Where-we-work

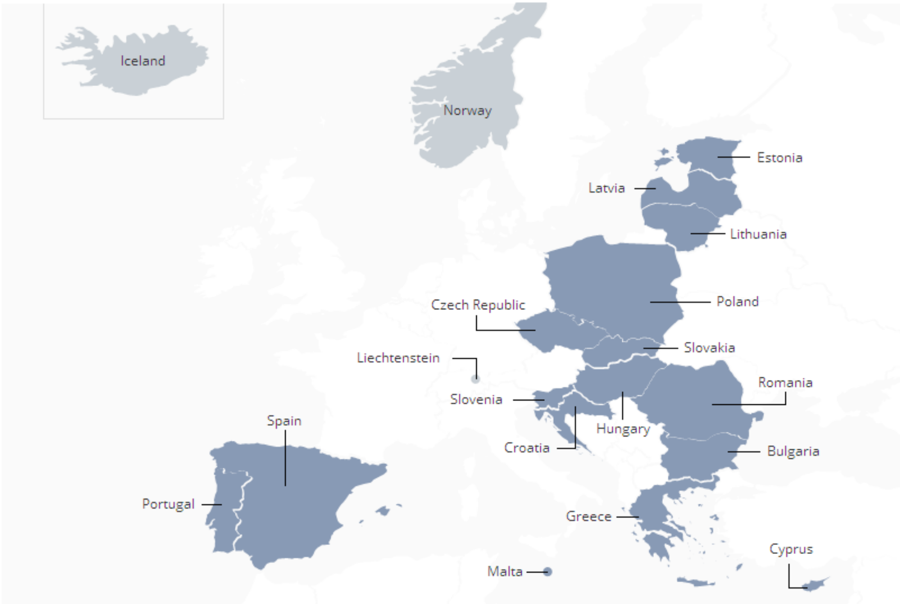

Figure 47. Beneficiary countries (Source: http://eeagrants.org/)

B.3.4 MAIN NATIONAL AND REGIONAL GRANT FUNDS AVAILABLE

Country/ Region	Promoter	Manager	Beneficiary	Budget	Investment size	Suitability for nZeb
Spain	Ministry of Industry, Energy and Tourism	IDAE	All building owners	€200 million		Medium
Spain	Action Plan on Energy Efficiency and Saving	IDAE	"Energy consuming centres"	€2,350 million		Low
Italy / Campania	Campania Region	Campania Region	Municipalities, local health authorities, hospitals, water management bodies	€115 million		Low
Italy / Lazio	Lazio Region	Lazio Region	Public buildings	€25 million		Medium

Country/ Region	Promoter	Manager	Beneficiary	Budget	Investment size	Suitability for nZeb
Italy / Bolzano	Autonomous Province of Bolzano	Autonomous Province of Bolzano	Residential buildings		> € 4000	Low
Italy / Piedmont	Piedmont Region	Piedmont Region	Public and residential buildings	€5 million		Low
Italy / Umbria	Umbria Region	Umbria Region	“Regional-interest buildings”	€2 million		Medium
Greece	Ministry of Environment and Energy	EPPERAA	Public school buildings	€40 million		Medium
Greece	Ministry of Environment and Energy	EPPERAA	Public buildings	€175 million[51]		Medium

B.3.5 ADVANTAGES, DISADVANTAGES AND OTHER CONSIDERATIONS

As it has been already noted, Grants are highly desirable from the perspective of the building owners, but it is obvious that they can rarely support financial sustainability, as they have zero revolving effect. Even so, Grants could be very useful in order to make some projects market attractive. In the case of energy efficiency projects, Actions Grants are used to “*finance actions to help achieving an objective part of a Union policy*”[52]. Grants could also be very useful for financing projects that incorporate pre-commercial technologies or in the early stages of commercial deployment or are otherwise prohibitively expensive[53].

The clear advantages of using Grants for financing, are:

- projects could potentially increase their market attractiveness,

[51] http://www.pireasnet.gr/LinkClick.aspx?fileticket=TL8X0PiEt9w%3D&tabid=1283
[52] “Financial Instruments 2014-2020 under European Structural and Investment Funds (ESIF)”, Symela Tsakiri, Brussels, 19-20 January 2015
[53] http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/financing_energy_renovation.pdf

- the combination of Grants with other instruments[54], such as bank loans, could provide a better solution that fulfills the expectations and needs of the building owners,
- they could be particularly suitable for economically depressed areas, immature or financially constrained markets,
- they could be particularly helpful for proof of concept and demonstration activities and to encourage uptake of innovative or beyond cost-optimal measures.

The disadvantages of Grants' project financing are:

- they offer low replicability as Grants' funds are limited,
- they have almost zero revolving effect, meaning that once the money given as a Grant they will be not returned to the donor in order to be used for another project,
- usually they are given through a time consuming and demanding procedure (competition), in terms of required technical capabilities and cost.

Concluding, it has to be emphasized that Grants are very important in order to support actions that they are not financial viable under market conditions and once they are used in combination with other financing tools, they may help create and widen the market.

[54]"Grants and financial instruments working together", FI-COMPASS (https://www.fi-compass.eu)

B.4 FISCAL &OTHER INCENTIVES

B.4.1 GENERAL DESCRIPTION

Fiscal incentives[55] usually are tax measures targeted to encourage and support certain measures. National and regional authorities introduce various taxes, penalties and fiscal incentives (Tax Reduction, Tax Credit, Reduced VAT, White Certificates (Energy Supplier Obligations), etc.) in order to support actions that will improve the energy efficiency of the buildings. Tax measures with the form of additional taxes and penalties could be called fiscal disincentive. Such an example could be the relation of the property taxes to the energy label (consumption) of a building. Likewise, incentives can be given to renovations that result in improved efficiency characteristics as they are depicted on the building's EPC. Authorities can create control mechanisms and impose penalties if an EPC fails to comply with energy measures. While some of the incentives are widely used like the tax reduction others are specific only for small number of countries. It is important to understand the pro and cons of these incentives in order to consider them in the financing of nZEB projects.

B.4.2 BRIEF DESCRIPTION OF MAIN FORMS OF FISCAL & OTHER INCENTIVES

B.4.2.1 Tax Incentives (Fina-Ret)

A tax incentive is "any measure that provides for a more favorable tax treatment of certain activities or sectors compared to what is available to general industry" or "*a reduction in taxes that encourages companies or people to do something that will help the country's economy*[56]". Tax incentives are considered a popular instrument due to the fact that they are consume less of the government's cash liquidity, than subsidies or grants. They can take various forms such as tax exemptions, income tax or VAT reduction. National policy makers adopt this measure and it is stated in a law containing all the details concerning eligibility criteria and the amount of allowance (usually as a percentage of the investment).

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[55]A fiscal incentive is a "*monetary benefit offered to consumers, employees and organizations to encourage behavior or actions which otherwise would not take place. A financial incentive motivates actions which otherwise might not occur without the monetary benefit*"
Online Business Dictionary (http://www.businessdictionary.com/definition/financial-incentive.html)
[56]Cambridge Dictionary (http://dictionary.cambridge.org/dictionary/english/tax-incentive)

Tax incentives are not appropriate for public buildings as they belong to the general government or public organizations.

B.4.2.2 Feed-in tariffs

A feed-in tariff is a premium in the energy price that is paid by the national authorities when purchasing power energy produced by PV installations and sold by individuals.

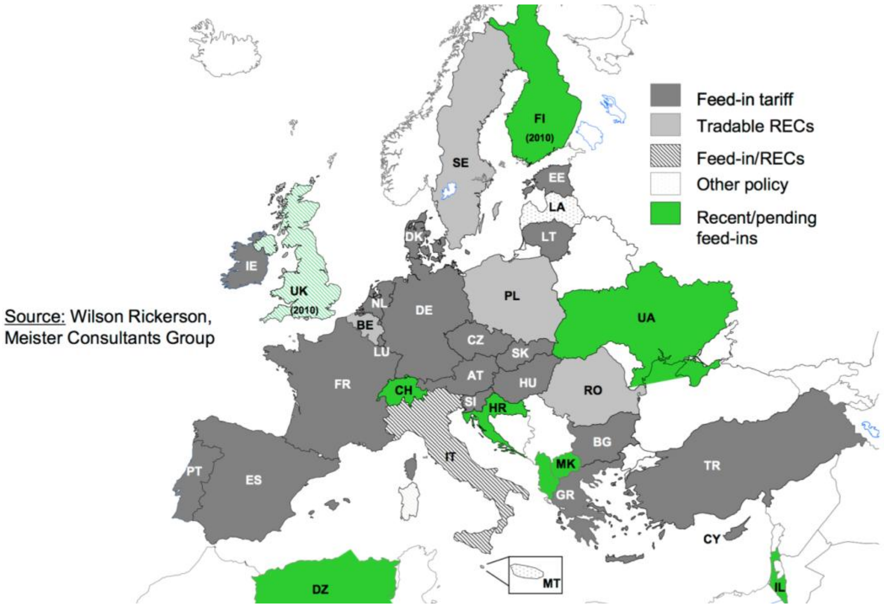


Figure 48. . Fit Policy: Application in Europe (Office of Energy Efficiency & Renewable Energy, 2016)[57]

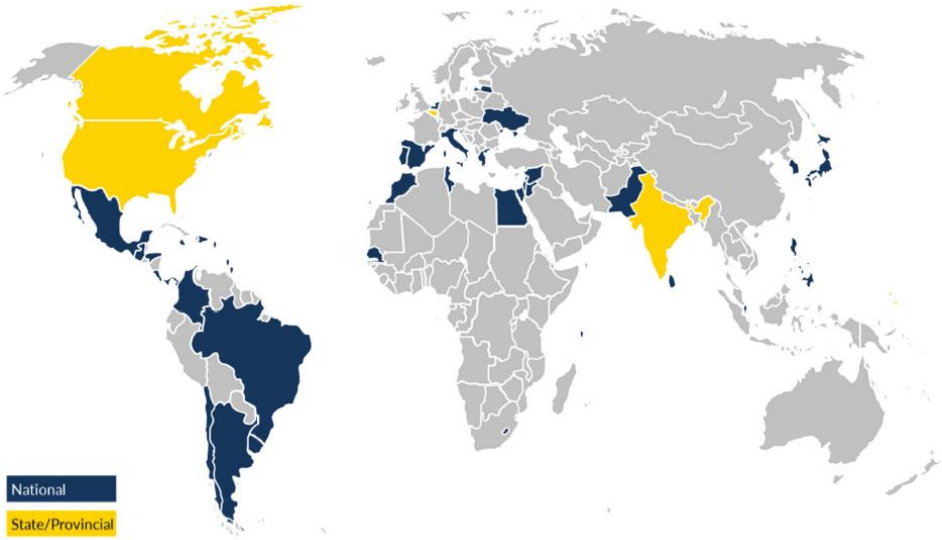
B.4.2.3 Net metering

Net metering allows individuals and businesses who generate their own electricity from renewable systems, usually photovoltaic panels, to feed electricity, they do not use, into the grid and credited at the full retail electric price. In some cases, producers are able to sell the excess electricity they generate their electric utility provider. The connection to the grid is necessary in order for the building to operate during PVs or any other renewable system are off time and to cover peak loads.

57 http://www1.eere.energy.gov/wip/solutioncenter/pdfs/tap_webinar_20091028.pdf

An outcome of the energy retrofitting studies of the twelve (12) municipal buildings that are reviewed under CERtuS is that the installation of a PV for net metering could be useful in order to become nZEB. Financially, the selection of using a net metering system, compared to a feed-in tariff, can be partially explained by the fact that feed-in tariffs are lower than the equivalent cost of electricity from the grid.

Net-metering is a very important step forward and it is available to all four South European countries (Greece, Italy, Portugal and Spain).



B.4.2.4 White Certificates

A white certificate, also referred to as an Energy Savings Certificate (ESC), Energy Efficiency Credit (EEC), or white tag, is an instrument issued by an authorized body guaranteeing that a specified amount of energy savings has been achieved. Each certificate is a unique and traceable commodity carrying a property right over a certain amount of additional energy savings and guaranteeing that the benefit of these savings has not been accounted for elsewhere[58].

58 http://wupperinst.org/uploads/tx_wupperinst/Pavan_BMU_10122009.pdf

B.4.2.5 On-Bill Repayment Mechanism

The On-Bill repayment mechanism allows for the energy-efficiency repayments to be collected within the utility, tax or bill payment as already been set up. As long as the Municipality, or any other client, has a good “credit history” paying its electricity, gas and other bills on time you can have a good indication of a low default risk and thus make the project more attractive to investors. From market practice on-bill repayment is popular among investments in buildings.

B.4.3 ADVANTAGES, DISADVANTAGES AND OTHER CONSIDERATIONS

Fiscal & other Incentives have the meaning of a grant in the long term, as they don’t support the construction or/and installation of a system or infrastructure but their use. Financially, incentives are not given as a percentage of the capital cost in the beginning of the project but are related with the use and the possible environmental benefits offered by the project to the local and general environment.

So, it is obvious that the main disadvantage of incentives is that they don’t contribute to the capital cost of the investment. On the other hand, they have many advantages, as:

- usually they support the efficient operation and use of the infrastructure or/and systems and not the construction or/and installation,
- with the same annual budget, they can support a bigger number of projects, compared with grants,
- they don’t require a costly and time consuming procedure, such as a competition in order to have a Grant,
- they trigger market money, with potential revolving effect.

Concluding, as long as a Project seems to be not attractive with market conditions, the use of incentives could be an efficient solution in terms of financial sustainability.

B.5 CONCLUDING REMARKS

The deep energy renovation (at least 60% energy savings compared to pre-renovation levels) and even more the energy renovation in order to become nearly Zero Energy Buildings (nZEB), is a technical and financing challenge. The most critical issues that they have to be faced and overcome are:

- Technical issues, related mainly to buildings' stability;
- Aesthetic issues, especially for listed buildings;
- Buildings' operation continuation;
- Possible complicate and long lasting procedures in order set up a call of tender;
- Possible bureaucracy;
- Financing issues

CERtuS Project results show that all these issues could be handled successfully, buildings' could achieve energy renovation and eventually be transformed in to nZEB. Another important outcome is that a variety of financing tools is available for financing buildings' energy retrofitting, but none of them can be assumed to be the most appropriate, even those that are dedicated to the specific financing cope. Many times, it has been proven that the use of a single financial tool cannot meet the needs of buildings deep renovation or vice versa buildings deep renovation projects do not fit to existing financial products or Funds' specific requirements. Therefore, a combination of existing financing tools may be needed in order to materialize the expected Projects.

According to Project's proposed methodology, it seems that even if Grants is the more desirable financial tool, usually grants funds are limited and so their use it is not the most efficient tool for implementing a large scale Project. In fact from municipalities point of view, Grants are desirable but usually there is not enough for the deep energy renovation of all buildings. More, Grants could be acceptable for specific projects, but as long as they have zero revolving effect (the money don't return to the promoter to give them for another project) they are the less favorable tool.

An hybrid financing scheme, that includes direct and indirect financing tools, seems to be the most appropriate for deep energy renovations, aiming towards Nearly Zero Energy Buildings (NZEB). In depth economic and financial analysis is fundamental in order to understand different project layers sustainability and market attractiveness. During project development phase, a detailed match funding should be prepared in order to combine several available financing sources and activate the application and the demand of the specific source. The final result of match funding should be the maximization of potential investment and energy efficiency savings, the efficient use of grants resources for long term payback investments.

In large scale projects different advantages can be obtained: local authorities should be able to better negotiate EPC contract and O&M Contracts, subsides funds could be obtained, higher energy efficiency results maybe proposed and guaranteed by ESCos.

Moreover such schemes could have increased structuring cost and therefore they are most appropriate for bigger investments. Therefore technical assistance resources are fundamental in order to help local authorities to prepare attractive and efficient projects. So, municipalities probably have to think about of renovated a big amount of their buildings stock, rather single buildings (Figure 50).

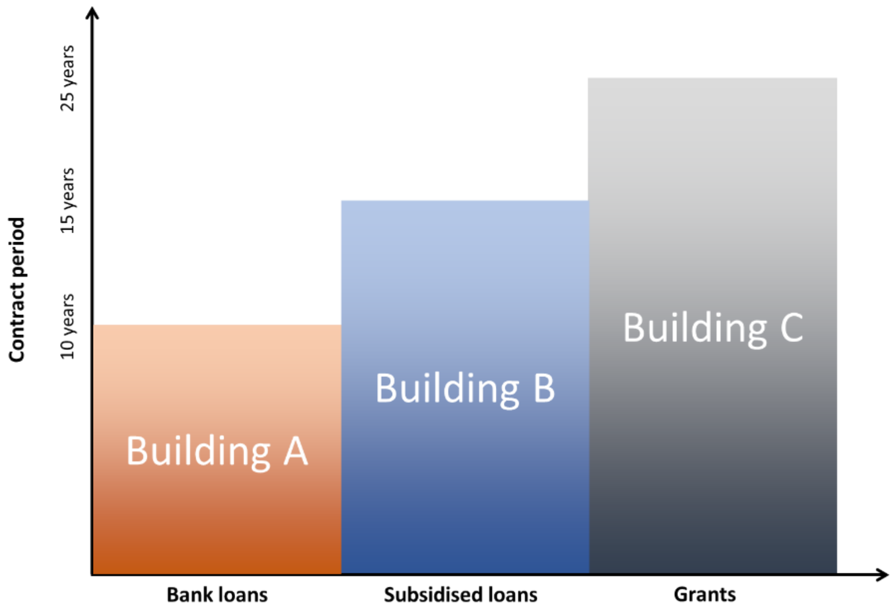


Figure 49. Conventional financing approach

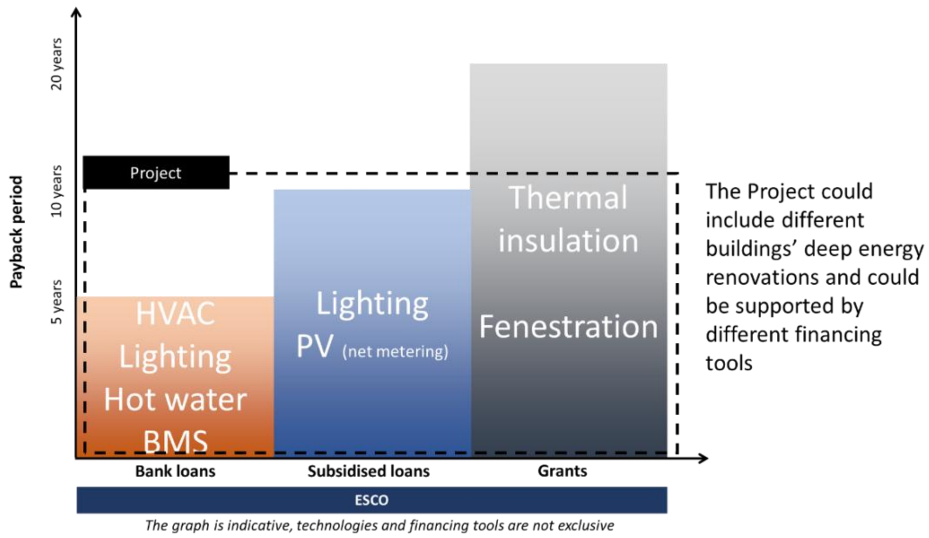


Figure 50. Potential alternative financing scheme

(V.R.)

