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Energy for Development

Technical and economic analysis of energy efficiency measures design: a public buildings case

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Abstract

One of the primary mission of the European Union in the lasts years has certainly became the reduction of carbon emissions and of the total energy consumption. Very often the public buildings are the most in need of energy improvements.

A primary role for the energy efficiency improvement spread, especially in the public sector, has to be played by national entities, funding projects and providing the proper actors for best solutions. The duty of this work is to present a specific case of a call for tender participation in the field of the energy efficiency optimization of selected premises and sites in the Wales region.

The main objectives of this project will be to improve the energy performance of its assets through measured and verified energy efficiency improvements and energy generation, to reduce emissions and save money through guaranteed annual cost savings or income generation.

After a quick socio-geographic description of the project site and the presentation of the buildings selected, the steps for the project implementation are taken. First, last year energy consumptions of the building will be determinate by energy bills examination and from that a load curve profile shall be generated. Thus the analysis of the most proper technologies to cover the load will start, considering several measures for renewables energy production or solutions for energy savings. Particular effort will be put on the PV modules dimensioning stage. We will comment the obtained result and try to identify the best solution, after it, our focus will move on the other technologies implemented and on the calculation of achievable savings.

In the last chapter we will try to estimate the feasibility of this asset through the description and the comprehension of an High Level Appraisal, an economical proposal of the project. The aim of this phase it to understand how convenient is this investment, dividing all the costs, the prices and the revenues of it we will identify a payback period for the total investment. Finally, we will draw our conclusion, summing up the main features of the work done with some consideration.

Key words: energy efficiency; renewable sources; photovoltaic panels sizing; biomass boiler; LED technology; water saving; technical and economic analysis.

Sommario

Una delle missioni principali dell'Unione Europea negli ultimi anni è stata certamente la riduzione delle emissioni di carbonio e del consumo totale di energia. Molto spesso gli edifici pubblici sono i più bisognosi di miglioramenti energetici. Un ruolo primario per la diffusione di una migliore efficienza energetica, in particolare nel settore pubblico, deve essere svolto da enti nazionali finanziando progetti e fornendo gli attori più adatti per le migliori soluzioni. Il compito di questo lavoro è quello di presentare un caso specifico di una partecipazione ad un bando di gara per selezionare un fornitore di servizi di ottimizzazione dell'efficienza energetica degli edifici selezionati nella regione del Galles.

Gli obiettivi principali di questo progetto saranno il miglioramento delle prestazioni energetiche delle proprie attività attraverso miglioramenti misurati e verificati dell'efficienza energetica e della generazione di energia; la riduzione delle emissioni ed il risparmio di denaro attraverso risparmi annuali garantiti o reddito generato. Dopo una rapida descrizione socio-geografica del luogo del progetto e la presentazione degli edifici selezionati, verranno presentate le fasi per l'implementazione del progetto. In primo luogo, i consumi energetici dell'anno precedente degli edifici verranno determinati delle bollette energetiche e da questi verrà generato un profilo di curva di carico, quindi inizierà l'analisi delle tecnologie più appropriate per coprire tale carico, considerando diverse misure per la produzione di energia rinnovabile o soluzioni per il risparmio energetico. Uno sforzo particolare sarà posto sulla fase di dimensionamento dei moduli fotovoltaici. Commenteremo il risultato ottenuto e cercheremo di identificare la soluzione migliore, dopo di ciò, ci concentreremmo sulle altre tecnologie implementate e sul calcolo dei risparmi ottenibili. Nell'ultimo capitolo cercheremo di stimare la fattibilità di questo investimento attraverso la descrizione e la comprensione del "High Level Appraisal", una proposta economica. L'obiettivo di questa fase è capire lo sforzo economico di questo progetto, analizzando singolarmente tutti i costi, i prezzi e i ricavi di questo, identificando un "payback time" dell'investimento totale. Infine, trarremo le nostre conclusioni riassumendo le principali caratteristiche del lavoro svolto con alcune considerazioni.

Parole chiave: efficientamento energetico; fonti rinnovabili; dimensionamento pannelli fotovoltaici; boiler biomassa; tecnologia LED; risparmio idrico; analisi tecnico economica

Introduction

One of the primary mission of the European Union in the last years has certainly become the reduction of carbon emissions and the total energy consumption, by means of energy efficiency improvements and aimed policies. In the European Union, the building sector is responsible of about 40% of the total final energy consumption and of 36% of the Europe global CO_2 emissions. Therefore it is necessary to endeavor to this significant and actual problem, focusing on the building sector.

Often, public buildings are the one in need of most energy improvements, this is due to several reasons: larger energy demand or consumption, absence of any previous energy measure and lack of economic means. A primary role for the energy efficiency improvement development, especially in the public sector, has to be played by national agencies funding projects and providing the proper insiders for best solutions.

This work will present the specific case of a national Contracting Authority aiming at selecting a Service Provider to work with it closely in order to optimize the energy efficiency of selected premises and sites in the Wales region. The contracting authority concerned is the Blaenau Gwent County Borough Council in partnership with the ReFit, a United Kingdom tender circuit of energy efficiency in public buildings.

Well aware that energy efficiency improvements are the most cost effective path to meeting energy challenges. The main objectives of this project will be to improve the energy performance of its assets through measured and verified energy efficiency improvements and energy generation, to reduce emissions and save money through guaranteed annual cost savings or income generation.

First, the company will be briefly introduced with its main activities of energy efficiency in the public sector and the concept of tender will be explained in all its mechanisms. Moving on, it will be taken in account the specific case of overseas tender, showing the possible examples of tenders available in the ReFit circuit and showing what is requested in such a proposal will be discussed. It will be indicate the mains aspects to keep in consideration during the realization of a tender response. We will present the technical and economics characteristics of two specific cases:

- Abertillery Sports Centre, Abertillery
- Willowtown Primary School, Ebbw Vale

After a quick socio-geographic description of the project sites and the description of the buildings selected, the steps for the project implementation will be taken. Last year energy consumptions of the building will be determinate by energy bills examination and from that a load curve profile shall be generated through the support of the software HOMER Energy. Once the load profile is available, the analysis of the most proper technologies to cover the load will be implemented, considering several measures for renewables energy source or solutions for energy savings. The chosen technologies for this project are:

- Photovoltaic panels
- LED technologies
- Water saver
- Sanitization of domestic hot water
- Biomass boiler

Particular effort will be put on the PV modules dimensioning stage. This delicate phase will start with the selection of a limited number of modules and inverters, based on practical considerations. Thus the best technical-economic configuration will be designed among the many scenarios implemented trough PVsys, an online photovoltaic dimensioning software. We will comment the results produced by the software and the best solution will be identified. Later, our focus will move on the other technologies implemented and on the calculation of achievable savings. Lastly, a proper economical analysis will be realized on the total investment costs.

Is this project economically feasible? In the last chapter this question will try to find an answer through the description and the comprehension of an High Level Appraisal, an economical proposal of the project. The aim of this phase it to understand how convenient is this investment, dividing all the costs, the price and the revenues of it we will identify a payback period for the total investment. Lastly a brief report will describe the other activities carried out during the five months stage in Zephyro

Chapter One

1.1 The company

ZEPHYRO S.p.A. (formerly Prima Vera S.p.A.) is a leading Company in the energy management sector and it is the first Italian Company to interface in international markets through an "hybrid" ESCo contract model.

Zephyro operates mainly with public entities in the energy sector and the management of technological systems. Thanks to the effectiveness of its business model, based on the management of complex factors of public tender, as deep knowledge of the structures, rapidity in the agreement, high financial flexibility, Zephyro made up a solid competitive position in the energy services market. In the last years, starting from 2015, Zephyro began an internationalization project, with the recent holding of a contract in Israel.

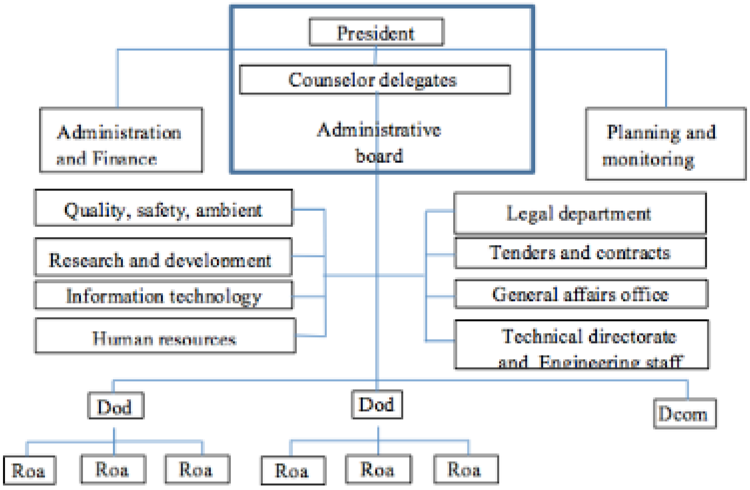

Figure 1 Company structure

1.1.1 History

The origins (2000 - 2002) Prima Vera (now Zephyro) was founded in the year 2000 and began operating on the national territory in the Energy sector.

Zephyro is investing mainly in the regional area (Lombardia) in the management and requalification of winter and summer air conditioning systems. In 2002 the Biomedical division was created for the Global Service Management of biomedical equipment in hospitals.

1.1.2 Business development (2002-2012)

In the following years Prima Vera (now Zephyro) develops its identity as an "hybrid" ESCO, focusing on energy efficiency activities and the construction of cogeneration, trigeneration and district heating plants. In 2012 a sector for the public lighting service was developed within the Energy Division of the company. The constant concern on the biological risk of bacterial contamination in air conditioning systems and water networks meant the creation of a specific sector for the plant sanitization service.

1.1.3 Recent development (2013 - 2014)

At the end of 2013, Prima Vera (today Zephyro) began its internationalization process, with the participation in a tender in Israel for the energy efficiency of all public health facilities with 11 centres divided into 2 clusters. At the end of 2014, the JV Prima Vera ("experience provider") and Tadiran ("local integrator") won the bid for both clusters. In the meantime, new commercial initiatives have been launched in Europe and North America, particularly in the Tri State Area (New York, New Jersey, Connecticut). Prima Vera then focuses on Research and Development with the participation in calls for proposals of the "European Funding Program for Research and Innovation HORIZON 2020" and through the development of its own collaboration relationships with various universities in Italy and the rest of Europe.

1.1.4 Today (2015-2017)

On December 21st 2015 Green Italy SpA, the first *Special Purpose Acquisition Company* (SPAC), a subject specialized in the green economy sector, admitted to trading on the multilateral trading system AIM Italia, organized and managed by Borsa Italiana, incorporated Prima Vera through merger and by acquiring its name. Today Zephyro works successfully in different Italian regions, as we can see on the figure below, and started a new projects of energy efficiency abroad especially in United Kingdom, Spain and China, always related to public buildings in particular public hospitals.

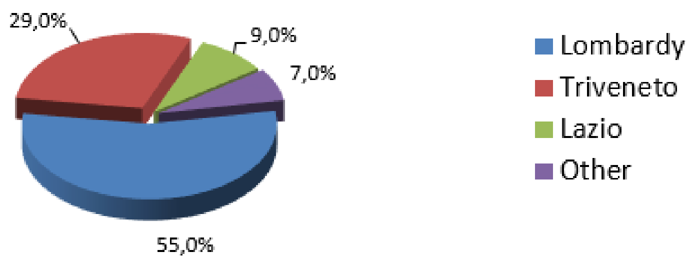

Figure 2 Zephyro's area of competence

1.1.5 Zephyro's activities

Zephyro offers its customers a wide range of advanced technological services for the energy sectors. Besides the main activities in the energy field the company has some ancillary activities as facility management and public lighting. Zephyro is an important player in Facility Management thanks to the quality of the services offered to the PA and to the Healthcare system, offering services integrated management. In particular: plant management, property management, gardening, cleaning, video-surveillance, reception, security etc. Considering the public lighting the company deals with the whole supply chain of this service, from the purchase of electric energy to running the plants, from energy streamlining to statutory compliance and the ordinary and extraordinary maintenance of lighting systems. In the Energy sector, Zephyro offers integrated energy efficiency solutions for complex structures, mainly consisting in facility management, cogeneration and trigeneration services, plant sanitization and energy services. Services as management and maintenance of all facilities technological systems, including the thermal heat supply analysis and execution of Energy Conservation Measures to large public and private facilities: hospitals, schools, universities and headquarters and other solutions in public lighting. The quality of the service offered is ensured by the Group's ability to cover the entire service chain. The activities faced by Zephyro include the design, the construction and the financing of energy requalification measures, but also the management and maintenance of technological systems (eg heating, air conditioning) together with the provision of related services (energy services, call centre, prompt intervention). At the end of the contract, the assets are transferred to customers. The reference clientele is almost entirely of a public nature (about 95%), mainly in the Health sector.

In 2014, research and development activities were increased with the participation in European tenders within the European Framework Program for Research and Innovation and collaborations with Universities (HORIZON 2020). In particular, Zephyro was granted €1.3 M for the implementation of the STEER project (energy consumption static and dynamic modelling). Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market. By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

1.2 Tender process

This paragraph aims to explain how does the tender mechanism generally work. This is a previous part of the mechanism compared to the activities described above. As a matter of fact, before starting any kind of measures Zephyro participated to a tender proposal, usually proposed by a public institution, but it may be also private. Usually tendering is a tool used by:

- Government departments, offices and agencies
- Private sector companies and business
- Non-government organizations

What is tendering? Tendering is the mechanism of making a proposal as a bid or an offer to an invitation for tender expressing thus an interest in response to it. Usually the institution will ask to the competitors to satisfy a particular need, like a good or a service and it will choose the offer that provides the best value for money for the project. In our case the main need is related to energy efficiency, thus reduction of energy consumption and environmental impact. These requests may vary according to the different kind of tender we are facing. As will be shown later, there are different kind of tenders Zephyro participate to and thus different kind of request, that can have more technical or economic nature or can have a fact-finding mission. Generally speaking, in the most cases the request have technical economic nature and different measures are usually offered as implementation of the already present technologies in the site or installation of new and better technologies, but also change the energy source from the conventional fossil materials to renewable energy sources and, last but not least, it has a remarkable role also the way we manage all these technologies and their consumptions. We will see later all the measures adopted by Zephyro in the several tender proposals.

Going back to the tender mechanism, after the tender is published all the competitors will prepare a response to the tender which will include a proper reply to all the points requested in the tender providing all the information and qualification deemed necessary. All the competitors have to submit their complete response before the institution deadline and with the method described in the tender by the contracting authority on pain of elimination if any of these aspects were not attended. During the tender period it will be possible to communicate with the contracting authority, in case clarifications on the tender are needed or to settle down a survey on the operation site. Once all the competitors submitted their response, the tenders are evaluated in accordance with defined criteria, which were well described in the tender. The supplier's offer, that meet in the best way all the requested points, win the contract and will start to collaborate with the institution on the topics developed in the tender response. Generally, after the contract have been awarded a formal agreement will be established between the successful tenderer and the contracting authority. In this document the focus will be on the overseas tendering, in particular in the United Kingdom area. It is important to understand that the approach for an overseas tender will be different due to several difficulties there will probably be as communication, different jurisdiction, legal consideration, added cost and lack of knowledge and understanding of international markets. At the same time there are a number of benefits as the opportunities to access to a wider and richer pool of business and the possibility to enhance the company growth.

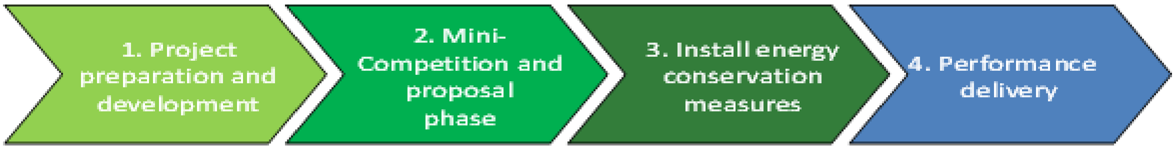

Figure 3 Tender path

Answering to a tender the provider has to consider all the aspects of the project, concerning not only the technical or the economic aspects, as installation and the cost of it, but all the several features that characterize a complex project as it may be an energy efficiency project. These may be project management, analysis and design, installation phase, performance delivery, pricing approach and achieving strategic goals and wider benefits.

During the evaluation of a response, each single aspect is considered and analysed and each of them has a different weight for the final result, as it is well explained and described in the tender document.

1.2.1 A tender response

Let's briefly analyse the single aspect of a tender response. When talking about a Project Management, we are talking about the duty of managing all the aspects of a project from the beginning to the end of it using a scientific and structured methodology. In our particular case the project management phase includes many different points as:

- project management / governance approach
- program plan
- risk and issue management plan
- sub-contractor procurement and management approach
- service continuity and/or interruption minimisation approach
- performance level M&V approach
- management to budget, timescales and quality
- key performance indicator achievement approach (potentially including but not limited to energy savings, CO2 targets, financial requirements or capital expenditure)

The analysis and design phase is the part of the project where you identify the overall direction that the project will take through the creation of the project strategy documents. It is important to describe clearly the process to follow in order to successfully design an optimal solution and in the same time identify all the possible stakeholders of this project in order to involve them whenever necessary. In our case the analysis and design phase includes:

- analysis approach
- approach to producing the high level appraisal(s)
- approach to producing the IGP(s)
- technical / service solution design
- how innovation is incorporated into the design phase
- proposed performance levels versus Contracting Authority requirements

- proposed financial savings (both through the guaranteed savings and wider savings proposed) and/or proposed business case
- proposed emissions reduction (such as absolute reductions or reduction per £)
- proposed wider benefits
- risk and risk reduction proposed in solution
- approach to meeting relevant design standards

The installation phase is the operative part of the project, in which all the designed phase come to life and many working aspects has to be considered as:

- installation approach (including appropriateness to property type and use)
- enabling service continuity during installation
- minimising disruption during installation
- works implementation schedule
- delivery of technical and/or service solutions
- commissioning and handover approach (including training)
- sub-contractor procurement and management

The performance delivery considers all the processes that you will follow to ensure ongoing successful performance and it includes:

- performance of technical / service solutions
- approach to provision of repair and maintenance services
- delivery of proposed performance levels
- delivery of proposed financial savings
- delivery of longer term asset management benefits and services
- delivery of emissions reduction
- innovation in service delivery
- risk management and risk reduction
- delivery of service continuity and minimising service interruption
- approach to the M&V of savings/performance levels

Economic values play a significant role in a Tender response, every aspect analysed before needs to be feasible from an economic point of view if the offer has to be really competitive. For this reason, generally in a tender there is pricing approach in which the tenderer has to demonstrate how to achieve the best value for money for the contracting authority showing for example, what it is included in your overhead rates and how the maximum overhead rates tendered provide value for money. Moreover, other aspects are considered as:

- cost and cost profile of the overall solution
- cost and cost profile of key individual components of the solution
- price of IGP(s)
- proposed financial savings
- payment approach (potentially covering payment based on performance)
- total cost of solution (potentially including the ability to maximise areas such as VAT recovery, capital allowances and income opportunities)
- performance of proposed solution against business case requirements

Beside these numerical and technical aspects there is also a social awareness in this project implementation, that take care of the wellness of all the community in which the building is inserted and not only the building itself. Reason why, during the project implementation, it is important to pay attention to bring optimal opportunities and benefits to local area in terms of occupation and economic growth including:

- achievement of economic goals and benefits, including job creation
- achievement of workforce goals
- achievement of environmental goals and benefits
- achievement of social goals and benefits

1.2.2 United Kingdom tendering: ReFit

Lately the company was awarded the ReFit contract, which allows Zephyro to participate, together with other fifteen EsCo, to many tenders in many places within the United Kingdom. These tenders are linked to energy efficiency and energy management field, particularly in public building such as schools or sport centres.

ReFit stands for RetroFitting, it is a successful initiative, it will give public sector organisations, as buildings or estate and support services and service providers a great opportunity to play their part in tackling climate change and helping to meet European, national, local and organisational targets to reduce carbon emissions. These result can be achieved by implementing their energy-efficiency and local energy-generation measures in order to sustain the climate mitigation. Basing on the principle of Energy Performance Contracting (EPC) this program is designed to help public sector to improve the energy performance of their buildings, increasing the share of renewables to 20% and move towards a 20% increase in energy efficiency and reduce their CO_2 emission by 80% by 2050 and achieve substantial guaranteed annual cost savings. The programme's ambition is to reach, by 2025, 40% of the public buildings, this would mean an investment amount of 400M £ and correspond to some 11 million m^2 of buildings retrofitted. The programme is supported by independent and public funded company, dedicated to providing the public sector with loans for energy efficiency projects, as Salix.

1.2.3 How does it work?

All the public buildings that want to be involved in this contract, as a client, will first need to sign a Memorandum of Understanding to the ReFit programme. It indicates interest and commitment at senior level. This allows the Program Delivery Unit (PDU) to develop a full retrofit project and to be a facilitator and financial advisor through the whole ReFit process. The process continues with a common procedure for all the project: first we have the identification of the buildings to be retrofitted and we set the energy savings target and the payback period, then, after a funding approach has been decided, an ESCO has to be chosen. In this part of the procedure the Refit brings an innovative approach, simplifying the procurement approach. It will be easier to select the service provider because the national authority provides a list of sixteen ESCO, previously selected for their competence and reliability, among which the client will choose the one with best project submitted. Once the ESCO is chosen, it will deliver the service promised, installing the energy conservation measures, and carrying out measurement and verification during the agreed period. Generally speaking, the energy efficiency measures adopted by the service provider can be:

- provision and installation of new equipment
- optimisation of equipment (including existing equipment)
- provision of related services
- maintenance in relation to any of the above (including water related solutions)

Considering the energy generation measures they could be:

- CHP
- Solar PV
- Biomass
- Other sources of energy supply and distribution – wind, energy from waste etc.

From an economic point of view, the investments may have different source: it can be made by the building owner, borrowed directly from banks or from public financial institutions like Salix or Public Works Loan Board or it can be financed by the ESCO itself, as showed in the following figure.

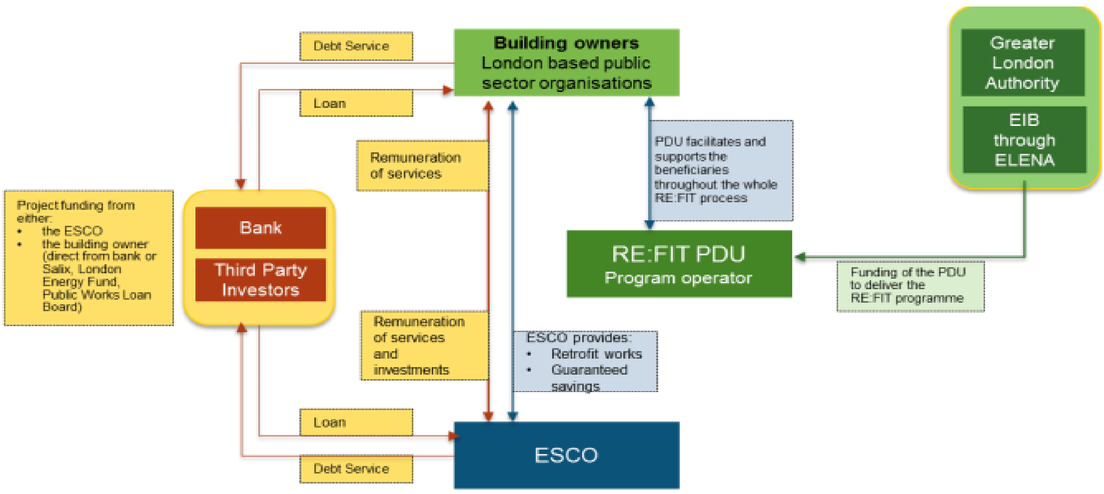

Figure 4. Operational and financial scheme

1.2.4 Several bid options

Before starting to describe the real case faced for this thesis it is important to highlight one last characteristic of these kind of tenders, which is the bid option. There are three main tendering options; the main difference is on the completeness of the response, mostly due to the presence of an economic detailed report on the investments that have to be done.

