CommONEnergy

DELIVERABLE 2.4

Interaction with local energy grid

European Commission

DG Research and Innovation

SP1 - Cooperation

Collaborative project

Large-scale integrating project

FP7-2013-NMP-ENV-EeB

GRANT AGREEMENT No. 608678

CommON*Energy*

Re-conceptualize shopping malls from consumerism to energy conservation

FP7 European Union Funding
for Research & Innovation

Technical References

Project Acronym	CommON*Energy*
Project Title	Re-conceptualize shopping malls from consumerism to energy conservation
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Project Duration	1 October 2013 – 30 September 2017 (48 Months)

Deliverable No.	D2.4
Dissemination Level	PU
Work Package	WP2
Lead beneficiary	CARTIF
Contributing beneficiary(ies)	EURAC, SINTEF, ITM-POWER
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Reviewed by	ACCIONA, SINTEF
Date	20/04/2015
File Name	WP2_D2.4_20141210_P04_Interaction with local energy grid

This document has been produced in the context of the CommON*Energy* Project.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 608678. The content of this document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the document lies entirely with the authors.

Contents

Executive summary

This document reports on the analysis of the interaction between shopping centres and the electrical grids to which they are connected. The objective is to identify key aspects, which allow improving the current status of such interaction, and identifying the capacities that these types of buildings could give as suppliers/providers of services to the grid.

For the development of this report, ten existing shopping centres have been taken into consideration. Three of them are demo-cases (Mercado del Val in Spain, Genova Ex Officine in Italy and City Syd in Norway) where the CommON*Energ*y project solutions will be applied. The other seven reference shopping centres are distributed throughout the whole of Europe (Belgium, Lithuania, UK, Italy and Austria), trying to cover as many of existing typologies as possible. These buildings will allow extrapolating the obtained results in a more objective way for a wide building stock.

Initially, the most relevant information with regard to the power grid has been collected – shopping centre interaction, key aspects of the electrical grid, the potentials between the shopping centres and the electrical grid to which they are connected, typical energy profiles and consumptions of shopping centres, and factors that could influence the interaction, such as climatic, urban and energy production / distribution context.

We also thoroughly analysed and selected the parameters and Key Performance Indicators (KPIs) that are considered most relevant in characterising the interaction between the malls and the electrical grid. These parameters have been divided in different categories: those that characterise the mall for its energy behaviour, those studying the possibility of incorporation of renewable energies, and those which describe the quality of the energy supply through a grid analyser. Regarding the KPIs, we selected as the most relevant the Load Match and the Grid Interaction index.

Two tools have been used to characterise the existing shopping malls, taking into account the parameters identified before. Covering the first two categories of parameters (energy behaviour and renewable energy), we developed a questionnaire addressed to owners / managers, with the aim to obtain specific information for each of the shopping centres. To study the quality of the grid, we used a grid analyser, but only in the Valladolid demo-case, as this equipment was only available there. The grid analyser has revealed the lack of quality in the grid to which the shopping centre is connected.

Moreover, we developed different daily energy profiles for each of the shopping centres following a specific methodology to calculate the Load Match and the Grid Interaction index with different possible energy efficient measures.

With the collected and analysed information, we identified the potentials in each of the existing shopping centres as possible improvement actions in the interaction between the buildings and the grid. Furthermore, we suggested solutions divided into on-site RES, Cogeneration, Energy Storage, Peak shaving and Energy saving, with the objective to exploit such potentials. Potentials and solutions in shopping centres depend on the specific characteristics of the context, such as weather conditions, location, energy profiles, size, typology, etc. With the available information, it has been possible to calculate the Load Match and the Grid Interaction index trying to understand how different solutions affect the interaction between the shopping centres and the electrical grid.