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PART C

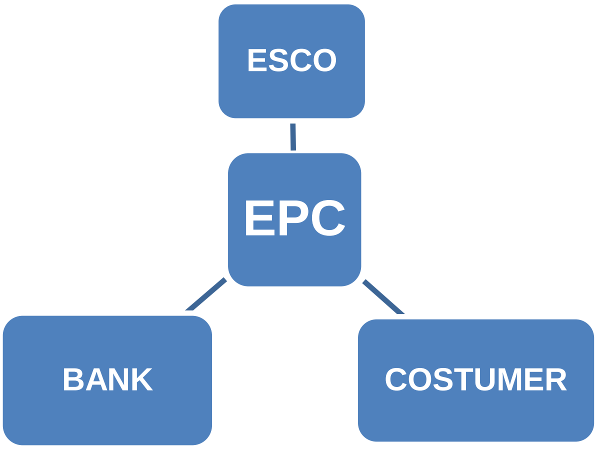
A GUIDE FOR SELECTING ENERGY SERVICE MODELS

C.1 THE TYPE OF EPC CONTRACTS

The Certus project provides that Municipalities, for the energy upgrading of its buildings in NZEB, use the instrument of the EPC contract and the Third Party Financing.

An EPC contract, according to **Directive 2012/27/EU** is defined:

'energy performance contracting'*: a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings.*



Then the parties of the EPC contract are usually two: the client and the ESCO that are often accompanied by a third party lender (i.e. Bank).

The municipality must identify among the types of contract that matches its needs and that it can still accommodate the market favors. In fact, the EPC is a contract between two parties which must both find their own conveniences in the conclusion of the same. As the contract is more balanced itssuccess is ensured.

There are multiple types of contracts that meet the above definition and differ from each other mainly for some peculiar aspects: the subject which finances investments, the duration of the contract, or not sharing the savings, etc.

It is well to specify that often the contract will not be exactly equal to one of these types but, in order to make it more adherent to the needs of parts, will be a mix of more kinds of contract.

Therefore, the different aspects, that permit to identify the "reference scenario", must be taken into account.

The following is a summary of the most used types of contracts and the roles played by each individual within single type of contract.

CONTRACT TYPE	CUSTOMER	ESCO	BANK
FIRST IN	• The customer pays a fixed fee that guarantees a guaranteed minimum saving of energy costs historical. • If the saving is major of the minimum fixed the customer have a positive adjustment at year end	• ESCO finances interventions with equity capital or through third Party Financing ("credit risk") • The ESCO makes the interventions of energy savings and governs installations, of which will maintain the property until the end of the contract (technical risk) • ESCO is for to 100% of the expected savings in contract; if the saving is major, the difference is shared with the customer	• The Bank finances the ESCO if not use the equity
FIRST OUT	• For the duration of the contract the customer continues to spend like before upgrading the energy efficiency	• ESCO finances the interventions with equity capital or through third Party Financing	• The Bank finances the ESCO if not use the equity

	• At the end of the contract the customer benefits of the savings resulting from energy saving measures	• For the duration of the contract, it receives 100% of the savings achieved by energy saving measures by which the ESCO can recover the credit, the costs and the profit	
GUARANTEED SAVINGS	• The customer finances the interventions with equity capital or through third Party Financing, accept the "credit risk • For the duration of the contract, receives 100% of the savings achieved • The customer pays a fixed fee for the services of the ESCO	• ESCO finds and organises the financing • ESCO guarantees a minimum energy savings agreed with the customer • Accept only the risk to the guaranteed performance "tecnical risk"	• The Bank finances the Custumer if not use the equity
SHARED SAVINGS	• Energy saving is divided between ESCO and the customer	• ESCO finances interventions with equity capital or through third Party Financing • The ESCO accepts the risk to the guaranteed performance ("technical risk") and accepts the "credit risk" • Energy saving is divided between ESCO and the customer	• The Bank finances the ESCO if not use the equity
PAY FROM SAVINGS	• The customer Finance interventions through third	• Finds and organizes the financing	• The Bank participates in the project

	Party Financing • The customer returns the debt in payments proportional to the savings achieved (the funder evaluates the technical project) • The customer accept the “credit risk” • For the duration of the contract, it receives 100% of the savings achieved • The customer pays a fixed fee for the services of the ESCO	• ESCO guarantees a minimum energy savings agreed with the customer • Accept only the risk to the guaranteed performance “technical risk”	and finances the customer, accepts a financial risk since it is reimbursed annually based on the cost savings achieved
FOUR STEPS	• The customer pays a fixed fee for the services of the ESCO	• ESCO finances the interventions according to the following mechanism: • Step 1: optimization of operation and maintenance (no investment) • Step 2: the saving obtained from Step 1 finances measures of energy saving simple and low cost • Step 3: the saving obtained from Step 1 and Step 2 finances energy saving measures medium size • Step 4: the saving obtained from preceding steps finance large energy saving measures	• There is not third-party financing

		and with return times longer	
Build-Own-Operate & Transfer (BOOT);	• The customer pays the energy bill and the service provided to the ESCO • At the end of the contract, the customer has the ownership of the property	• The ESCO designs, builds, finances, governs the new plants and owns the property for a defined period of time (usually with Purpose companies); when the period of time established is finished, it transfers ownership to the customer (technical and credit risk) • For the duration of the contract, receives 100% of the savings achieved	• The Bank finances the ESCO
CHAUFFAGE	• The customer entrusts the management of its plants to the ESCO and pays a fee equal to the historical spending or lower	• ESCO pays the energetic bills and bills of fuel for the duration for the contract (technical risk) • ESCO finances the maintenance/ redevelopment / upgrading interventions of the existing installations • For the duration of the contract, it receives 100% of the savings achieved	• The Bank finances the ESCO if not use the equity

Table 28. Type of EPC contract

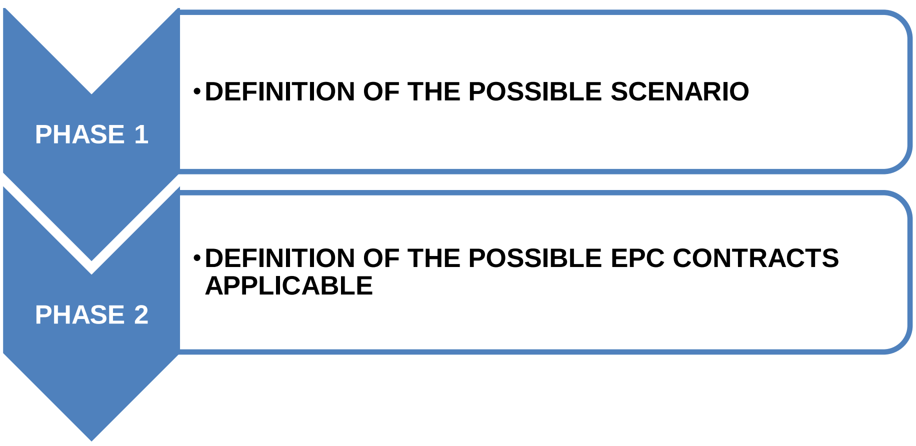
C.2 METHODOLOGY

In order to proceed to a choice of the most suitable type of EPC contract it is necessary to adopt a methodology identifying all possible needs and barriers without missing possible contingencies that could affect the success operation.

The following method, applied in the project CERtuS, has given good results and is easily adaptable to the needs of each municipality.

It is important to point out that this method does not provide the criteria by which the Municipality can go to the selection of buildings to make nZEB but only indicate the path to follow to identify the type of EPC Contract better suitable to the specific chosen building.

The methodology is based on two steps: in the first, the conditions and the feasibility of the initiative are been setted and in the second, the type of contract to be offered.



The following describes, for each phase, the steps that need to be covered and the reasons connected with them.

C.2.1 PHASE 1 - “DEFINITION OF THE REFERENCE SCENARIO”

The goal of this first phase is to verify the existence of the minimum conditions because, for the projects presented, there could be a partnership with the private sector through the instruments of the EPC contract and the FTT, according to standard market conditions; where this does not occur the methodology identifies the ways and / or indicates the tools to create such conditions. In fact, if you want to involve an external partner for the implementation of interventions to improve efficiency, ESCOs or Sponsor, we must ensure that the project can provide returns to these two new subjects and that ensures the project margins and indexes, company variable for company and market by market but which are usually represented by IRR value and cash flow. These indices are clearly influenced by the cost of money that needs to support the company to carry out the works, both in case of accessing external funding and funding with equity capital. If the technical design does not allow that the average market indices are respected, it is necessary to bring the project to the minimum lease payments.

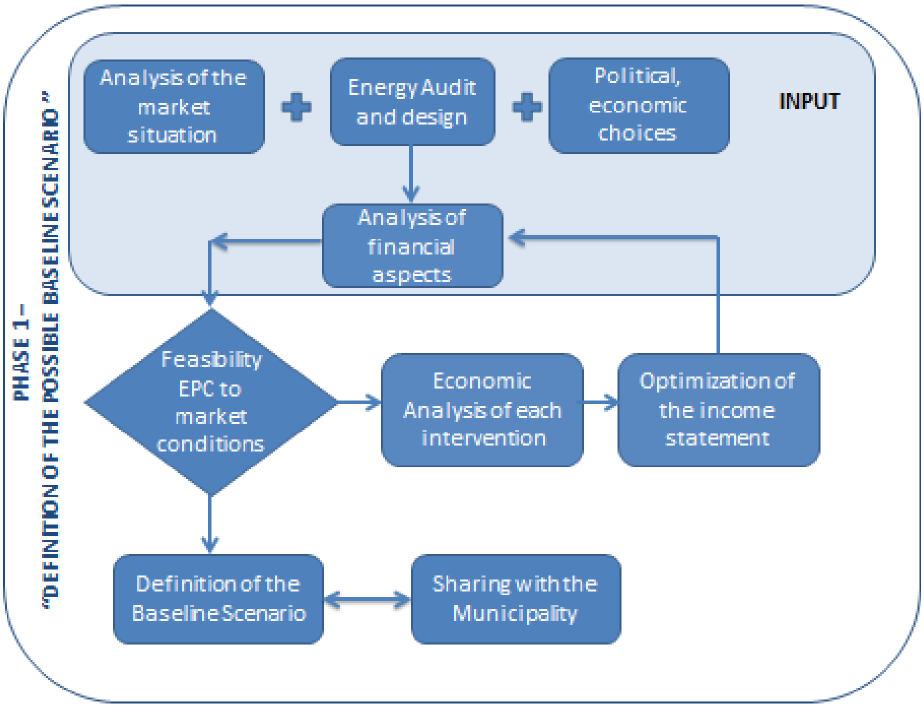


Figure 51 Flow chart of the phase 1 of the methodology

Therefore, in this phase, the data of the municipality, the legislative and political situation in force, the economic conditions, the possible sources of funding, and finally the technical and financing characteristics of the energy efficiency improvements previously identified following audits are identified. Therefore, all the elements that might affect the project as they are linked to boundary situations and they can strongly influence the choice of the type of contract are identified.

In particular, it is necessary to find a set of data of In-Put for the construction of an EPC contract:

- Data relating to the economic situation of the Municipality and to the national context,
- The presence of any legislative constraints,
- The political-economic choices and strategies of the Municipality relating to energy efficiency measures,
- The support initiatives applicable to redevelopment (incentives, concessional funds, tax exemptions, etc.),
- The market situation in which the initiative will be developed (the cost of money, the cost of energy carriers, taxes, ...),
- The project data related to energy efficiency (energy saving, use of alternative sources, etc.) and indications of technical and economic data (cost of interventions, cost savings of carriers, potential, etc.),
- The data resulting from a first financial analysis of the projects in order to assess the possibility of proposing to the market of ESCo a contract to standard market conditions.

Once acquired this data and performed this first evaluation, if there are the economic feasibility conditions under standard market conditions, it is possible to proceed by defining the "Reference Scenario". If this condition is not met, some purely economic measures can be taken into account such as the reduction of the investment, use of direct capital of the municipality, use of incentives, recourse to concessional funds, etc., in order to identify the feasibility of a maximum . This process is iterative and it should be repeated several times until you find the optimal condition to offer the market.

This process leads to the definition of "Reference Scenario" ie the technical and economic conditions in order to choose the type of contract to be applied and then the partner with whom to realize the energy efficiency project for a nZEB building.

This concludes the first phase of the proposed methodology which is a fairly long preparatory phase, because it includes the interaction with different subjects such as planners, administrators, lawyers, etc.

C.2.2 PHASE 2 - "DEFINITION OF POSSIBLE APPLICABLE TYPE CONTRACTS"

The objective of the second phase is the identification of the EPC contract type to apply based on the Reference Scenario previously identified and based on the characteristics of each project developed.

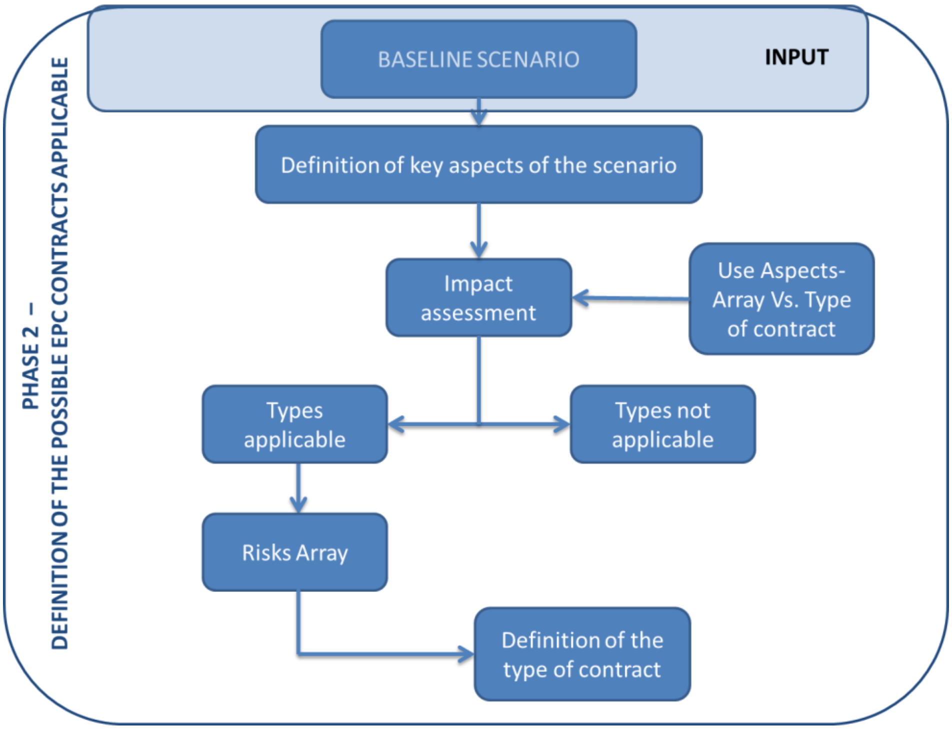


Figure 52 Flow chart of the phase 2 of the methodology

In the second phase it is possible to start with a well-defined scenario: a list of needs, constraints, boundary conditions that the type of contract must respect.

Since not all of these factors influence the choice of a type of contract with respect to another, we proceed first to a identification of the significant aspects and binding of each scenario: **Key Aspects**.

So it has been built a table, as shown in the following paragraph, in which are summarized the various aspects which should be highlighted in each reference scenario, finally to analyze and identify all key aspects.

Then we proceed to a detailed assessment of the impact that each key aspect has on single type of contract (such as the inability of a municipality to directly fund the energy upgrading works automatically exclude all those types of contracts which provide for direct investment through the help of the third-party financing (TPF) instrument). For this evaluation using the Matrix Vs. Key Aspects Contract type, as shown below, allowing you to give a numerical evaluation of the impact, positive or negative, for each key aspect for each type of contract.

From this evaluation we are only identified the types of contracts that do not have a negative impact, thereby reducing the choice to a limited number of contracts.

The contracts are so identified virtually all effect and thus switching to compare them with each other through the use of the Matrix of Risks hereafter.

Therefore, it is possible to identify risks and make a first evaluation about those assigned to the Municipality and to the ESCO in order to assess them and prepare to support them immediately placing special attention to the most critical ones.

The latter assessment, own of the municipality, leading to define the type of contract to be used or, as often happens, a mix of the types selected in order to tailor the contract to be awarded to the needs of the projects and of the two Contracting Parties.

C.3 THE REFERENCE SCENARIO

Every administration who has to choose how to proceed to implement a project and define which contractual instruments to use, has to evaluate many aspects: technical, financial and economic aspects, which in this time of economic crisis take on a significant weight, but also regulatory and legislative, administrative and political aspects, etc.

The reference scenario is precisely this set of information to be considered.

The Reference Scenario can therefore be defined as the set of the needs, constraints, expectations of a redevelopment project that will direct the feasibility.

C.3.1 KEY ASPECTS

Each scenario contains many aspects to be taken into account: some are important in the choice of the type of contract and others are not relevant.

The key aspects are the ones that have a strong impact in the choice of the type of contract.

To identify them is useful to use a table like the one shown below in which, in addition to list of key aspects and their origin, it is necessary to indicate for each of the key aspects the quantitative and / or qualitative data related to the specific project that can help to define the suitability of the individual contract Type.

BASELINE SCENARIO			
ORIGIN	**KEY ASPECT**	**VALUTATION**	**NOTE**
Design	Total value of the investments	"High/Medium/Low"	"Value"
	Payback time of the investments	"High/Medium/Low"	9-10 years
Administrative	Constraints on contractual times	"YES/NO"	"max "
	Possibility of the Municipality to contract debts	"YES/NO"	

Economic	Capacity of the Municipality to finance all the interventions	"High/Medium/Low"	"Value"
	Capacity of the Municipality to finance a part of the interventions	"High/Medium/Low"	"Value"
Political	Need to obtain an immediate cost savings	"YES/NO"	" %"
	Possibility to defer the savings after the return of investments	"YES/NO"	
	Additional induced economic savings	"YES/NO"	" Estimated value"
	Constraints on the implementation time of the interventions	"YES/NO"	"Value"
	Inserting purchase of energy carriers in the EPC contract	"YES/NO"	
Legislative	Existence of incentives, concessional funds, tax relief	"YES/NO"	"What?"
	Possibility to access to the incentives by ESCO	"YES/NO"	
	Possibilty of the Municipality to use some incentives to repay a portion of the Minority Investment	"YES/NO"	
Internal	Know of the tools (EPC contract, TPF)	"YES/NO"	

Table 29. Key aspects of the baseline scenario

It is obvious that the table lists only some of the possible Key Aspects and may be customized and implemented according to the needs.

This implementation should be made keeping in mind the characteristics of each of the types of contracts mentioned in the previous chapter.

The key aspects are all those fixed and indispensable conditions in the construction of a contract that have impact on the choice of the type of contract.

C.3.2 Key Aspect Array vs. type of contracts

To assess the impact that the conditions (Key Aspects) have on the applicability of the various types of contract it is designed a methodology that seeks to transform objective evaluation into numbers.

The application of this method is to assign, for each key aspect in the Reference Scenario and for each type of contract, a value according to the weights shown in the table below. This weight expresses the impact that every aspect has on the type of contract considered.

IMPACT ON THE TYPE CONTRACT	VALUE
Applicable	1
Indifferent	0
Shortly applicable	-1
Not applicable	-2

Table 30. Legend of the values corresponding to each key aspect of the baseline scenario

Once carried out the analysis of all the key aspects you run the sum of the values obtained by type of contract and then all the types of contracts that have been awarded a total negative value can be discarded because are not very effective or not applicable in the reference scenario took concerned.

In this way they reduce the types of contract to be taken into account and to assess. Only these will be compared through the application of the Risk Matrix as described in the previous chapter.

C.4 RISK ARRAY

As indicated in Chapter C.2, after identifying a number of the applicable Contract Types for the specific project through the use of "Matrix Key Aspects Vs. Type Contracts", you need to compare these agreements with each other to try to identify what that best meets specific needs.

To do this the "Risk Matrix" has been created as a possible decision support which is based on the following principle: each contract creates risks for each of the contracting parties.

This is especially true for the EPC contract that has technical, managerial, financial and economic aspects.

In order to prevent these risks and deal with them, you must first identify them and then evaluate to which of the contracting parties the risk competes.