Option 1 - PARTNER BID

> "Supplier selection is based primarily on supplier capability and approach in response to the project, response to specific Contracting Authority requirements, pricing rates and costs for Investment Grade Proposals. There may be no detailed technical solution bid as part of the Tender Response, although this may be required at some point before (or soon after) Contract award. The Contracting Authority is typically selecting a delivery "partner" not a specific technical proposal or bid performance level (although there may be minimum performance levels required under the Contract which would be set out in the Project Brief). This approach aims to recognise the potential cost and resource requirements of detailed bidding. It may also help enable tendering of very bespoke or complex requirements and also make smaller value opportunities more viable." (Services, 2015)

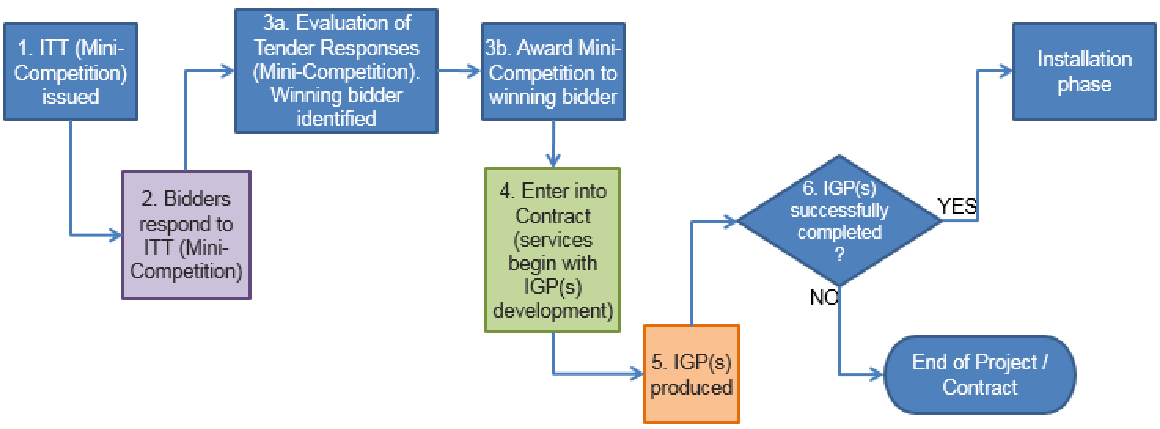

Figure 5 Partner bid flow chart

Option 2 - TARGET BID

> "This essentially includes high level appraisals as part of the Mini-Competition (for all or an identified selection of the total property portfolio) and supplier selection includes evaluation of supplier technical solutions and commercial proposals (covering areas such as the proposed ECMs and guaranteed savings proposed across the relevant premises). It may also include a range of other criteria including, but not limited to, supplier capability and/or approach in response to the requirements, pricing rates and costs for the Investment Grade Proposals." (Services, 2015)

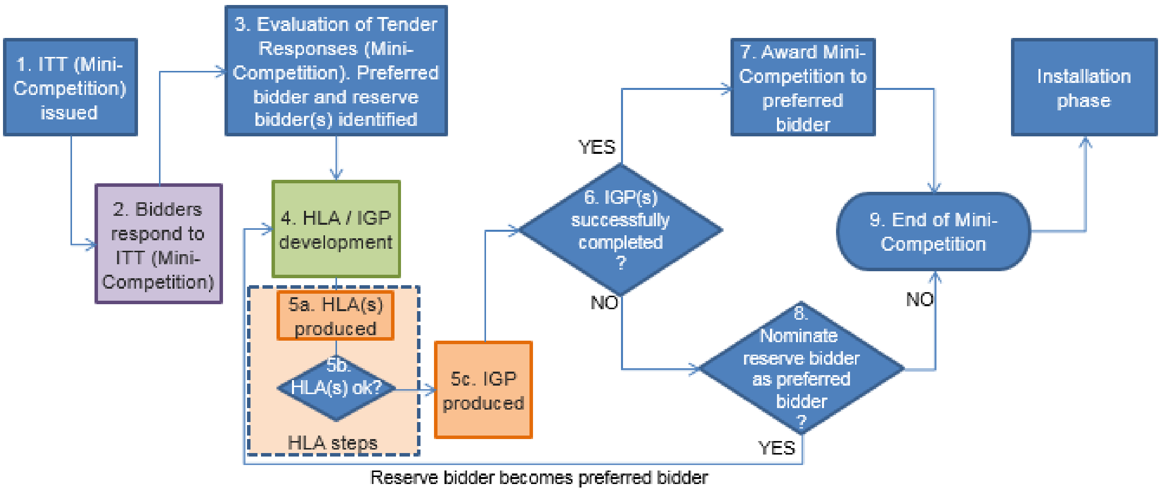

Figure 6 Target bid flow chart

Option 3 - INVESTMENT GRADE BID

"This is similar to the Target Bid but includes a more detailed technical and commercial proposal on specific selected properties, essentially meaning that the Mini-Competition includes an Investment Grade Proposal, for all or an identified selection of the total property portfolio. A lesser level of detail may then be required for all, some, or none of the remaining property portfolio" (Services, 2015)

In the next paragraph it will be analysed the study case, which is a target bid on several public buildings.

1.2.5 The thesis casa: a target bid

The case analysed in this thesis and showed in the next chapter will be a *TARGET BID* case, which means it is necessary to implement a High Level Appraisals (HLA) in the first part of tender response and a more detailed Investment Grade Proposal (IGP) if the HLA was accepted by the contracting authority. Let's see what HLA and IGP are:

HLA is an initial understanding and/or proposal for a project. Requirements will be specified within the Project Brief and will typically require an assessment of a defined number of properties to identify the benefits and savings opportunity along with associated costs. High level appraisals are not a full proposal in their own right, but would be used to form the basis of requirements for the Investment Grade Proposal (IGP). **IGP** is a key part of the analysis and design phase of the project. An IGP is likely to require comprehensive details of the proposals including, but not limited to ECMs to be used, guaranteed annual energy savings, tonnes of CO2 to be saved, capital and ongoing annual service costs, financial details (including payback model) and the Measurement and Verification (M&V) approach. It is easy to understand how the IGP is a complex and detailed report to produce and for this reason is usually requested after a first screening of the tenderer competences made by the HLA analysis. Usually, if the HLA report result relevant than an IGP report is requested. Once the IGP(s) are agreed, including any financing approach for the whole or parts of the project, these will be fundamental to any implementation phase required under the Contract.

1.2.6 Conclusions

In conclusion, in this first chapter, we briefly described where does Zephyro company come from, what are the main activity of this ESCO and how a tender award works in broad terms. It has been described the tender mechanism and all the aspects that should be considered in a tender response, after which the analysis of a specific tender circuit began: The ReFit tender circuit.

The Refit has been summarily described both from a social/environmental point of view and from a technical point, showing which are the measures typical of these kind of project and showing how the bid mechanism is composed, presenting the main differences among the possible bids. The next chapters will describe a particular real target bid case developed by the company for the Refit circuit in the Wales region. The focus will be on all the measures implemented and on the technical aspects, as the design, the dimensioning and the economic values, neglecting all the other aspect mentioned above that are typical of a tender. After showing all the measures implemented in this project the third chapter will focus on the economic phase of each technical measures, introducing the HLA process, in which all the economic aspects of such investment will be analysed. Last part of this thesis will be a comment on the obtained result and a discussion on a possible sensitivity analysis.

Chapter Two

2.1 The case studied: Blaenau Gwent

2.1.1 Case presentation

Figure 7 Blaenau Gwent towns

Blaenau Gwent County Borough Council (the Contracting Authority) is a Local Authority in South East Wales with a population of around 70,000 residents with approximately 31,000 households. The main towns are Ebbw Vale, Abertillery, Brynmawr and Tredegar and Blaina. Blaenau Gwent, County borough, is included in the 50% most deprived areas in Wales, according to the Welsh Index of Multiple Deprivation and has the greatest number of residents classified as fuel poor of all Local Authorities in Wales.

Figure 8 Blaenu Gwent county

The Contracting Authority intends to select a Service Provider to work with it closely in order to optimise the energy efficiency of selected premises and sites, improve the energy performance of its assets through measured and verified energy efficiency improvements and/or energy generation, reduce emissions and save money through guaranteed annual cost savings and/or income generation. For this first part of the tender six THLAs (Tendered High Level Appraisals) will be required as part of this Target Bid response. The buildings requiring THLAs have been selected for their representative nature and they are schools and activity centres.

In summary, the six buildings chosen for THLAs are:

- Abertillery Sports Centre, Abertillery
- Bryn Bach Park, Tredegar
- Bert Denning Centre, Brynmawr
- Bryn Bach Primary School, Tredegar
- Willowtown Primary School, Ebbw Vale
- Cwm Primary School, Ebbw Vale

Among these six buildings two has been selected and the analysis reported from now on will regard only the Abertillery Sports Centre (ASC) in Abertillery and the Willowtown Primary School (WPS) in Ebbw Vale. The first is a medium size sport centre, with swimming pools, gym and training area (ca 3200 m^2).

Figure 9 Aerial view of Abertillery Sport Centre

Willowtown Primary School was stablished in its current, purpose-built building in January 2007, moving from the original adjacent school buildings from 1908. It now has upwards of 440 learners per day. (ca 3100 m^2). These two buildings have been selected because representative of the two main categories in this set of buildings proposed in this tender: schools and sport centres. In the next pages, it is possible to observe the two sites floors plans, given in the tender annex documentation.

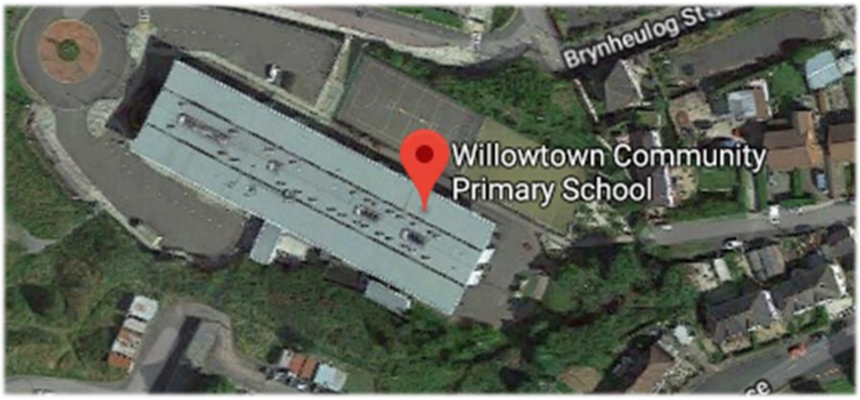

Figure 10 Aerial view of Willotown Primary School

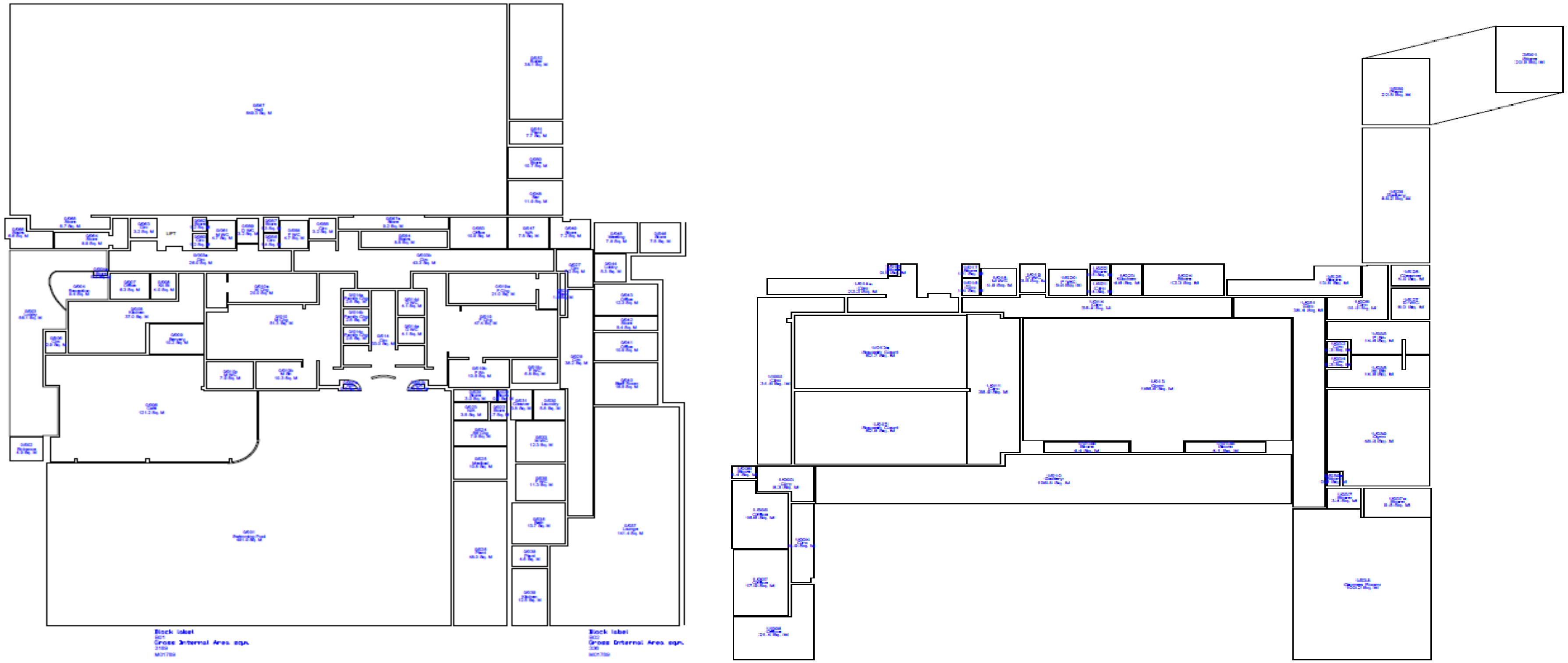

Figure 11 ASC Floors plan

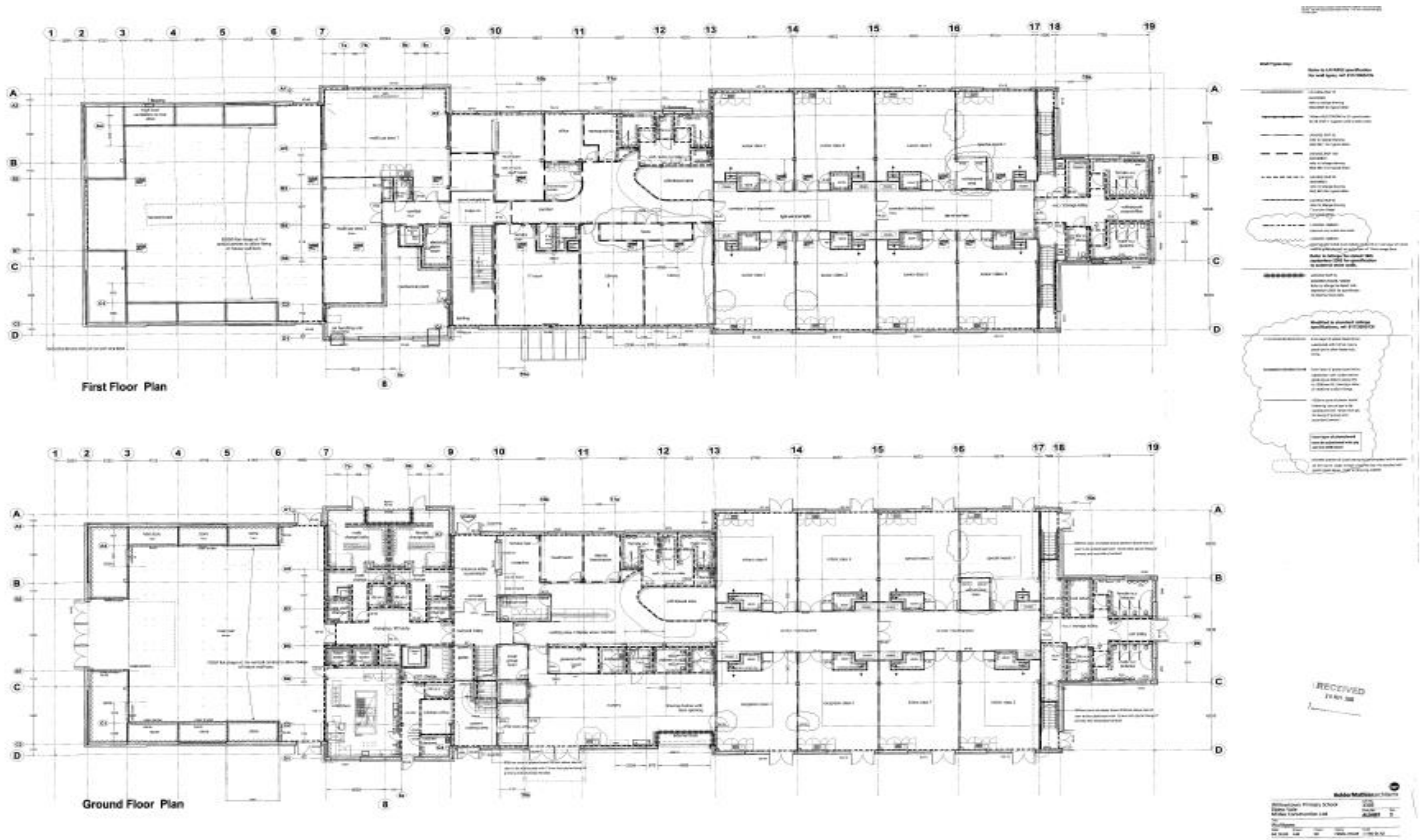

Figure 12 WPS floors plan

2.1.2 Consumption

Before starting with the design phase it is necessary to understand which are the needs of our clients and try to dimension them in order to give a proper numerical solution. First step is to calculate the energy, electrical and thermal need, in order to elaborate a first load curve and from that one try to design the best energy solution. In order to generate our load curves we used the energy bills provided by the authority, in particular we decided to use the energy bills of all the year 2016, believing that the difference from the current year 2017 would have been negligible. We had to use a one year bills because we had to identify a load curve for each season, as was asked by our calculus software. Here below are reported the two excel files edited by the potential client for ASC and WPS electrical and gas consumption:

1-Apr-2013 to 7-Apr-2017

	Site	Account	From Date	Read Date	Est	Metered kWh	MD	kVA	Net Cost (£)	Net avg p/kWh	Gross (£)	VAT (£)	Bill this period (£)	CCLnet(£)	Billed kWh	Inv date
7	Abertillery Sports Centre	047231062	01/04/2013	30/04/2013		40.707	0	200	4.657,58	11,44	5.589,10	931,52	5.589,10	0,00	40.707,	01/05/2013
39			01/01/2016	31/01/2016		41.501	95	200	4.740,38	11,42	5.688,46	948,08	5.688,46	0,00	41.501,	01/02/2016
40			01/02/2016	29/02/2016		35.098	91	200	4.022,92	11,46	4.827,50	804,58	4.827,50	0,00	35.097,7	01/03/2016
41			01/03/2016	31/03/2016		35.036	85	200	4.075,60	11,63	4.887,56	811,96	4.887,56	0,00	35.035,9	08/04/2016
42			01/04/2016	30/04/2016		36.639	89	200	4.059,10	11,08	4.866,28	807,18	4.866,28	204,81	36.638,7	03/05/2016
43			01/05/2016	31/05/2016		38.315	95	200	4.243,71	11,08	5.087,08	843,37	5.087,08	214,18	38.314,7	01/06/2016
44			01/06/2016	30/06/2016		37.808	95	200	4.172,11	11,03	5.003,76	831,65	5.003,76	211,35	37.808,4	04/07/2016
45			01/07/2016	31/07/2016		38.519	101	200	4.239,69	11,01	5.087,62	847,93	5.087,62	215,32	38.518,7	02/08/2016
46			01/08/2016	31/08/2016		37.658	92	200	4.152,65	11,03	4.981,59	828,94	4.981,59	210,51	37.658,3	02/09/2016
47			01/09/2016	30/09/2016		37.085	92	200	3.866,23	10,43	4.639,47	773,24	4.639,47	207,31	37.085,2	04/10/2016
48			01/10/2016	31/10/2016		35.855	82	200	3.941,58	10,99	4.729,90	788,32	4.729,90	200,43	35.855,2	02/11/2016
49			01/11/2016	11/11/2016		12.935	79	200	1.416,56	10,95	1.699,87	283,31	1.699,87	72,31	12.935,4	01/12/2016
50			01/11/2016	11/11/2016		**-12.935**	**-79**	**-200**	**-1.416,56**	10,95	**-1.699,87**	**-283,31**	**-1.699,87**	**-72,31**	**-12.935,4**	01/12/2016
51			12/11/2016	30/11/2016		34.796	79	200	3.799,21	10,92	4.559,05	759,84	4.559,05	194,51	34.796,4	07/12/2016
52			12/11/2016	30/11/2016		**-34.796**	**-79**	**-200**	**-3.799,21**	10,92	**-4.559,05**	**-759,84**	**-4.559,05**	**-194,51**	**-34.796,4**	09/05/2017
53			01/11/2016	30/11/2016		34.972	79	200	3.804,43	10,88	4.565,32	760,89	4.565,32	195,49	34.971,5	09/05/2017
54			01/12/2016	31/12/2016		35.540	77	200	4.125,88	11,61	4.951,05	825,17	4.951,05	198,67	35.540,4	03/01/2017
55			01/12/2016	31/12/2016		**-35.540**	**-77**	**-200**	**-4.125,88**	11,61	**-4.951,05**	**-825,17**	**-4.951,05**	**-198,67**	**-35.540,4**	09/05/2017
56			01/12/2016	31/12/2016		35.848	76	200	4.137,19	11,54	4.964,63	827,44	4.964,63	200,39	35.848,2	09/05/2017
57			01/01/2017	31/01/2017		35.725	77	200	3.897,74	10,91	4.677,28	779,54	4.677,28	199,70	35.724,8	01/02/2017
58			01/02/2017	28/02/2017		32.394	77	200	3.533,34	10,91	4.240,01	706,67	4.240,01	181,08	32.394,4	02/03/2017
59			01/02/2017	28/02/2017		**-32.394**	**-77**	**-200**	**-3.533,34**	10,91	**-4.240,01**	**-706,67**	**-4.240,01**	**-181,08**	**-32.394,4**	09/05/2017
60			01/02/2017	28/02/2017		32.551	76	200	3.531,32	10,85	4.237,58	706,26	4.237,58	181,96	32.551,2	09/05/2017
61			01/03/2017	31/03/2017		39.185	90	200	4.298,12	10,97	5.157,75	859,63	5.157,75	219,04	39.184,6	04/04/2017
62			01/03/2017	31/03/2017		39.266	90	200	4.305,43	10,96	5.169,52	864,09	5.166,52	219,50	39.265,8	09/05/2017