As a general conclusion and after studying the ten reference shopping centres, we verified that there is a significant potential for improvement in the interaction between the buildings and the energy grid. The potential for integration of renewable energies such as solar (through PV) and wind (wind turbines) is noticeable. This also depends on the weather conditions, the availability of free spaces where it is possible to integrate the systems, but also without obstacles that could compromise the effective functioning. With the integration of renewables and relative self-consumption it is possible to reduce the electrical demand from the grid to which the shopping centre is connected. Cogeneration systems are also very useful in terms of self-consumption and demand reduction from the grid, producing at the same time electricity and thermal energy, also allowing a decrease of the overall primary energy. The replacement of old or bad sized lighting or HVAC systems has of course a great potential of reducing electrical consumption and impact on the grid. This is also possible through the improvement of the envelope performance, and through suitable control and management systems, enabling to manage the demand optimising the way in which the shopping centre consumes / distributes the electricity. Energy storage systems allow collecting energy produced by renewables energies or when the grid is in valley period with low electricity demand and then use it or feed in the grid in peak periods.

1. Importance, critical aspects and potential of shopping mall-grid interaction

Shopping malls have high energy savings and carbon emissions reduction potential due to their large lighting loads, high population density and hence, a large air conditioning demand. Energy retrofitting processes applied in most buildings have consisted of incorporating energy producing technologies and using highly efficient HVAC and lighting technologies for reducing energy consumption. However, in the new energy landscape, the increasing power consumption also requires maintaining power grid safety and reliability with less mismatching between electricity generation and demand. Power grid fluctuations in both power demand and generation, even for few minutes; induce an effort to supplementary setting on conventional production units. Hence, nowadays with the trend towards more complex, flexible and dynamic systems as well the higher penetration of distributed and centralised renewable energy systems, the issue of peak reduction of demand/generation mismatch has gained importance. At the same time, shopping malls cover important surface areas and are a reference point for citizens, with possibilities to provide services to both the grids and the community.

1.1 Relevant aspects of grid

A conventional power system is characterised by large scale generation sources that inject large amounts of energy into the transmission grid, which in turn is transported to passive distribution networks, and then delivered to the end-users. In this paradigm, energy flows only in one direction: from the central power station to the network and the consumers.

Currently and little by little, this concept of conventional power system is changing from a centralised to distribution generation systems. Distributed generation refers to a variety of small, modular power-generating technologies that can be combined with load management and energy storage systems to improve the quality and/or reliability of the electricity supply. They are distributed because they are placed at or near the point of energy consumption, unlike traditional centralised systems, where electricity is generated at remotely located, large-scale power plant and then transmitted down power lines to the consumer.

Distributed energy encompasses a wide range of technologies including wind turbines, solar power, fuel cells, micro turbines, reciprocating engines, load reduction technologies, and battery storage systems. Some of these technologies could be highly intermittent in nature, relying on variable time-dependent resources. Therefore, the grid could be asked to compensate when theses productions are not sufficient and adsorb excess production even in times of low demand.

Implementing distributed energy can be as simple as installing a small, stand-alone electricity generator to provide backup power at an electricity consumer's site or it can be a more complex system, highly integrated within the electricity grid and consisting of electricity and thermal generation, energy storage, and energy management systems. Shopping centre owners/managers sometimes own the small-scale, on-site power generators, or they may be owned and operated by the utility or a third party (National Renewable Energy Laboratori-www.nrel.gov).

Within its 2020 energy strategy, the European Union has proposed a 20% reduction of primary energy consumption and CO_2 emissions, as well as 20% of total final energy consumption coming from renewable sources (European Commission – ec.europa.eu). Therefore, this concept of distributed energy will continue increasing in the following years.

There are some problems associated to the grid, encouraging to invest in the current infrastructure’s refurbishment and to define new strategies to alleviate the issue:

- Difficulties to store a large amount of electricity both on a single site and for the comprehensive grid. Hence, self-consumption should be promoted with electricity demand profiles similar to the production ones. At the overall grid level, this is achieved with the control and management by the electric operators that must foresee and supervise the generation and transport facilities in real time in order to match the power production with the energy demand by end-users. Thus, for each day, they make a forecast of the demand curve, which is adjusted according to actual needs. This could be more problematic for current and future grids because of the volatility of RES production. For a conventional grid, it is easier to solve since it is based on power plant electricity generation, which should be timed to match the demand. If the individual building increases its self-consumption, it would alleviate this issue.