According to literature and to consolidated practice, risk analysis usually concerns the following macro-categories of risk:

- Governance: lack of control, change of control, etc…
- Political/Social: risk of facing changes in regulations or complication of authorization procedures, loss of reputation/credibility
- Economic/Financial: risk of incurring changes in market prices of electricity, raw material, etc…
- Environmental: risk of incurring limited availability of natural resources, possible damages to the fauna, flora, Earth, water, air, etc…
- Technical/ Construction: construction defects, change of technology, etc..
- Commercial/Operations: demand, supply, etc…

These risks may arise during the different phases of the energy efficiency project managed through an EPC contract; then, for each phase, the following table describes all possible risks and their drivers.

PHASES	TYPE OF RISK	DRIVER OF RISK
ENERGY AUDIT	Risk of audit	Wrong or not correct audit
		False detection/estimation of maintenance and repair costs
		False detection/estimation of potential regulatory changes
PLANNING	Risk of planning	Incorrect or unsuitable design
		Increase in design costs
AUTHORIZATION	Regulatory Risks	Lack of regulations / lack of information about regulations
		Delays / difficulties obtaining authorizations and permits
	Political Risks	Sociopolitical instability
FINDING FUNDING	Financial Risks	Obtaining funding
		Fluctuation in interest rates
START WORK AND CONSTRUCTION	Environmental Risks and conditions of the site	Environmental impact of the intervention (eg. Noise)
		Static and Geological conditions of the site
		Discovery finds historical/archaeological
	Construction Risks	Non conformity to the project
		Delayed delivery or impossibility of completion of the works
		Increase in construction costs
		Possible default of subcontractors
MANAGEMENT	Market Risk	Increased operating costs (maintenance, etc.)
		Change of use, occupation, mode of use of the building
		Increases in energy costs
		Regulatory changes
		Change of the incentive system
		Change in taxes (tax and VAT)
		Increase in insurance costs

PHASES	TYPE OF RISK	DRIVER OF RISK
		Changes in the dynamics of the indices of the royalties revisional
		Change in the rate of inflation
	Counterparty Risk	EELL Rating
		ESCo Rating
		Risk of default by ESCo
		Financial and technical reliability of suppliers of heat and electricity
		Provider of incentives
	Technological Risk	Lack of performance of technologies/facility
		plant shutdown/breaking plant
		Increase in maintenance
		Damages for accidents or erroneous management
		Risk resulting from innovative technologies
	Externa lRisks	Occurrence of acts of God
		Climate risk
		Damage to third parties

Table 31 Types of risks during the energy efficiency process managed through a EPC contract

Defined the possible risks (it is clear that this table can be implemented according to the needs of each) you can go on, taking into account each Type of Contract EPC, to give a numerical rating related to each of the parties.

In order to indicate how each risk is distributed between the ESCO and the Municipality in each EPC contract, it is assumed to be assigned the following scores:

2,0	**Maximum risk**
1,5	**Prevailing risk**
1,0	**Risk-sharing between the parties**
0,5	**Minimal risk**
0,0	**No risk**

Table 32 Legend of the scores assigned in the risks array

So, considering the types of risk and assigning the above scores, it is possible to obtain the following table that shows, for each EPC contract, how each driver risk is, exclusively or overwhelmingly, in charge of the ESCo or Municipality.

RISK ARRAY

PHASES	TYPE OF RISK	DRIVER OF RISK	FIRST IN		FIRST OUT		GUARANTEED SAVINGS		SHARED SAVINGS		PAY FROM SAVINGS		FOUR STEPS		BOOT		CHAUFFAGE	
			ESCo	EELL	ESCo	EELL	ESCo	EELL	ESCo	EELL	ESCo	EELL	ESCo	EELL	ESCo	EELL	ESCo	EELL
ENERGY AUDIT	Risk of audit	Wrong or not correct audit	2		2		2		2		2			2	2		2	
		False detection/estimation of maintenance and repair costs	2		2		2		2		2		2		2		2	
		False detection/estimation of potential regulatory changes	2		2		2		2		2			2	2		2	
		Evaluation %	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	33%	67%	100%	0%	100%	0%
PLANNING	Risk of planning	Incorrect or unsuitable design	2		2		2		2		2			2	2		2	
		Increase in design costs	2		2		2		2		2			2	2		2	
		Evaluation %	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	100%	100%	0%	100%	0%
REGULATORY	Regulatory Risks	Lack of regulations / lack of information about regulations	1,5	0,5	1,5	0,5	1,5	0,5	1,5	0,5	1,5	0,5			2		1	1
		Delays / difficulties obtaining authorizations and permits	1,5	0,5	1,5	0,5		2	1,5	0,5		2			2		2	
		Socio political instability	2		2		2		2		2				2		2	
		Evaluation %	83%	17%	83%	17%	58%	42%	83%	17%	58%	42%	0%	0%	100%	0%	83%	17%
PROCUREMENT OF FINANCE	Financial Risks	Obtaining funding	2		2			2	2			2			2		2	
		Fluctuation in interest rates	2		2			2	2			2			2		2	
		Evaluation %	100%	0%	100%	0%	0%	100%	100%	0%	0%	100%	0%	0%	100%	0%	100%	0%
STURT UP AND CONSTRUCTION	Environmental Risks and conditions of the site	Environmental impact of the intervention (eg. Noise)		2		2		2		2		2		2		2		2
		Static and Geological conditions of the site	2		2		2		2		2			2	2		2	
		Discovery finds historical/archaeological	1,5	0,5	1,5	0,5	1,5	0,5	1,5	0,5	1,5	0,5		2	2		2	
		Evaluation %	58%	42%	58%	42%	58%	42%	58%	42%	58%	42%	0%	100%	67%	33%	67%	33%
	Construction Risks	Non conformity to the project	2		2		2		2		2			2	2		2	
		Delayed delivery or impossibility of completion of the works	2		2		2		2		2			2	2		2	
		Increase in construction costs	2		2		2		2		2			2	2		2	
		Possible default of subcontractors	2		2		2		2		2		2		2		2	
		Evaluation %	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	25%	75%	100%	0%	100%	0%
MANAGEMENT	Market Risk	Increased operating costs (maintenance, etc.)	2		2		2		2		2		2		2		2	
		Change of use, occupation, mode of use of the building	2		2			2	2	1		2					2	
		Increases in energy costs	2		2			2		2		2		2	2		2	
		Regulatory changes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Change of the incentive system	1,5	0,5	2		2		1,5	0,5	2				2		2	
		Change in taxes (tax and VAT)		2		2		2		2		2		2		2		2
		Increase in insurance costs	2		2		2		2		2			2	2		2	
		Changes in the dynamics of the indices of the royalties revisional	1	1													1	1
		Change in the rate of inflation	0,5	1,5	2		2				2			2	2		1,5	0,5
		Evaluation %	67%	33%	81%	19%	56%	44%	57%	43%	56%	44%	25%	75%	79%	21%	75%	25%
	Counterparty Risk	EELL Rating	2		2			2	2			2	2		2		2	
		ESCo Rating		2		2		2	1	1		2		2		2		2
		Risk of default by ESCo		2		2		2	1	1		2	2			2		2
		Financial and technical reliability of suppliers of heat and electricity	2		2		0,5	1,5	2		0,5	1,5		2	2		2	
		Provider of incentives	1,5	1	2		1	1	2		2	2		2	2		2	
		Evaluation %	52%	48%	60%	40%	15%	85%	80%	20%	21%	79%	40%	60%	60%	40%	60%	40%
	Technological Risk	Lack of performance of technologies/facility	2		2		2		2		2			2	2		2	
		plant shutdown/breaking plant	0,5	1,5		2		2	0,5	1,5		2		2	2		2	
		Increase in maintenance	2		2		2		2		2		2		2		2	
		Damages for accidents or erroneous management	2		2		2		2		2		2		2		2	
		Risk resulting from innovative technologies	2		2		2		2		2		2		2		2	
		Evaluation %	85%	15%	80%	20%	80%	20%	85%	15%	80%	20%	60%	40%	100%	0%	100%	0%
	External Risks	Occurrence of acts of God		2		2		2		2		2		2		2		2
		Climate risk	2		2		0,5	1,5	1	1	0,5	1,5		2	2		2	
		Damage to third parties		2		2		2		2		2		2	2			2
		Evaluation %	33%	67%	33%	67%	8%	92%	17%	83%	8%	92%	0%	100%	67%	33%	33%	67%
TOTAL RISKS			75%	25%	78%	22%	58%	42%	75%	25%	58%	42%	27%	73%	85%	15%	80%	20%

The following figure shows the risk allocation between ESCo and Municipality in the different EPC contract.

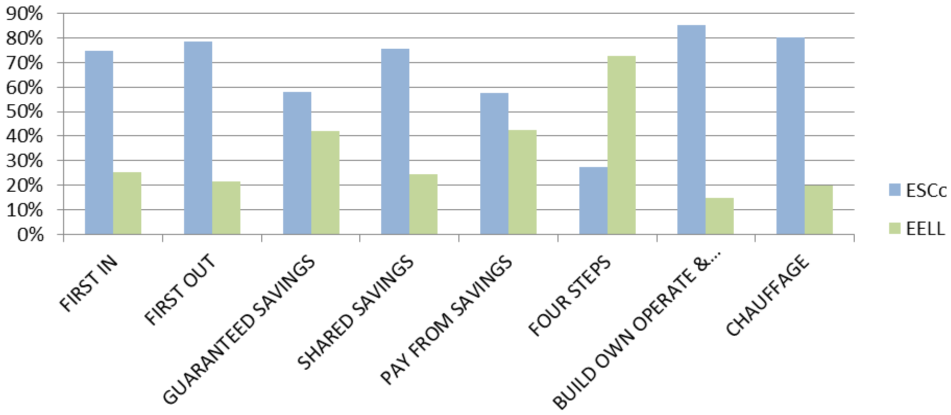


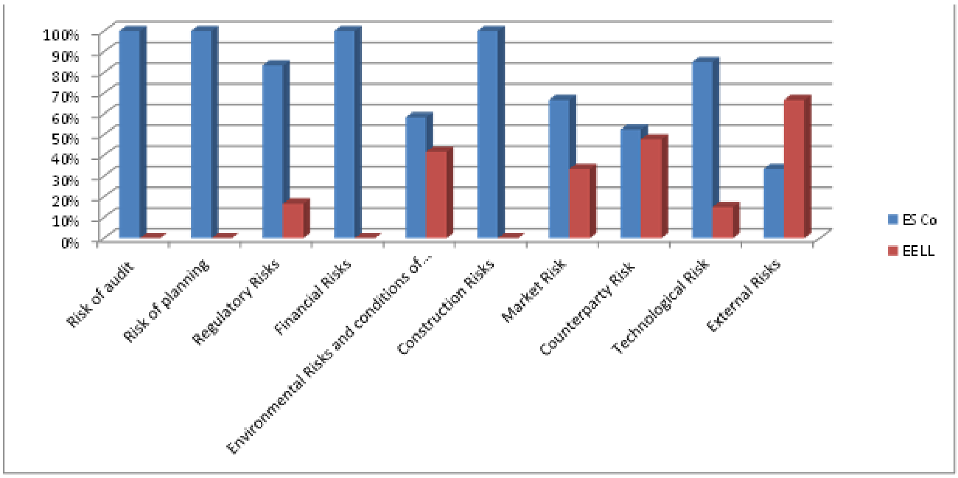
Figure 53 -Risk allocation in EPC contract

It is clear that in the definition of ESCO is intrinsically provided the need to take risks and the magnitude of these risks compared with the earnings identifies the attractiveness of a given initiative. The right balance of risk diversification and cost savings between the parties determines the success of an initiative to improve energy efficiency based on an EPC contract.

The following graphics show as the risks are shared between the ESCO and the Municipality in the different type of the EPC contract.

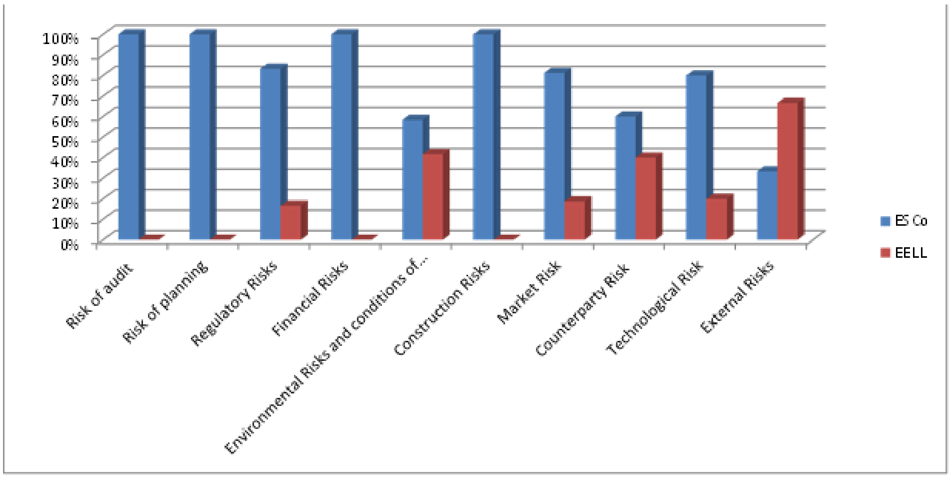
FIRST IN

Only the External risks are weighed more for public administration (PA), all other risks analyzed are completely borne by the ESCO or a percentage that is never less than 50%. Altogether the ESCO assumes 75% of the risks.



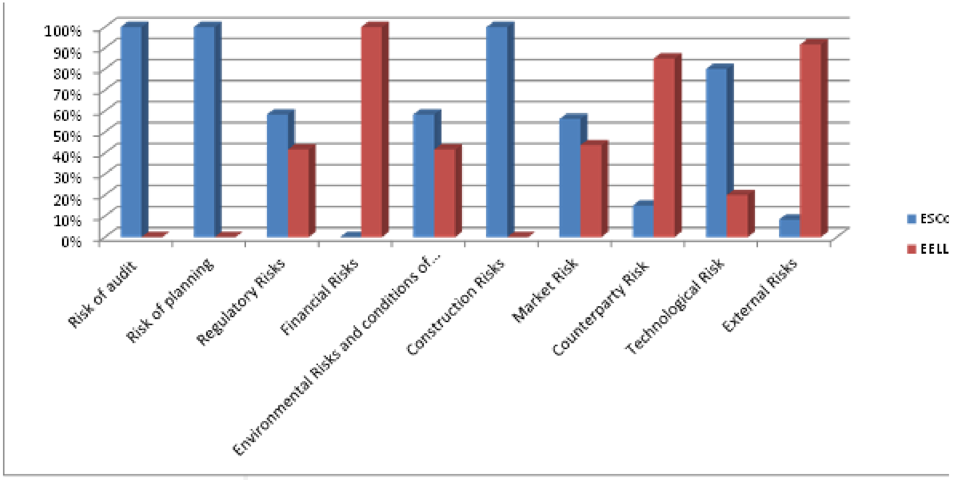
FIRST OUT

Only the External Risks are weighed more for public administration, all other risks are analyzed fully charge the ESCO or a percentage that is never less than 58%. Overall, the ESCO assumes 78% of the risks.



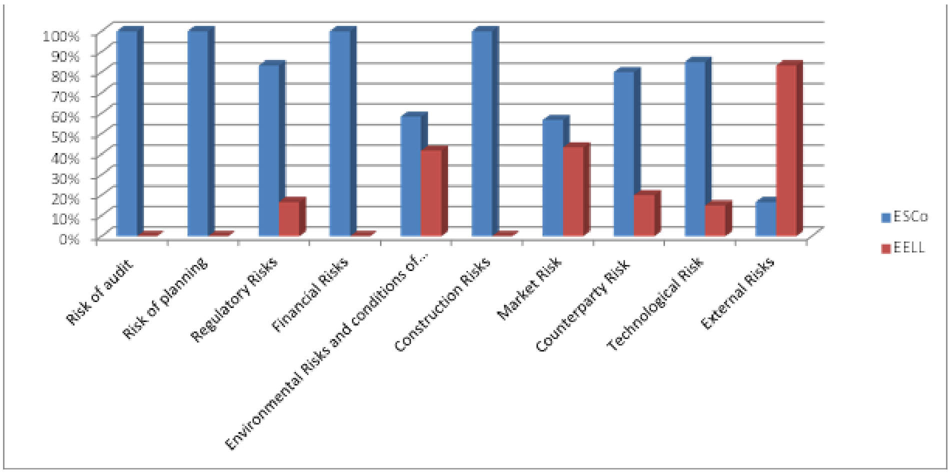
GUARANTEED SAVINGS

In this case, a high percentage of risk which mainly deals with Financial Risk, Counterparty and Exterior remains in charge of public administration; only the Risk Audit, Design and Construction remain totally in charge the ESCO while the remaining risks are balanced with a lead for the PA. Overall, the ESCO assumes 58% of the risks.



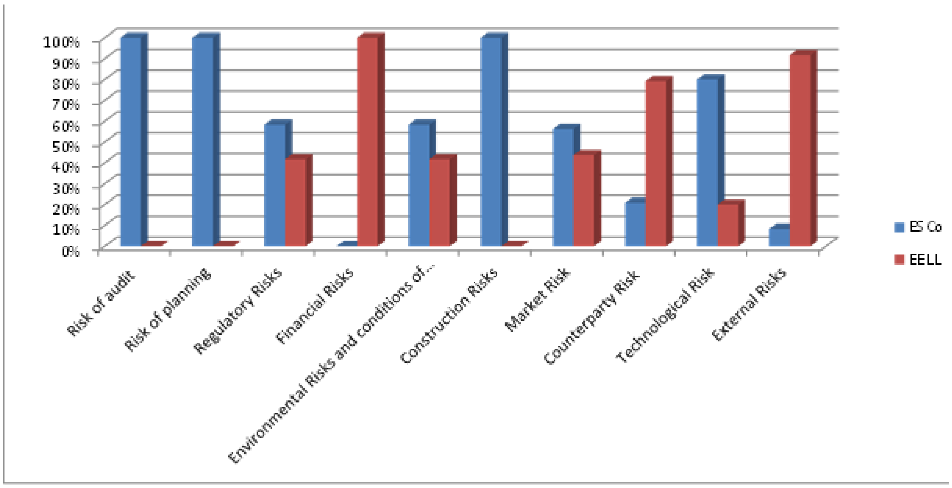
SHARED SAVINGS

Only the External Risks remain for a good percentage in the load to the PA, while all the others remain in load to ESCO for percentages that are never lower than 57%. Altogether the ESCO assumes 75% of the risks.



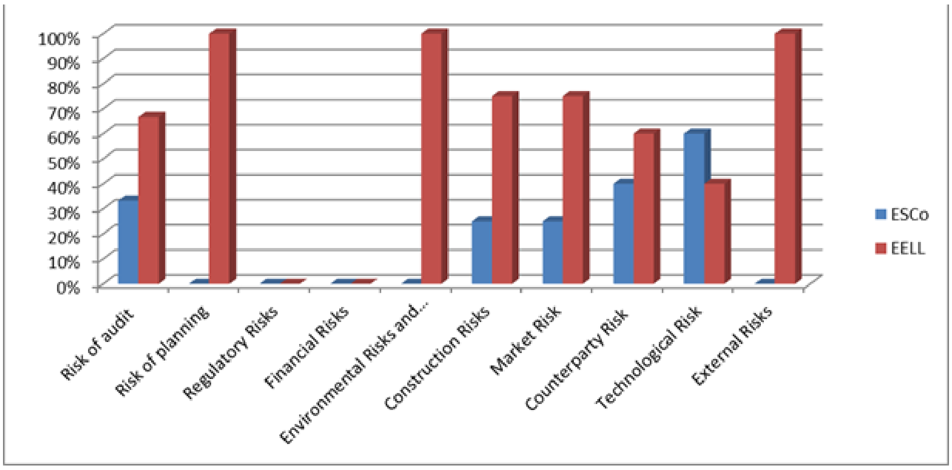
PAY FROM SAVINGS

In that case an high percentage of risk remain in charge of the public administration with regard to the Financial Risk, Counterparty and External; The Risks of Audit, Design and Construction remain totally in charge of ESCO while the remaining risks are balanced with a lead for the PA that never exceeds 42%. Overall, the ESCO assumes the 58% risk.