Figure 13 ACS electricity bill

Electricity bills overview

1-Apr-2013 to 7-Apr-2017

	Site	Account	From Date	Read Date	Metered kWh	MD	kVA	Net Cost (£)	p/kWh	Gross (£)	VAT (£)	Bill this period (£)	Energy units (£)	Other (exCCL,En,Duos) (£)	'Fixd Chg1' (£)	Billed kWh	Inv date
7	Willowtown Community Primary School	4853210000	01/04/2013	30/04/2013	11.622	44	100	1.333,16	11,47	1.599,79	266,63	1.599,79	1.210,89	122,27	13,99	11622	01/05/2013
43			01/10/2015	31/10/2015	12.111	0	70	1.350,67	11,15	1.619,82	269,15	1.619,82	1.243,55	107,12	2,13	12111,2	02/11/2015
44			01/11/2015	30/11/2015	13.142	0	70	4.676,56	11,13	1.754,00	**-2.922,56**	4.967,95	1.361,62	3.314,94	2,1	13142,4	01/12/2015
45			01/12/2015	31/12/2015	11.554	0	70	2.957,35	11,20	1.550,09	**-1.407,26**	3.213,95	1.184,57	1.772,78	2,1	11553,6	04/01/2016
46			01/01/2016	31/01/2016	12.631	40	70	1.401,22	11,16	1.690,02	288,80	1.690,09	1.302,73	98,49	0	12631	01/02/2016
47			01/02/2016	29/02/2016	11.286	42	70	1.253,51	11,19	1.513,19	259,68	1.513,15	1.161,34	92,17	0	11286	01/03/2016
48			01/03/2016	31/03/2016	12.257	43	70	1.360,25	11,20	1.644,88	284,63	1.644,87	1.261,83	98,42	0	12257	08/04/2016
49			01/04/2016	30/04/2016	10.771	39	70	1.147,98	10,71	1.383,44	235,46	1.383,41	995,13	92,64	0	10771	03/05/2016
50			01/05/2016	31/05/2016	11.607	44	70	1.240,61	10,73	1.493,92	253,31	1.493,93	1.079,95	95,78	0	11607	06/06/2016
51			01/06/2016	30/06/2016	10.242	40	70	1.106,12	10,83	1.330,63	224,51	1.330,61	956,28	92,59	0	10242	04/07/2016
52			01/07/2016	31/07/2016	8.934	38	70	967,05	10,84	1.162,21	195,16	1.162,17	821,55	95,56	0	8934	02/08/2016
53			01/08/2016	31/08/2016	6.692	16	70	718,95	10,76	863,55	144,60	863,52	585,93	95,62	0	6692	02/09/2016
54			01/09/2016	30/09/2016	11.025	40	70	1.182,98	10,73	1.419,61	236,63	1.419,64	1.028,72	92,63	0	11025	04/10/2016
55			01/10/2016	31/10/2016	11.880	43	70	1.259,79	10,61	1.511,83	252,04	1.511,79	1.097,82	95,56	0	11880	02/11/2016
56			01/11/2016	30/11/2016	13.989	45	70	1.481,21	10,59	1.777,52	296,31	1.777,51	1.310,43	92,58	0	13989	01/12/2016
57			01/12/2016	31/12/2016	11.580	43	70	1.291,90	11,16	1.550,27	258,37	1.550,34	1.065,45	161,72	0	11580	03/01/2017
58			01/01/2017	31/01/2017	14.246	47	70	1.508,75	10,59	1.810,58	301,83	1.810,55	1.333,54	95,57	0	14246	01/02/2017
59			01/02/2017	28/02/2017	11.351	45	70	1.203,61	10,60	1.444,34	240,73	1.444,33	1.053,57	86,59	0	11351	02/03/2017
60			01/03/2017	31/03/2017	14.124	51	70	1.498,13	10,61	1.797,84	299,71	1.797,81	1.323,61	95,57	0	14124	03/04/2017

Figure 14 WPS electricity bill

Gas bills overview

Bills with Read dates in date range: 1-Apr-2013 to 31-Mar-2017

	Site	Account	From Date	Read Date	Est	Cons	Units	Cal.Val	Net Cost(£)	p/unit	Gross (£)	VAT(£)	CCLnet(£)	Inv.date	Bill this period (£)	Created date
7	Abertillery Sports Centre	20419673	02/03/2013	01/04/2013	E	137 503	kWh	39.30	4 350.01	3.164	5 220.01	870.	243.38	01/04/2013	5 220.01	23/04/2013
39		20419673	02/11/2015	01/12/2015		87 370	kWh	38.90	2 216.98	2.537	2 660.38	443.4	168.62	09/12/2015	2 660.38	15/12/2015
40		20419673	02/12/2015	01/01/2016		82 231	kWh	38.90	2 123.02	2.582	2 547.62	424.6	158.71	11/01/2016	2 547.62	15/01/2016
41		20419673	02/01/2016	01/02/2016		104 524	kWh	38.90	2 587.80	2.476	3 105.36	517.56	201.73	09/02/2016	3 105.36	12/02/2016
42		20419673	02/02/2016	01/03/2016		111 443	kWh	38.90	2 705.69	2.428	3 246.83	541.14	215.08	10/03/2016	3 246.83	10/03/2016
43		20419673	02/03/2016	01/04/2016		111 893	kWh	39.20	2 741.44	2.45	3 289.73	548.29	215.95	08/04/2016	3 289.73	19/04/2016
44		20419673	02/04/2016	01/05/2016		98 523	kWh	39.20	2 040.43	2.071	2 448.52	408.09	192.12	12/05/2016	2 448.52	18/05/2016
45		20419673	02/05/2016	01/06/2016		76 844	kWh	39.20	1 732.08	2.254	2 078.50	346.42	149.85	09/06/2016	2 078.50	10/06/2016
46		20419673	02/06/2016	01/07/2016		64 921	kWh	39.20	1 533.81	2.363	1 840.57	306.76	126.60	08/07/2016	1 840.57	11/07/2016
47		20419673	02/07/2016	01/08/2016		56 817	kWh	39.20	1 430.12	2.517	1 716.14	286.02	110.79	12/08/2016	1 716.14	16/08/2016
48		20419673	02/08/2016	01/09/2016		55 054	kWh	39.20	1 403.55	2.549	1 684.26	280.71	107.36	09/09/2016	1 684.26	14/09/2016
49		20419673	02/09/2016	01/10/2016		58 532	kWh	39.20	1 437.49	2.456	1 724.99	287.5	114.14	10/10/2016	1 724.99	10/10/2016
50		20419673	02/10/2016	01/11/2016		79 554	kWh	39.20	1 772.93	2.229	2 127.52	354.59	155.13	11/11/2016	2 127.52	15/11/2016
51		20419673	02/11/2016	01/12/2016		97 959	kWh	39.20	2 031.93	2.074	2 438.32	406.39	191.02	09/12/2016	2 438.32	14/12/2016
52		20419673	02/12/2016	01/01/2017		107 041	kWh	39.20	2 187.36	2.043	2 624.83	437.47	208.73	10/01/2017	2 624.83	13/01/2017
53		20419673	02/01/2017	01/02/2017		107 809	kWh	39.20	2 198.94	2.04	2 638.73	439.79	210.23	10/02/2017	2 638.73	10/02/2017
54		20419673	02/02/2017	01/03/2017		95 406	kWh	39.20	1 956.44	2.051	2 347.73	391.29	186.04	10/03/2017	2 347.73	14/03/2017

Figure 15 ASC gas bill

Gas bills overview

Bills Created during period: 1-Apr-2013 to 7-Apr-2017

	Site	Account	From Date	Read Date	Est	Cons	Units	Cal.Val	Net Cost(£)	p/unit	Gross (£)	VAT(£)	CCLnet(£)	Inv.date	Bill this period (£)	Created date
6	Willowtown Community Primary School	M04458	02/02/2013	01/03/2013		39 364	kWh	39.20	1 287.98	2.5992	1 545.57	257.59	69.67	09/03/2013	1 545.58	02/04/2013
42			02/10/2015	01/11/2015		19 331	kWh	39.20	604.30	2.03662	725.16	120.86	37.31	09/11/2015	725.15	10/11/2015
43			02/11/2015	01/12/2015		26 760	kWh	39.30	764.34	2.03661	917.21	152.87	51.65	09/12/2015	917.21	09/12/2015
44			02/12/2015	01/01/2016		36 903	kWh	39.20	996.07	2.03659	1 195.29	199.22	71.22	11/01/2016	1 195.30	12/01/2016
45			02/01/2016	01/02/2016		39 854	kWh	39.20	1 061.87	2.0366	1 274.25	212.38	76.92	09/02/2016	1 274.26	11/02/2016
46			02/02/2016	01/03/2016		39 353	kWh	39.30	1 039.51	2.03659	1 247.41	207.9	75.95	10/03/2016	1 247.40	10/03/2016
47			02/03/2016	01/04/2016		40 243	kWh	39.20	1 070.56	2.03661	1 284.67	214.11	77.67	08/04/2016	1 284.65	11/04/2016
48			02/04/2016	01/05/2016		27 798	kWh	39.30	647.31	1.44831	776.77	129.46	54.21	12/05/2016	776.77	16/05/2016
49			02/05/2016	01/06/2016		13 151	kWh	39.20	412.96	1.44834	495.55	82.59	25.64	09/06/2016	495.55	10/06/2016
50			02/06/2016	01/07/2016		7 725	kWh	39.30	317.45	1.44834	380.94	63.49	15.06	08/07/2016	380.93	11/07/2016
51			02/07/2016	01/08/2016		7 149	kWh	39.20	314.33	1.44833	377.20	62.87	13.94	12/08/2016	377.20	15/08/2016
52			02/08/2016	01/09/2016		5 646	kWh	39.20	289.63	1.44837	347.56	57.93	11.01	09/09/2016	347.56	12/09/2016
53			02/09/2016	01/10/2016		7 714	kWh	39.30	317.26	1.44824	380.71	63.45	15.04	10/10/2016	380.71	12/10/2016
54			02/10/2016	01/11/2016		23 807	kWh	39.70	588.06	1.44829	705.67	117.61	46.42	11/11/2016	705.68	11/11/2016
55			02/11/2016	01/12/2016		34 472	kWh	39.40	756.98	1.4483	908.38	151.4	67.22	09/12/2016	908.38	12/12/2016
56			02/12/2016	01/01/2017		35 121	kWh	39.30	774.00	1.44829	928.80	154.8	68.49	05/01/2017	928.80	13/01/2017
57			02/01/2017	01/02/2017		37 348	kWh	39.40	810.60	1.4483	972.72	162.12	72.83	10/02/2017	972.71	13/02/2017
58			02/02/2017	01/03/2017		35 614	kWh	39.40	763.04	1.44829	915.65	152.61	69.45	10/03/2017	915.66	13/03/2017

Figure 16 WPS gas bill

2.1.3 The load curve generation

Once we could quantify the energy load requested by the buildings we start to outline a load curve for each season of the year, differentiating summer from winter. This procedure is reasonable considering the higher need of electric energy during summer, due to the intensive use of air conditioning for examples, or the higher need of thermal energy during winter for heating reasons. A proper energy software has been used for the load curve design: HOMER ENERGY.

The HOMER Pro® micro grid software by HOMER Energy is the global standard for optimizing micro grid design in all sectors, from village power and island utilities to grid-connected campuses and military bases. This software originally was designed for the development of off grid plants based mainly on renewables energy, but it has been used in this case just for the construction of the load curve, which is one of its main features. Homer has a very well provided library in which different kind of load models have been developed in order to cover all the several load scenarios a designer may face during a grid implementation project. Before generating the load curve, the model has been chosen on the basis of the needs of the building considered, in particular we decided to select as a model for our case the "public buildings" models. Once the load model was selected, the load curve has been generated and the curve has its shape, as reported below:

Figure 17 Homer load curve

After the shape of the curve has been developed by Homer, we could work on excel with the data available from the energy bills. From the monthly energy bills, we extracted a mean value hour by hour per each day of the month, after we found a value it was necessary to multiply it for the factor obtained in Homer in order to have different values hour by hour starting from the mean value. More in details, we used a mediated value from the Homer load curve and applied it to the mean value of consumption per hour from the energy bills referred to each month of the year.

2.1.4 The implementation phase

In this tender call, the client expressly asked to implement a photovoltaic plant in order to cover part of the electrical load and a biomass boiler for the thermal load. For these reasons, we started to look for a software for the photovoltaic dimensioning request and a software for a biomass boiler-dimensioning request. At the end two software have been selected: "PVsys" for the photovoltaic plant design and "progetto biomasse" for the biomass boiler dimensioning. The first is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone, pumping and DC-grid (public transportation) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools. This software is geared to the needs of architects, engineers, researchers. The latter is an online software that gives you the order of magnitude of the biomass boiler depending on the available biomass material. It is important to remember that this software is able to give only a rough idea of the dimension of the boiler and it may be useful only for a first approach to the dimensioning of it, which is what was asked in the tender call.

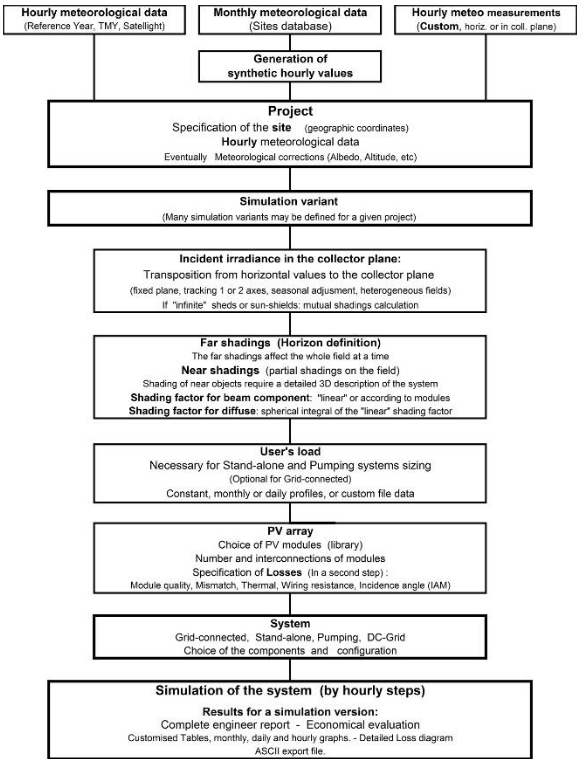

Figure 18 PVsys dimensioning procedure

2.2 The photovoltaic system

Let's focus now on the photovoltaic system dimensioning and give a look to all the steps needed to dimension the system in a proper way. The design path is showed on the side image; once we obtained reliable values hour per hour for each month of the year the first step in the PVsys is to identify the site of the project, which was Blaenau Gwent, with the right values of longitude, latitude and altitude of the site. Next step was to consider the orientation of the building itself respect to the North direction and the tilt angle of the photovoltaic panels. As showed below:

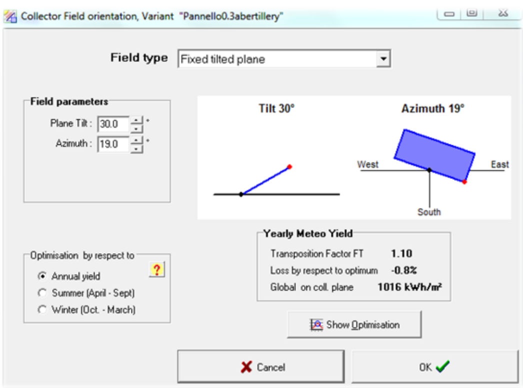

Figure 19 Building orientation

This kind of data were not available in the tender documentation, but we had to extract them: starting from the trivial Google maps images and from the North direction we easily calculated the angle between the North direction and the tangent of one side of the building and put that value in the software. Considering the tilt angle value, the optimal value of 30° has been chosen, because all the roof used were flat and did not consider a further analysis on the optimal tilt angle.

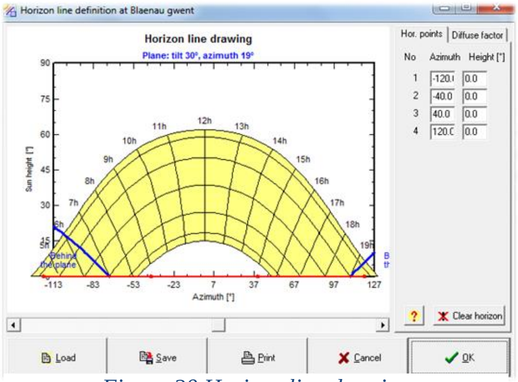

Figure 20 Horizon line drawing

Next step is the horizon line drawing, in which is requested to define any shadings for objects at least ten times far away the photovoltaic field size. In the selected buildings we did not have these kind of problems and the standard model of horizon drawing has been implemented. As mentioned before this step considered only the far shadings problem, the next step instead the near shading problem, in this window is necessary to define if any object may cause the shadowing of any panel installed. As already said the building considered in this work do not have these kind of problem thanks to the height of the building itself and the absence of any disturbing object near the building. After all these introduction measures, it was finally possible to define the load curve and set the values obtained thanks to Homer and Excel into the PVsys software.

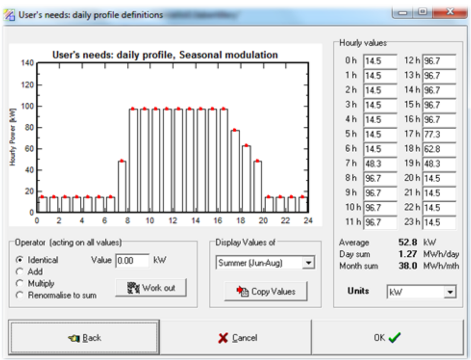

Figure 21 Load curve implementation

Thus values had been introduced for single hours of the day per each season of the year, because we selected the voices “Daily profiles” and “Seasonal modulation”. Last thing to do after the load profile has been inserted in the software is to enter the information that the plant on which we are working on will be connected to grid. The fact that we are working with a grid connected buildings is not negligible for the project implementation, in particular referring to the energy storage issue.

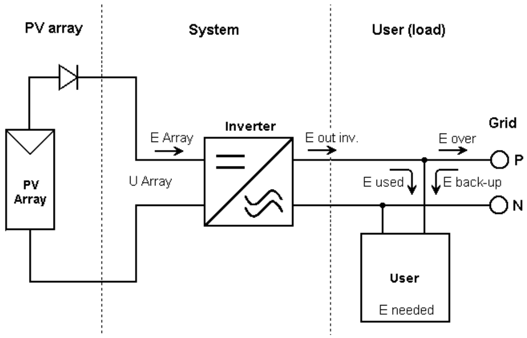

Figure 22 Plant scheme

As well known, an important problem of renewable sources is the dispatchability of energy, which is not always available as per the traditional sources but it depends on the source availability (sunny day or windy day). To avert this problem usually renewables technologies are accompanied by energy storage units, as batteries. In this project the buildings considered are connected to the grid, for this reason we decided to avoid any unit of storage and to release the extra electrical power directly in the grid instead of store it in a battery. This decision was taken after some considerations: first, unit of storage are usually expensive and the use of it would have a remarkable impact on the investment dimension, secondly the space required for this kind of technology is not negligible and lastly the UK government gives incentives for the operator that releases back to the grid the electrical energy produced, doing so these incentives could reduce the investments and reduce the payback time of it. The scheme of our designed project is reported on the side. After this last step, it could be finally possible start to work on the dimensioning of the photovoltaic plant. In order to achieve the best result some constraints have to be considered: we had to respect different problems of physical, technical and economic nature. On one side it was necessary to consider the available space on the roof of the buildings where to install the modules, on the other side we had to find the best technical solution in terms of number of modules, number of inverters, power of modules, power of inverter and array disposition (in series or in parallel disposition). Before starting with the iterative process to determine the best trade off solution among all the possible solutions, the calculation of the available space on the roof has to be implemented. To do that it had been trivially used the google maps software and its function "measure distance" on the buildings roofs, reducing the area founded by the 25% in order to keep in consideration, during the calculation, that some space may not be usable and that part of the usable space was needed for the plant support and auxiliary structure.

Figure 23 Building measurement

2.2.1 The preliminary dimensioning phase

Finally, the real dimensioning phase began in which we had to find the best trade off solution. The PVsys software shall make available to the user hundreds of different modules, inverters and units of storage, so many to achieve thousands of different configurations, so it was necessary to select some starting option in order to reduce the number of available variables and work only on some of them, chosen with some basis. In the first part of the dimensioning it had been attempted to use several configuration of panels and inverters in order to try to estimate which range of peak power was more suitable for the available space and for the load at hand.

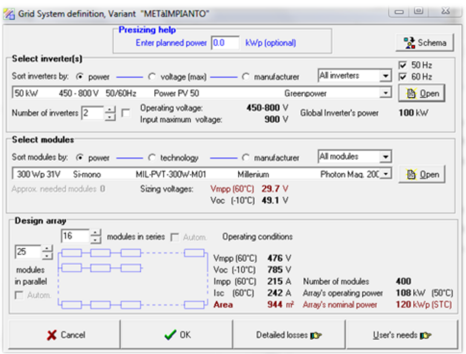

Figure 24 PVsys operative window

After several tries considering the photovoltaic panels, a set of peak power had been selected because of their results. Those peak power could lead to a suitable panels area and on that values the dimensioning of the inverter was based. Numerically speaking a range from 200W to 600W nominal power for the panels and from 50kW ac to 60kW ac for the inverter.

2.2.2 Abertillery case study preliminary results:

Inverters

- G334 Leonics: operating voltage 165-300V, global power:42kW, max voltage 350V
- SUNWAY TG 57 Santerno: operating voltage 430-760V, global power 43.6 kWac, max voltage 880V
- SUNWAY TG 61 Santerno: operating voltage 315-630V, global power 46.9 kWac, max voltage: 740V
- SOLARMAX 60 Sputnik: operating voltage 430-800V, global power:50.8 kWac, max voltage 900V
- SOLARMAX 60 Sputnik: operating voltage 430-800V, global power 50.8 kWac, max voltage 900V
- IPG 60K Conergy: operating voltage:493-780V, global power: 54.0 kWac, max voltage: 965V
- SUNWAY TG 71 Santerno: operating voltage: 430-760V, global power: 54.5 kWac, max voltage: 880V
- SINVERT SOLAR Siemens: operating voltage 450-750V, global power 57 kWac, max voltage 900V

Panels modules

- Titan 32-230 by Titan Energy: Vmpp (60°C) 45.8 V Voc(-10°C) 71.7V
- Titan 24-150 by Titan Energy: Vmpp (60°C) 29.1 V Voc(-10°C) 47.0V
- Vsg 435 by Ertex Solar: Vmpp (60°C) 51.2 V Voc(-10°C) 82.2V
- Vsg 580 Ertex Solar: Vmpp (60°C) 45.8 V Voc(-10°C) 71.7V

2.2.3 Willowtown case study results:

Inverters

- IPG 60K Conergy: operating voltage 493-780V, global power 54.0 kWac, max voltage 965V
- SUNWAY TG 71 Santerno: operating voltage 430-760V, global power 54.5 kWac, max voltage 880V
- SINVERT SOLAR Siemens: operating voltage 450-750V, global power 57 kWac, max voltage 900V
- SUNWAY TG 82 Santerno: operating voltage 430-760V, global power 62.7 kWac, max voltage 880V
- SIRIO 80 K Aros: operating voltage 330-700V, global power 65.0 kWac, max voltage 800V
- SUNWAT TG 90 Santerno: operating voltage 315-630V, global power 68.4 kWac, max voltage 740V
- SUNNY CENTRAL 60 SMA: operating voltage 450-800V, global power 60 kWac, max voltage 880 V.