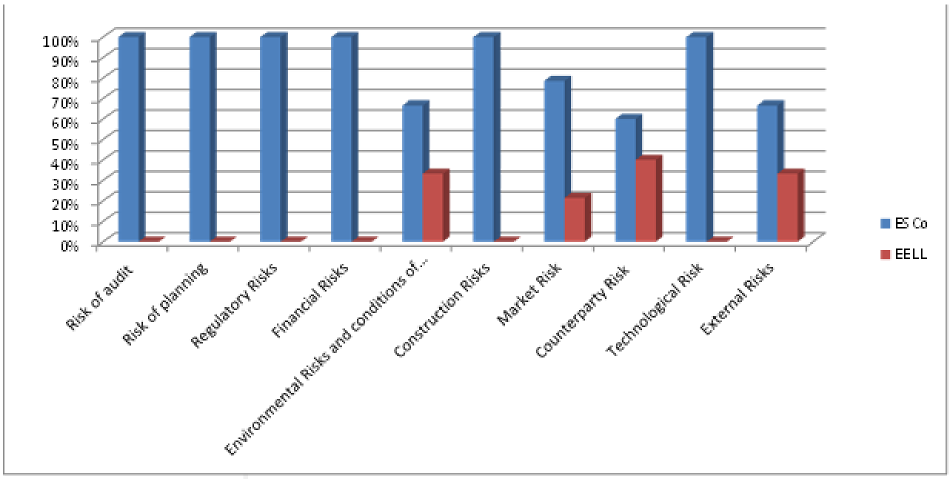
FOUR STEPS

In general is a low risk contract where the totality of risks remains in load to the PA except as regards the technological risk that is reported to the ESCO to 60%. Overall, the ESCO assumes the 27% risk.



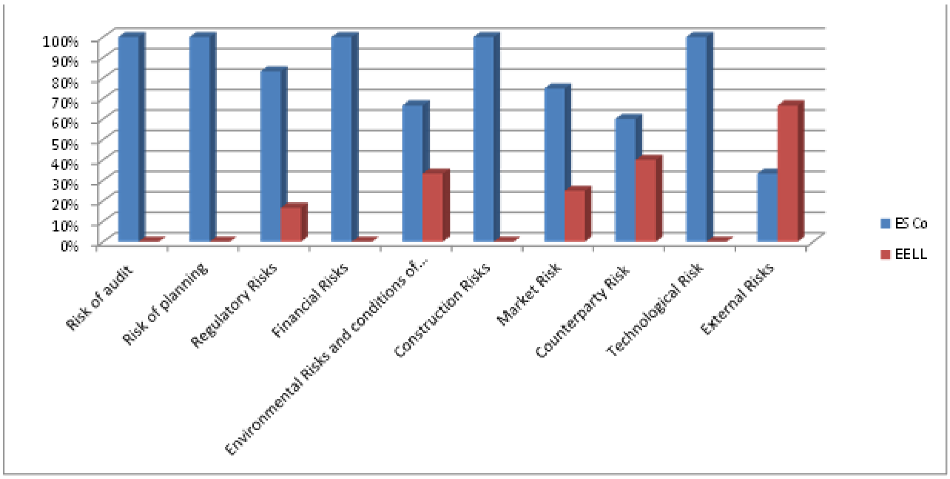
BOOT

The ESCO assumes total of 85% of the risks, many specific risks do not fall on the PA and in any case does not act never more than 40% specific risk.



CHAUFFAGE

Only The External Risks remain for 67% in charge of the PA, other specific risks or are invalid or do not take more than 40% value. Overall, the ESCO assumes the 80% risk.



After the analysis of the matrix of risks related to the types of contracts it will be easier to make the necessary assessments to define the type of contract that best suits the specific project requirements. With the same matrix you can evaluate how to build a customized agreement that incorporates the features of contracts and best suits the specific needs

C.5 CONCLUDING REMARKS

This short chapter wants to suggest a methodology that the Public Administration can use to define an EPC contract well balanced between the parties and able to accept the demands of the Municipality.

This methodology aims to be only a logical path that can be adapted and modified according to the needs and requirements.

It is obvious that, if the objective of the Municipality is to turn the buildings they own in nZEB, it is important to consider the ESCO market for a real public/private partnership that passes through a contract palatable to the market.

(M.M, A.M.)

PART D

LESSONS LEARNT AND RECOMMENDATIONS

D.1 LESSONS LEARNT

The purpose of this section is to bring together any experience and knowledge gained by the implementation of CERtuS activities.

D.1.1 DESIGN, CONSUMPTION AND PERFORMANCE ASSUMPTIONS LESSONS

The renovation options for existing buildings should be implemented by group of measures, based on preliminary studies and evaluations and on analyses of their final impact, instead of in-advance defined and fixed single measures. These renovation options should include technical and financial actions.

For example, the replacement of windows produces post-required actions (e.g painting) which affects the building envelope and is related to the additional wall insulation. Moreover, the technical aim of such interventions is the reduction of the heat losses and the improvement of the indoor conditions. So the additional wall insulation without the replacement of the windows (in some cases):

- it is not as efficient for the reduction of heat losses;
- makes the replacement of the windows a non-financeable solution as they would be installed later. In this case the potential energy reduction will also be estimated on a lower base case scenario (it is referred to the estimated energy consumption after the additional insulation).

Thus, the renovation measures must be based on a carefully determined design and evaluation approach. The total effect of planned measures must defined on systematic approach.

A renovation option should be totally profitable. Otherwise it could be never implemented, excluding the projects in which other benefits could be reached.

The payback time of energy related renovation is the controlling factor but in some cases the longer pay-back time can be accepted if this prevents risks or material damages and/or obvious structural defects, which could cause bigger investments in the future. Obviously, the value of energy savings of one particular measure with reasonable payback time can also be combined with a measure of longer payback time if the mixture is technically and economically viable and attractive.

The deep renovation is complex and expensive. Thus, the implementation of energy performance design studies must be addressed through some tasks, giving priority, to:

- The measures which must be carried out because of risks and obvious damages found during the design stage (they can be very expensive later);
- Energy saving measures with zero and low-cost investments and short payback time (e.g. tightening of windows, door, adjusting running time of HVAC and lighting);
- Energy saving measures with reasonable payback time;
- Improvement of the energy efficiency by long-term effective installations, such as RES and hybrid or/and passive systems replacing fossil fuels.

This approach and procedure requires a short- and long-term maintenance plan and also allocation of resources in a way that life-cycle curve of a building will be optimized.

It is very difficult to reach the nZEB threshold by developing projects in public-private partnership at market conditions involving an ESCo.

The investments on the existing buildings tend to focus on measures with short and medium payback period which usually generate around 30%-40% energy savings. This is the current obtainable threshold in the market and varies across the involved countries and building types. Further energy savings are therefore achievable only by increasing investments, that are not always cost-efficient at market conditions and that usually need to be financed with specific ad-hoc financial instruments and/or public grant.

In order to make investments which are more sustainable for ESCos, the renovation projects, when possible, could consider alternative ways compared with the standard EPC contract.

For example, to implement other types of contracts, a global service or a direct procurement by the Municipality

Small size energy efficiency projects are not rare in the public sector of Southern European countries. Whereas energy efficiency projects - generally tend to be larger both in investment and in reduction effects - could be a good option to aggregate more than one initiative.

This aggregation could be useful to obtain cost efficiency, incremental revenues and synergies.

Financial barriers are considered by the stakeholders as the main barriers for nZEB renovations.

This fact is worsened, in some cases, by the decreased interest, political decision-making and the shortage of public funds. The promulgation of ambitious energy plans accompanied by suitable tax policy, as well by incentives, is seen necessary to boost energy renovation not only in the majority of the involved countries, but probably also in other South and East European countries.

The lack of knowledge of retrofitting technologies, especially the innovative ones, and the unclear energy policies has been identified as the main barrier from the technical point of view.

Moreover, this lack of knowledge also depends on the absence of credible energy savings data, uncertainty of maintenance costs and complexity of the installations.

When the renovation options are not financially sustainable, is due generally to several factors, as:

- Technological solutions which are currently available in the market are quite expensive if compared with the obtained savings costs. This has a negative impact on the economic and financial feasibility of the projects;
- The medium and long payback-time of some specific measures;
- The additional costs caused by special constructions or systems, required for listed buildings, compared with conventional ones,
- Energy efficiency interventions may improve the ability of public authorities to identify the significance of proper maintenance frequency, compared with the conditions before renovation. Usually this will come up when annual maintenance costs increase, (entirely sustained by the ESCO). This aspect - although it initially increases public expenses - is fundamental for the proper maintenance of the new systems.

D.1.2 RECOMMENDATIONS

In order to encourage nZEB interventions and financing them at market conditions some actions should be considered. Those do not necessary derive from the investigations and other analysis done within the CERtuS project. They are proposed, as stimulus for thinking, concerning the feasibility and sustainability of the nZEB interventions:

- Increase the use of public buildings during the daytime by additional activities, when it is possible (e.g. sport and social activities during the evening/night, office activities during the day). If the use of a building can be extended from a normal/conventional use, it will bring benefits, as the optimisation of the building usability and profitability.
- Increase ESCo services, which, in addition to hard facility management (e.g. mechanical, fire and electrical services), could offer them the possibility to carry out auxiliary services such as soft facility management, (e.g. cleaning services, green care, reception). This would provide additional revenues to the ESCOs, and would make it more attractive.
- At the end of the implementation of the renovation works and when the building has reached the defined requirements and standards and / or when it comes fully operational, a further opportunity to increase energy efficiency interventions could be possible. This deals with the participation of financial institutions (e.g. institutional investors, funds, etc.) investing money into the ESCO.

Consequently, the ESCo could bring more resources to carry out extra projects. This scheme may solve ESCO's undercapitalization or decrease their need of financial resources.

CERtuS project promotes the implementation of Energy Efficiency and encourages stakeholders creating business frameworks that are favourable to investments.

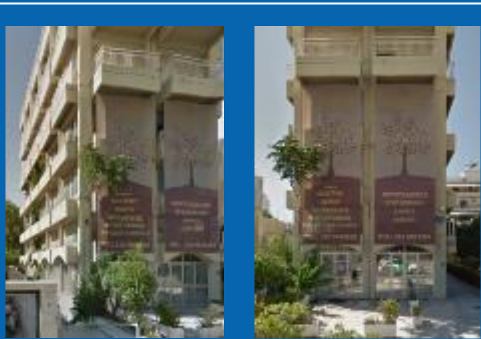
CERtuS has adapted existing energy service models and procedures and has identified financing schemes that are suitable for the building projects and the specific requirements of each municipality.

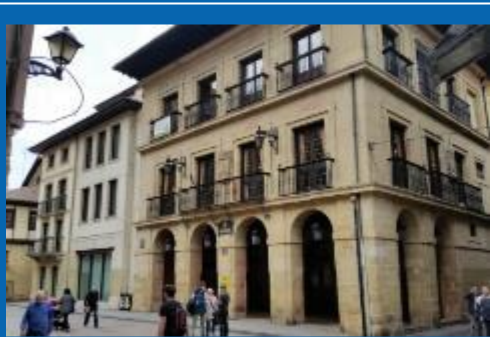
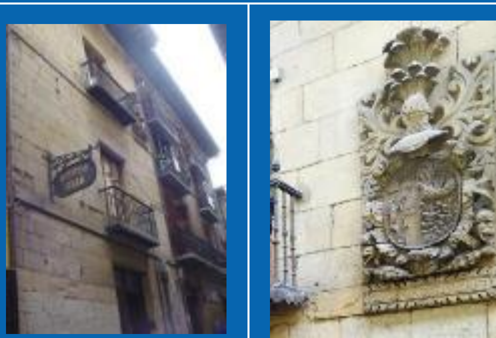
- ❖ CERtuS renovation design has succeeded to show that energy consumption for heating, cooling, ventilation and lighting can be significantly reduced with the share of renewable energy. The same principle is in force and achievable in the many cases of the historic buildings, when an interdisciplinary approach, both theoretical and technological, ensure the implementation of quality interventions in accordance with the specific characteristics of the historic buildings.
- ❖ CERtuS renovation design, even if innovative, purposefully is not at the forefront. This choice better reflects market conditions, has less risk and is closer to investors requirements for safe investment options.
- ❖ CERtuS has developed a methodology and a Simplified Economic Evaluation Tool, aiming to provide support to municipalities to prepare and evaluate the potential of energy efficiency and deep renovation retrofitting to be financed with an energy service contract.
- ❖ CERtuS has developed a methodology which assesses the risk and evaluate the specific requirements for each municipality to identify existing energy service models and procedures and the most suited mix of market money, subsidy funds and grants needed to finance nZEB renovation and energy efficiency interventions.

CERtuS results' replication is facilitated by the development of guidelines and training material, capacity building in municipalities, workshops and web tools.

ANNEX — CERtuS EXAMPLES OF TECHNICAL AND ECONOMIC EVALUATION OF THE nZEB RENOVATIONS

CERtuS PILOTS

IMPLEMENTATION OF nZEB PUBLIC BUILDINGS OF SOUTHERN EUROPEAN COUNTRIES THE EXPERIENCE OF CERtuS PROJECT	
Messina, ITALY	**Alimos, GREECE**
 Zanca Palace – City Hall	 City Hall
 Palace of Culture “Antonello da Messina”	 Municipal Library
 Satellite Palace	 Municipal Offices

IMPLEMENTATION OF nZEB PUBLIC BUILDINGS OF SOUTHERN EUROPEAN COUNTRIES THE EXPERIENCE OF CERtuS PROJECT	
Coimbra, PORTUGAL	**Errenteria, SPAIN**
 City Hall	 Town Hall
 Municipal House of Culture	 Kapitain Etxea
 Elementary School of Solum	 Lekuona

MESSINA, ITALY

Zanca Palace

ZANCA PALACE - MESSINA ITALY

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

Palazzo Zanca is a courtyard-detached building, developed in an articulated platform through five pavilions. The building structure was built according to the "Hennebique" system in reinforced concrete (Portland cement). Three out of five pavilions have a continuous system of masonry in reinforced concrete, conversely, two other pavilions have a frame system with bricks, as infill wall. The external part of the envelope is in "fake stone". All the windows are single glazed with wood frames. The structure of doors is equal to the windows, except 3 doors on the ground floor are glass and metal doors. All the windows have simple shutters. The building is shaded by other building to the North and by ever green trees to the South. The main façade oriented to the East is not subject to any shading. A thermal survey made in the building shows that walls present, generally, good thermal performance. Conversely, the windows, with single glazing and wood frames, present insulation problems, aggravated by aging. Some characteristics of the building contribute to poor thermal performance. The building presents many pathologies, such as condensation and mould growth. The HVAC is ensured with several heat pumps. The split units have more than fifteen years now, and their efficiency is reduced. The air circulation and renewal is ensured naturally, there are not systems of forced ventilation. Lighting is mainly supplied by incandescent and fluorescent lamps.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The interventions of deep renovation are still considered too risky and they do not attract the local market players. There are therefore objective difficulties for the insertion of energy improvements. Administration is trying to raise funds from national and regional funding programs.

Legislative Obstacles

Renovating the historic buildings to today's standards through the use of renewable energy technologies and deep renovation is a difficult issue. The main objective, in these cases, is to find intelligent ways of approaching the historic building conservation and energy efficiency, without cause any visual impact or modify integrity of historical fabrics.

RENOVATION SCHEME

Building Envelope : Opaque Envelope: it is expected inserting a high performance plaster that improves slightly envelope performance. Glazing: the existing glazing and frames with total U-value of 5,80 W/m^{2}K will be replaced by selective glazing and thermal break with total U- value 1,6 W/m^{2}K, total solar transmissions 42,1 %, light transmission 0,682.

HVAC: The proposed HVAC systems are VRV (Ceiling-Mounted Cassette) with COP of 3.91 and EER of 3.46, according the instructions of the relevant regulations.

Lighting: All lamps of the building will be replaced with new LED lamps, after a better zoning of the fixtures. In addition, day lighting sensors will be installed on the luminaires that provides on/off switching. Also, an occupancy sensor can be connected to the daylighting sensor so that the lights can be turned ON or OFF based on light levels and occupancy detection.

RES: A PV system of 126 kWp will be installed on the roof of the building. This value ensures just over 25% of post renovation consumption of electricity.

Energy management system: A Building Automation Control System (BACS) to optimise the building's mechanical and electrical equipment will be installed.

Passive solar gains: appropriate ventilation openings are located both at monumental stair windows and at the main atrium, so to ensure an appropriate exchange of the air and a constant ventilation.

Equipment: Consumptions were evaluated separately for office's equipment and CED. The envisaged interventions are divided into three types: (i). staff's training to a rational use of office equipment; (ii). purchases regulated by Green Public Procurement (GPP model), by providing clear environmental criteria for products and services and giving a favourable evaluation to the products with better energy class; (iii) control systems which manage, command and regulate the behaviour of other devices or systems.

BRIEF DESCRIPTION

Palazzo Zanca is located on the seafront, at the same place of the historic town hall, which was destroyed twice before by earthquakes in 1783 and then definitively in 1908. It had been restored using the original architectural materials after the earthquake of 1908 and its restoration belongs to the reconstruction plans of the city. The works of the ruined building began in December 1914 and were completed in 1924. The building's style is neoclassical and consists of two floors above ground. Its dimensions are the same for each floor.

All rooms are in municipal office use. The building is usually in use between 0h:00 and 24h:00 from Monday to Sunday, but the services are available and employees present only between 7h:30 and 19:h30. The building hosts about 750 employees and it is visited by an large number of visitors.

GENERAL INFORMATION

Year of construction:

1914

Area/Volume:

13.500 m^2, distributed in two floors/ 95.000 m^3 .

Building Use :

City hall/ multiple functions of public utility

ZANCA PALACE - MESSINA ITALY

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before renovation is equal to 1,306,563 kWh/year and the energy consumption on square meter is equal to 97 kWh/m^2. The energy consumption savings are equal to 774,308 kWh/year, that means an energy expenditure saving of 139,375 Euro/year.

CO_2 Savings

The CO_2 savings are 277,098 tons/year, with respect to the mix for electricity production (base year for calibration 2015).

RES Integration

The installation of a 126kWp PV system for energy generation is expected to produce about 176,400 kWh/y.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Costs	2,309,752 €
Energy Savings	774,308 kWh/year 139,375 €/ year
CO_2 Savings	277,098 tons/year
Maintenance Savings	77,620 €/ year
Potential Savings (energy + maintenance)	216,995 €/year
Simple Payback	11 years

ECONOMIC EVALUATION

Renovations cost

The total investment cost is equal to 2,309,752 Euro that means an investment cost per square meter of 171.09 Euro/m^2.

Economic Savings

The energy expenditure saving is 139,375 Euro/year. The maintenance expenditure post renovation is lower than before by 77,620 Euro/year. This situation affects positively, at economic level, on the total savings achievable by the intervention, in fact the economic saving both energy and maintenance is about 216,995 Euro/year.

Project Payback Period

The Project Payback period is 11 years considering the maintenance savings but the cash flows are not sufficient to implement a financial structure at market condition.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	700,000
False celings	244,352
Lighting system (internal+external)	321,000
Renewable energy (PV)	226,800
Windows – Low-e /thermal break	817,600
Investment for Renovation	2,309,752

FINANCING SCHEME

Energy Performance Contract

The strategy of Messina's Municipality is to promote the nZEB concept, despite its inability to financing the needed renovation options under the current tight economic conditions. Dealing with the expensive renovation of Zanca Palace, the most suitable operational financial scheme corresponds to a solution which combines the use of three types of public/private partnerships EPC contracts, with provision of specific conditions, in order to make the project attractive for the ESCo market.

To make it palatable to the market projects and allow a contract term not exceeding nine years is necessary: (i) reduce the investment value postponing interventions that bring lower energy benefits (see. adjacent Table); (ii) a contribution from the Municipality on investment of 30%; (iii) recourse to financing with concessional funds or use of incentives of the Energy Bill. In this way, the investment is reduced by about € 800,000, the pay-back of the project for the ESCO is greatly reduced.

Duration of EPC

In accordance with the measure of separated investments, the contract duration is of 9 years with an IRR for an ESCO equal to 5,5.

Financial Sources

The Municipality can directly finance part of the renovation measures through the National Operational Programme on Italian Metropolitan Cities for an amount of 450 k€ that corresponds to approximately 30% of the total investment of the building renovations. The remaining cost will be funded by an ESCO through the 'Conto Termico 2' and own resources as well by subsidized and dedicated funds (national and European).

Other considerations

The total investment of the municipality for the three projects would amount to about 2,000 k€ which would be fully covered by the National Operational Programme on Italian Metropolitan Cities, any other remaining funds would allow to directly realize the deferred works.

SEPARATED INVESTMENTS	COST €	SAVING €
Windows– Low-e /thermal break	817.600	5.980

Palace of Culture “Antonello da Messina”

PALACE OF CULTURE “ANTONELLO DA MESSINA” - MESSINA ITALY

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

Palacultura is a detached building. The shape of the building, very articulated both in plan and in elevation, is a parallelepiped on a rectangular base on which is erected the inverted pyramid structure. The main axe of the building is elongated along the north-south axis. Building’s envelope is made of wide range of materials, mainly steel and concrete. The glazed surface area of the inverted pyramid structure covers a considerable part of the building, around 40%. All windows have single glazing with aluminium frames and simply shutters. Facades are not subject to any shading. The building as a whole has a low energy performance. The opaque envelope has a low thermal inertia and many thermal bridges due to the type of wall construction. In addition, windows have low air-tightness. The doors present significant heat losses. The indoor conditions are not optimal, in winter and in summer. The HVAC is ensured with several ceiling mounted split, for the forced ventilation and air conditioning. The ventilation is ensured both naturally as well as through the mechanical system. There is forced ventilation in every room. Lighting is mainly supplied by fluorescent lamps. There is no mechanism to control lighting and installations are dated. The main energy needs of the building are covered by electricity, but there are also present small plants using natural gas for heating.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The main economic barrier to the implementation of the renovation plan is the limited budget of the municipality to cover part of the high overall investment. The Municipality is trying to raise funds from national and regional funding programs. Additional limit is the undeveloped ESCo market in Sicily and the lack of adequate, long-term financial instruments, for the high overall investment requested.

Legislative Obstacles

There were not specific regulatory obstacles identified in the renovation design. However must be pointed out that the Regional Landscape Plan of the Province of Messina imposes constraints on the entire city centre. However, for the specific building was possible foreseen the change of existing glazing or, in alternative, the affixing of photovoltaic films.

RENOVATION SCHEME

Building Envelope: Opaque Envelope: the approach of the building renovation includes extra internal insulation on the three upper floors. The internal coat it will be possible with a new layer with high insulation value. The insertion of an internal insulation decreases the floor area of the building but it is the only possible solution in the case of a prospectus with the external geometry as difficult as that of the Palace of Culture. Will be used the panels of cork and plasterboard thickness up to 4 cm. Glazing: also, the existing glazing and frames will be replaced by selective glazing and thermal break frame in PVC. Regarding the frames, they were chosen to include window frames with thermal break.

HVAC: The use of more environmental friendly HVAC systems was investigated but VRV appeared to be the most suitable choice. The Variable Refrigerant Volume (VRV) systems offer high levels of energy efficiency, as well as flexibility. They operate quietly and provide the user full control of the environmental temperatures.

Lighting: It is expected to replace the existing lighting by with the introduction of LED lamps and, where it is possible, to insert of intelligent on/off system.

RES: On the roof of the building will be installed a photovoltaic system of 28 kWp: this size ensures about 18% of post renovation consumption of electricity.

Passive solar gains/insulation: A green roof is suggested to give two great advantages: at first it will decrease heat losses during winter season, working as thermal insulation and then, it will hinder heat input, during summer season, working as a reflecting system for sunlight.

Equipments: The envisaged interventions are divided into three types: (i). staff’s training to a rational use of office equipment; (ii). purchases regulated by Green Public Procurement (GPP model), by providing clear environmental criteria for products and services and giving a favourable evaluation to the products with better energy class; (iii) control systems which manage, command and regulate the behaviour of other devices or systems.

BRIEF DESCRIPTION

Palacultura is an imposive building of Messina, lying nearly the marina of the city. It consists of three areas for cultural activities and has several equipment, as: a public library, a museum, a theatre of 850 seats, an outdoor amphitheatre, among the largest and most modern in Italy and even an exhibition area located on the terrace.
The inverted pyramid structure has been obtained by exploiting the considerable flexibility offered by materials such as cement and steel and taking into account that Messina is an earthquake risk zone.
The building designed in 1975 and after various events, was completed only at the end of 2000. It comprises six floors above ground. The dimensions in height and shape are very different for each floor. Cultural activities are hosted in the first three levels, while the other three (those with the opaque envelope) are occupied by offices. The building is, usually, in municipal office use and, on the occasion, on the museum exhibitions or theatre performances. The municipal services are available and employees present between 7h30 and 19h30, five days weekly. The building hosts about 200 employees and visitor numbers change according to the activities taking place at the palace.

GENERAL INFORMATION

Year of construction:

1975 / 2009

Area/Volume:

10,300 m^2

Building Use :

Multifunctional center

PALACE OF CULTURE "ANTONELLO DA MESSINA" - MESSINA ITALY

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before renovation is equal to 408,733 kWh/year and the energy consumption on square meter is equal to 40 kWh/m^2.

The energy consumption savings are equal to 228,860 kWh/year, that means an energy expenditure saving of 41,195 Euro/year.

CO_2 Savings

The CO_2 savings are 76,213 tons/year.

RES Integration

On the roof of the building will be installed a photovoltaic system of 28 kWp: this size ensures about 18% of post renovation consumption of electricity.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Costs	1,114,175 €
Energy Savings	228,860 kWh/year 41,195 €/ year
CO_2 Savings	76,213 tons/year
Maintenance Savings	839 €/year
Potential Savings (energy + maintenance)	42,034 €/year
Simple Payback	27 years

ECONOMIC EVALUATION

Renovations cost

The total investment cost is equal to 1,114,175 Euro, that means an investment cost per square meter of 108 Euro/m^2.

Economic Savings

The maintenance expenditure post renovation is lower than before by 839 Euro/year. This situation affects positively, at the economic level, on the total savings achievable by the intervention. In fact the economic saving both for energy and maintenance is about 42,034 Euro/year.

Project Payback Period

The Project Payback period is very long, 26.5 years considering maintenance, and the project cash flows are very low. This situation has a very negative impact on the sustainability of the project and consequentially on the attractiveness for an ESCo.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
Lighting system (internal)	252,150
Renewable energy (PV)	50,400
Building envelope	500,000
Windows - Low-e /thermal break	261,625
BACS	50,000
Investment for Renovation	1,114,175

FINANCING SCHEME

Energy Performance Contract

The strategy of Messina's Municipality is to promote the nZEB concept, despite its inability to financing the needed renovation options under the current tight economic conditions. Dealing with the expensive renovation of Palace of Culture, the most suitable operational financial scheme corresponds to a solution which combines the use of three types of public/private partnerships EPC contracts, with provision of specific conditions, in order to make the project attractive for the ESCo market.

To make it palatable to the market projects and allow a contract term not exceeding nine years is necessary:

a) reduce the investment value postponing interventions that bring lower energy benefits (see. Table);

b) a contribution from the Municipality on investment of 30%;

c) recourse to financing with concessional funds or use of incentives of the Energy Bill;

In this way, the investment is reduced by about € 600,000, the pay-back of the project for the ESCO is greatly reduced.

The project is still not sustainable for an ESCO.

Duration of EPC

In order to allow the sustainability of the contract in the market is necessary to extend the contract duration at least 15 years.

Financial Sources

The Municipality can directly finance part of the renovation measures through the National Operational Programme on Italian Metropolitan Cities for an amount of 153 k€ that corresponds to approximately 30% of the total investment of the building renovations. The remaining cost will be funded by an ESCO through the Conto Termico 2 and own resources as well by subsidized and dedicated funds (national and European).

Other considerations

To allow for a greater financial commitment to ESCOs could be included in the contract also management of other outside maintenance services. As the municipality may entrust to third parties, including services for the public and the management of certain cultural activities increasing revenues and margins for further investment.

SEPARATED INVESTMENTS	COST €	SAVING €
Building envelope	603.625	4.258

Satellite Palace

SATELLITE PALACE- MESSINA ITALY

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The building was built for residential use and each floor hosts several residential units / apartments. This residential building typology has been converted in office and public space without any planning or adaptation. Furthermore, the building even if it is owned and managed by one entity (the municipality), is subdivided into individual office suites (originally residential units) and is in use by organisations of different size, needs and business types. This results in areas with favourable, less favourable and poor indoor environment and further complicates the physics and the overall performance of the building. Besides, some characteristics and technical standards of the building contribute to its poor thermal performance. The orientation is not favourable demanding high heating energy consumption during the winter (supplementary in the north exposition) and high cooling energy consumption during the summer. In addition the facades do not have any protection from solar radiation. The external walls have a medium thermal inertia with over-media ceiling height, this aspect increases the envelope energy thermal response during the summer, but causes disadvantages during the winter. Still, the windows are the old type with a single glazing and aluminium frames and present insulation problems and limited air tightness. The building presents many pathologies, such as condensation and mould.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The municipality has no specific financing to improve public buildings. There are therefore serious difficulties to undertake energy improvements. The Administration is trying to raise funds from national and regional funding programs.

Legislative Obstacles

There are no legislative obstacles to the renovation of this building.

BRIEF DESCRIPTION

Palazzo Satellite is a municipal building of Messina. The building is located in the historic centre of the city, near the central station. The building includes many functions of municipal government, including the Local Health Unit, the municipal Police management and several Municipal Departments.

Building style is modern; it is an example of a frame structure made of reinforced concrete. The walls are made of masonry and the floors are in slab and masonry. The building is constituted of 5 floors above ground. The dimensions are the same for each floor.

The building is usually in use between 0h00 and 24h00 from Monday to Sunday only for the municipal police management. The public activities of employees are carried out only between 7h30 and 19h30. The building hosts about 200 employees and it is visited by an indeterminate number of public.

RENOVATION SCHEME

Building Envelope: Opaque Envelope: among the actions planned, there is the facades renovation, it is planned to ensure the safety of unsafe parts and, where necessary, to do an important refurbishment. Another change concerns the reconstruction of the plaster of the facades, using a thermal insulation plaster. Among other interventions there is waterproofing of the roof, so it is expected to enter under the floor of a fibre-reinforced bituminous membrane. Glazing: also, the existing glazing and frames will be replaced selective glazing and thermal break frame in PVC. Regarding the frames is chosen to include window frames with thermal break. It is chosen to use windows with PVC frames. Glasses chosen are selective double glazing with air chamber 6/13 mm.

HVAC: Almost all working rooms, have air conditioning systems. It is expected to insert a false ceiling in all circulation areas and, where possible in all rooms of the building. The result is a decrease in the net height of the rooms to be heated and creation of a channel for heating and lighting installations.

Lighting: It is expected to replace the existing lighting with the introduction of LED lamps and, where possible, to insert intelligent dimmerable systems.

RES: The choice is the installation of a PV system with120 kWp. This ensures about 84% of post renovation consumption of electricity.

Passive solar gains/insulation: it is foreseen a green roof that will give two great advantages: (i) it will decrease heat loss during winter season working as thermal insulation, (ii) it will hinder heat input during summer season working as a reflecting system for sunlight.

Energy management system: a centralised Building Automation Control System (BACS) is foreseen to control the building's heating, cooling and ventilation, lighting and other systems through a Building Management. This distributed system includes networked computers, all electronic devices useful to control security, lighting in general and emergency lights as well rooms' humidity and temperature.

Equipments: The envisaged interventions are divided into three types: (i). staff's training to a rational use of office equipment; (ii). purchases regulated by Green Public Procurement (GPP model), by providing clear environmental criteria for products and services and giving a favourable evaluation to the products with better energy class; (iii) control systems which manage, command and regulate the behaviour of other devices or systems.

GENERAL INFORMATION

Year of construction:

1970

Area/Volume:

6.870 m^2 (about 1.350 m^2 to floor) / 18.550 m^3

Building Use :

Municipal Office / City Hall

SATELLITE PALACE - MESSINA ITALY

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before renovation is equal to 340,626 kWh/year and the energy consumption on square meter is equal to 50 kWh/m^2 yearly.

The energy consumption savings are equal to 308,557 kWh/year, that means an energy expenditure saving of 55,540 Euro/year.

CO_2 Savings

The CO_2 savings are 98,545 tons/year.

RES Integration

The potential integration of RES was investigated and several options were considered. The optimum choice regards the installation of photovoltaic systems on the roof and on the walls of the building. The installed capacity will be 120 kWp with an estimated PV total saving 168,000 kWh.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Costs	1,629,738 €
Energy Savings	308,557 kWh/ year 55,540 €/ year
CO_2 Savings	98,545 tons/year
Maintenance Savings	- 598 €/year
Potential Savings (energy + maintenance)	54,942 €/year
Simple Payback	29 years

ECONOMIC EVALUATION

Renovations cost

The refurbishment investment cost is equal to 1,629,738 Euro (excluded VAT), that means an investment cost per square meter of 237.2 Euro/m^2.

Economic Savings

The energy expenditure saving is 55,540 Euro/year.

The maintenance expenditure post renovation is higher than before by 598 Euro/year. This affects negatively, at economic level, on the total savings achievable by the intervention and also on the payback period. In facts, the economic saving both for energy and maintenance is 54,942 Euro/year.

Project Payback Period

The Project Payback period is very long, 29 years considering the maintenance, and the project cash flows are very low. This situation has a very negative impact on the sustainability of the project and consequentially on the attractiveness for an ESCo.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	500,000
Lighting system (internal)	101,000
Renewable energy (PV)	216,000
Building Envelope	792,538
Control system (BACS)	20.000
Investment for Renovation	1,629,738

FINANCING SCHEME

Energy Performance Contract

The strategy of Messina's Municipality is to promote the nZEB concept, despite its inability to financing the needed renovation options under the current tight economic conditions. Dealing with the expensive renovation of Satellite Palace, the most suitable operational financial scheme corresponds to a solution which combines the use of three types of public/private partnerships EPC contracts, with provision of specific conditions, in order to make the project attractive for the ESCo market.

To make it palatable to the market projects and allow a contract term not exceeding nine years is necessary:

a) reduce the investment value postponing interventions that bring lower energy benefits (see. Table);

b) a contribution from the Municipality on investment;

c) recourse to financing with concessional funds or use of incentives of the Energy Bill.

The project is still not sustainable for an investment of an ESCO.

Duration of EPC

In order to allow the sustainability of the contract in the market is necessary to extend the contract duration at least 15 years.

Financial Sources

The Municipality can directly finance the renovation measures through the National Operational Programme on Italian Metropolitan Cities for an amount of 1.400 k€ that corresponds to approximately 100% of the total investment of the building renovations. The Municipality will recover part of the investment incentives through the 'Conto Termico 2'.

Other considerations

The total investment of the municipality for the three projects would amount to about 2,000 k € which would be fully covered by the National Operational Programme on Italian Metropolitan Cities.

SEPARATED INVESTMENTS	COST €	SAVING €
Waterproofing foundations	237.168	3,205

ALIMOS, GREECE

City Hall

CITY HALL – ALIMOS GREECE

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

This is a detached building. Only the northwest side of the stairwell is in contact with heated areas of the neighbouring building. Each floor is divided into two areas; the office space and the entrance hall separated with insulated walls as the latter is a non-heated area.
The walls are insulated with 4 cm of extruded polystyrene placed in between the two brick layers and the windows have double glazing in an aluminium frame. In general the building envelope does not present any problem with respect to airtightness.
Regarding the HVAC there are two types of air conditioning systems used: a) small split systems b) ceiling mounted and floor standing units with inlet and outlet vents, which supply heating and cooling by using electricity.
Lighting is mainly supplied by fluorescent T8 lamps with magnetic ballast.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

This building hosts numerous services and employees but the current situation can change depending on the needs of the municipality. A potential increasing of the number of the services or the employees of the City Hall will increase the energy consumption and the payback period of the investment as well.
The required investment for simultaneous implementation of all the foreseen energy efficiency measures is quite large and, this presents a serious difficulty for the Municipality. So, in order for the Municipality to proceed with this renovation plan, inflow of capital from third parties is required.

Legislative Obstacles

There were not regulatory obstacles identified in the renovation design. In Greece the legislation defining the levels of nZEB and the expected contribution of RES is under development. So, it is important the "nearby areas", as indicated by the Energy Performance of Buildings Directive, EPBD, to be defined as flexibly as possible in order to facilitate the integration of RES and make nZEB levels achievable.

RENOVATION SCHEME

Building Envelope

Opaque Envelope: The most suitable option is the addition of 5 cm external insulation of 0.032 W/mK. Glazing: The optimum choice should have low–e coating glazing and window mean U-value 1.80 W/m^{2}K. Shading: External retractable louvers are selected as shading devices for all the facades except the north one. The louvers are sized in order to provide full shading during summer. Natural/Night ventilation: Air vents equipped with dampers will be installed on the north and south façade of the building so as to achieve cross ventilation on each floor. Passive solar system: To be avoided the overheating of the offices on the south part, appropriate openings will be integrated to allow the circulation of the solar gains.

HVAC

The new HVAC system will be a multi-zone VRV system and it includes three external and forty four internal units. In addition the Heat Recovery Ventilation System (HRV), will modulate the temperature and humidity of incoming fresh air to match indoor conditions.

Lighting

All lamps of the building will be replaced with new LED lamps. Also, daylight sensors will be installed on the luminaires located close to the windows.

RES

A PV system of 15.26 kW will be installed on the roof of the building and the annual energy production will be 20,900 kWh.

Building Energy Management System

The BMS will control, monitor and record data such as air temperatures, hours of operation and power consumption, of each VRV cassette. Also it will control, monitor and record the lighting energy consumption of each floor separately and the operation of each Lux sensor. In all windows and doors will be placed on/off touch connected with each VRV cassette operation.

BRIEF DESCRIPTION

The City Hall of Alimos is located close to the sea coast and enjoys a good sea view from the upper floors. It comprises five floors and a basement. The first two levels and the basement were constructed in 1986 whilst the other 3 were added in 1996.

The shape of the initial two-floor building is elongated along the N-S axis. The 5-storey addition, at the back side, has a rectangular shape and consists of two adjacent building blocks. The orientation of the whole complex deviates 30o from south due west.

The occupation profile of all floors is from 07:30 to 15:30 on week days apart from 4th floor (Mayor's office) which is occupied from 07:30 to 17:30. The employees of the City hall are 78 and the visitors are around 130 per day.