Panels modules:

- Titan 32-300 by Titan Energy, Vmpp: (60°C) 29.4 V Voc(-10°C) 49.2V
- Titan 32-300 by Titan Energy, Vmpp: (60°C) 45.8 V Voc(-10°C) 71.7V
- Vsg 435 by Ertex Solar, Vmpp: (60°C) 51.2 V Voc(-10°C) 82.2V
- Vsg 580 by Ertex Solar, Vmpp: (60°C) 68.2 V Voc(-10°C) 109.5V
- Titan 32-230 by Titan Energy, Vmpp: (60°C) 45.8 V Voc(-10°C) 71.7V
- Titan 24-150 by Titan Energy, Vmpp: (60°C) 29.1 V Voc(-10°C) 47.0V

2.2.4 The dimensioning phase

After the selection of these models a first calculation was started, during which we let the program run each time for a different panel and with a different inverter. For each combination of panels, the best configuration in series or in parallel had to be found; we tried to set the arrays in different formation, series and parallel, in order to get the maximum power respecting the constraint of the available space on the roof, which was the discriminating factor to respect it compulsorily. After the best trade off among power and occupied space was found, it was necessary to start a first economic analysis in order to understand the order of magnitude of the investment requested and to have roughly an idea on which investment may be convenient. To do that a first approach payback time had been implemented, in which only the materials cost had been considered and not the installation and maintenance costs or the other voices included in the real payback time. The reason of this decision is that all the other voices not considered in this first approach payback time are very similar in the two cases considered because the modules total prices are almost the same and we considered the cost of installation and maintenance as a percentage of the total photovoltaic modules cost. It is necessary to remember that the payback period had to be maximum 8 years for normal buildings and 10 years for schools, as the tender clearly indicates. In this first part of the economic analysis we trivially calculated the payback period considering the earnings from the new investments and the total costs that the investment meant. Considering the earnings, we had to consider two sources: one is the saved money the client would not have to spend anymore because it is receiving electrical energy from the photovoltaic field and the other source is the money the client would be receiving while selling electrical energy back to the national service provider. The next is to introduce some formula used in this first approach to the payback period calculation, the following formula will show how the cost of photovoltaic modules, supports for the plant and inverters cost were obtained from the information the PVsys produced. In particular, each configuration implemented in the system gave as an output many values as:

- Number of modules
- Number of inverter
- Number of modules support
- Energy produced by the PV field
- Energy from the PV field reinserted in the grid
- Energy from the PV consumed by the building
- Energy taken from the grid
- Energy needed by the building

Starting from these data we had to introduce some economic values and some general costs as:

- Module price
- Inverter price
- Plant support price

These values had been partially obtained by real Italian suppliers and partially calculated from the available data. We started form the prices we could find contacting some of our suppliers and from those numbers we tried to identify the prices of every modules and inverters we used. Working on these kind of data it had to be extracted some economic results as:

- Photovoltaic modules cost
- Plant support cost
- Total inverter cost

All these above values were used to calculate our first payback period and thus to decide on which plant configuration would be implemented the HLA economic analysis. To obtain the photovoltaic modules we trivially multiplied the modules number for the module price:

$$Tot_{modules_{cost}} = N_{modules} * Module_{price}$$

Same procedure for the plant support total cost:

$$Tot\_support\ \_cost = N_{support} * Support_{price}$$

In which the number of supports had been identified as a percentage of the total number of module, the 30% of the total number of modules.

$$Tot\_inverter\_cost = N_{inverter} * Inverter_{price}$$

The total investment in this first part resulted as the sum of the three costs calculated before:

$$Tot\_invest = \sum tot\_cost$$

Considering now the earnings, they had been calculated, as explained before, by the product of the electrical energy produced by the photovoltaic field time the energy price you would had pay that electrical energy from the grid:

$$\Delta€_{saved} = E_{pv} * E_{price}$$

The other earnings come from the energy produced by the photovoltaic system, that cannot be consumed by the building in that moment and so is reinserted in the national grid, which buy it at an incentive price.

$$\Delta€_{earned} = E_{pv}{}' * E_{price}$$

Summing now these two voices we could obtain the total amount of money the client could obtain thanks to this investment:

$$\Delta€_{tot} = \Delta€_{saved} + \Delta€_{earned}$$

And finally with the total cost calculated before and the total earned money we could obtain our first approach payback period:

$$PBT = \frac{Tot_{invest}}{\Delta€_{tot}}$$

Here below reported the payback time of all the modules implemented in the project:

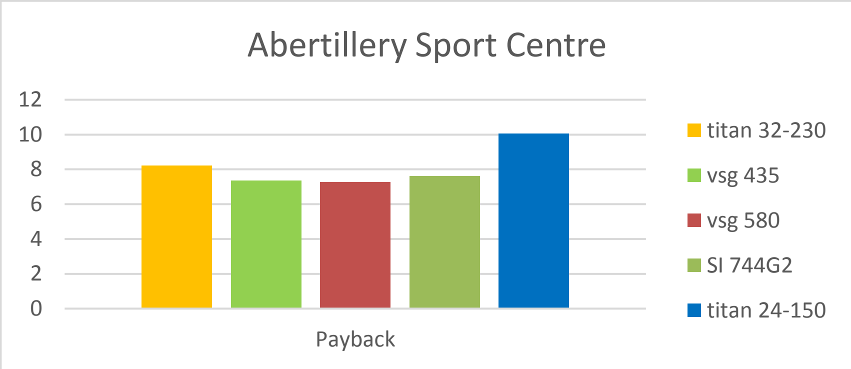

Figure 25 Abertillery payback comparison

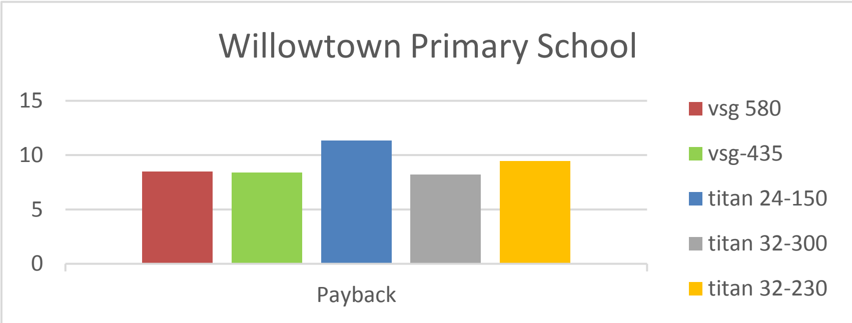

Figure 26 Willowtown payback comparison

2.2.5 The PVsys results

From the two graphs is possible to see that the best solution is:

- Abertillery: VSG 580 module (4.5 m^2 per module) and SOLARMAX 50 C inverter
- Willotown: titan 32-300 module (2.5 m^2 per module) and Sunny central 60 inverter

these are the two cases with the shortest payback period which means the most convenient investment. Here are reported some characteristic of the panels and the inverters respectively for the Abertillery Sport Centre and the Willowtown Primary School,

SolarMax	50C	80C	100C	300C
Lato ingresso (DC)				
Massima potenza DC*	66 kW	105 kW	130 kW	400 kW
Intervallo di tensione PPM	430…800 VDC			
Massima tensione di ingresso	900 VDC			
Intervallo di tensione STC generatore solare (aiuto per la definizione della commutazione del modulo nelle celle SI mono e poli)	540…635 VDC			
Corrente d'ingresso	0…120 ADC	0…180 ADC	0…225 ADC	0…720 ADC
Picchi di corrente	<4 % peak-peak			
Lato d'uscita (AC)				
Potenza nominale	50 kW	80 kW	100 kW	300 kW
Prestazione max	55 kW	88 kW	110 kW	330 kW
Tensione	3 * 400 +10 % / –15 % VAC			
Corrente d'uscita	0…77 AAC	0…122 AAC	0…153 AAC	0…459 AAC
Fattore di potenza (FP)	>0,98			
Frequenza nominale di rete / Campo	50 Hz / 45...52 Hz			
Fattore di distorsione	<3 %			
Dati di sistema				
Consumo notturno	2…7 W			
Rendimento massimo	96 %			
Rendimento europeo	94,8 %			
Temperatura ambiente	–20 °C…40 °C			
Grado di protezione	IP20			
Programma di accensione	PWM (IGBT) con trasformatore			
Umidità relativa	0...98 %, nessuna condensa			
CE conforme, a norma	EN 61000-6-2, EN 61000-6-4, EN 50178			
Test	„Typ Bauart geprüft" TÜV Rheinland			
Indicazione	Display LC a due righe, con retroilluminazione			
Comunicazione dati	Interfaccia RS232 / RS485 integrata			
Dimensioni (LxPxH)	120 x 80 x 130 cm			2 x 120 x 80 x 180
Peso	735 kg	805 kg	935 kg	2600 kg

Figure 27 Abertillery inverter characteristics

Electrical Characteristics	
STC Power Rating P_{mp} (W)	580
Open Circuit Voltage V_{oc} (V)	98.7
Short Circuit Current I_{sc} (A)	7.81
Voltage at Maximim Power V_{mp} (V)	79.1
Current at Maximim Power I_{mp} (A)	7.33
Panel Efficiency	13.4%
Fill Factor	75.2%
Power Tolerance	-5.00% ~ 5.00%
Maximum System Voltage V_{max} (V)	1000
Maximum Series Fuse Rating (A)	
Temperature Coefficients	
Temperature Coefficiency of I_{sc}	0.030 %/ºC
Temperature Coefficiency of V_{oc}	-0.32 %/ºC
Temperature Coefficiency of P_{mp}	
Mechanical Characteristics	
Cell Type	Polycrystalline Cell

Figure 28 Abertillery panel characteristics

Technical Data	Sunny Tripower 60
Input (DC)	
Max. generator power	90000 Wp
Rated power (DC)	61240 W
Max. input voltage	1000 V
MPP voltage range (at 400 Vac / 480 Vac)	570 V to 800 V / 685 V to 800 V
Min. input voltage (at 400 Vac / 480 Vac)	565 V / 680 V
Start input voltage (at 400 Vac / 480 Vac)	600 V / 720 V
Max. input current / max. short-circuit current	110 A / 150 A
Number of independent MPP inputs/strings per MPP input	1/1 (split up in external combiner box)
Rated DC input voltage (at 400 Vac / 480 Vac)	630 V / 710 V
Output (AC)	
Rated power at nominal voltage	60000 W
Max. apparent AC power	60000 VA
Max. reactive power	60000 Var
Nominal AC voltage	3 / PE, 400 V to 480 V, ±10 %
AC voltage range	360 V to 530 V
AC power frequency/range	50 Hz / 44 Hz to 55 Hz 60 Hz / 54 Hz to 65 Hz
Rated power frequency/rated grid voltage	50 Hz / 400 V
Max. output current (at 400 Vac / 480 Vac) / rated output current	87 A / 72 A / 87 A
Power factor at rated power / displacement power factor adjustable	1 / 0 overexcited to 0 underexcited
THD	≤ 1 %
Feed-in phases/connection phases	3 / 3
Efficiency	
Max. efficiency / Euro-eta / CEC at 400 Vac / CEC at 480 Vac	98.8 % / 98.3 % / 98.0 % / 98.5 %
Protective devices	
Input-side disconnection point	●
Ground fault monitoring/grid monitoring	● / ●
Integrable DC surge arrester / AC surge arrester	Type II / type II + III (combined)
AC short-circuit current capability / galvanically isolated	● / –
All-pole sensitive residual-current monitoring unit	●
Protection class (as per IEC 62109-1) / overvoltage category (as per IEC 62109-1)	I / AC: III; DC: II
General data	
Dimensions (W/H/D)	570 / 740 / 300 mm (22.4 / 29.1 / 11.8 inches)
Weight	75 kg (165.3 lb)
Operating temperature range	-25°C to +60°C (-13°F to +140°F)
Noise emission, typical	58 dB(A)
Self-consumption (at night)	< 3 W
Topology / cooling concept	Transformerless / active
Degree of protection (according to IEC 60529 / UL 50E)	IP65 / NEMA 3R
Climatic category (as per IEC 60721-3-4)	4K4H/4Z4/4B2/4S3/4M2/4C2
Max. permissible value for relative humidity (non-condensing)	95 %

Figure 29 Willowtown inverter characteristics

Electrical Characteristics	
STC Power Rating P_{mp} (W)	300
Open Circuit Voltage V_{oc} (V)	44.0
Short Circuit Current I_{sc} (A)	9.60
Voltage at Maximim Power V_{mp} (V)	36.5
Current at Maximim Power I_{mp} (A)	8.50
Panel Efficiency	11.0%
Fill Factor	71.0%
Power Tolerance	-5.00% ~ 5.00%
Maximum System Voltage V_{max} (V)	
Maximum Series Fuse Rating (A)	
Temperature Coefficients	
Temperature Coefficiency of I_{sc}	
Temperature Coefficiency of V_{oc}	
Temperature Coefficiency of P_{mp}	
Mechanical Characteristics	
Cell Type	Polycrystalline Cell

Figure 30 Willowtown panel Characteristics

Thanks to PVcalc, an online software, we could estimate also the Levelised Cost of Energy and the Internat Rate of Return.

Project Summary:	
Nominal power (kWp)	245
Purchase value (GBP)	294000
Own Funds (GBP)	294000
Loan amount (GBP)	0
Present value of net income' (GBP)	534456
Levelised energy cost (€/kWh)	0.128
Loan type	Redeemable
Amortisation time (y)	8.6
Dividend (GBP)	NA
Dividend (%)	NA
IRR before tax (%)	9.5
Eff. tax rate (%)	0.0
IRR (%)	9.5

Figure 31Willowtown fincial summary

Project Summary:	
Nominal power (kWp)	232
Purchase value (GBP)	208800
Own Funds (GBP)	208800
Loan amount (GBP)	0
Present value of net income' (GBP)	520285
Levelised energy cost (€/kWh)	0.096
Loan type	Redeemable
Amortisation time (y)	6.7
Dividend (GBP)	NA
Dividend (%)	NA
IRR before tax (%)	13.8
Eff. tax rate (%)	0.0
IRR (%)	13.8

Figure 32 Abertillery financial summary

Moreover here below are reported the summary files produced by the system in which are summarised all the main information about the project site, project implemented technologies and loads.

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Grid-Connected System: Simulation parameters

Project :	**abertillery sport center**			
Geographical Site	**Blaenau gwent**		**Country**	**United Kingdom**
Situation	Latitude	51.8°N	Longitude	3.2°W
Time defined as	Legal Time	Time zone UT+0	Altitude	100 m
	Albedo	0.20		
Meteo data :	Blaenau gwent , synthetic hourly data			
Simulation variant :	**Simulation variant**			
	Simulation date	09/10/17 14h50		

Simulation parameters				
Collector Plane Orientation	Tilt	30°	Azimuth	-75°
Horizon	Free Horizon			
Near Shadings	No Shadings			
PV Array Characteristics				
PV module Si-poly	Model	**VSG 580**		
	Manufacturer	Ertex Solar		
Number of PV modules	In series	8 modules	In parallel	50 strings
Total number of PV modules	Nb. modules	400	Unit Nom. Power	580 Wp
Array global power	Nominal (STC)	**232 kWp**	At operating cond.	208 kWp (50°C)
Array operating characteristics (50°C)	U mpp	578 V	I mpp	359 A
Total area	Module area	**1731 m²**		
PV Array loss factors				
Heat Loss Factor	ko (const)	29.0 W/m²K	kv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C, wind 1 m/s)			NOCT	45 °C
Wiring Ohmic Loss	Global array res.	52.5 mOhm	Loss Fraction	3.0 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss			Loss Fraction	3.0 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1-bo (1/cos i - 1)	bo Parameter	0.05
System Parameter	System type	**Grid-Connected System**		
Inverter	Model	**SOLARMAX 50C**		
	Manufacturer	Sputnik		
Inverter Characteristics	Operating Voltage	430-800 V	Unit Nom. Power	50 kW AC
Inverter pack	Number of Inverter	4 units	Total Power	200 kW AC
User's needs :	daily profile	Seasonal modulation		
	average	1238 kWh/Day		

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Grid-Connected System: Detailed User's needs

Project : **abertillery sport center**

Simulation variant : **Simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	-75°
PV modules	Model	VSG 580	Pnom	580 Wp
PV Array	Nb. of modules	400	Pnom total	**232 kWp**
Inverter	Model	SOLARMAX 50C	Pnom	50 kW ac
Inverter pack	Nb. of units	4	Pnom total	**200 kW ac**
User's needs	daily profile	Seasonal modulation	global	452 MWh/year

daily profile, Seasonal modulation, average = 1238 kWh/day

	0 h 12 h	1 h 13 h	2 h 14 h	3 h 15 h	4 h 16 h	5 h 17 h	6 h 18 h	7 h 19 h	8 h 20 h	9 h 21 h	10 h 22 h	11 h 23 h	
Summer	14.5 96.7	14.5 96.7	14.5 96.7	14.5 96.7	14.5 96.7	14.5 77.3	14.5 62.8	48.3 48.3	96.7 14.5	96.7 14.5	96.7 14.5	96.7 14.5	kW kW
Autumn	13.7 91.5	13.7 91.5	13.7 91.5	13.7 91.5	13.7 91.5	13.7 73.2	13.7 59.5	45.8 45.7	91.5 13.7	91.5 13.7	91.5 13.7	91.5 13.7	kW kW
Winter	14.3 95.4	14.3 95.4	14.3 95.4	14.3 95.4	14.3 95.4	14.3 76.3	14.3 62.0	47.7 47.7	95.4 14.3	95.4 14.3	95.4 14.3	95.4 14.3	kW kW
Spring	14.0 93.3	14.0 93.3	14.0 93.3	14.0 93.3	14.0 93.3	14.0 74.6	14.0 60.6	46.6 46.6	93.3 14.0	93.3 14.0	93.3 14.0	93.3 14.0	kW kW

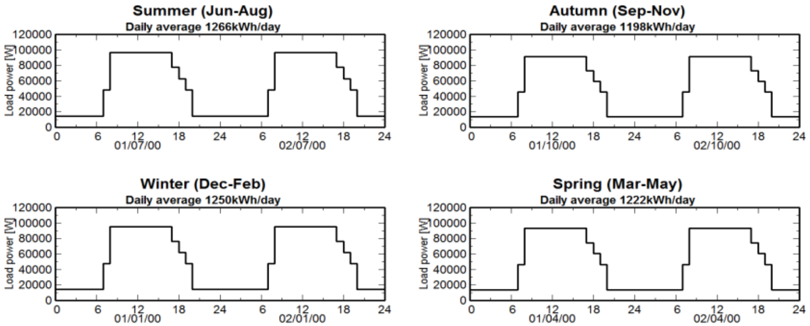

Figure 33 Abertillery summary PVsys report

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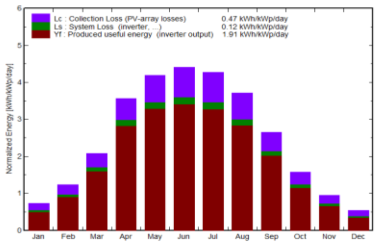
Grid-Connected System: Main results

Project : **abertillery sport center**
Simulation variant : **Simulation variant**

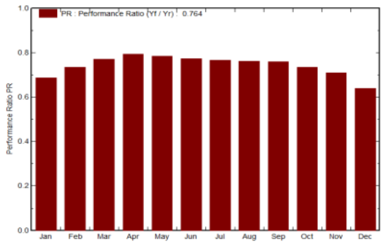
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	-75°
PV modules	Model	VSG 580	Pnom	580 Wp
PV Array	Nb. of modules	400	Pnom total	**232 kWp**
Inverter	Model	SOLARMAX 50C	Pnom	50 kW ac
Inverter pack	Nb. of units	4	Pnom total	**200 kW ac**
User's needs	daily profile	Seasonal modulation	global	452 MWh/year

Main simulation results				
System Production	**Produced Energy**	**161 MWh/year**	Specific	696 kWh/kWp/year
	Performance Ratio PR	76.4 %		

Normalized productions (per installed kWp): Nominal power 232 kWp



Performance Ratio PR



Simulation variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	EOutInv kWh	EffArrR %	EffSysR %
January	20.0	3.40	22.6	21.4	3980	3604	10.16	9.20
February	33.0	3.60	34.4	32.8	6361	5860	10.68	9.84
March	63.0	5.70	64.3	61.8	12307	11510	11.05	10.34
April	105.0	8.00	106.9	103.2	20832	19691	11.26	10.64
May	136.0	11.20	129.8	125.1	24987	23641	11.12	10.52
June	138.0	14.10	132.4	127.7	25129	23750	10.97	10.36
July	139.0	16.00	132.5	127.8	24920	23558	10.86	10.27
August	120.0	15.90	115.3	111.1	21609	20398	10.83	10.22
September	81.0	13.70	79.7	76.5	14961	14057	10.84	10.19
October	47.0	10.40	48.8	46.4	8951	8306	10.60	9.83
November	25.0	6.70	28.3	26.9	5084	4650	10.39	9.50
December	15.0	4.60	16.6	15.6	2764	2459	9.64	8.58
Year	922.0	9.48	911.5	876.4	171884	161485	10.89	10.23

Legends:	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	EOutInv	Available Energy at Inverter Output
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

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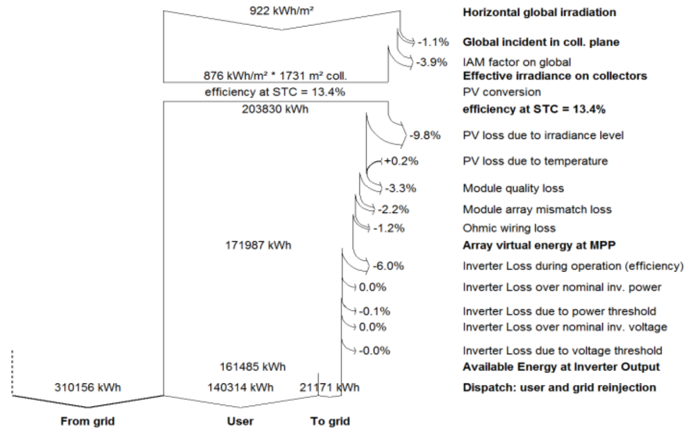
Grid-Connected System: Loss diagram

Project : **abertillery sport center**
Simulation variant : **Simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	-75°
PV modules	Model	VSG 580	Pnom	580 Wp
PV Array	Nb. of modules	400	Pnom total	**232 kWp**
Inverter	Model	SOLARMAX 50C	Pnom	50 kW ac
Inverter pack	Nb. of units	4	Pnom total	**200 kW ac**
User's needs	daily profile	Seasonal modulation	global	450 MWh/year

Loss diagram over the whole year



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Grid-Connected System: Simulation parameters

Project :	**Willotown primary school**			
Geographical Site		**Blaenau Gwent**	**Country**	**United Kingdom**
Situation	Latitude	51.8°N	Longitude	3.2°W
Time defined as	Legal Time	Time zone UT+0	Altitude	100 m
	Albedo	0.20		
Meteo data :	Blaenau Gwent , synthetic hourly data			
Simulation variant :	**IMPIANTO INTERI**			
	Simulation date	04/10/17 16h40		

Simulation parameters

Collector Plane Orientation	Tilt	30°	Azimuth	26°
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module Si-mono	Model	TITAN 32-300		
	Manufacturer	Millenium		
Number of PV modules	In series	16 modules	In parallel	51 strings
Total number of PV modules	Nb. modules	816	Unit Nom. Power	300 Wp
Array global power	Nominal (STC)	**245 kWp**	At operating cond.	220 kWp (50°C)
Array operating characteristics (50°C)	U mpp	499 V	I mpp	442 A
Total area	Module area	**1926 m²**		

PV Array loss factors

Heat Loss Factor	ko (const)	29.0 W/m²K	kv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C, wind 1 m/s)			NOCT	45 °C
Wiring Ohmic Loss	Global array res.	36.1 mOhm	Loss Fraction	2.9 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss			Loss Fraction	3.0 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1-bo (1/cos i - 1)	bo Parameter	0.05

System Parameter	System type	**Grid-Connected System**		
Inverter	Model	**Sunny Central 60**		
	Manufacturer	SMA		
Inverter Characteristics	Operating Voltage	450-800 V	Unit Nom. Power	60 kW AC
Inverter pack	Number of Inverter	3 units	Total Power	180 kW AC
User's needs :	daily profile	Seasonal modulation		
	average	357 kWh/Day		

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Grid-Connected System: Detailed User's needs