GENERAL INFORMATION

Year of construction:

1986

Area/Volume:

1,302 m^2 / 3,612 m^3

Building Use :

City Hall

CITY HALL – ALIMOS GREECE

RENOVATION SCHEME EVALUATION

Three alternative renovation options were carried out with the aim to achieve lower payback time for the renovation investment and increase the potential to attract private funding. Option A excludes only the external insulation, Option B excludes only the replacement of the glazing and Option C excludes both interventions. The most financially attractive was the Option C.

As can be seen the savings are comparable between the two options but the cost and the simple payback period are varying substantially. For this reason Option C was selected for implementation.

Energy Savings

The energy consumption (for heating, cooling, and lighting) before renovation is equal to 111,965 kWh/year and the energy consumption per square meter is equal to 102 kWh/m^2. After renovation (Option C) the consumption is reduced to 8,795 kWh/year or 8 kWh/ m2. Specifically, the energy efficiency interventions, excluding the electricity generated by the PV system, reduce the energy consumption to 27 kWh/m^2 by generating savings equal to 82,270 kWh/year. These savings represent 73% of the energy consumption before renovation. The remaining demand is covered up to 70% by the PV system which produces 20,900 kWh/year.

CO_2 Savings

The CO_2 savings resulting from Option C are 102.02 tons/year.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

	ALL INTERVENTIONS	OPTION C
Energy Savings kWh/year	104,537	103,170
Costs €	310,943	172,088
Savings €/year	17,988	17,790
Simple Payback	17.2	9.7
CO_2 Savings tons/year	103.37	102.02

ECONOMIC EVALUATION

Renovations cost

The cost of the interventions which are excluded is 83505 € for the external insulation and 55,350 € for the windows.

Economic Savings

The total annual economic savings are equal to 17,790 € and consist of the energy and maintenance expenditure savings that are 14,354€ and 3,436 € respectively.

FINANCING SCHEME

Under the current challenging economic conditions, municipality of Alimos has limited financial resources for implementing the energy retrofit. The most suitable financing model is to assign the project to an Energy Service Company (ESCo). The ESCo is responsible to secure the total investment cost, the implementation of the project, the maintenance during the contract period and, guarantee the energy performance of the agreed solutions. The money savings, corresponding to the energy savings, will be shared between the ESCo and the Municipality, according to the "Shared Savings" model contract.

Financial Structure of Project

The most market efficient financing source for implementing the project is market money (private equity, bank loan), followed by Subsidised Loan. The least favourable one is Grants since they have zero revolving effect. Even so, in many nZEB renovations Grants are necessary for turning a project market attractive and marketable. The optimum financial structure should involve the provision of sufficient subsidised loans as the latter improve the attractiveness of the project and make it marketable.

The optimum financial structure consists of:

- Equity investment by the ESCo - 24%
- Subsidized Loan - 65%
- VAT Facilities - 11%

The expected project payback period is approximately 10 years, while the duration of the EPC is 15 years which is still market acceptable.

Other considerations

The EPC takes into provision that the relevant money savings are allocated to the repayment of the investment, allowing 5% annual money saving to be enjoyed by the Municipality who has zero contribution to the capital cost. Once the EPC is concluded all money savings will be enjoyed by the Municipality.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	80,336
Lighting system	18,905
Renewable energy	25,707
Shading	25,000
Cross Solar Heat	1,230
Control system	20,910
Investment for Renovation	172,088

Municipal Library

MUNICIPAL LIBRARY– ALIMOS GREECE

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

It is a detached building and the construction is a typical one of the period and region.
The walls consist of double brick and reinforced concrete for the load bearing structure. The walls are insulated with 5 cm of extruded polystyrene placed in between the two brick layers and the roof slab is insulated with 8 cm extruded polystyrene. The windows have double glazing in an aluminium frame.
The envelope has many thermal bridges due to the type of wall construction and these problems have not been addressed adequately in the thermal study. The building envelope does not present any problem with respect to airtightness.
Also, splits and floor standing air conditioning systems are used for heating and cooling the building via electricity. The ground and the first floor use extra oil radiators for heating.
Lighting is mainly supplied by fluorescent T8 lamps with magnetic ballast.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The fact that the municipality rents this building gives rise to risks as the relocation of the library might take place before the end of the payback period. However, this is considered a medium to low level risk.
The total cost of the energy consumption is low and this fact affects the final payback period of the investment which is quite long for certain interventions. This happens because the daily operation is short and the energy demand of the services/activities taking place in this building is modest.

Legislative Obstacles

In a building which has central heating system it is not always easy to abolish this system and/or replace it with more flexible ones. This obstacle appears when there are more than one owner and not all of them agree with this change. In this case the regulation regarding multi – owner buildings applies and requires either a unanimous vote or a majority vote. For this reason the most feasible choice is to improve the existing central heating system. Likewise, the installation of PVs on the roof has to be approved by all owners of the building.

RENOVATION SCHEME

Building Envelope

Opaque Envelope: The most suitable option is the addition of 5 cm external insulation of 0.032 W/mK.
Glazing: The optimum choice should have low–e coating glazing and window mean U-value 1.80 W/m^{2}K.
Natural/Night ventilation: Air vents equipped with dampers will be installed on the north and south façade of the building so as to achieve cross ventilation on each floor.

HVAC

The existing systems will be replaced with new A/C systems more efficient [EER 3– 4.4] and they will be used only for cooling.
Regarding the heating of the building it was considered that the optimum choice is the conversion of the old boiler to a new Pellet boiler which is more environmental friendly. Also the central heating system pipes will be insulated and the central heating water pump will be replaced with a new one inverter technology in order to reduce the electricity consumption.

Lighting

All lamps of the building will be replaced with new LED lamps. Also, daylight sensors will be installed on the luminaires located close to the windows.

RES

A photovoltaic system of 5.73 kWp will be installed on the building's roof and the annual energy production will be 8,040 kWh.

Thermostats and power meter

The use of a Thermostat in every room of the building will ensure that the desired internal air temperature will be stable and will prevent the excess use of energy. Additionally in order to record and storage the energy consumption of the A/C system, lighting and pc units so as to detect the energy intensive units we will install power meters to the electrical board of each floor.

BRIEF DESCRIPTION

The Municipal Library building was constructed in 1984. It comprises five floors and a basement. The Municipality rents the first three storeys and the basement and houses the Municipal Library, offices, school activities and dancing courses. The rest of the building is residential.
The shape of the building is elongated along the N-S axis. The orientation of the whole complex deviates 53o from south due west.

The occupation profile of all floors is from 07:30 to 15:30 on week days. The employees of the Municipal Library are 13 and the visitors are around 70 per day.

GENERAL INFORMATION

Year of construction:

1984

Area/Volume:

611 m^2 / 2,185 m^3

Building Use :

Library-Offices

MUNICIPAL LIBRARY– ALIMOS GREECE

RENOVATION SCHEME EVALUATION

Three alternative renovation options were carried out without the building envelope improvement with the aim to achieve lower payback time for the renovation investment and increase the potential to attract private funding. Option A excludes only the external insulation, Option B excludes only the replacement of the glazing and Option C excludes both interventions. Among all the options only the initial one satisfies the CERtuS targets but the most financially attractive was the Option C. As can be seen the savings are comparable between the two options but the cost and the simple payback period are varying substantially. For this reason Option C was selected for implementation.

Energy Savings

The primary energy consumption (for heating, cooling and lighting) before renovation 122,195 kWh/year and the primary energy consumption per square meter is equal to 241 kWh/m^2. After renovation (Option C) the consumption is reduced to 15,148 kWh/year or 29.9 kWh/m^2. Specifically, the energy efficiency interventions, excluding the electricity generated by the PV system, reduce the consumption of the primary energy to 75.8 kWh/m2 by generating savings equal to 83,728 kWh/year. These savings represent 68.5% of the energy consumption before renovation. The remaining demand for electricity is covered up to 63% by the PV system which produces 8,041 kWh/year. Additionally, the energy consumption for heating is covered by biomass which means that in total 90% of the building's energy demand is covered by renewable energy sources.

CO_2 Savings

The CO_2 savings resulting from Option C are 39.73 tons/year.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

	ALL INTERVENTIONS	OPTION C
Primary Energy Savings kWh/year	108,614	107,047
Costs €	127,994	39,988
Savings €/year	4,764	4,667
Simple Payback	26.9	8.6
CO_2 Savings tons/year	40.31	39.73

ECONOMIC EVALUATION

Renovations cost

The cost of the interventions which are excluded is 38,007 € for the external insulation and 50,000 € for the windows.

Economic Savings

The total annual economic savings are equal to 4,667 €. The energy expenditure savings are 6,167 but post renovation maintenance is higher than before by 1,500 €/year.

FINANCING SCHEME

Under the current challenging economic conditions, municipality of Alimos has limited financial resources for implementing the energy retrofit of the selected buildings. The most suitable financing model is to assign the project to an Energy Service Company (ESCo). The ESCo is responsible to secure the total investment cost, the implementation of the project, the maintenance during the contract period and, guarantee the energy performance of the agreed solutions. The money savings, corresponding to the energy savings, will be shared between the ESCo and the municipality of Alimos, according to the "Shared Savings" model contract.

Financial Structure of Project

The most market efficient financing source for implementing the project is market money (private equity, bank loan), followed by Subsidised Loan. The least favourable one is Grants since they have zero revolving effect; Grants' money once used, they never come back to the market. Even so, in many nZEB renovations Grants are necessary for turning a project market attractive and marketable. The optimum financial structure should involve the provision of sufficient subsidised loans as the latter improve the attractiveness of the project and make it marketable. According to the study the optimum financial structure consists of:

- Equity investment by the ESCo - 24%
- Subsidized Loan - 65%
- VAT Facilities - 11%

The expected project payback period is approximately 15 years, while the duration of the EPC is 15 years which is not favourable but still market acceptable.

Other considerations

The EPC takes into provision that the relevant money savings are allocated to the repayment of the investment, allowing 10% annual money saving to be enjoyed by the Municipality who has zero contribution to the capital cost. Once the EPC is concluded all money savings will be enjoyed by the Municipality.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	18,881
Lighting system	2,645
Renewable energy	9,840
Night Ventilation	4,920
Control system	3,702
Total Investment	39,988

Municipal Offices

MUNICIPAL OFFICES – ALIMOS GREECE

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

This is a detached building with a construction system typical for the period and region.
The walls are insulated with 5 cm of extruded polystyrene placed in between the two brick layers. The roof slab is insulated with 6 cm extruded polystyrene while there is a mineral fibre suspended ceiling in the office space. The windows have double glazing in an aluminium frame.
The envelope has thermal bridges resulting from the type of wall construction.
Regarding HVAC, split air conditioning systems are used for both heating and cooling.
The lighting system is mainly constituted by fluorescent T8 lamps with magnetic ballast.

BRIEF DESCRIPTION

The building houses the environmental and hygiene services of the Municipality. It is one-floor building surrounded by a large open area with a parking lot and a vehicle repairing facility. The construction was completed in 1986.
The neighbouring buildings are in sufficient distance so that there is no important shadowing and the building enjoys full sunshine.
The building has an orthogonal shape and is elongated along the E-W axis and oriented 33° from North due East.
The occupation profile is from 07:30 to 15:30 on week days. There are 20 employees and about 10 visitors per day.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks
As the building operates during the daytime only, the energy consumption is low compared to buildings with 24h operation. This fact affects the final payback period of the investment which is quite long, reaching 23 years for certain interventions such as thermal insulation and replacement of windows.
The cost of more innovative systems (solar cooling, geothermal, etc.) is considerably high and so their integration in the building is not a feasible solution unless they are eligible for subsidies by state or other sources.

Legislative Obstacles
There is a restriction regarding the total power of the PVs which can be installed in buildings. For public buildings the installed capacity can be 100% of the maximum capacity agreed with the Utility. This limits the size of the proposed PV system even though there is space for a larger one.

RENOVATION SCHEME

Opaque Envelope: The most suitable option is the addition of 5 cm external insulation of 0.032 W/mK.

Glazing: The optimum choice should have low–e coating glazing and window mean U-value 1.80 W/m^2K.

Natural/Night ventilation: Air vents equipped with dampers will be installed on the north and south façade of the building so as to achieve cross ventilation on each floor.

HVAC
The new HVAC system will be a multi-zone VRV system and it includes three external and forty four internal units. In addition the Heat Recovery Ventilation System (HRV), will modulate the temperature and humidity of incoming fresh air to match indoor conditions.

Lighting
All lamps of the building will be replaced with new LED lamps. Also, daylight sensors will be installed on the luminaires located close to the windows.

RES
A PV system of 26.7 kW will be installed on the roof of the building and the annual energy production will be 20,900 kWh.

Building Energy Management System
The BMS will control, monitor and record data such as air temperatures, hours of operation and power consumption, of each VRV cassette separately. Also it will control, monitor and record the lighting energy consumption of each floor separately and the operation of each Lux sensor.
In all windows and doors will be placed an on/off touch connected with each VRV cassette operation.

GENERAL INFORMATION

Year of construction:
1986

Area/Volume:
446 m^2 / 1,518 m^3

Building Use :
Offices

MUNICIPAL OFFICES – ALIMOS GREECE

RENOVATION SCHEME EVALUATION

Three alternative renovation options were carried out without the building envelope improvement with the aim to achieve lower payback time for the renovation investment and increase the potential to attract private funding. Option A excludes only the external insulation, Option B excludes only the replacement of the glazing and Option C excludes both interventions. The most financially attractive was the Option C. As can be seen the savings are comparable between the two options but the cost and the simple payback period are varying substantially. For this reason Option C was selected for implementation.

Energy Savings

The energy consumption (for heating, cooling and lighting) before renovation is equal to 30,160 kWh/year and the energy consumption per square meter is equal to 97 kWh/m2. After renovation (Option C) the consumption is reduced to 0 kWh/year. Specifically, the energy efficiency interventions, excluding the electricity generated by the PV system, reduce the energy consumption to 25 kWh/m2 by generating savings equal to 21,278 kWh/year. These savings represent 71% of the energy consumption before renovation. The remaining demand is covered up to 100% by the PV system which produces 37,300 kWh/year. The surplus energy of 28,428 kWh/year will be used on the other uses as it is mentioned above.

CO_2 Savings

The CO_2 savings resulting from Option C are 57.9 tons/year.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

	ALL INTERVENTIONS	OPTION C
Energy Savings kWh/year	59,543	58,578
Costs €	124,396	86,266
Savings €/year	7,454	7,205
Simple Payback	16.7	12.0
CO2 Savings tons/year	58.9	57.9

ECONOMIC EVALUATION

Renovations cost

The cost of the interventions which are excluded is 25,830 € for the external insulation and 12,300 € for the windows.

Economic Savings

The total annual economic savings are equal to 7,205 €. More specific the energy expenditure savings are 4,031 but post renovation maintenance is higher than before by 970 €/year so economic saving from both energy and maintenance is 3,061 €/year. Additionally, the energy expenditures of the building reduced due to the use of the surplus energy from PVs by 4,144 €/year.

FINANCING SCHEME

Under the current challenging economic conditions, municipality of Alimos has limited financial resources for implementing the energy retrofit of the selected buildings. The most suitable financing model is to assign the project to an Energy Service Company (ESCo). The ESCo is responsible to secure the total investment cost, the implementation of the project, the maintenance during the contract period and, guarantee the energy performance of the agreed solutions. The money savings, corresponding to the energy savings, will be shared between the ESCo and the municipality of Alimos, according to the "Shared Savings" model contract.

Financial Structure of Project

The most market efficient financing source for implementing the project is market money (private equity, bank loan), followed by Subsidised Loan. The least favourable one is Grants since they have zero revolving effect; Grants' money once used, they never come back to the market. Even so, in many nZEB renovations Grants are necessary for turning a project market attractive and marketable. The optimum financial structure should involve the provision of sufficient subsidised loans as the latter improve the attractiveness of the project and make it marketable. According to the study the optimum financial structure consists of:

- Equity investment by the ESCo - 14%
- Subsidized Loan - 75%
- VAT Facilities - 11%

The expected project payback period is approximately 13 years, while the duration of the EPC is 15 years which is not favourable but still market acceptable.

Other considerations

The EPC takes into provision that the relevant money savings are allocated to the repayment of the investment, allowing 5% annual money saving to be enjoyed by the Municipality who has zero contribution to the capital cost. Once the EPC is concluded all money savings will be enjoyed by the Municipality.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	21,550
Lighting system	4,041
Renewable energy	45,977
Night Ventilation	3,874
Control system	10,824
Total Investment	86,266

COIMBRA, PORTUGAL

Town Hall

TOWN HALL - COIMBRA PORTUGAL

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The building has 3 floors and 2 intermediate floors and it is oriented with an axis of 10º, with the main façade oriented to West.

The external walls are made of stone masonry and have a thickness of 90 to 145 cm. All the windows and balcony doors are of single glazing with wood frames. A thermal survey made in the building showed that walls present a good thermal performance but the windows, with single glazing with wood frames, present insulation problems, aggravated by aging, contributing to high heat losses during winter.

The building does not present major pathologies, such as condensations or mould growth.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The Municipality has no financial plan to improve this specific building, with the exception of the roof whose intervention was already planned. The Municipality is trying to raise funds from national and European funding programs.

Legislative Obstacles

Coimbra - part of the historic city center, older University buildings and other urban structures - is since June 22th 2013 inscribed on the World Heritage List of UNESCO. The Property inscribed is called University of Coimbra — Alta and Sofia (http://worldheritage.uc.pt/). The Coimbra Town Hall is included in this area and therefore strong restrictions are applied in the renovation of such building due to the protection rules. Therefore, it is not possible to implement any change in the building envelope able to cause any visual impact.

RENOVATION SCHEME

Building Envelope

Regarding the insulation, the walls present a good thermal performance. The roof is to undergo an already planned renovation soon. Therefore, the improvement of the opaque envelope was not considered in the renovation plan.

The windows present high thermal losses. However, since the building is part of the property "University of Coimbra — Alta and Sofia" inscribed on the World Heritage List of UNESCO several strong restrictions are applied in the renovation of such building due to the protection rules and it is not possible to implement any change in the building envelope that causes a visual impact. Therefore, it is not possible to replace the windows by double glazed windows using standard solutions, since the original frame must be maintained.

HVAC

The HVAC system is constituted by 8 multi-split units and 21 mono-split units with a total cooling power of 273.02 kW. Most of the systems are old and are most likely to have low levels of efficiency. The replacement of mono-split systems by multi-split systems and the concentration of multi-split systems in less units was not considered, since the impact of the installation process on the building operation would be much higher. Therefore, it was always considered the replacement by systems of the same type, but with higher efficiency, keeping the same total power.

Lighting

The actual lighting system is constituted by several different types of lamps and luminaires, including fluorescent linear T8 and T5 lamps, several types of compact fluorescent lamps, incandescent lamps, halogen spots and projectors and metal halide lamps. The planned action is to replace all lamps by LEDs.

RES

Since the building is part of the property "University of Coimbra — Alta and Sofia" inscribed on the World Heritage List of UNESCO several strong restrictions are applied in the renovation of such building due to the protection rules. Therefore, the use of traditional PV panels was not considered due to its high visual impact. Therefore, it was considered the use of solar tiles, to replace the actual roof. It was considered the installation of 2,102 m2 (with the different directions of the roof) of thin film PV panels, ensuring an installed power of 126.1 kWp. This will ensure a generation of 143.3 MWh/year.

BRIEF DESCRIPTION

The building is located in the downtown of Coimbra and it was built after the demolition of part of the old Monastery of Santa Cruz. The demolitions works and construction was carried out mainly between 1876 and 1879, but some construction works were developed gradually until the beginning of the 20th century. The building is used as the town hall of the Municipality of Coimbra, being mainly constituted by offices and storage areas.

Brief video presentation:
https://www.youtube.com/watch?v=IrsS95cpta4

The building usually has occupation between 7h30 and 19h30 (Monday to Friday). However, the public only have access between 9h00 and 17h00. The building has 220 employees and is visited by more than 25,000 users/year.