Project : **Willotown primary school**
Simulation variant : **IMPIANTO INTERI**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	26°
PV modules	Model	TITAN 32-300	Pnom	300 Wp
PV Array	Nb. of modules	816	Pnom total	**245 kWp**
Inverter	Model	Sunny Central 60	Pnom	60 kW ac
Inverter pack	Nb. of units	3	Pnom total	**180 kW ac**
User's needs	daily profile	Seasonal modulation	global	130 MWh/year

daily profile, Seasonal modulation, average = 357 kWh/day

	0 h / 12 h	1 h / 13 h	2 h / 14 h	3 h / 15 h	4 h / 16 h	5 h / 17 h	6 h / 18 h	7 h / 19 h	8 h / 20 h	9 h / 21 h	10 h / 22 h	11 h / 23 h	
Summer	3.30	3.30	3.30	3.30	3.30	3.30	3.30	11.00	21.90	21.90	21.90	21.90	kW
	21.90	21.90	21.90	21.90	21.90	17.50	14.20	10.90	3.30	3.30	3.30	3.30	kW
Autumn	4.70	4.70	4.70	4.70	4.70	4.70	4.70	15.60	31.30	31.30	31.30	31.30	kW
	31.30	31.30	31.30	31.30	31.30	25.00	20.30	15.60	4.70	4.70	4.70	4.70	kW
Winter	4.50	4.50	4.50	4.50	4.50	4.50	4.50	15.10	30.10	30.10	30.10	30.10	kW
	30.10	30.10	30.10	30.10	30.10	24.10	19.60	15.00	4.50	4.50	4.50	4.50	kW
Spring	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	14.30	29.40	29.40	kW
	29.40	29.40	29.40	29.40	29.40	23.50	19.10	14.70	4.40	4.40	4.40	4.40	kW

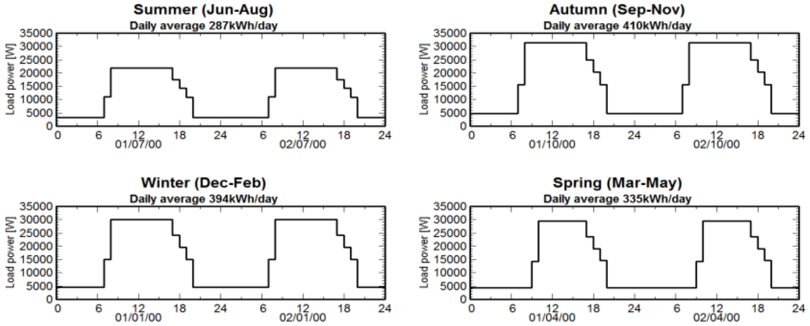

Figure 34 Willowtown summary PVsys report

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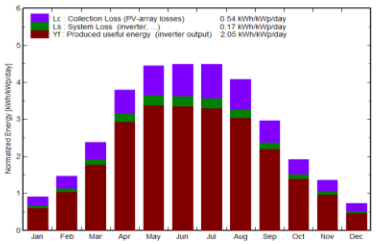
Grid-Connected System: Main results

Project : **Willotown primary school**
Simulation variant : **IMPIANTO INTERI**

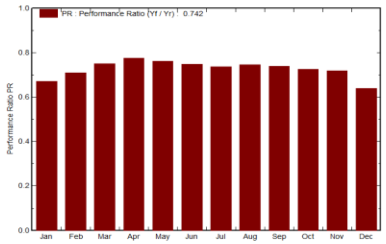
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	26°
PV modules	Model	MIL-PVT-300W-M01	Pnom	300 Wp
PV Array	Nb. of modules	816	Pnom total	**245 kWp**
Inverter	Model	Sunny Central 60	Pnom	60 kW ac
Inverter pack	Nb. of units	3	Pnom total	**180 kW ac**
User's needs	daily profile	Seasonal modulation	global	130 MWh/year

Main simulation results				
System Production	**Produced Energy**	**183 MWh/year**	Specific	747 kWh/kWp/year
	Performance Ratio PR	74.2 %		

Normalized productions (per installed kWp): Nominal power 245 kWp



Performance Ratio PR



IMPIANTO INTERI

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	EOutInv kWh	EffArrR %	EffSysR %
January	20.0	3.40	28.3	27.1	5128	4640	9.42	8.53
February	33.0	3.60	41.0	39.4	7820	7124	9.91	9.03
March	63.0	5.70	73.7	71.1	14685	13519	10.35	9.53
April	105.0	8.00	113.8	110.0	23271	21583	10.62	9.85
May	136.0	11.20	137.8	133.3	27764	25748	10.46	9.70
June	138.0	14.10	134.7	130.0	26640	24685	10.27	9.52
July	139.0	16.00	139.1	134.6	27120	25111	10.13	9.37
August	120.0	15.90	126.7	122.4	24922	23110	10.22	9.48
September	81.0	13.70	89.1	86.0	17482	16143	10.19	9.41
October	47.0	10.40	59.4	57.2	11492	10556	10.04	9.22
November	25.0	6.70	40.5	38.9	7793	7132	9.98	9.14
December	15.0	4.60	22.7	21.8	3949	3548	9.05	8.13
Year	922.0	9.48	1006.6	971.7	198066	182898	10.22	9.43

Legends:	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	EOutInv	Available Energy at Inverter Output
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

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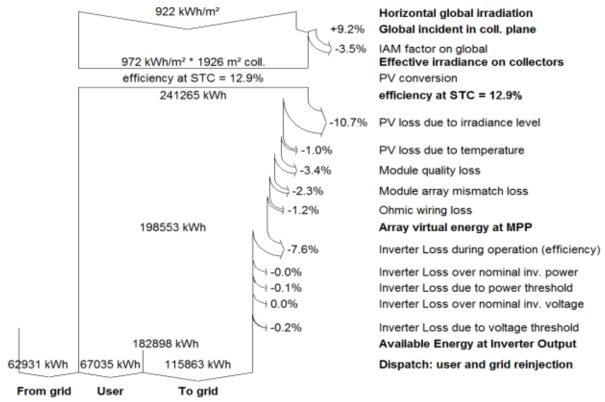
Grid-Connected System: Loss diagram

Project : **Willotown primary school**
Simulation variant : **IMPIANTO INTERI**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	26°
PV modules	Model	MIL-PVT-300W-M01	Pnom	300 Wp
PV Array	Nb. of modules	816	Pnom total	**245 kWp**
Inverter	Model	Sunny Central 60	Pnom	60 kW ac
Inverter pack	Nb. of units	3	Pnom total	**180 kW ac**
User's needs	daily profile	Seasonal modulation	global	130 MWh/year

Loss diagram over the whole year



2.2.6 Comments on results

Here are reported some graphs on the results obtained thanks to the PVsys implementation, in order to give a more clear idea of what are the results obtained. The first three graphs are referred to the Abertillery case.

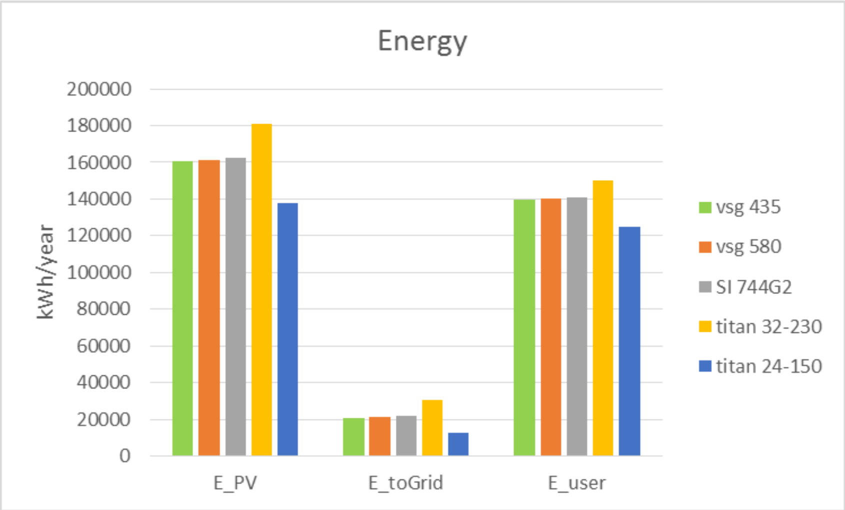


Figure 35 Abertillery PV energy summary

Is possible to notice how the order of magnitude of energy produced E_PV is similar for most of the modules, some deviations for the modules with the least nominal power. The same trend is proposed for the energy transferred to the grid and the consumed by the user, because those values are a percentage of the produced energy.

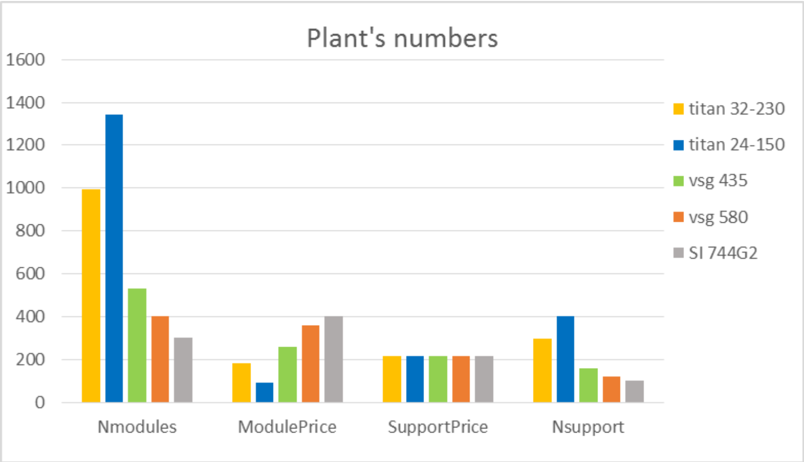


Figure 36 Characteristic plant's numbers

Those values resulted useful to determine the initial investment cost because are related to the operative structure of the plant. The best solution resulted to have a mean module price but a lower number of supports due to the smaller quantity of modules requested. The support price was considered the same for all the modules but the quantity of it changed with the number of modules requested. As a matter of fact, the number of support, Nsupport, is proportional to the number of modules installed, Nmodules.

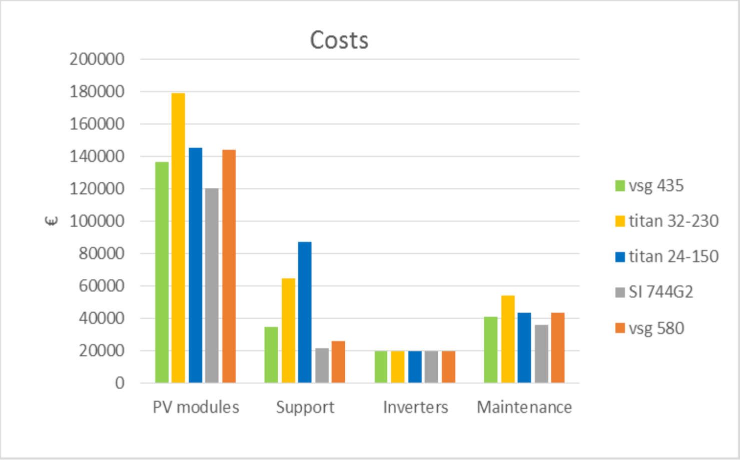


Figure 37 Abertillery PV costs summary

The costs are crucial factor for the payback time calculation, the maintenance cost are proportional to the cost of the photovoltaic modules, because they are proportional to the number of modules installed. The best solution results to have one of the lower support cost and a mean modules cost. The inverter cost is the same for all the cases, keeping the same technology and number of it. Here below are reported the same characteristic graphs but for the Willowtown case.

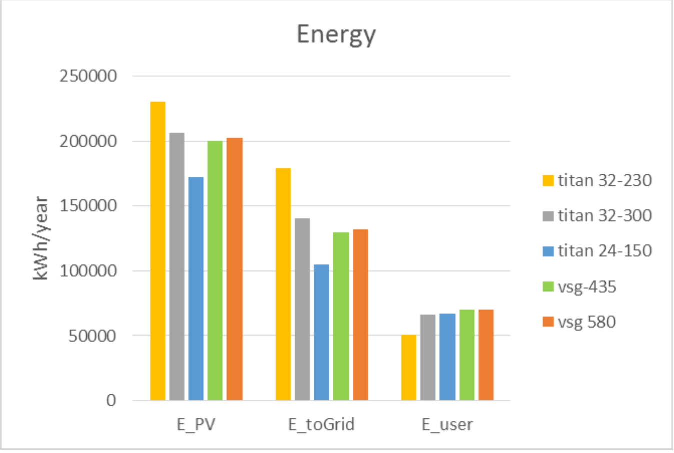


Figure 38 Willowtown PV energy summary

It is interesting to notice the best solution result to be the Titan 32-300 which has a mean value of energy produced, but we can notice the different division of the energy produced compared to the previous case. This difference will be well explained in the next pages. It is mainly due to the oversize of the plant installed, leading to an overproduction of energy that can be injected in the grid as already described.

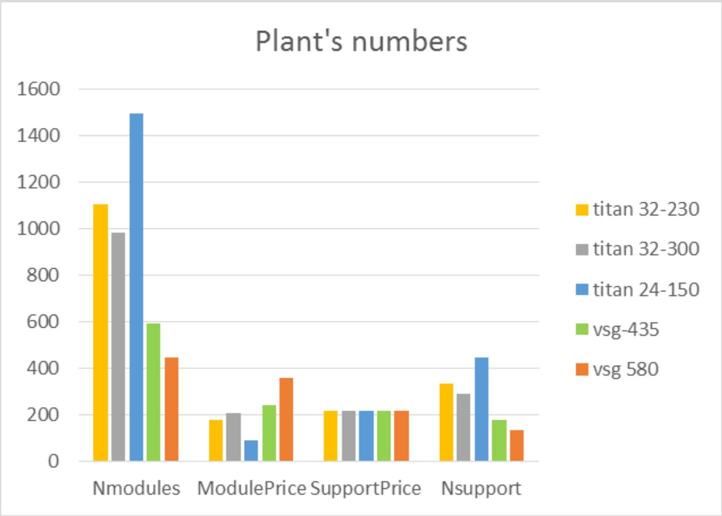


Figure 39 Characteristic plant's numbers

The number of modules implemented are similar to the previous case, showing a reverse proportion to the nominal power of the modules: the higher is the power of the module the lower usually is the total area requested for a fixed load. As the Abertillery case we can notice the best solution is a mean number of modules that lead also to a limited number of needed support structure.

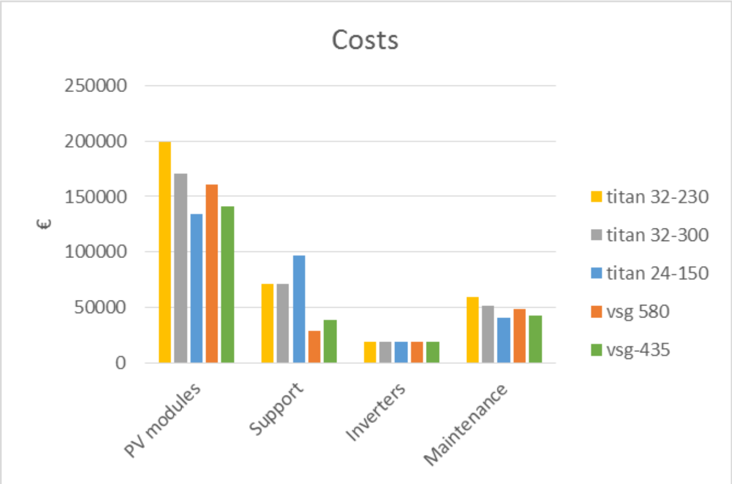


Figure 40 Willowtown PV costs summary

This case the best solution presents a significant total cost of PV modules and a good support cost. In this plant configuration part of the expenditure related to the modules costs can be tempered by the income of the extra electricity sale.

We could notice many interesting results from this report generated by the PVsys software. First of all is important to notice that the two buildings have a different electric load respectively 444000 kWh/yr for Abertillery and 133000 kWh/yr for Willowtown. Regarding the roof space available the two cases are comparable but not really similar, 1700 m^2 Abertillery 1900 m^2 Willowtown. This light difference in the roof space leads to a remarkable difference in the result: on the Willowtown case we implemented 816 modules of 300 W, while in Abertillery we decided to implement 400 modules of 580 W. The module size decision had to respect two important constraints: first had to be the most convenient solution, in terms of euro/kWh, and secondly had to be the most productive solution. To be the most productive it was necessary to cover as much as roof as possible keeping in mind the module disposition problem, which meant the parallel or in series string installation. During the array's design phase, for each configuration it was possible to set the modules on a series or on a parallel configuration, combining this two possibilities clearly the total surface and the array's nominal power changed dramatically.

Figure 41 PVsys arrays disposition

Even if it may seems incoherent to choose a larger module for a smaller area and vice versa, it is not because those solution chosen were the technical solution that covered the available space in the best way. The core of the dimensioning problem was to exploit in the best way the circa 200 m^2 difference among the two cases and, after the some Excel calculation, it was clear that a smaller module could fit better and remain a convenient economic solution. Clearly the best solution would had been a trade-off and a combination of larger and smaller modules, but this solution was not feasible in the software used.

However the final results are very similar, we designed two plants with similar total nominal power, 232 kWp for Abertillery and 245 kWp for Willowtown, using a similar number of inverter of a similar power, 4 inverters Solarmax 50C for Abertillery and 3 inverters Sunnycentral 60. As it seems reasonable the production per squared meter are comparable, respectively 876 kWh/ m^2 for Abertillery and 872 kWh/ m^2 for Willowtown, but a remarkable differences are present in the subdivision of the energy produced. Even if producing comparable electricity, 161485 kWh/yr for Abertillery and 182898 kWh/yr for Willowtown, the first consumes 140314 kWh/yr, around the 85% directly for its own use and reinsert in the grid 21171 kWh/yr (15%), while Willowtown consumes 67035 kWh/yr, around the 36% and reinsert in the grid 115863 kWh/yr (64% of the total). It possible to explain this difference with the fact that Abertillery has a much larger energy demand, with an energy load almost four times the Willotown's one. To understand the explanation given we need to keep in mind that the production of electrical energy from renewable energy is restricted in some hours and is not scalable on the user demand. Reason why is possible to have extra energy produced when not really necessary for the user or a production lower than the one expected to satisfy the user need in some hours of the day. Other factor to keep in mind to understand the obtained results are the different load demand during all day long: an elementary school would need energy mainly during the morning hours and the early afternoon. While a sport centre, as the Abertillery one, will need energy during all day long especially during the evening, when the majority of people get to the sport centre and no sun light is available. Starting from these considerations we can see how Abertillery, with its large energy demand, consumed the main part of the energy produced during daylight time and used energy grid for the evenings hours, reinserting a small percentage of the energy produced in the grid. On the other side Willowtown Primary School covers 55% of its demand with renewable energy and the remaining 45% with grid energy. We could read the 55% as the load referred to the morning and the early afternoon, when sunlight is still available and the 45% for the late afternoon, in which is necessary to rely on the grid. Keeping analysing the Willowtown case we can see a large electricity production directly injected in the grid and not consumed by the building. Main reason for this phenomena is the oversizing of the photovoltaic plant, as a matter of fact it was not necessary such a large installation in the Willowtown case to satisfy the building energy demand. Nevertheless we decided to follow the contracting authority's request and let some of the buildings to produce more energy and sell it back to the national grid, or directly on a smart local grid becoming a producing hub for the local community. As a matter of fact the contracting authority's idea for the next future is to connect more public building to each other in a local smart grid and make some buildings produce electricity for a larger part of the small community area.

2.3 The other technologies implemented

Before start to analyse in a deeper way the economic aspects of these investment in the HLA format prepared for the tender is necessary to show the other Energy Conservation Measures (ECM) planned for the two case study. In particular, we implemented the following ECMs:

- LED technology
- Water saver
- Antibacterial technology

For each of these measure applied it had been necessary to calculate the payback period, even if a real comparison among different options was not done because there were no different models with economic differences. Let’s now start to see more in details, in the next paragraph, what this other ECMs are about.

2.3.1 LED technology

Let’s start from the LED technology; reading the tender documentation it was clear that all the lighting system was obsolete and did not have any kind of LED technology. Reason why we decided to implement this convenient technology in this project. Let’s briefly introduce this technology: the light-emitting diode (LED) is one of the most energy-efficient lighting technologies. Its peculiarity is that it lasts longer, is more durable and has a better light quality than other types of lighting. From an energy savings point of view, it has a highly energy efficient lighting technology because it uses at least 75% less energy, last 25 times longer and release much less heat than incandescent lighting. In the two analysed cases we did not have the electrical consumption related to the only lighting system but we could obtain it by some approximation; it had been decided to consider the 20% of the total electrical load as lighting load and from that value work on it. So getting back the energy bills used to define the load curve, the lighting load curve was implemented. The next step was to consider the KWh/year a single LED would consume and to do that we had to define first the power of the single LED bulb and secondly the numbers of hours per year we believed the bulb would be on. On this latter part we could find the operating hours of the Abertillery Sport Centre and of the Willotown Primary School on the tender documentation and from that files have an idea of how many hours per day the lights should be on. In particular, being both public buildings, the idea was to consider the lights on during all the period the building would be operative, considering the fact that schools and sport centres are never not lightened, we assumed the lights would be on 10 hours per day. Referring to the days the two buildings would be operative, a slight difference had been identified: the primary school would have more vacation period, in which no light is requested, compare to a sport centre, that could work, potentially almost all year long, excluded for few days. For this reason, the two buildings will have different operative days and thus a different payback period. Respectively the ASC and the WPS will have 350 and 300 operative days. Next step is to assume a reliable value for the bulb power and this assumption was more difficult to decide without a site survey in the buildings, but still with the great experience of the colleagues and many years of work on average value had been identified in 35W LED bulb.

Once all these parameters were set we could start the calculation of the cost of investments and the savings this technology would lead to. In order to know how many bulbs were necessary for the lightning we had to calculate the total kWh consumed per year by one single bulb, which is given by the product of the bulb power time the hours it worked in one year:

$$E_{TOT} = P_{LED} * H_{day} * DAY_{year}$$

Now we have the energy consumed by one single bulb over a year and dividing the energy consumed with the new LED by it we obtain the number of LEDs to install:

$$N_{LED} = \frac{E_{consumedwithLEd}}{E_{tot}}$$

Knowing the total number of LED necessary we could estimate a cost for all of them:

$$Tot\_cost_{LED} = Price_{LED} * N_{LED}$$

Next step is to estimate the savings the LED system would provide, which is easily calculated by the price of electricity time the electricity saved thanks to the LED installed:

$$\Delta €_{saved} = Price_{el} * kWh_{saved}$$

Finally, a first payback time period simply dividing the total investment by the savings the LED technology could provide to the client

$$PBT = \frac{Tot\_cost_{LED}}{\Delta €_{saved}}$$

Here below are reported the two excels files showing the calculation done, as explained before, to evaluate a first payback period.

	A	B	C	D	E
1		E_saved[kWh]	CO2_save	Savings[£]	Payback
2		10631.52	4.0555	1 610.25	3.121654
3					
4	h/day	10	hours		
5	day/yr	300	days		
6	Power	35	W		
7	Energy_LED	105	kWh/yr		
8	Energu_need	26 578.80	kWh/yr		
9	N_LED	253.1314286			
10	Price_LED	31.20	£		
11	Invest_TOT	7 896.56	£		
12					
13	E_consumato con led	15 947.28			
14	N_led	151.8788571			

Figure 42 Willowtown payback calculation

	A	B	C	D	E
1		E_saved[kWh]	CO2_saved[ton]	Savings[£]	Payback
2		35546.72	13.55965181	5 383.91	2.451968
3					
4	h/day	10	hours		
5	day/yr	360	days		
6	Power	35	W		
7	Energy_LED	126	kWh/yr		
8	Energu_need	88 866.80	kWh/yr		
9	N_Lampadine	705.2920635			
10	Price_LED	31.20	£		
11	Invest_TOT	13 201.16	£		
12					
13	consumo con LED	53 320.08			
14	N_led	423.1752381			

Figure 43 Abertillery payback calculation

It is possible to notice that the payback period is of the same order of magnitude, around 2-3 years. We could now start to analyses another technology implemented in this project.

2.3.2 Water saver

Usually when speaking of ECMs, any water savings technology is not really considered an effective measure or the water saving concept usually does not coincide with the energy savings idea, but nevertheless, water savings is getting really important, especially nowadays and above all in some part of the world where water availability is running out. This low opinion of water measure may have probably economic reason, due to the fact that these kind of investments, on one side are not really economically remarkable, but on the other side they are not really remunerative or significant; so they are definitely characterized by a poor interest. Even if the area of the United Kingdom is not heavily wracked by water availability the contractor included in the tender mechanism also the possibility to work on the water savings and proposed to implement some measure on water savings, for this reason we decided to focus also on those technologies that assure a water save, in particular it was decided to apply a simple but efficient technology: a tap aerator. Tap aerators are also known as flow regulators. The aerator is a small attachment that either fits onto the end of the tap or can be inserted inside of the existing spout. These water saving devices will control the amount of water that flows through the tap without affecting the water pressure as they mix the water with air. The aerator acts as a sieve, separating a single flow of water into many tiny streams which introduces the air in to the water flow. Even if there is less space for the water to flow through, the water flow is reduced, resulting in water savings. As the water pressure is maintained, most people don't notice a difference in the amount of water coming out of an aerated faucet yet benefit from the water efficiency. Tap aerators are of most use to those with older taps in their home which run on average around 15 litres of water per minute, adding an aerator to an older tap can reduce this to as little as 6 litres of water per minute, reducing thus more than 50% of water consumption. Tap aerators can save as much as up to half your water usage through this way. When using aerated water, the benefits will not be only in the water bills, but will expand in natural gas and electricity bills, simply because thanks to this technology the water used is reduce and in the same time also the energy requested to heat that water is reduced. One last example of this simple technology regards the water pressure, thanks to the aerator any user won’t feel any difference in the stream pressure even if the water grid pressure will reduce This simple measure resulted extremely effective in the water consumption balance, especially in the Arbetillery sport centre, in which we had to face many water points and the consumption was definitely high around 6500 m^3 per year. Here below are reported the consumption excel files provided by the contracting authority.

Water bills overview

Bills Created during period: 1-Apr-2013 to 7-Apr-2017

Site	Account	From Date	Read Date	Water m3	Water £	Sewage m3
Abertillery Sports Centre	781091001	05/01/2013	31/03/2013	1 914.00	2 597.99	1 818.00
		01/04/2013	05/04/2013	111.00	153.97	105.00
		06/04/2013	08/07/2013	1 825.00	2 546.10	1 734.00
		09/07/2013	01/10/2013	2 246.00	3 099.10	2 134.00
		02/10/2013	06/01/2014	2 918.00	4 001.10	2 772.00
		07/01/2014	31/03/2014	2 327.00	3 201.95	2 211.00
		01/04/2014	01/04/2014	28.00	39.10	26.00
		02/04/2014	02/07/2014	3 261.00	4 522.48	3 098.00
		03/07/2014	30/09/2014	1 920.00	2 708.38	1 824.00
		01/10/2014	05/01/2015	1 806.00	2 563.30	1 716.00
		06/01/2015	08/04/2015	2 784.00	3 867.87	2 645.00
		09/04/2015	06/07/2015	2 872.00	3 854.78	2 728.00
		07/07/2015	05/10/2015	3 248.00	4 347.06	3 086.00
		06/10/2015	13/01/2016	1 893.00	2 593.86	1 798.00
		14/01/2016	31/03/2016	1 608.00	2 194.42	1 528.00
		01/04/2016	04/04/2016	82.00	113.30	78.00
		05/04/2016	05/07/2016	1 919.00	2 649.29	1 823.00
		06/07/2016	04/10/2016	1 335.00	1 878.04	1 268.00
		05/10/2016	10/01/2017	1 335.00	1 887.12	1 268.00
			Total	**35,432.00**	**48,819.21**	**33,660.00**

Figure 44 Abertillery water consumption

And following the Willotown consumption, which are definitely lower around 1500 m^3 per year

Water bills overview

Bills Created during period: 1-Apr-2013 to 7-Apr-2017

Site	From Date	Read Date	E	Water m3	Water £	Sewage m3
Willowtown Community Primary School	19/10/2012	10/04/2013		596.00	987.77	565.94
	11/04/2013	24/10/2013		895.00	1 435.92	849.87
	25/10/2013	09/04/2014		867.00	1 362.63	823.28
	10/04/2014	12/10/2014		879.00	1 424.39	834.67
	13/10/2014	17/04/2015		933.00	1 494.67	885.95
	18/04/2015	15/10/2015		565.00	968.29	536.51
	18/04/2016	31/10/2016		641.00	1 099.21	608.67
		Total		**5,376.00**	**8,772.88**	**5,104.89**

Figure 45 Willotown water consumption

In order to estimate the number of water points in the two buildings we had to work on their plants, showing the water points and identify all sinks, showers or similar in which the technology could be applied. After the total number of water points had been identified, considering both showers and sinks, it was necessary to assume some operative period of each point. We had to envisage how many times this sinks and showers were used and for how long, in order to have an idea of the water used and thus, after the ECM installation, of the water saved. This had to be a part of the entire water consumption, because assuming that the entire water consumption was related to the only water points consumption would had been a big overestimation of the actual water consumption by the water points. With the next formulas will be shown how the total water saved and the payback was evaluated. The first step, after identify the number of showers and sinks, was to assume the litres of saved water per minute and we found that value around 5 l/min for a shower and 4 l/min for a sink. Next step is to define an operative time, which was 5 min/time for a shower and 0.4min/time for a sink, then we had to decide a reasonable number of time the water points were used per day, respectively 6 and 8 times per day (showers and sinks). In order to evaluate the effective savings we had to multiply the saved water per minute time the minute per day the water point worked, time the number of time in a day.

$$Saved_{water} = T_{day} * T_{usage} * S_{min} \quad ; \quad \left[\frac{l}{day}\right] = \left[\frac{use}{day}\right] * \left[\frac{min}{use}\right] * \left[\frac{l}{min}\right]$$

After summing the saved water from sinks and showers is possible to evaluate the money saved thanks to the new technology implemented.

$$\Delta€_{saved} = Saved_{water} * Price_{water}$$

And finally calculate the first payback period, knowing the initial investment cost

$$PBT = \frac{Tot\_cost_{water\ saving}}{\Delta€_{saved}}$$

Here below are reported the excel sheet in which the calculation of the water savings and thus of the money savings had been computed.

	A	B	C	D	E	F	G	H	I	J	K	L
1			punti acqua		risparmio doccia							
2	bagni	10	30		5	l/min						
3	cucine	5	10		risparmio rubinetto						consumo_tot[m3/yr]	6 861.00
4	docce	30	30		4	l/min						
5			70									
6												
7										risparmio totale	1 221.00	m3/yr
8					risparmio doccia	150	l/day				1949.6928	£/yr
9	prezzo	1.5968	£/m3			37500	l/yr					
10	durata doccia	5	min/volta			37.5	m3/yr			PAYBACK	0.102580263	
11	utilizzo doccia al giorno	6	volte/giorno		risparmio totale	1 125.00	m3/yr	1796.4	£/yr			
12												
13	durata lavandino	0.4	min/volta		risparmio rubinetto	9.6	l/day			rompigetto_rubinett	2	€
14	utilizzo lavandino al giorno	6	volte/giorno			2400	l/yr			rompigetto_doccia	4	€
15						2.4	m3/yr					
16					risparmio totale	96.00	m3/yr	153.2928	£/yr			

Figure 46 Abertillery payback calculation

The price of water, as the price of electricity or natural gas, was listed in the tender documentation. Thus a first simple payback period could be evaluated also for this simple technology as will be shown below.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1			punti acqua		risparmio doccia								
2	WC	19	57		5	l/min					consumo_TOT	1500	m3/yr
3	Kitchen	2	8		risparmio rubinetto								
4					4	l/min							
5													
6											risparmio totale	260.00	m3/yr
7												415.168	£/yr
8					risparmio doccia	150	l/day						
9	prezzo	1.5968	£/m3			37500	l/yr				PAYBACK	0.234845	
10	durata doccia	5	min/volta			37.5	m3/yr						
11	utilizzo doccia al giorno	6	volte/giorno		risparmio totale docce	0.00	m3/yr	0	£/yr				
12											rompigetto_rubinetto	1.5	€
13	durata lavandino	0.4	min/volta		risparmio rubinetto	16	l/day				rompigetto_doccia	4	€
14	utilizzo lavandino al giorno	10	volte/giorno			4000	l/yr						
15						4	m3/yr						
16					risparmio totale rubinetti	260.00	m3/yr	415.168	£/yr				

Figure 47 Willowtown payback calculation

It is possible to notice how the payback period have the same order of magnitude and are very similar, both definitely little. As mentioned before this technology does not have a remarkable economic impact, because the cost of the aerators is negligible, but in the same time it reduces the water consumption by at least 50% which is a very interesting result to work on. We could now focus on the next measure implemented in the project.

2.3.3 Sanitization of Domestic Hot Water

Speaking of technical measure to reduce the energy consumption, both in electrical and thermal terms, the idea was to introduce the technical knowhow of the company in the possible solution that are implementable for this project. As mentioned at the beginning of this work, Zephyro worked many years in the energy efficiency sector specializing its competence in the hospital sector and in particular in the field of sanitisation of system, as for example the water network system. Working many years in the hospital sector Zephyro had implemented sanitisation technique that may result useful also if implemented in our project. As a matter of fact, the sanitisation of the network water system form some kind of bacteria is a compulsory procedure not only in hospital but in every public buildings and in particular in those kind of building extremely attended as schools or sport centre. For this reason, we decided to implement this chemical process that will allow on one side the elimination of a kind of bacteria and on the other side to reduce the energy consumption. The bacteria concerned is the legionella, legionellosis is a collection of infections that are caused by legionella pneumophila and related to Legionella bacteria. The severity of legionellosis varies from mild febrile illness to a potentially fatal form of pneumonia that can affect anyone. Water is the major natural reservoir for legionellae, and the bacteria are found worldwide in many different natural and artificial aquatic environments, such as cooling towers; water systems in hotels, homes, ships and factories; respiratory therapy equipment; fountains; misting devices and pools. The actual method to eliminate the risk of legionella proliferation in the two buildings analysed is to keep the water boiler temperature at 60°C temperature, at which the bacteria does not survive. This new method proposed is based on the use of clorammina, a chemical compound that allows with small quantities to ensure a good level of disinfection from legionella and also the elimination of biofilm without damaging the pipes or the ability of water, without involving the production of by-products. The innovation of this chemical compound is the new operative temperature, as a matter of fact 45°C are now sufficient to prevent any kind of legionella spread. Thanks to this technique we achieve a double benefit, on one side we assure the removal of this dangerous bacteria and on the other side we reduce the boiler consumption reducing its operative temperature from 60°C to 45°C and thus reducing the energy bills. In order to calculate this energy savings is first necessary to identify the amount of water circulating in the domestic hot water plant and how much it costs, in energy terms, to heat it up. As usual the water bills available in the annex do not make any differentiation among the water used in the domestic hot water, so we had to assume it as a percentage of the total water used, around 40%. Next step is to evaluate the heat needed to heat up the water from the reference temperature of 15°C to the operating temperature.

$$E_{need} = C_{water} * (T_{op} - T_{ref})$$

The energy saved is the difference between the two energy needed

$$E_{saved} = E_{need60°C} - E_{need45°C}$$

The earnings are simply the money saved by consuming less fuel, due to the lower temperature reached

$$\Delta€_{saved} = E_{saved} * F * Price_{NG}$$

Where F is a conversion factor from kWh to m^3 of natural gas.

Here below are reported the calculation sheets in which are reported the energy saved reducing the heat generation, the investments cost for the chemical process and the payback time of the investments, given by the ratio of these two lasts. Respectively the first for Willowtown case and the second for Abertillery case. For the payback time calculation:

$$PBT = \frac{Tot\_cost_{sanification}}{\Delta€_{saved}}$$

	A	B	C	D	E
1					
2	consumo_tot	6 559.00	m3/yr	6559000	kg/yr
3	ACS	2623.6	m3/yr	2623600	kg/yr
4					
5	E_65	25.507222	kW		
6	E_45	15.304333	kW		
7	E_saved	10.202889	kW	89 377.31	kWh/yr
8					
9	risparmio	13 537.09	£		
10	PAYBACK	1.1080671			

Figure 48 Willowtown payback calculation

	A	B	C	D	E
1	consumo_	1500	m3/yr	1500000	kg/yr
2	ACS	600	m3/yr	600000	kg/yr
3					
4	E_65	5.833333	kW		
5	E_45	3.5	kW		
6	E_saved	2.333333	kW	20 440.00	kWh/yr
7					
8	risparmio	3 095.84	€		
9	PAYBACK	4.845208			

Figure 49 Abertilery payback calculation

It is possible to notice how the two payback period are significantly different, due to the very different volume of water used in one year by the two buildings. At the same time the investment cost remains the same because, even if it is plausible to consider a comparable size boiler for the two cases (the sport centre one would be clearly bigger) the amount of chemical compound and the cost of the process remain the same, so does the price of it. For this reason, the payback time would be clearly different. Let's now introduce the last technology implemented in this tender project.

2.3.4 Biomass boiler

The last technology implemented in this project referred to thermal energy consumption, in particular, we focused on the heating system boiler. In the procurement document the client expressly introduce the possibility to implement a biomass boiler and the trigeneration, but considering those measures as a further possibility to be proposed and designed in a next phase, in the eventuality our project awards this project evaluation.

Regarding the trigeneration, is a very fascinating and competitive technology in which the production of electricity and heat is flanked by the production of cooling, fulfilling three function in only one complex machine. As it is easily understandable this technology is not simple to design neither to implement and for this reason we decided not to pursue it at least in this first phase of the project implementation. Regarding the biomass boiler, this is a well known and consolidated technology, that consist in the substitution of the traditional fuels like fossil fuels, with lower environmental impact materials as the biomaterials (woods, crops, woodchips, etc.). This technology leads to lower emission of CO_2 and reduce the expenditure related to the fuel consumed, due to the large availability of biomaterials compared to fossil fuels. The latter technology is definitely less complex to design, at least in broad terms, for this reason, even if not requested in this preliminary phase of the tender, we decided to implement a brief technical solution in order to give an idea of the size of the boiler needed. To give to the client an idea of a proper solution we used “progetto biomasse” a dimensioning online software that gives as an output the order of magnitude of the nominal power of a biomass boiler.

Figure 50 Boiler dimensioning software

The necessary input in such software were several:

- total volume of the buildings at hands;
- climate zone of the building;
- total amount of biomass available;

The first parameter is easily obtainable by the floors plans of the buildings available in the tender annex, the climate zone was a parameter ranked from A to F depending on the sum of the factor degree-days. The degree-day of a location is the unit of measurement that estimates the energy necessary to maintain a comfortable climate in the building. It represents the sum, extended to every day of a conventional annual heating period, of the average daily temperature increases necessary to reach the threshold of 20 °C. The higher the degree-day value, the greater the need to keep the heating system and the lower is the climate zone parameter. In the case studied, both the locations were identified as a climatic zone D. It is important to notice that the actual available biomass in the project area was not known, at least in this initial phase, but for sake of simplicity was assumed that all the biomass needed for the thermal load was available. We took this assumption just to design a first solution that adopt a totally renewables response, even if a solution with a double fuel, fossil and biomass, was possible to pursue. Here below is reported the result from the online software for Abertillery:

Caratteristiche Impianto Termico	
Energia primaria ?	Kwh/anno 11.162.791
L'energia primaria è sufficiente a riscaldare abitazioni (nella tua zona climatica) fino ad un volume di	mc 206.718
Zona climatica	D
Volume utenza	mc 6.500
Fabbisogno di potenza della caldaia	**kW 195**
Fabbisogno annuo di energia termica	**kWh 351.000**
Lunghezza rete teleriscaldamento ?	m 0
Analisi Economica	
Costo investimento ?	**€ 51.500**
Produzione netta annua energia termica	kWh 351.000
Consumo biomassa	**t/anno 148**
Ricavo lordo annuo	€ 38.541
Costi esercizio annui	€ 14.836

Figure 51 Abertillery biomass boiler report

We could see how a 195 kW nominal power boiler was suggested for the Abertillery case for an expenditure of ca 50.000 €. A positive feedback on the design comes from the fact that the annual thermal energy load produced by the designed biomass is definitely similar to the load declared by the contracting authority for the building in hand.

Below is the Willowtown case:

Caratteristiche Impianto Termico	
Energia primaria	Kwh/anno 83.720.930
L'energia primaria è sufficiente a riscaldare abitazioni (nella tua zona climatica) fino ad un volume di	mc 1.550.388
Zona climatica	D
Volume utenza	mc 5.253
Fabbisogno di potenza della caldaia	**kW 158**
Fabbisogno annuo di energia termica	**kWh 283.662**
Lunghezza rete teleriscaldamento	m 0
Analisi Economica	
Costo investimento	**€ 44.018**
Produzione netta annua energia termica	kWh 283.662
Consumo biomassa	**t/anno 120**
Ricavo lordo annuo	€ 31.147
Costi esercizio annui	€ 11.237

Figure 52 Willowtown biomass boiler report

Even in this case the software designed a 158 kW nominal power biomass boiler with an initial investment of ca 40.000€. Thanks to this software, it was possible to determine, in broad terms, the nominal power suitable for the two cases and it is possible to notice how the two values are similar for the buildings, mainly because they got a similar floor area and thus comparable volumes.

Once we determined the nominal power of the boiler we could start some calculation to evaluate the achievable savings in terms of natural gas consumption avoided. The main idea, for this broad terms analysis, was to estimate how much would cost to supply natural gas to the boiler and how much would cost to use biomasses. Starting from the value of kWh per cubic meter of natural gas and kWh of kilograms of biomass we evaluated the amount necessary to cover the thermal load of one year

$$M_{fuel} = E_{need}/E_{produced\ per\ mass\ unit}$$

Once we estimated the quantity necessary, we could calculate the cost of the fuel used

$$Cost_{fuel} = M_{fuel} * Price_{fuel}$$

Next step we easily evaluated the saved money with the new fuel as the difference of the two costs.

$$\Delta€_{saved} = Cost_{NG} - Cost_{biomass}$$

We can now estimate a first payback period by calculate the ratio of the total investment cost done for the biomass boiler and the saved money achieved with this investment.

$$PBT = \frac{Tot\_cost_{biomass\ boiler}}{\Delta€_{saved}}$$

Finally here are reported the two Excel calculation sheet

	A	B	C	D	E	
1	output	1.035.399,45	kWh/yr		P_nomBoiler	
2	input	1.218.117	kWh/yr		195	kW
3	PriceNG	0,207122	€/m3			
4	PriceBiomass	0,035	€/kg			
5	NG	123.354	m3/yr			
6	Biomass	358.270	kg/yr			
7	Δ€	13009,87719				
8						
9	Payback	3,011750183				
10	Boiler	39182,5	€			

Figure 53 Abertillery calculation

	A	B	C	D	E	
1	output	284908,1	kWh/yr		P_nomBoiler	
2	input	335186	kWh/yr		157	kW
3	PriceNG	0,207122	€/m3			
4	PriceBiomass	0,035	€/kg			
5	NG	33.943	m3/yr			
6	Biomass	98584	kg/yr			
7	Δ€	6505,342				
8						
9	Payback	5,16268				
10	Boiler	33585	€			
11						
12	Biomass	15000	kg/yr			

Figure 54 Willowtown calculation

We can see how the two boilers have a similar nominal power and thus a comparable payback time. The result is coherent with the fact that the two buildings have a similar volume to heat, even if the Abertillery Sport Centre has a much higher thermal energy consumption due to other energy expenditure that would not be considered in the space heating balance, as the swimming pool heater system or others. An extra voice that need to be considered when calculating the payback time of this technology is the CO_2 saved switching to a biomass fuel, Usually, the quantitative of CO_2 produced does not change significantly, reason why it had been neglect in this first analysis, but is still a quantitative than need to be accounted in the economical phase. As a matter of fact, the contracting authority, basing on the financial sustain of national incentives policy will pay money for each kilogram of CO_2 avoided. This precious parameter will be considered during the next phase, in the HLA implementation.

2.4 Suppliers

Last aspect to introduce in this chapter would be the supply of all the technologies introduced above. This is a large and articulated theme that is well explained in the tender response, explaining how the supplier would be selected and how the relationship with it would be managed. The starting idea, considering the fact that we are working on an overseas tender, was to collaborate with locals suppliers in order to reduce remarkably cost voices, but we quickly understood that was not easy to start a convenient and reliable commercial relationship in such a little period. For this reason it was decided to relate above all to our old suppliers, mainly based in Italy, here is reported the list of our suppliers for each technology implemented:

- AB Company for PV panels;
- Sanipur for Chemical treatments and watersaver;
- Avic for PV panels;
- Re Heat for biomass boiler;
- ZinCO for PV panels;
- LedLux Italia for the LED;

2.5 Conclusions

In this chapter all the technology implemented for this project has been showed and analysed. The results had been commented and a brief comparison among the different solutions for the two cases was done. We could definitely identify the photovoltaic systems as the main energy conservative measure between the one realised for the two buildings, in terms of design effort, calculation and time consuming. Also from an economic point of view it was surely the most significant technology. Analysing all the technologies in terms of innovation it is possible to notice on one side technologies that are nowadays more common to meet, as photovoltaic panels or the LED technology, while on the other side it was interesting to note and comment some technologies that are less common. The most innovative would surely be the chemical process of sanitization through the cloroammina compound addition. Analysing the different technologies, it was clear how technologies have different impact on the project scenario, testified by a different payback time. Is important to keep in mind how all the technologies we deal with need to be considered as an unique investment and not separately. This approach had influenced the economical decision during the HLA implementation. Let’s now start with the third chapter and more detailed economic analysis.

Chapter Three

3.1 The High Level Apprail

In this chapter it will be analysed one of the phases of the tender, in particular we will focus on the High Level Apprail. The **HLA** is an initial understanding and/or proposal for a project. Requirements will be specified within the Project Brief and will typically require an assessment of a defined number of properties to identify the benefits and savings opportunity along with associated costs. High level appraisals are not a full proposal in their own right, but would be used to form the basis of requirements for the Investment Grade Proposal (IGP).

The HLA structure is divided in sections, each of them with a different function:

- Section 1: Project details
- Section 2: Baseline, in which the operative time table of each building is listed together with the total loads per year and the price for energy, water and CO_2
- Section 3: energy conservation measures, in which all the ECMs implemented in the project are listed, focusing on the savings planned to achieve and the income calculated by each technology.
- Section 4: project pricing tables, in which the main financial aspects are considered as the hourly rate pricing for the single operators
- Section 5: summary cash flow: all the cost are here represented and the final payback time is calculated together with the yearly cash flow for the group of all the technologies.

3.1.1 Section 1: Project details

In this first section project is identified showing the provider and the contracting authority's names.

Project details

Provider:	Zephyro s.pa.
Contracting Authority	Blaenau Gwent County Borough Council
Contracting Authority's project name / code	RM3768

Figure 55 Project identification

3.1.2 Section 2: Baseline

In this section the operative time table of each building is listed together with the total loads per year, divided in electric and thermal energy, water load and CO_2. This section give an idea of the actual load scenario for each building.

Premises (building/ asset) name	Year of data	Main heating fuel - please specify	Total electricity usage	Total electricity cost	Electricity rate	Annual electricity usage per m²	Total electricity CO₂ tonnes per year	Total gas usage	Total gas cost
			Annual kWh	£ per Yr	£/kWh	kWh/m²/Yr	Tonnes/Yr	Annual kWh	£ per Yr
Abertillery Sports Centre	2016/17	Natural Gas	479.426	£ 59.928,25	£0,125	136	182,88	997115,00	18.646,05
Willowtown Primary Scho	2016/17	Natural Gas	136.441	£ 17.055,13	£0,125	42	52,05	268684,00	5.024,39

Premises (building/ asset) name	Gas rate	Annual gas usage per m²	Total gas CO₂ tonnes per year	Total water usage	Total water cost	Total sewerage usage	Total sewerage cost	Total energy usage	Total energy cost	TOTAL CO₂ tonnes/Yr
	£/kWh	Wh/m²/Y	Tonnes/Yr	m3 / Yr	£ per Yr	m3 / Yr	£ per Yr	kWh	£	Tonnes/Yr
Abertillery Sports Centre	0,0187	282,8695	183,269737	6861	9181,39	6517	11574,19	1.476.541,00	£ 78.574,30	366,15
Willowtown Primary Scho	0,0187	83,28704	49,3841192	1265	1692,82	1201	2132,98	405.125,00	£ 22.079,52	101,43

Figure 56 Total load per year

In the same sheet are reported the operative time of each building, useful to determine the consumption rate during the day.