GENERAL INFORMATION

Year of construction:

1876-1879

Area/Volume:

5,880 m^2 / 40,575 m^3

Building Use :

City Hall / Multiple functions of public utility

TOWN HALL - COIMBRA PORTUGAL

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before the renovation, considered as baseline, is equal to 305,107 kWh/year (electricity) and the energy consumption by square meter is about 51.9 kWh/m^2. After the renovation the energy consumption drops to 55,508 kWh/year (electricity only) and the energy consumption by square meter is equal to 9.4 kWh/m^2. Which means 42,739 Euro/year of savings. The renovation will lead to 72.1% savings in the building.

CO_2 Savings

The savings resulting from the PV system, lamp replacement and HVAC replacement by others with higher efficiency are equal to 34.92 tons/year.

RES Integration

In the evaluation of the PV generation it was considered the self-consumption of 90% of the energy. RES will ensure 72.1% of the total energy consumption.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Energy Savings	249,599 kWh
Costs	723,949 €
Savings	42,739 €/year
Simple Payback	16.94 years
CO_2 Savings	34.92 tons/year

ECONOMIC EVALUATION

Payback Period

The project payback period is close to 17 years This payback is calculated without considering the Financing Scheme.

Total Cost

The technical investment cost is equal to 632.068 Euro (excluded VAT), which means the investment cost per square meter is 107.5 Euro/m^2.

Economic Savings

The energy expenditure savings are 34,880 Euro/year

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	80,209
Lighting system (internal)	16,917
Renewable Energy - PV	534,942
Building Envelope	0
Control system	0
Investment for Renovation	632,068

FINANCING SCHEME

Energy Performance Contract

On the basis of Deliverable D3.5 the implementation of the “shared savings” EPC contract (considered to be the most widespread among the four CERtuS countries) was chosen. The ESCo is supposed to invest through a Special Purpose Vehicle (SPV).

Duration of EPC

Duration of EPC: 25 years

Financial Sources

Given the Renovation Scheme selected and the characteristic of the project, ESCo involvement is possible at current market conditions but it needs a mix of source of finance, in particular the use of Subsidies Funds:

- Equity is about 26% of the whole financial source
- Senior Debt is about 61% of the whole financial source
- VAT Facilities is about 13%

Equity Pay Back Period

The project equity payback period is 18 years

Other considerations

In this case, the project generates enough cash flows to pay the debt but it is not able to remunerate sufficiently the capital invested by the ESCo. As a consequence, an ESCo intervention at market conditions should be considered sustainable but not profitable enough.

INVESTMENTS (ESCOs)	€
Investment for renovation	632,068
Starting liquidity	0
Interests and Banking Fees	8,927
Total Investments exc. VAT	640,995
VAT	91,881
TOTAL INVESTMENTS	**732,876**

FINANCIAL SOURCES (ESCOs)	€	%
Equity	192,299	26
Senior debt	448,697	61
Grant	0	0
Subsided Funds	0	0
Total Financial Sources exc. VAT	640,995	87
VAT	91,881	13
Total Financial Sources	401,959	100

Municipal House of Culture

MUNICIPAL HOUSE OF CULTURE - COIMBRA PORTUGAL

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The building is oriented with an axis of 20º, with the main façade oriented to East. This orientation is not optimal, but it is possible to install solar systems with little deviation from the south.

There are two areas of the building loaned to other entities:

- Part of floor -2 is one refectory used by the University of Coimbra;
- Part of floor -3 is used by the CAPC - Círculo de Artes Plásticas de Coimbra (cultural association of contemporary art).

These spaces are managed by such entities, but they receive electricity from the main board of the building, being the electricity paid by the Municipality.

The building external walls are made of breeze blocks and bricks and have a thickness of 20 to 55 cm. The windows are of single glazing with aluminum frames. Almost all windows have interior shutters. The exception is the front floor where darkened windows are used. The doors have the same characteristics of the windows.

The back façade presents signs of condensations, mainly in areas covered with vegetation.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The Municipality has no financial plan to improve this specific building, with the exception of the roof whose intervention is already in implementation. The Municipality is trying to raise funds from national and European funding programs.

Legislative Obstacles

There are no major legislative obstacles to the renovation of this building.

RENOVATION SCHEME

Building Envelope

The roof has been renovated (replacement of the asbestos-cement slabs by a sandwich panel constituted by two thermolacquered metal sheets with 80 mm of polyurethane insulation).

Other renovation options, requiring construction works in the façades were considered. However, the renovation options requiring major construction works, incompatible with the normal activities of the building, should be avoided due to the incompatibility between use and renovation works.

All the windows used in the building are of single glazing with aluminium frames. The replacement of windows by double glazing windows was not considered in this plan since the option to replace the HVAC system present higher cost-effectiveness and is more easily assessed and monitored. However, such replacement should be considered in future renovations of the building.

HVAC

The HVAC in most of the building is ensured by mono-split systems with heat pumps installed in the wall or roof with a total power of 239.27 kW. The replacement of the several mono-split systems by multi-split systems was not considered, since despite the potential lower purchase cost of multi-split systems the costs of installation would be higher and mainly the impact of the installation process on the building operation would be much higher. Therefore, it was considered the replacement by other mono-split systems with higher efficiency, keeping the same total power. In the renovation plan the replacement of such systems by new systems with higher efficiency was considered, being selected a system with EER of 5.2 and COP of 5.74

Lighting

The actual lighting system is mainly constituted by fluorescent linear T8 lamps with electromagnetic ballast. The planned action is to replace all lamps by LEDs.

RES

In the renovation plan it was considered the installation of PV panels oriented to south, but keeping the orientation of the building (azimuth of 20º) in order to minimize the visual impact of the PV panels. Therefore, it was considered the installation of 770 PV panels, ensuring an installed power of 181 kWp. This will ensure a generation of 254.2 MWh/year.

lower energy consumption.

BRIEF DESCRIPTION

The building was built in 1991-1993 and opened on October, 26th 1993.

The building is located near to the city center and near to the University.

It is used as Municipal House of Culture and has several cultural equipment, such as library, auditorium and art gallery, as well as several offices. The building has 8 floors, with 3 floors below and 4 floors above the ground floor.

The building has 80 employees and is visited by 17,500 users/year and works with the following schedule.

July 15th to September 15th:

Monday to Friday: 9h00 – 18h30

September 16th to July 14th:

Monday to Friday: 9h00 – 19h30

Saturday: 11h00 – 13h00 and 14h00 and 19h00

The users have access to the rooms of public use only after 10h00.

GENERAL INFORMATION

Year of construction:

1991-1993

Area/Volume:

13,225 m^2 / 39,944 m^3

Building Use :

The building is the Municipal House of Culture and has several cultural equipment, such as library, auditorium and art gallery.

MUNICIPAL HOUSE OF CULTURE - COIMBRA PORTUGAL

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before the renovation, considered as baseline, is equal to 487,229 kWh/year (electricity) and the energy consumption by square meter is about 49.4 kWh/m^2. After the renovation the energy consumption drops to 13,479 kWh/year (electricity only) and the energy consumption by square meter is equal to 1.4 kWh/m^2. Which means 65,742 Euro/year of savings. The renovation will lead to 97.2% savings in the building.

CO_2 Savings

The savings resulting from the PV system, lamp replacement and HVAC replacement by others with higher efficiency are equal to 66.27 tons/year.

RES Integration

In the evaluation of the PV generation it was considered the self-consumption of 90% of the energy. RES will ensure 95.1% of the total energy consumption.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Energy Savings	473,750 kWh
Costs	396,656 €
Savings	65,742 €/year
Simple Payback	6.03 years
CO_2 Savings	66.27 tons/year

ECONOMIC EVALUATION

Payback Period

The energy and maintenance project simple payback period is 6 years. This payback is calculated without considering the Financing Scheme.

Total Cost

The technical investment cost is equal to 338,274 Euro (excluded VAT), which means the investment cost per square meter is 26.6 Euro/m^2.

Economic Savings

The energy expenditure savings are 53,081 Euro/year

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	126,945
Lighting system (internal)	17,121
Renewable energy	194,208
Building Envelope	0
Control system	0
Investment for Renovation	338,274

FINANCING SCHEME

Energy Performance Contract

On the basis of Deliverable D3.5 the implementation of the "shared savings" EPC contract (considered to be the most widespread among the four CERtuS countries) was chosen. The ESCo is supposed to invest through a Special Purpose Vehicle (SPV).

Duration of EPC

Duration of EPC: 15 years

Financial Sources

Given the Renovation Scheme selected and the characteristic of the project, ESCo involvement is possible at current market conditions because the project is able to generate enough cash flows to pay back the loan and to remunerate the capital invested by the ESCo.

- Equity is about 26% of the whole financial source
- Senior Debt is about 60% of the whole financial source
- VAT Facilities is about 14%

Equity Pay Back Period

The project equity payback period is 13 years.

Other considerations

With this financial structure, an ESCo intervention is possible and the remuneration of the invested capital, in terms of IRR, should be considered adequate for this kind of projects.

INVESTMENTS (ESCOs)	€
Investment for renovation	338,274
Starting liquidity	500
Interests and Banking Fees	4,803
Total Investments exc. VAT	343,577
VAT	58,382
TOTAL INVESTMENTS	**401,959**

FINANCIAL SOURCES (ESCOs)	€	%
Equity	106,073	26
Senior debt	240,504	60
Grant	0	0
Subsided Funds	0	0
Total Financial Sources exc. VAT	343,577	85
VAT	58,382	14
Total Financial Sources	401,959	100

Elementary school of Solum

MUNICIPAL HOUSE OF CULTURE - COIMBRA PORTUGAL

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The building is oriented with an axis of 200º, with the main façade oriented to East. This orientation is not optimal, but it is possible to install solar systems with little deviation from the south.
There are two areas of the building loaned to other entities:

- Part of floor -2 is one refectory used by the University of Coimbra;
- Part of floor -3 is used by the CAPC - Círculo de Artes Plásticas de Coimbra (cultural association of contemporary art).

These spaces are managed by such entities, but they receive electricity from the main board of the building, being the electricity paid by the Municipality.
The building external walls are made of breeze blocks and bricks and have a thickness of 20 to 55 cm. The windows are of single glazing with aluminum frames. Almost all windows have interior shutters. The exception is the front floor where darkened windows are used. The doors have the same characteristics of the windows.
The back façade presents signs of condensations, mainly in areas covered with vegetation.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks
The Municipality has no financial plan to improve this specific building, with the exception of the roof whose intervention is already in implementation. The Municipality is trying to raise funds from national and European funding programs.
Legislative Obstacles
There are no major legislative obstacles to the renovation of this building.

RENOVATION SCHEME

Building Envelope
The roof has been renovated (replacement of the asbestos-cement slabs by a sandwich panel constituted by two thermolacquered metal sheets with 80 mm of polyurethane insulation).
Other renovation options, requiring construction works in the façades were considered. However, the renovation options requiring major construction works, incompatible with the normal activities of the building, should be avoided due to the incompatibility between use and renovation works.
All the windows used in the building are of single glazing with aluminium frames. The replacement of windows by double glazing windows was not considered in this plan since the option to replace the HVAC system present higher cost-effectiveness and is more easily assessed and monitored. However, such replacement should be considered in future renovations of the building.
HVAC
The HVAC in most of the building is ensured by mono-split systems with heat pumps installed in the wall or roof with a total power of 239.27 kW. The replacement of the several mono-split systems by multi-split systems was not considered, since despite the potential lower purchase cost of multi-split systems the costs of installation would be higher and mainly the impact of the installation process on the building operation would be much higher. Therefore, it was considered the replacement by other mono-split systems with higher efficiency, keeping the same total power. In the renovation plan the replacement of such systems by new systems with higher efficiency was considered, being selected a system with EER of 5.2 and COP of 5.74
Lighting
The actual lighting system is mainly constituted by fluorescent linear T8 lamps with electromagnetic ballast. The planned action is to replace all lamps by LEDs.
RES
In the renovation plan it was considered the installation of PV panels oriented to south, but keeping the orientation of the building (azimuth of 20º) in order to minimize the visual impact of the PV panels. Therefore, it was considered the installation of 770 PV panels, ensuring an installed power of 181 kWp. This will ensure a generation of 254.2 MWh/year.
lower energy consumption.

BRIEF DESCRIPTION

The building was built in 1991-1993 and opened on October, 26th 1993.
The building is located near to the city center and near to the University.
It is used as Municipal House of Culture and has several cultural equipment, such as library, auditorium and art gallery, as well as several offices. The building has 8 floors, with 3 floors below and 4 floors above the ground floor.
The building has 80 employees and is visited by 17,500 users/year and works with the following schedule.
July 15th to September 15th:
Monday to Friday: 9h00 – 18h30
September 16th to July 14th:
Monday to Friday: 9h00 – 19h30
Saturday: 11h00 – 13h00 and 14h00 and 19h00
The users have access to the rooms of public use only after 10h00.

GENERAL INFORMATION

Year of construction:
1991-1993

Area/Volume:
13,225 m^2 / 39,944 m^3

Building Use :
The building is the Municipal House of Culture and has several cultural equipment, such as library, auditorium and art gallery.

MUNICIPAL HOUSE OF CULTURE - COIMBRA PORTUGAL

RENOVATION SCHEME EVALUATION

Energy Savings

The energy consumption before the renovation, considered as baseline, is equal to 487,229 kWh/year (electricity) and the energy consumption by square meter is about 49.4 kWh/m^2. After the renovation the energy consumption drops to 13,479 kWh/year (electricity only) and the energy consumption by square meter is equal to 1.4 kWh/m^2. Which means 65,742 Euro/year of savings. The renovation will lead to 97.2% savings in the building.

CO_2 Savings

The savings resulting from the PV system, lamp replacement and HVAC replacement by others with higher efficiency are equal to 66.27 tons/year.

RES Integration

In the evaluation of the PV generation it was considered the self-consumption of 90% of the energy. RES will ensure 95.1% of the total energy consumption.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Energy Savings	473,750 kWh
Costs	396,656 €
Savings	65,742 €/year
Simple Payback	6.03 years
CO_2 Savings	66.27 tons/year

ECONOMIC EVALUATION

Payback Period

The energy and maintenance project simple payback period is 6 years. This payback is calculated without considering the Financing Scheme.

Total Cost

The technical investment cost is equal to 338,274 Euro (excluded VAT), which means the investment cost per square meter is 26.6 Euro/m^2.

Economic Savings

The energy expenditure savings are 53,081 Euro/year

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	126,945
Lighting system (internal)	17,121
Renewable energy	194,208
Building Envelope	0
Control system	0
Investment for Renovation	338,274

FINANCING SCHEME

Energy Performance Contract

On the basis of Deliverable D3.5 the implementation of the "shared savings" EPC contract (considered to be the most widespread among the four CERtuS countries) was chosen. The ESCo is supposed to invest through a Special Purpose Vehicle (SPV).

Duration of EPC

Duration of EPC: 15 years

Financial Sources

Given the Renovation Scheme selected and the characteristic of the project, ESCo involvement is possible at current market conditions because the project is able to generate enough cash flows to pay back the loan and to remunerate the capital invested by the ESCo.

- Equity is about 26% of the whole financial source
- Senior Debt is about 60% of the whole financial source
- VAT Facilities is about 14%

Equity Pay Back Period

The project equity payback period is 13 years.

Other considerations

With this financial structure, an ESCo intervention is possible and the remuneration of the invested capital, in terms of IRR, should be considered adequate for this kind of projects.

INVESTMENTS (ESCOs)	€
Investment for renovation	338,274
Starting liquidity	500
Interests and Banking Fees	4,803
Total Investments exc. VAT	343,577
VAT	58,382
TOTAL INVESTMENTS	**401,959**

FINANCIAL SOURCES (ESCOs)	€	%
Equity	106,073	26
Senior debt	240,504	60
Grant	0	0
Subsided Funds	0	0
Total Financial Sources exc. VAT	343,577	85
VAT	58,382	14
Total Financial Sources	401,959	100

ERRENTERIA, SPAIN

City Hall

CITY HALL – ERRENTERIA SPAIN

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The building was extensively renovated in 2000, hindering the task of encountering a balance between investment and energetic improvements. The envelope presents acceptable thermal transmittance and existing systems are relatively modern. The building does not present significant airflow infiltrations and it is regularly maintained. Concerning Renewable Energy Systems (RES), the geometry and location of the building represent major constrains for their installation. The building is located in the Old Town, characterised by narrow streets and urban density, which reduce the sun incidence on roofs. Furthermore the original building is listed and its historic value cannot be extensively altered. Additional equipment cannot be installed inside the building as each room has a well-defined use, limiting the selection of new systems to be installed.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The lack of public budget and the low availability of financial schemes can reduce the possibilities to implement the proposed renovation scheme. The equipment installed in the City Hall can be considered as modern and with a considerable remaining life time. Its efficiency might be improved by raising awareness of users but the effect cannot be easily quantified. Furthermore, in Spain PV system up to 100 kW may not sell electricity and are required to donate this electricity, thus extending the payback periods.

Legislative Obstacles

The City Hall was declared "Municipal ensemble" according to the Basque Government Decree 101/1996 of May 7th, which means that solutions with high visual impact or which might harm the building's integrity cannot be applied.

RENOVATION SCHEME

Building Envelope

As the building was refurbished in 2000, walls, roof and windows present thermal transmittance values that do not justify high investments, since the real impact in the energy demand reduction would be low. The improvement of the thermal transmittance would require extensive works, entailing the temporary reallocation of functions and employees. The achievements in energy demand reduction will not be worth the investment.

HVAC

The heating system is a centralised system, independently regulated in different areas of the building. It is formed by radiators warmed by hot water produced by a gas boiler, supplying hot water to two buildings: Kapitain Etxea and the City Hall. As the system will be separated, the total power is currently. The heating system will be improved by means of a high Coefficient of Performance (COP) condensing boiler. The boiler proposed in the renovation scheme has a COP of 1.1 and a total power of 130 kW. The cooling system is divided in independent phases. The first phase is used to cool the administrative area, a double-flow air to air system. The second phase is a varied refrigerant volume (VRV) solution formed by 8 condenser units connected to 7 evaporator units. Each evaporator unit is independent and it is controlled manually by means of a remote control. Condenser units are controlled by timers that limit their working period to the timetable of the City Hall. The VRV system offers acceptable levels of energy efficiency and meets users flexibility, so no interventions are foreseen.

Lighting

In the renovation scheme proposed, fluorescent lamps will be substituted by LED lamps. Where possible, automatic controllers will be installed.

RES

The renovation scheme includes the installation of Photo Voltaic (PV) panels on the roof of the building. Considering the useful surface, panels will be installed on the sloped roofs. The plant, of 40.2 kWp, will be made of standard monocrystalline panels and will occupy a surface of 332 m^2.

BRIEF DESCRIPTION

Errenteria City Hall has an appreciable square ground plan, which defines one side of the Herriko Plaza, the meeting point for five of the seven streets of the medieval town. The construction of the building started in 1603 and it was inaugurated in 1607. The City Hall suffered important damages, as Errenteria was burned in 1638 by the French troops. Looting and destruction were so extensive that, in a first attempt, it was decided to construct a new building. Nevertheless, in 1654 it was agreed to start with the reconstruction, which lasted till 1666. The City Hall corresponds to the typical Basque structure, made in sandstone ashlars. The building has a ground floor and two storeys, with a retracted raised part added at a later date. Each floor has four rooms distributed symmetrically. In 2000 an extension project started, which resulted in the merger of three existing buildings: the original building of the 17th century and other two buildings with less relevance, but contributing to the practical use and the overall streetscape.

The project was undertaken to improve efficiency of the local government, facilitate circulation, structural stability and guarantee the unitary use of a single building. This entailed the erection of a new structure behind the original façades of the two less significant buildings. The historic City Hall was also renovated. The existing interior courtyard was kept as a key element of the plan yet covered with a skylight. The courtyard provides daylight to the interior office spaces.