Premises specific operational hours/ occupancy

Day	Hours of operation	Abertillery Sports Centre	Willowtown Primary School
Monday	From - To	0600 to 22.30	0800 to 1800
Tuesday	From - To	0600 to 22.30	0800 to 1800
Wednesday	From - To	0600 to 22.30	0800 to 1800
Thursday	From - To	0600 to 22.30	0800 to 1800
Friday	From - To	0600 to 22.30	0800 to 1800
Saturday	From - To	0700 to 1900	Closed
Sunday	From - To	0700 to 1900	Closed

Figure 57 Operative hours for building

And lastly is reported the inflation rate for the main voices, to keep in mind for the price analysis requested.

Energy unit and inflation rates for the HLA

	£ per kWh	%
Electricity unit rate (explain if day / night / blended in line with ITT)	0,125	
Gas unit rate	0,0187	
[Other fuel rate]		
Energy price annual inflation assumption (% change per annum)		4
Feed-in tariffs (FIT) assumption annual inflation (% change per annum)		0
Renewable heat incentive (RHI) assumption annual inflation (% change per annum)		0

Figure 58 Inflation rate

3.1.3 Section 3: energy conservation measures

This part is the main core of the HLA; firstly a table indicates all the measures applied and in which building

	ECM Description	[illegible]	[illegible]
ECM 1	PV	x	x
ECM 2	LED	x	x
ECM 3	BOILER	x	x
ECM 4	WATERSAVER	x	x
ECM 5	CLOROAMMINA	x	x

Figure 59 ECMs summary

Secondly, a large table shows, for each building and technology, work/optimisation fees as anticipated savings and costs for every field: electricity, natural gas, water, etc. the evaluation is done in absolute and in percentage terms.

ECMs		Premises name	Premises name
PV		ABERTILLERY	WILLOWTOWN
Works/Optimisation Services Fees	£	210.753,49	237.458,53
Electricity: Anticipated Savings against Base Line	kWh per annum	161.485,00	252262
Electricity: Anticipated Savings against Base Line	% of Base Line	35,89%	189,82%
Total Anticipated Savings against Base Line	kWh per annum	161.485,00	252.262,00
Total annual carbon savings	t CO_2 e	61,60	96,22786252
Total Anticipated Savings against Base Line	£ per annum	23.853,38	11632,25
Income: Anticipated Savings	£ per annum	14.479,46	21.405,01
Net savings	£ per annum	34.491,95	27.037,26
ECM simple payback period	Years	6,11	8,78
LED		ABERTILLERY	WILLOWTOWN
Works/Optimisation Services Fees	£	27.502,42	8.225,58
Electricity: Anticipated Savings against Base Line	kWh per annum	44.433,40	13289,4
Electricity: Anticipated Savings against Base Line	% of Base Line	10,00%	10,00%
Total Anticipated Savings against Base Line	kWh per annum	44.433,40	13.289,40
Total annual carbon savings	t CO_2 e	16,94956476	5,069374524
Additional costs (e.g. extra maintenance)	£ per annum	1.375,12	411,28
Total Anticipated Savings against Base Line	£ per annum	6.729,88	2012,812524
Net savings	£ per annum	5.354,76	1.601,53
ECM simple payback period	Years	4,09	4,09

WATERSAVER		ABERTILLERY	WILLOWTOWN
Works/Optimisation Services Fees	£	135,92	57,93
Water & sewerage: Anticipated Savings against Base Lin	m^3	1.221,00	260,00
Water & sewerage: Anticipated Savings against Base Lin	£	1.949,69	415,17
Additional costs (e.g. extra maintenance)	£ per annum	6,80	2,90
Net savings	£ per annum	1.942,90	412,27
ECM simple payback period	Years	0,07	0,14

BIOMASS BOILER		ABERTILLERY	WILLOWTOWN
Works/Optimisation Services Fees	£	62.500,00	41.981,25
Gas: Anticipated Savings against Base Line	kWh per annum	1.035.399,45	282.032,83
Gas: Anticipated Savings against Base Line	% of Base Line	100,00%	100,00%
Total Anticipated Savings against Base Line	kWh per annum	1.035.399,45	282.032,83
Total annual carbon savings	t CO_2 e	128,1928059	35,27447186
Additional costs (e.g. extra maintenance)	£ per annum	21.038,50	7.028,26
Total Anticipated Savings against Base Line	£ per annum	13.009,88	3579,902046
Income: Anticipated Savings	£ per annum	25.638,56	7.054,89
Net savings	£ per annum	17.609,94	3.606,53
ECM simple payback period	Years	3,55	11,64
WATER TREATMENT, MONOCLORAMMINA		ABERTILLERY	WILLOWTOWN
Works/Optimisation Services Fees	£	18.750,00	18.750,00
Electricity: Anticipated Savings against Base Line	kWh per annum	89.377,31	20440
Electricity: Anticipated Savings against Base Line	% of Base Line	20,11%	15,38%
Total Anticipated Savings against Base Line	kWh per annum	89.377,31	20.440,00
Total annual carbon savings	t CO_2 e	34,09	7,80
Additional costs (e.g. extra maintenance)	£ per annum	900,00	900,00
Total Anticipated Savings against Base Line	£ per annum	13.537,09	3.095,84
Net savings	£ per annum	12.637,09	2.195,84
ECM simple payback period	Years	1,48	8,54

Figure 60 Work/optimisation service fees

In the last part of Section 3 the cost voice is broken down in several subsections regarding the different fees, here is reported the excel sheet.

Premises totals (over Payback Period)		ABERTILLERY	WILLOWTOWN
COSTS			
1 - IGP Services Fee	£	£ 1.320	£ 840
2 - Works/Optimisation Services Fee	£	£ 319.642	£ 306.473
3 - M&V Services Fee	£	£ 1.320	£ 840
4 - Maintenance Fee	£	£ 19.801	£ 18.396
A - TOTAL COSTS	£	£ 342.083	£ 326.550
SAVINGS + INCOME			
7 - Total Anticipated Savings against Base Line	£	£ 25.524	£ 20.321
8 - Income: Anticipated Savings	£	£ 35.678	£ 28.460
Projected emissions reduction against Base Line	tCO_2e	240,84	144,37
B - TOTAL SAVINGS + INCOME	£	£ 61.202	£ 48.781
PAYBACK			
Simple Payback (A / B)	Years	5,58940794	6,694234421

Figure 61 Cost subdivision

Each fee refers to a precise service that had to be implemented in this phase or would be implemented in a successive phase if the project turned to be awarded. The IGP service fee is the cost related to the realization of the IGP itself, necessary after the award phase, the work/optimisation service fee is the cost of the implementation of the project while the last two fees. Measurement and Verification (M&V) and maintenance are both related to phases next to the installation of the technologies.

M&V are useful to understand the effectiveness of the technology installed. On one side measuring some relevant values and analysing the change of them after the installation, on the other side maintenance is a fundamental process to assure a continuous and reliable function of the technology at desired levels. Lastly the payback period for each building is reported, this time all the technologies investment costs are summed up and considered in one payback. It is possible to notice how the two payback period are similar probably due to the similar investments cost and the comparable areas of the two buildings. More over it is important that both the payback times are lower than the 10 years constraint declared by the contracting authority.

For the sake of completeness here below it is reported the IGP service cost break down showing how each part of the IGP, as audit, measurement or documentation covers a certain percentage of the total final cost. As explained before these values derive from technical and economical studies implemented by the Zephyro's team.

IGP Service Fee per Premises

		Premises (building / asset)				
		ABERTILLERY	WILLOWTOWN			
IGP COST PER PREMISES (BUILDING/ASSET)	€	1320	840			

Breakdown of IGP Service Fee costs

Activity	Person days worked	Day rate	Total cost
Audit	9	45%	2269,35
Measurement	7	35%	1765,05
Documentation	4	20%	1008,6
Other - add row as required			
PROJECT TOTAL			€ 5.043,00

Figure 62 IGP's subdivision

3.1.4 Section 4: project pricing tables

In this section the main financial aspects are considered: this part may not have a technical nature but has the same importance for the tender award, as a matter of fact this part concern the financial aspects of all the project and the company decides for the economic aspect that are more affecting the company itself. Many significant parameters are here decided as the hourly rate pricing for the single operators, the overhead and profit percentage and other important voices. As said before this part may not result interesting from a technical point of view but its evaluation by the contracting authority has such a relevant weight on the tender final award and this is the reason why it was impossible to neglect those sections. First tables reported are the several overhead and profit percentage respect to the total final cost.

		Overhead	Profit	Total Base Addition
1A	% addition on base internal labour rates	2,50%	6,00%	8,50%
1B	% addition on base material costs or internal non-labour	1,50%	3,50%	5,00%
1C	% addition on base Sub-Contractor cost	2,50%	2,50%	5,00%

Figure 63 Overhead and profits

Overhead is an accounting term that refers to all ongoing business expenses not including or related to direct labor, direct materials or third-party expenses that are billed directly to customers. A company must pay overhead on an ongoing basis, regardless of whether the company is doing a high or low volume of business. It is important not just for budgeting purposes but for determining how much a company must charge for its products or services to make a profit. Examples of overhead are:

- Accounting and legal expenses
- Administrative salaries
- Depreciation
- Insurance
- Licenses and government fees
- Rent

Overhead costs tend to be fixed, which means that they do not change from period to period. Next table is on the risk premium. A risk premium is the return in excess of the risk-free rate of return an investment is expected to yield; an asset's risk premium is a form of compensation for investors who tolerate the extra risk, compared to that of a risk-free asset, in a given investment.

	Savings Guarantee Risk Premium	5%

Figure 64 Savings guarantee risk premium

On the next table is showed the company financial approach on one of the most operative and practical aspect of a project: the base internal rate for each role. Those numbers are taken in full consent with the technical and the economic committee, based on the large experience of those groups.

	Role title	Hourly rate	Day rate
3.1	Project manager	£ 44.22	£ 252.04
3.2	Audit/ analysis engineering resource - senior level	£ 68.78	£ 392.06
3.3	Design engineering resource - senior level	£ 68.78	£ 392.06
3.4	Audit/ analysis engineering resource	£ 54.04	£ 308.05
3.5	Design engineering resource	£ 54.04	£ 308.05
3.6	Quantity surveyor	£ 60.00	£ 342.00
3.7	Measurement and verification engineer	£ 60.00	£ 342.00
3.8	Construction manager	£ 49.13	£ 280.04
3.9	Commercial/ procurement manager	£ 44.22	£ 252.04
3.10	CDM co-ordinator	£ 58.96	£ 336.05
3.11	Bid manager	£ 39.30	£ 224.03
3.12	Finance manager	£ 39.30	£ 224.03
3.13	Legal resource	£ 100.00	£ 570.00
3.14	Director	£ 117.91	£ 672.10

Figure 65 Base internal labour rates

Next table shows the percentage change in the summary project cost in case of an amendment in the project terms previously defined in the tender.

% Value Amendment (negative values for reductions, positive values for increases)	Summary Project Cost			
	Up to £500k	£500k up to £1m	£1m up to £2.5m	Over £2.5m
Target Bid	2%	1%	0%	-2%

Figure 66 Value amendment

Last table reporter refers to the IGP cost that would be necessary in a later phase in case of the tender award. To notice we did not do any price difference for the kind of asset we are working on, but just differing the price on the surface of it.

Building / asset size	Maximum IGP Services Fee for office	Maximum IGP Services Fee for school	Maximum IGP Services Fee for other property
Under 1,000m²	£ 669.05	£ 669.05	£ 669.05
1,000m² - 2,499m²	£ 1.338.11	£ 1.338.11	£ 1.338.11
2,500m² - 4.999m²	£ 2.000.17	£ 2.000.17	£ 2.000.17
5,000m² - 9,999m²	£ 2.676.23	£ 2.676.23	£ 2.676.23
10,000m² - 19,999m²	£ 3.345.29	£ 3.345.29	£ 3.345.29
20,000m² and over	£ 4.014.35	£ 4.014.35	£ 4.014.35

Figure 67 IGP pricing

3.1.5 Section 5: summary cash flow

This final section summarise all the cost evaluated before and shows how those costs are spread along the 10 years period. It is interesting to notice how costs have different periodicity, the IGP service fee is a *una tantum* cost that is compared only at the beginning of the project, because it regards the design of it, as the work optimisation fee, that regard the practical implementation of it. On the other hand other costs need to be faced more often because assure the proper functioning as the maintenance and the measurement & verification procedure.

Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
1 - IGP Services Fee	£ 5.043	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
2 - Works/Optimisation Services Fee	£ 1.029.220	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
3 - M&V Services Fee	£ 5.043	£ -	£ -	£ 5.043	£ -	£ -	£ -	£ 5.043	£ -	£ -
4 - Maintenance Fee	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038	£ 91.038
5 - Facilitation Services Rebate and/or CCS Fee	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
6 - Any other costs	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
A - TOTAL COSTS [sum of the above]	£ 1.130.344	£ 91.038	£ 91.038	£ 96.081	£ 91.038	£ 91.038	£ 91.038	£ 96.081	£ 91.038	£ 91.038

Figure 68 Costs summary

The second table, in opposition with the previous one, shows the positive revenues as the savings achieved and the income that could be generated, year by year.

All values in £'s

Savings and income	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
7 - Total Anticipated Savings against Base Line	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829	£ 118.829
8 - Income: Anticipated Savings [leave blank if not requested in ITT]	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556	£ 112.556
9 - Any other Anticipated Savings	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
B - TOTAL SAVINGS + INCOME [Sum of the above]	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386	£ 231.386

Figure 69 Savings and income summary

Lastly, combining the two previous tables it is possible to generate a cash flows, it is an item that reports the aggregate change in a company's cash position resulting from any gains (or losses) from investments and changes resulting from amounts spent on investments in capital assets such as plant and equipment.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Net cash flow [B - A]	-£ 898.959	£ 140.347	£ 140.347	£ 135.304	£ 140.347	£ 140.347	£ 140.347	£ 135.304	£ 140.347	£ 140.347
Cumulative cash flow	-£ 898.959	-£ 758.611	-£ 618.264	-£ 482.960	-£ 342.613	-£ 202.265	-£ 61.918	£ 73.386	£ 213.733	£ 354.081

Figure 70 Cash flow

It is possible to notice how the cumulative cash flow turn out positive at the end of the seventh year, which mean that the payback time of the whole investment is seven years. Even if some single investments may have a larger payback period than other the calculation sheet consider it as a part of a bigger investment and it leads to a "compensation" solution among the different investments. As will be better explained in the next paragraph is clear how some technology has a different "specific gravity" in the investments cost, but they may be lighten by another technology.

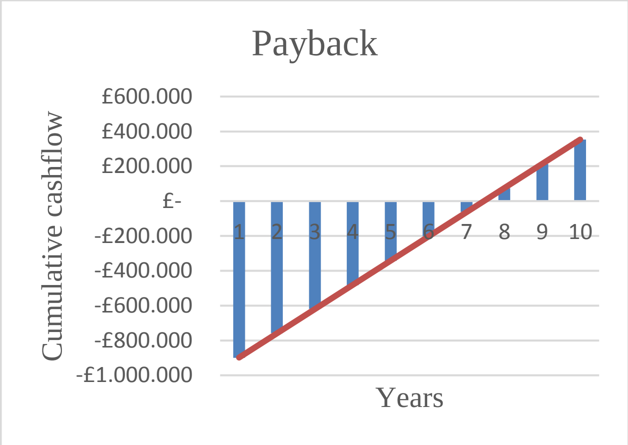


Figure 71 Final payback

3.2 Comments

Commenting the obtained results, some considerations need to be done on some points. First observation may be done on the payback time, which result not so long considered the technologies implemented and definitely make the technical solution designed a feasible development and a fruitful project. The explanation to this positive results can be find in the approach of the High Level Apprail. Is important to remember that during this kind of technical-economical analysis we were working with a comprehensive approach, considering all the technologies implemented as only one investments, divided per each building. In the HLA we did not divided every single technology with its cost, savings, income generation and a payback time, leading thus to an unique result for all the technologies and all the buildings considered. This method is explained by the fact that the HLA is a first approach technical-economical analysis, in which the provider has to present a comprehensive proposal to the tender and need to consider all the several investment as one. This approach is preferred in order to give a clear idea to the contracting authority of which is the order of magnitude of the asset on hand.

This method can bring significant advantages, in fact some technology resulting less competitive or marketable because economically unsustainable could be clipped by some more convenient investments. The more convenient investment could divert part of its savings or income to the less convenient one, making both of them sufficiently competitive to implement. Is clear how this mechanism is feasible only if the comprehensive approach to the investment is use.

3.3 Complete results

Concluding, these were the main measures designed for the two cases considered and the main economical aspects related to the investments. These two cases had been chosen for the large number of ECMs designed and the consistency of the result, but for sake of completeness the other cases and results are briefly reported. The other sites considered in the tender response where:

- Bryn Bach Park, Tredegar
- Bert Denning Centre, Brynmawr
- Bryn Bach Primary School, Tredegar
- Cwm Primary School, Ebbw Vale

For several reason we did not apply all the technologies in all the sites, some of them did not have a proper roof space for the photovoltaic installation or some did not have a thermal load for a biomass boiler installation. In the next table are showed all the planned ECMs for each site.

		Premises (building / asset)					
	ECM Description	ABERTILLERY	BERTDENNING	BRYNPRIMARY	CWMPRIMARY	WILLOWTOWN	BRYNSPORT
ECM 1	PV	X	X	X	X	X	
ECM 2	LED	X	X	X	X	X	X
ECM 3	BOILER	X	X	X	X	X	X
ECM 4	WATERSAVER	X	X	X	X	X	X
ECM 5	CLOROAMMINA	X		X		X	X

Figure 72 ECMs installed

For each of these sites we implemented the same solutions described above and with the same method, the main parameters were evaluated as the total investments, savings achieved and payback time. To not overload the document here are reported just some graphs to give an idea of all the cost faced for each technology, avoiding to report all the Excel sheets for each building and ECM.

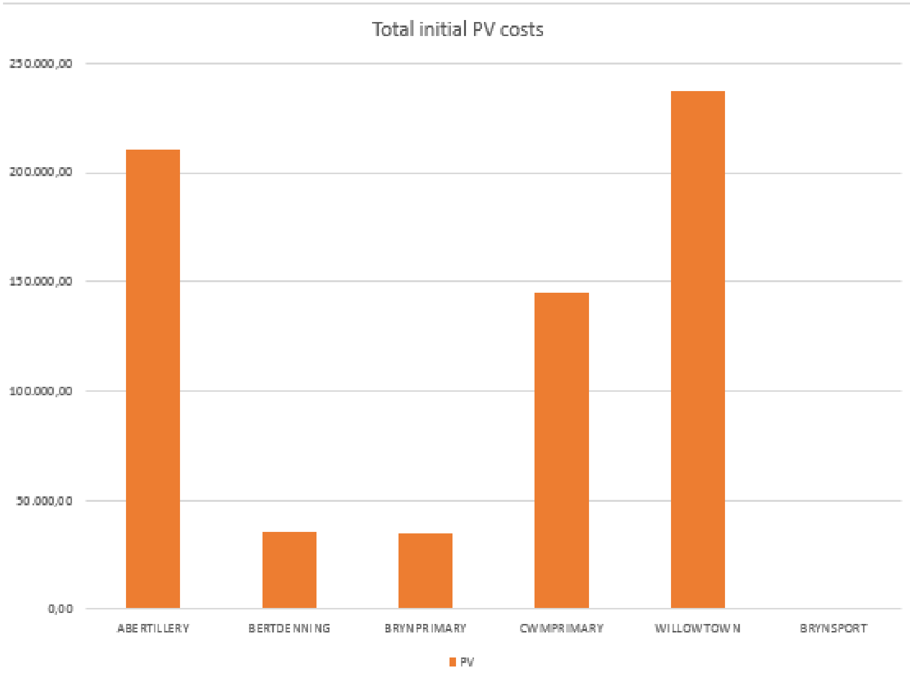


Figure 73 PV initial costs

Is easy to notice the different investment done among the buildings, mainly due to the available space on the roofs. As mentioned before some buildings were designed as "electricity hub" for the community, oversizing the plant installed, while others, as the Bryton Sport Center, could not have this technology installed for the peculiar structure of the roof.

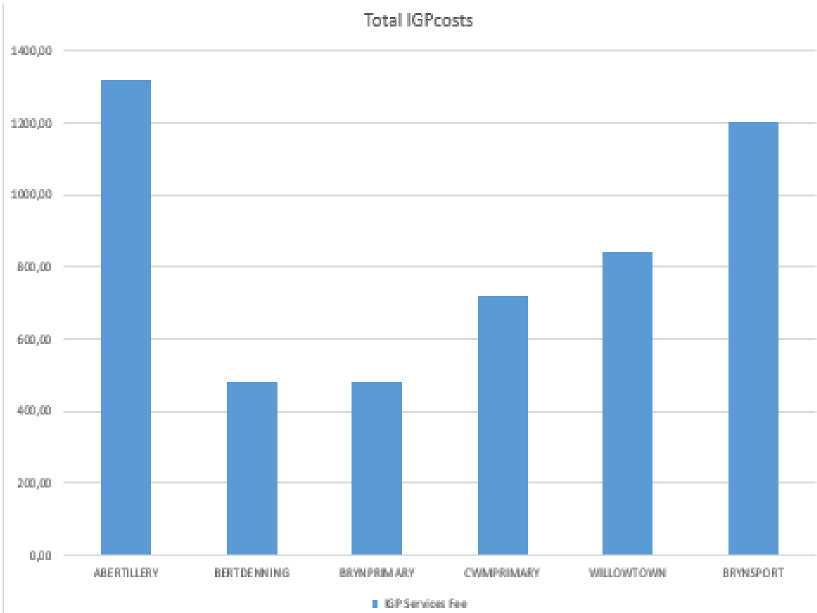


Figure 74 IGP costs

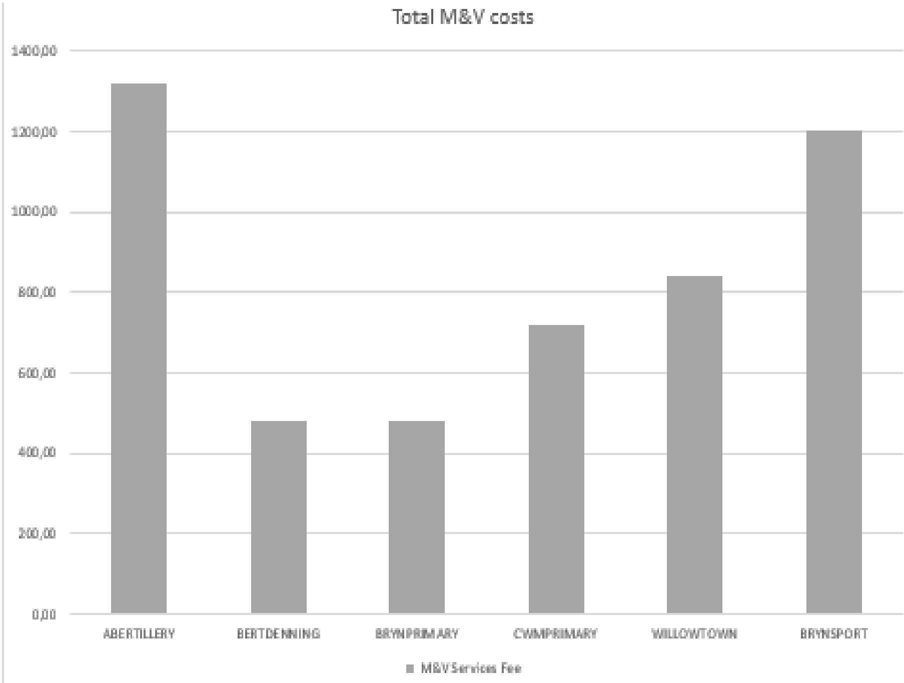


Figure 75 Measurement&Verification costs

We can easily see how both the IGP and the Measurement and Verification costs have the same trend for each building. This similar development is due to the fact that these are fixed costs decided by the company and depending on the total surface of each building. so being the are always the same, the graphs maintain the same trend changing only the order of magnitude of the investment.