GENERAL INFORMATION

Year of construction:

1603-2000

Area/Volume:

2,961 m2 / 11,418 m3

Building Use :

City Hall

CITY HALL – ERRENTERIA SPAIN

RENOVATION SCHEME EVALUATION

Energy Savings

Currently, the building has a final energy consumption of 131,630 kWh in gas and 147,530 in electricity and a total primary energy consumption of 517,999 kWh. The renovation scheme proposed will reduce final energy consumption to 127,040 kWh in gas and to 60,783 kWh in electricity and to 286,954 kWh in primary energy. Primary energy savings will therefore be 231,045 kWh. Considering electricity and gas prices of 2015 in Spain, expenditure savings will be 12,374 € per year.

CO_2 Savings

The CO_2 savings are estimated in 57.36 tons per year.

RES Integration

39% of energy will be supplied by renewable energy systems. PV will provide a generation of 38,757 kWh.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Primary Energy Savings	231,045 kWh
Costs	169,684 €
Energy Savings	12,374 €/year
Manteinance + energy	21,478 €/year
Simple Payback	5.6 years
CO_2 Savings	57.36 tons/year

ECONOMIC EVALUATION

Payback Period

The Project payback period is 9 years. From an ESCo point of view, some extra investment is considered in order to provide the project with sufficient liquidity to pay interests, banking fees and to finance initial working capital.

Total Cost

The total investment cost is 169,683 Euro, which represents an investment cost per square meter of 57.30 Euro/m^2.

Economic Savings

The energy expenditure is 11.698 Euro/year. The expenditure for maintenance after renovation is lower than before of 9.781 Euro/year. This situation affects positively, at economic level, on the total savings achievable by the intervention: the economic saving, energy and maintenance, is about 21.478 Euro/year.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	9,760
Lighting system (internal)	10,493
Renewable energy	149,430
Investment for Renovation	169,683

FINANCING SCHEME

Energy Performance Contract

Although the project has an adequate payback time, the cash flows does not create an attractive contract to the ESCo to market conditions. In order to make the project desirable for an ESCo, an important financial support should be given to the project and the duration of the EPC contract should be extended. In this case, a specific financial structure was implemented assuming:

(a) Equity investment by the ESCo 9%;

(b) Subsided Funds for 40%;

(c) Grant for 40%.

The implementation of this EPC contract leads to a reduction of expenditure for the Municipality of around 10.365 Euro/year, resulting from the 5% shared energy savings of 585 Euro less the reduction in maintenance costs of 9.781 Euro. Three types of contracts are best placed to meet the needs of the Municipality: First In, First Out and Shared Savings. All three contracts transfer more than 70% of the risk to the ESCO thereby ensuring the Municipality which has declared to have not experience in managing of EPC contracts. The contract that offer greater guarantees to the City is the first out with 78% of the risks allocated to ESCO.

Duration of EPC

The duration of the EPC contract is of about 20 years.

Financial Sources

The optimal solution could be the Shared Saving contract in which: (i)the energy savings is shared between ESCO and the Municipality (for only 5%) in order to reduce the duration of the contract that in this way would be around in 20 years; (ii) All of the interventions will be performed by the ESCO who assumes the technical risk and guarantees the savings; (iii) The Municipality finances directly part of the interventions through the funds of the SEAP and by using loan funds.

Other considerations

In order to make the investment more sustainable for the ESCo the project could consider alternative ways to the standard EPC contract, for example to implement other kind of contract or a global service or a direct procurement by the Municipality. In addition, given the small dimension of the project, it could be a good option to aggregate more than one initiative. This aggregation could be useful to obtain cost efficiency, incremental revenues and synergies.

Kapitain Etxea

KAPITAIN ETXEA – ERRENTERIA SPAIN

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The Municipality has already defined a project for the inclusion of an elevator and a new staircase, while improvements on the energetic behaviour of the buildings are addressed in the CERtuS project. Due to the change of use of the building, it is difficult to estimate values before and after interventions. Real consumption of the building is not useful, as the archive is sporadically used and is not comparable with the Centre that will be open to the public from 10 am to 8 pm every day. The energy performance has therefore been calculated simulating the new use of the building, both for current and future conditions. Nevertheless, lighting and HVAC system installed in the building are not sufficient to guarantee the use and enjoyment of the Centre by people. In order to meet higher comfort conditions, HVAC system should be resized and proper lighting should be guaranteed. This will result in an increase in the energy demand. However, the continuous use of the building will guarantee appropriate maintenance, thus avoiding costs associated to abandonment and will permit citizens benefitting from their heritage.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

Also if the building has limited dimensions and there is no need of major investment, the lack of public budget still remains a barrier. While the building's envelope retrofitting will significantly improve the energy efficiency, performances and benefits of PV panels in this specific location are limited.

Legislative Obstacles

The Old Town has been listed due to its historical values. In the case of Kapitain Etxea this entails that the external walls have to be preserved with no alterations. Solutions with high visual impact or which might harm the building's integrity cannot be applied.

RENOVATION SCHEME

Building Envelope

The energy demand analysis of the current situation shows that windows and walls are the main weak elements and roof and ground contribute to thermal loses.

Opaque Envelope: Front and rear walls are constructed in sandstone ashlar, with a U-value of 2.60 W/m^{2}K. Interventions are possible only in the inner surface and should guarantee the minimum floor area reduction. Insulation will use mineral wool and mortar render to achieve a U-value of 0.35 W/m^{2}K. The roof is a timber structure in a bad state of conservation, which will be replaced by a similar but with improved insulation and waterproof materials, to reduce the U-value from 2.42 to 0.24 W/m2K. Slab on ground will also be improved, reducing U-value from 2.42 to 0.22 W/m^{2}K.

Glazing: Existing glazing and frames will be replaced by low e coated, air filled windows and wooden frames in order not to modify the aesthetic of the building. The existing skylight will be eliminated to include PV panels.

HVAC

One of the criteria to renovate the system was to avoid heat radiators and underfloor heating. Air Handled Unit (AHU) combining ventilation, heating and cooling was selected. Also if air ducts will be larger, the unique system will overcome the problem of lack of space. The AHU will be provided with a heat recovery system.

Lighting

Current lighting system presents different types of luminaries, irregularly distributed and with high visual impact. The new system will be designed according to the standard values. Also if the system will be more efficient, actual values are below the recommended power, thus installed power will increase to meet comfort conditions.

RES

The renovation scheme includes the installation of Photo Voltaic (PV) panels. Due to the small dimensions of the building, power supplied will not be high, being 3.4 kWp. Monocrystalline panels will be placed instead of the skylight. Despite it is not the best orientation, is the area which is less affected by shading and will reduce visual impact.

BRIEF DESCRIPTION

After the catastrophic fire in 1638, Errenteria started rebuilding the city. The most outstanding houses of the historic centre date back to this period. One of these ancestral houses is nowadays known as the Captain's House (Kapitain Etxea in Basque). It is a terraced building of rectangular ground plan with a gable roof perpendicular to the principal facade made of sandstone ashlar. Although it initially had a ground floor and two stories separated by flat roofs, the upper part has suffered alteration: the floors are no longer at their original height and the openings interrupt the flat roofs. In 1925 the original building was divided in two and nowadays it is possible to distinguish the differences only between the roofs. There is one single row of openings on the ground floor and projecting balconies with forged iron railings on the first and second floors. While the right-hand side is residential, the left-hand side has been used for cultural activities, as a result of which the facade has been cleaned and the interior has been transformed in 1984.

Currently the building is used as part of the municipal archive, as it presents poor accessibility conditions and entrance has been restricted to municipal employees. The Municipality decided to refurbish the building to host the Center of the Basque Costume. The new use of the building will therefore require interventions aimed at improving accessibility and comfort conditions.

GENERAL INFORMATION

Year of construction:

1650 (aprox.)

Area/Volume:

395 m^2 / 1,362 m^3

Building Use :

Municipal archive

KAPITAIN ETXEA – ERRENTERIA SPAIN

RENOVATION SCHEME EVALUATION

Energy Savings

Currently, the building has a final energy consumption of 54,383 kWh in gas and 14,602 in electricity and a total primary energy consumption of 93,039 kWh. According to the renovation scheme proposed there will be no gas consumptions but the final energy consumption in electricity will increase in 9,464 kWh. Primary energy savings will be 44,919 kWh. Considering electricity and gas prices of 2015 in Spain, expenditure savings will be 4,971 € per year.

CO_2 Savings

The CO_2 savings are estimated in 4.95 tons per year.

RES Integration

12% of energy will be supplied by renewable energy systems. PV will provide a generation of 3,389 kWh.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Energy Savings	44,919 kWh
Costs	111,636 €
Savings	4,971 €/year
Simple Payback	22 years
CO_2 Savings	4.95 tons/year

ECONOMIC EVALUATION

Payback Period

The project payback is 22 years considering the maintenance savings.

Total Cost

The total investment cost is 111,636 Euro, which represents an investment cost per square meter of 295 Euro/m^2.

Economic Savings

The energy expenditure is 1.528 Euro/year.

The expenditure for maintenance after renovation is lower than before of 3.455 Euro/year. So, the economic saving, energy and maintenance, is about 4.971 Euro/year.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
HVAC	21,540
Lighting system (internal)	26,624
Renewable energy	12,602
Building envelope	50,870
Investment for Renovation	111,636

FINANCING SCHEME

Energy Performance Contract

The project involves a change of use of the building: from archive to Centre of the Basque Costume. For this reason, a comparison with the previous situation as regards energy consumption and savings obtainable is not possible. The project is not able to pay-back the investment in 15 years by itself because economic savings are minimal compared to investment costs. As a consequence, the implementation of an EPC contract is very difficult. Despite all, a possible way of implementation of a theoretical EPC contract should have the following features: (a) Equity investment by the ESCo 10%; (b) Grant for 88%. The analysis shows that only two types of contracts, are best placed to meet the needs of the City of Errenteria: Guaranteed Saving and Shared Saving. The Shared Savings transfers more than 70% of the risk to the ESCO thereby ensuring the Municipality, while the guaranteed Savings contract moved to ESCO about 60% of the risks.

Duration of EPC

The duration of the EPC contract is of about 25 years, higher than the normal market condition.

Financial structure

The optimal solution could be to build based on a mix of the two types in which:

(i) all of the interventions are performed by the ESCO, who assumes the technical risk and guarantees the savings; (ii) most of the work is funded by the City which assumes the financial risk while a small portion is funded directly by the ESCO; (iii) the ESCO performs maintenance and shares the savings achieved for the part that is measurable. In fact, as said previously, in these two cases is not possible to define the basic situation being different situations of use of the raw properties and after renovation. The municipality should consider a public / private partnerships by the involvement of the ESCO also in activities related to the provision of other services linked to the new use. The ESCO could be involved not only for the construction of the photovoltaic but also, for example, for the assignment of the maintenance of the entire post-restructuring structure and for the management of a part of the services inside it.

Other considerations

In order to make the investment more sustainable for the ESCo the project could consider alternative ways to the standard EPC contract, for example to implement other kind of contract or a global service or a direct procurement by the Municipality. In addition, given the small dimension of the project, it could be a good option to aggregate more than one initiative. This aggregation could be useful to obtain cost efficiency, incremental revenues and synergies.

Lekuona

LEKUONA– ERRENTERIA SPAIN

BUILDING CURRENT CONDITION - TECHNICAL AND OTHER PROBLEMS DETECTED

The Municipality of Errenteria has undertaken an ambitious project to transform a former industrial building into a modern cultural centre. The building is labelled as Energy Category A and has been designed to present very low energy consumption and CO_2 emissions compared to a standard building. Suitable envelope typologies and materials, use of RES or efficient systems were considered from the beginning of the project. As the deep renovation designed has been already approved through a participative approach with citizens, few improvements can be achieved. However, some actions have been detected, especially related to the use of RES that will be used to achieve better results. Moreover, considering the willingness of the Municipality to improve the efficiency of its municipal buildings, the measures that are proposed in the frame of CERtuS project will be considered in the near future.

ECONOMIC, FINANCIAL AND LEGISLATIVE CONSTRAINS

Economic/Financial Risks

The Municipality and the provincial Government of Gipuzkoa have already invested an important budget of around 6,5 million € for the renovation of the building. The risk of implementing new measures should not be underestimated, mainly due to the legal uncertainty of the use of PV. The use of PV panels is drastically limited by a series of fees that penalize the cost effectiveness of the installed system. Additionally, the produced electricity that is not consumed must be dropped in the net without compensation.

Legislative Obstacles

Part of the building is subjected to the Spanish Coastal Law 22/88 (1988), which protects the area up to 20 meters from the estuary's shore. The portion of the building included in this area will therefore be maintained and restored.

RENOVATION SCHEME

Building Envelope

The new constructive typologies of the envelope elements are in compliance with the aim of nZEB buildings. The project presents a good balance between retaining elements of the existing building and meeting energy conservation parameters.

Opaque envelope: Original walls, constructed of two layers of masonry with an air gap and no insulation, will be insulated internally by means of mineral wool and plasterboard, in order to protect the aesthetic of the fabric. The new walls will be new masonry with a similar insulation treatment. The existing roof, made of reinforced concrete will be augmented by corrugated sandwich panels of high density mineral wool.

Glazing: All the windows will be replaced with double-glazing with an air gap.

HVAC

Heating Ventilation and Air Conditioning (HVAC) system will be centralized and will use water-to-air Air Handling Units (AHUs), gathering all functions together. Various AHUs will be installed on the roof to distribute the conditioned air to the assigned rooms or areas. Domestic Hot Water (DHW) necessary to supply the heating part of the system will be provided by a pellet biomass boiler. All requirements for the selection of efficient equipment and comfort have been fulfilled and no modifications have been proposed.

Lighting

Lighting has been designed according to the Spanish and European Normal standards CTE – DB HE and UNE – EN 12464.1. Also in this case, energy efficiency and comfort parameters are met

RES

The heating system will be supplied by a biomass pellet-fired boiler of 201 kW of nominal power was selected. All the energy consumption related to the heating system will come from a renewable source. 450 PV panels will be installed, for a solar surface of 281 m^2. Panels will be installed keeping the orientation of the building in order to minimize the visual impact. PV ensures a generation of 35.75 MWh/year, with a specific production of 1050 kWh/kWp/year.

BRIEF DESCRIPTION

Lekuona is a family name associated to a long tradition of bakers. As time goes by, the small shop became an industrial bakery. The need of adapting the business to a changing environment required a technological development. For this reason, the company decided to move, at the end of the 60's, to an industrial building located nearby the river, known as the "Lekuona building". The bakery continued its activity in the building till 2005. Lekuona building, which is currently abandoned, is owned by the Municipality of Errenteria, in charge of preserving, rehabilitating and reusing it. The building is partially protected by the Coastal Law and its industrial character should be preserved. The Municipality is carrying out an ambitious project to transform the building into a dance school and cultural centre that will be known as "Dantzagune – Arteleku", as part of the Strategic Plan of the city, aiming to become a cultural and creative centre.

The Lekuona building is formed by a large central structure with two adjacent buildings for a total area of around 2000 m^2. The building has three floors and a basement. It has a rectangular shape with an adjacent trapezoid. The ground floor and first floor have similar shapes, but the second floor is a later extension of the building. The renovation project, which has been already approved by the Municipality, will have a larger area, as a new part will be constructed. The design proposed is in line with energy efficiency standards and will be qualified as "A class" according to the Technical Building Code of Spain (CTE).

GENERAL INFORMATION

Year of construction:

1963

Area/Volume:

4,406m^2 / 20,328 m^3

Building Use :

Industrial

LEKUONA– ERRENTERIA SPAIN

RENOVATION SCHEME EVALUATION

Energy Savings
The installation of PV panels will permit achieving 35,745 kWh savings

CO_2 Savings
The CO_2 savings are estimated in 23.19 tons per year.

RES Integration
59% of energy will be supplied by renewable energy systems, by the combined used of PV panels and biomass boiler, estimated in 194,568 kWh.

PARAMETERS OF THE RENOVATION SCHEME- TOTAL

Energy Savings	35,745 kWh
Costs	126,588 €
Savings	5,004 €/year
Simple Payback	25 years
CO_2 Savings	23.19 tons/year

ECONOMIC EVALUATION

Payback Period
The payback period is more than 30 years.

Total Cost
The total investment cost is 126,588 Euro, which represents an investment cost per square meter of 29 Euro/m^2.
These costs consider only the installation costs of photovoltaic system, not originaly planned in the renovation project.

Economic Savings
Considering that the building is originally abandoned, the savings are represented by the lower cost of electricity purchase. This failure cost is calculated in € 3,704 / year.

INVESTMENT FOR RENOVATION – TOTAL

INVESTMENTS	€
Renewable energy	126,588
Investment for Renovation	126,588

FINANCING SCHEME

Energy Performance Contract
The project has borned to redevelop a derelict site and not used by the population in order to turn it into a cultural center. This project, already approved by the Municipality, is being expanded through the introduction of photovoltaic system with the aim of making the nZEB building. These conditions do not allow a comparison with the previous situation as regards energy consumption and the relative savings obtainable after renovation scheme but we can say that the variation to the project will produce energy and economic savings compared to initial conditions. For this project, an ESCo intervention is not possible at market conditions because cash needed to serve the debt service is much more than cash generated by the project. In order to make the project desirable for an ESCo, an important financial support should be given to the project and the duration of the EPC contract should be extended. In this case, a specific financial structure was implemented assuming: (a) Equity investment by the ESCo 9%; (b) Grant for 59%; (c) subsided Funds 25%. The analysis shows that only two types of contracts, are best placed to meet the needs of the City of Errenteria: Guaranteed Saving and Shared Saving. The Shared Savings transfers more than 70% of the risk to the ESCO thereby ensuring the Municipality, while the guaranteed Savings contract moved to ESCO about 60% of the risks.

Duration of EPC
The duration of the EPC contract is of about 25 years, higher than the normal market condition.

Financial structure
The optimal solution could be to build based on a mix of the two types in which:
(i) all of the interventions are performed by the ESCO, who assumes the technical risk and guarantees the savings; (ii) most of the work is funded by the City which assumes the financial risk while a small portion is funded directly by the ESCO; (iii) the ESCO performs maintenance and shares the savings achieved for the part that is measurable. In fact, as said previously, in these two cases is not possible to define the basic situation being different situations of use of the raw properties and after renovation. The municipality should consider a public / private partnerships by the involvement of the ESCO also in activities related to the provision of other services linked to the new use.

Other considerations
In order to make the investment more sustainable for the ESCo the project could consider alternative ways to the standard EPC contract, for example to implement other kind of contract or a global service or a direct procurement by the Municipality. In addition, given the small dimension of the project, it could be a good option to aggregate more than one initiative. This aggregation could be useful to obtain cost efficiency, incremental revenues and synergies.

FURTHER INFORMATION

FURTHER READING

International publications and websites

- **BPIE,** *Scaling up deep energy renovations - unleashing the potential through innovation & industrialisation***,** published in October 2016 (on line)
  http://bpie.eu/wp-content/uploads/2016/11/BPIE_i24c_deepretrofits.pdf

- **BPIE,** *Renovation in practice,* published in December 2015 (on line)
  http://bpie.eu/wp-content/uploads/2015/12/Renovation-in-practice_08.pdf

- IEA Annex 61, *Business and Technical Concepts for Deep Energy Retrofit of Public Buildings,* completed project on 2016, (on line)
- http://www.iea-ebc.org/projects/ongoing-projects/ebc-annex-61/

- **ZEBRA 2020**- *nearly Zero-Energy Building Strategy 2020 – Strategies for a nearly Zero.Energy Building market transition in the European Union,* (on line)
  http://zebra2020.eu/