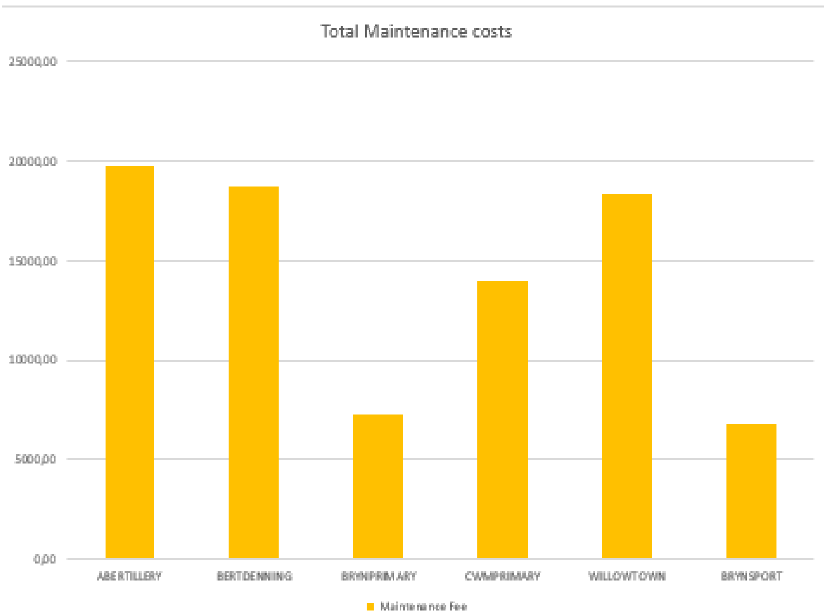


Figure 76 Maintenance costs

Considering the maintenance costs, they are proportional to the number of technologies installed in each building. As a matter of fact, the more energy savings measures are installed, the more maintenance is requested with its relative costs. Reason why the Abertillery Sport Centre and the Willowtown Primary School result the buildings with the highest investments cost, considering that on those two cases all the available technologies were installed.

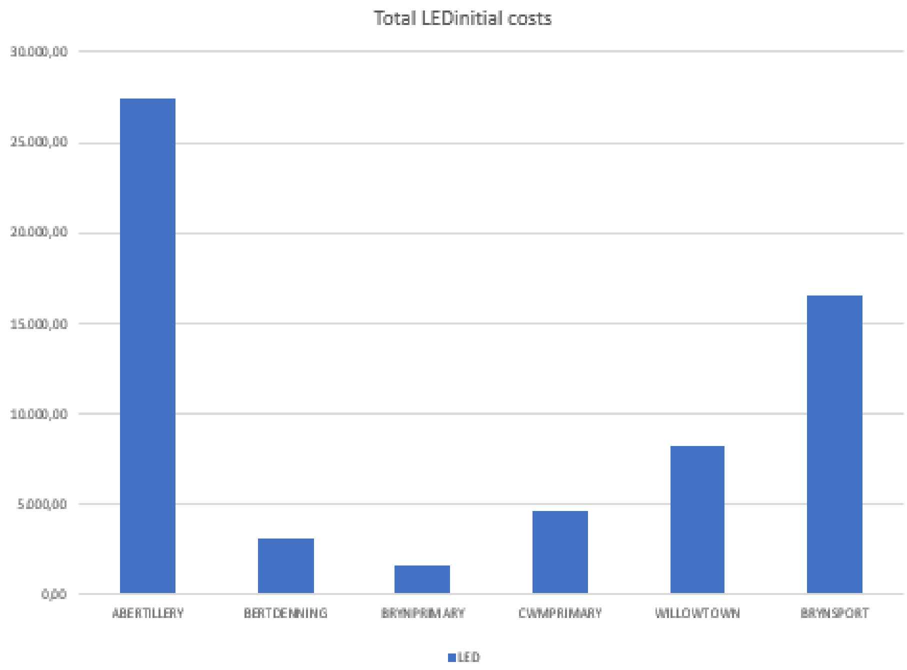


Figure 77 LED installation costs

Regarding the LED installation cost is proportional to the number of lights in each building, the more lights were in the building the more LEDs had to be installed in the substitution phase. Is interesting to notice the remarkable difference in the number of LEDs installed among the sport centres and the primary schools, showing how sport centres have a much more large lighting system.

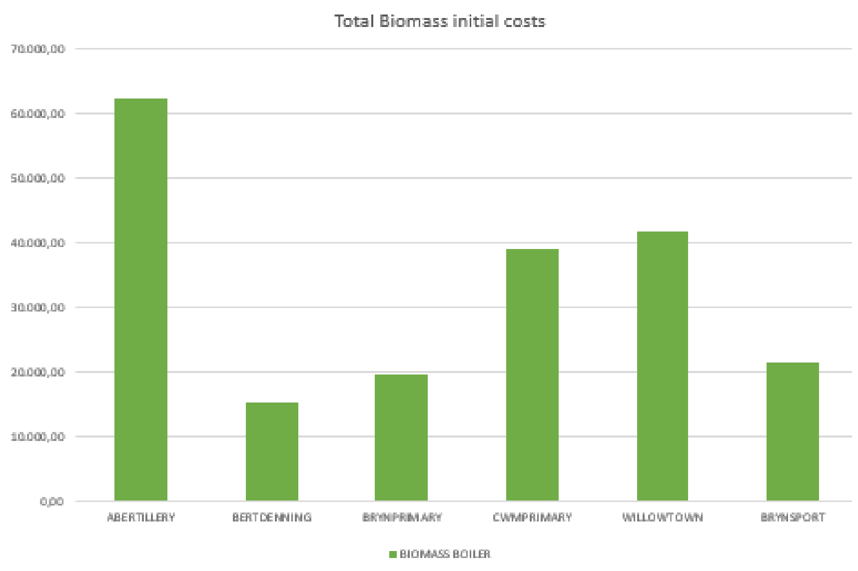


Figure 78 Biomass boiler initial costs

Referring to the biomass boiler is possible to notice how the installation cost are different from one other, depending mostly on the thermal load provided by the contracting authority. It is reasonable that the sport centre has a larger thermal demand than an elementary school.

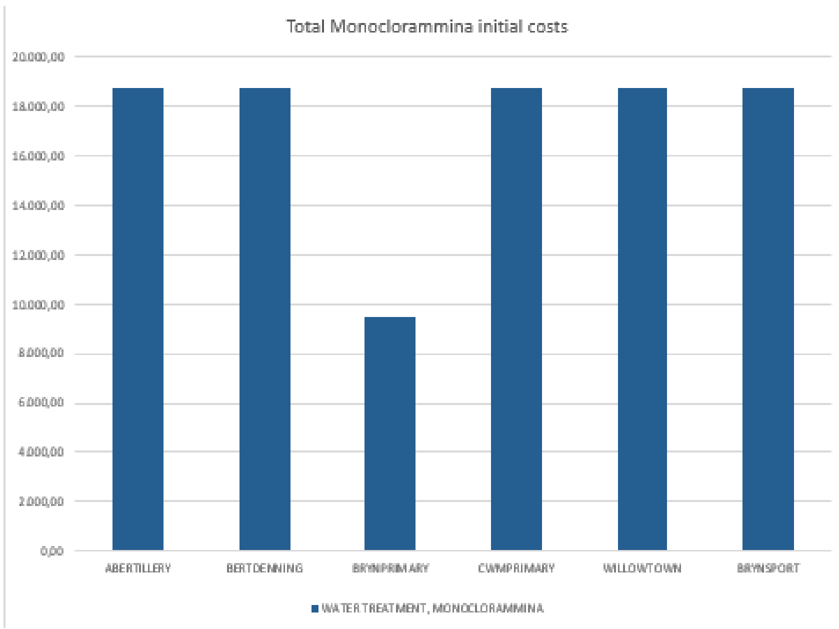


Figure 79 Monocloroammina costs

The Monocloroammina technology did not depend linearly to the building water volume but had different dimension for range of water volume. For this reason we can see that almost all the buildings have the same installation cost, because their water volume remain in the same range.

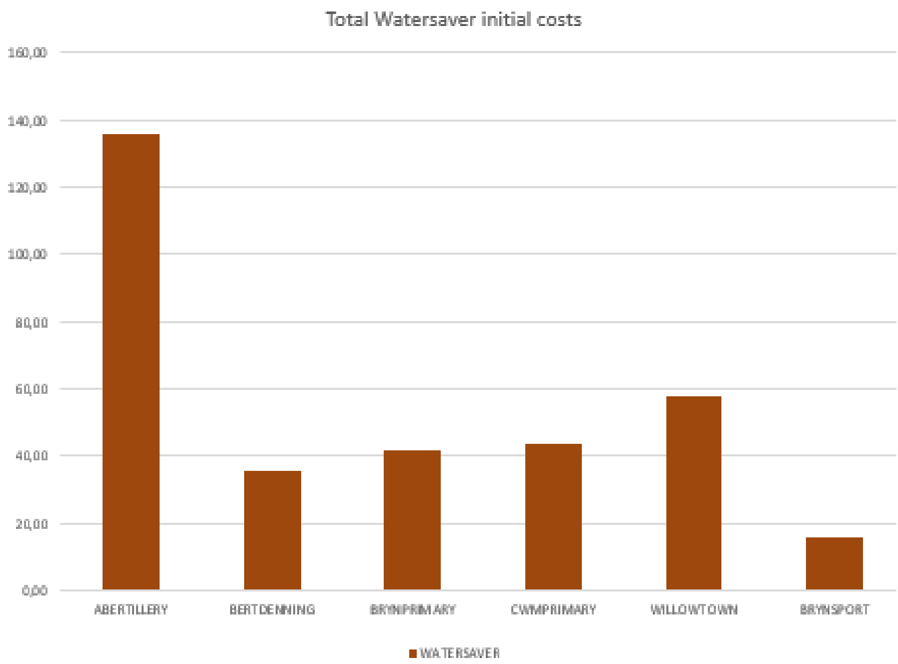


Figure 80 Watersaver costs

As already mentioned, this investment was probably the most economic thanks to the small investment cost requested and its size depended on the number of water points present in each building.

We now report the total investments done for each site and the High Level Appraisal excel file compiled.

Premises totals (over Payback Period)		ABERTILLERY	BERTDENNING	BRYNPRIMARY	CWMPRIMARY	WILLOWTOWN	BRYNSPORT
COSTS							
1 - IGP Services Fee	£	£ 1.320	£ 480	£ 480	£ 721	£ 840	£ 1.201
2 - Works/Optimisation Services Fee	£	£ 319.642	£ 72.942	£ 65.943	£ 207.357	£ 306.473	£ 56.864
3 - M&V Services Fee	£	£ 1.320	£ 480	£ 480	£ 721	£ 840	£ 1.201
4 - Maintenance Fee	£	£ 19.801	£ 24.751	£ 7.291	£ 13.988	£ 18.396	£ 6.810
A - TOTAL COSTS [Sum of 1 to 6]	£	£ 342.083	£ 98.654	£ 74.195	£ 222.788	£ 326.550	£ 66.076
7 - Total Anticipated Savings against Base Line	£	£ 57.130	£ 6.659	£ 7.978	£ 11.920	£ 20.321	£ 14.822
8 - Income: Anticipated Savings	£	£ 40.118	£ 9.060	£ 9.924	£ 18.296	£ 28.460	£ 6.698
Projected emissions reduction against Base Line	tCO_2e	240,84	36,38	43,09	83,50	144,37	62,26
B - TOTAL SAVINGS + INCOME [Sum of 7 to 9]	£	£ 97.248	£ 15.720	£ 17.902	£ 30.215	£ 48.781	£ 21.520
PAYBACK							
Simple Payback	Years	5,58940794	6,275874705	4,144585355	7,373310888	6,694234421	3,070421964

Figure 81 Total payback periods

Is possible to notice how the payback time are, more or less, of a similar order of magnitude. Not all the buildings are subject to the same amount of investments, the shorter payback period are due to the absence of a consistent investment as the photovoltaic. As a matter of fact, some cost definitely had a larger weight on the total cost, like it happened for the two cases studied. Even if not reported to not overload the document, the costs structure is similar to the one of the two cases reported. Is easy to imagine how the heaviest investment is the photovoltaic technology and the lightest one is the water saver. The big initial investment is followed by remarkable costs during the lifetime of the technology itself, as the maintenance costs. We can see in the next graph are reported all the costs faced in the investment phase, on one side they are reported in absolute terms, while in the next graph they are reported on a relative percentage scale for each sites took in consideration during the implementation of this project.

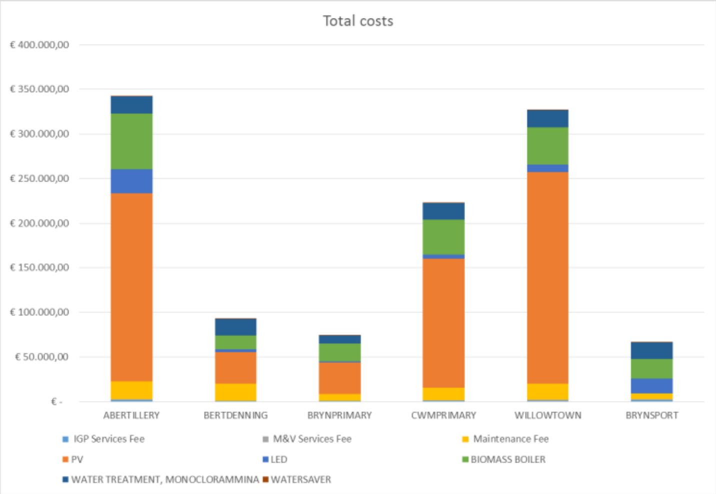


Figure 82 Total costs per building

Is easy to see how the main investment cost in each case was the photovoltaic installation, especially in the building with large roof availability and identified as possible energy hubs for the community. The relative weight of each technology in even more clear in the next graph.

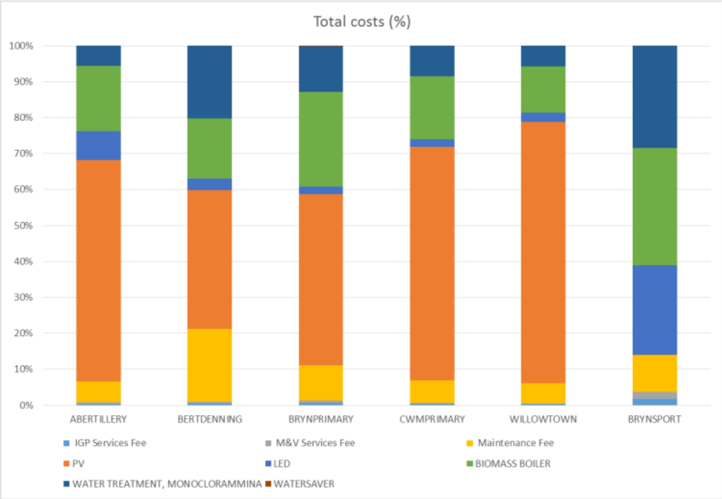


Figure 83 Total cost on percentage

The primary role of the photovoltaic technology is confirmed and is also notable how in some cases other technologies may result more consistence than other cases. For example the biomass and LED technologies in the Bryan Bach Park, motivated by the absence of the photovoltaic installation, or the biomass boiler in the Bryan primary school, due to a remarkable thermal energy demand.

3.3 Conclusions

In this chapter we analysed the HLA, that is the core of the economic offer made up for the project. We could observe the several voices that are involved in an economic tender proposal, even if not a proper technical aspect it was still interesting to understand how this kind of mechanism works. Keeping in mind that this part of the response is definitely one of the most important for the final tender evaluation.

We could quantify each measure applied in this project both in energy terms and in economic terms and could identify which technology had the more remarkable impact on the project and which did not, in terms of money spent, money saved, or environmental impact (CO_2 saved).

Moreover, we broke down the cost voices and understood the meaning of some of them as the overhead and the base internal labour rate. In the last part, we focused on the payback time and the cash flow of the entire investment, making sure to be under the 10 years constraint. Finally, we enlarged our analysis briefly to all the buildings involved in this project implementation noticing the consistency of the obtained results with the previous ones. In the next paragraph will be showed other activities done during the 5 months stage at Zephyro.

3.4 Other activities carried out during the stage

As mentioned in the previous paragraphs the overseas tender is just one of the activities performed by Zephyro. During the five months stage it was possible to work on many other events not only related to the energy efficiency field. The other main projects faced during the period were always related to the overseas tendering process, but of a different kind. One project was a tender response for a target bid and the other one was a response for a preliminary invitation to a tender circuit. The first one provides for a ambitious project of energy efficiency and energy production from solar panels for the city of London, in particular for the transportation system of London, including:

- London's buses;
- London Underground;
- Docklands Light Railway (DLR);
- London Overground;
- Tramlink;
- London River Services; and
- Victoria Coach Station.

Being a tender bid it was not required to provide a detailed technical solution, specific technical proposal or guaranteed solution performance levels. The only request was to answer to several request of different topics regarding:

- Project management
- Analysis and design
- Installation phase
- Performance delivery
- Achieving strategic goals and wider benefits
- Pricing approach
- Price criteria

The second project faced, instead , was not a target bid neither a partner bid, but was an invitation to tender for the Provision of Carbon and Energy Infrastructure Upgrade Services in Countess of Chester hospital NHS. This tender offered the chance to access to a prestigious tender circuit in the large hospital Chester County scenario, that would mean, in case of award, the possibility to work on many efficiency projects. To award this challenging tender it was not necessary to implement any technical solution, but it was necessary to demonstrate to the contracting authority our competence in the sector. As a matter of fact, it was requested to describe our work methodology and our know how in the energy efficiency field. To show the company experience in the response we had to answer several questions and annex examples from our older project implemented to testify the way of working and managing all the projects phases.

Beside the tender field, during the five months I had the opportunity to cooperate in many other interesting project the company was working on. As mentioned in the first chapter Zephyro has been focusing on the Research and Development field with the participation in calls for proposals of the "European Funding Program for Research and Innovation HORIZON 2020", in particular putting its effort in the STEER project (Support Tool for Energy Efficiency pRogrammes in medical centres). This project was implemented to meet the greenhouse gas reduction targets set by the European Commission and to provide the energy efficiency sector with a basic analytical and decision support tools. The aim of this project is to create a tool that will provide medical centres with information on the medical centre’s ideal energy consumption in different scenarios and on the most appropriate energy reduction plan for the medium-long term. The project’s primary proposal is to identity the main variables that are responsible for the energy consumption in medical centres and give to each of them a weight. A novel mathematical model will be produced which will reproduce energy consumption in given scenarios. It will be used by energy managers and decision makers to evaluate and compare future investments and actions to reduce energy consumption, also on the basis of their economic return. For the project realization I had to identify the hospital equipment mainly used in a common hospital, than identify and quantify the energy consumption of each single machine in order to break down the energy bills in a discrete scheme.

Lastly, together with other company members we had been working on enhancing the international dimension of the company, putting our effort on creating new economical relationships with important commercial groups in the Chinese region of Guangdong, in particular in Foshan and in Abu Dhabi. Thanks to the Italian-Chinese chamber of commerce in Milan we could meet several actors of the Foshan commercial field and start to have initial contacts. Moreover, moving our focus on the Abu Dhabi area, we started to cooperate with an Esco consortium specialized on building energy efficiency projects, the same service provided by Zephyro in Italy.

Conclusions

This study presents the implementation of a project, aiming at energy savings and CO2 emissions reduction through conservative measures and renewable technologies installation. Nowadays, climate change, energy economy, development of renewable energies and increase in air quality are some of the actual and central subjects we need to focus on. These needs remain the focal points of any policy, at any level both national and international.

In this thesis it has been shown how useful and powerful the calls for tender are, allowing the most competent ESCo in Europe to participate and cooperate on ambitious projects all around Europe. They also opened the opportunity to many clients to benefit from economical services of these companies with the best value for money. We decided to focus on two cases faced in the tender.

Moreover, thanks to the support of dimensioning software it was possible to size and design several technologies and energy measures. Homer Pro was used to generate the building's load curve. The PVsys software was used for the dimensioning phase of the photovoltaic panels. The Progetto Biomasse program evaluated the size of the biomass boilers. This project provides for several technologies, some of them with major economic impact, as the photovoltaic panels and the biomass boiler, while other energy conservative measures, as the LED, the water saver and the Cloroammina compound, resulted more economic, but efficient as well.

During the photovoltaic plant design phase we analyzed many different modules and scenarios, trying to identify the best tradeoff for technical solution and investment cost, using the payback time parameter. After implementing many different solutions the modules **VSG 580** for Abertillery and **Titan 32-300** for Willowtown was selected, with respectively the two inverters **SOLARMAX 50 C** and **Sunny central 60**.

Moreover, we designed a preliminary size of the two biomass boilers: **195 kW** of nominal power for Abertillery and **158 kW** of nominal power for Willowtown, to cover the heating space energy demand.

Beyond producing energy from renewable sources, we identified the consumption decrease a crucial factor for the CO_2 emissions reduction. Reason why several savings measures were implemented as the LED, the water savers and the monoclorammina compound addition in the domestic hot water boiler. These improvements resulted very efficient, assuring 40% savings in the electricity bill and 50% of water savings.

Furthermore, we addressed the introductive question on the feasibility of the project. Trying to find an answer, we implemented a High Level Appraisal, an economical proposal of the project, in which all the costs of the whole investment were reported. We focused on the detailed division of the costs, analysing the impact of each one on the feasibility of the investment and on its payback time. We identified the main costs of the investment: initial and maintenance costs and we recognised the importance of some parameters for the final cost of the investment. In particular, in the HLA implementation we had to consider some "business cost" typical of a profit guided company, as the overhead and the profit addition rate on labour, base materials or sub-contractors costs. It was necessary to reach a compromise between the client and the company requests on the final price proposed.

Finally, we demonstrated the feasibility of the investment calculating a seven years payback time for the whole investments implemented in the case studied. This interesting result was achieved partly thanks to the economic price achieved on the photovoltaic panels and partly thanks to the incentives provided by the national authority and this is one of the main result from this study: the authority role. The UK has a binding target of 15% final energy consumption from renewable sources by 2020 and the Department for Business, Energy & Industrial Strategy has recently reaffirmed the UK's commitment to the sector, despite Brexit.

The message is clear: renewable energy is here to stay and, in this context, the real estate sector is embracing the opportunity to play a new role in this energy scenario. There are several advantages for pursuing the use of renewable technologies in the real estate sector such as lower energy bills, due to the possibility of selling electricity back to the grid (smart grid), or becoming a local producer for the community around, like the Willowtown case studied. Other advantages are energy price stability, and where available, subsidies derived from the governmental support regime. Furthermore, commercial activities can take advantages from reputational benefit of their "green policy", as economical returns.

The UK's energy future, as for the Europe one, will necessarily require a mix of low-carbon solutions, which subsequently will shift the focus on different range of renewable technologies and their implementation.

The future is in the decentralization of the power production, where every energy consumer may be a producer himself thanks to the fragmentation of the producing system. Keeping well in mind that, while technology and regulations may be changing in the future, sustainability will always be a must and therefore the real estate sector has a big role to play in the disaggregation of energy generation forging new implementation of renewable technologies.

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