- During peak demand and when the RES production is low, special plants start working, which implies an overcost, the need to build these seldom-used facilities and depend in the supply from other countries. End-users assumed part of these over costs in the payment of the invoices. On the other hand, when RES production is high the grid could be filled sometimes with unneeded electricity. The time-variable prices of electricity are influenced by these aspects.

New concepts in the current energy grid have emerged in order to solve the previous problems by increasing the control and awareness over the consumed energy. The participation of the end-users in the management of the energy with energy counters allows knowing the consumption profiles and the time-dependent cost of energy consequently pushing them to use energy in valley moments in order to reduce the bill. For example, solar energy production is generated mainly during the demand peak for shopping malls. If end-user could integrate such facilities in shopping centres, self-consumption would be high (often at or near 100 %) reducing the energy need to generate additional electricity through in fossil fuels/nuclear power plants while also benefitting from receiving a payment for injecting the surplus of energy into the grid. Additionally, the match between production and demand could be improved by modifying some of the flexible demand profiles or using excess electricity for additional services (e.g., e-vehicle charging station or hydrogen production) and in general exploiting times of low (i.e., overproduction) electricity prices. Therefore, shopping centres have high potential in contributing to the solution and assisting in managing the issue that have arisen regarding the RES integration, energy management and to support the grid.

1.2 Description of potential interaction between building and grid

In Europe, buildings are responsible of about 40% of the energy consumption, which causes buildings – and shopping centres - to have a significant impact on the grid to which they are connected.

Figure 1 shows how the service sector, which includes shopping centres, has a very high influence in the final electricity consumption in Europe (around 30%). As a consequence, shopping centres have a big influence on the electricity profiles, especially on the local grid where they are located.

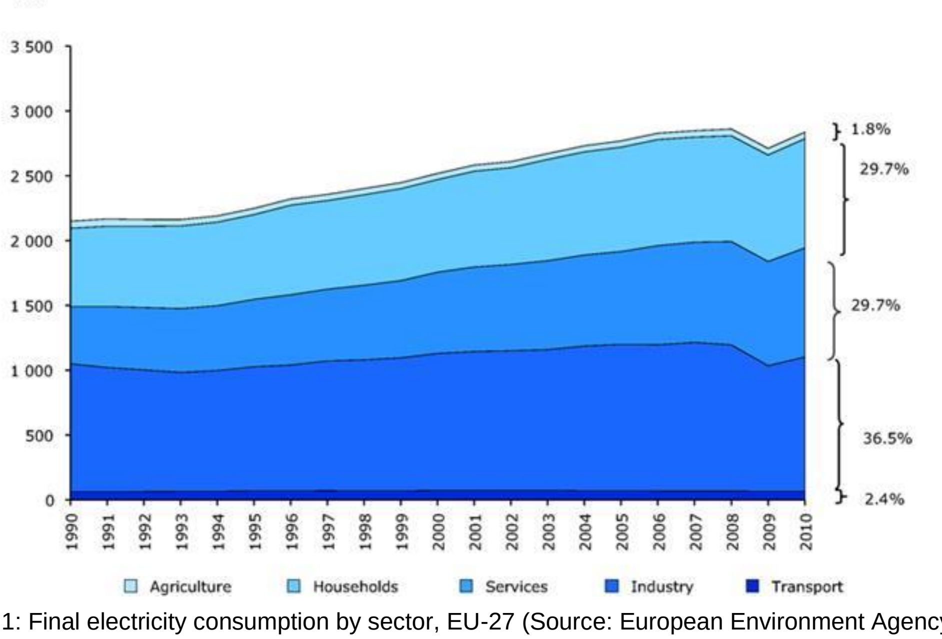


Figure 1: Final electricity consumption by sector, EU-27 (Source: European Environment Agency)

To be more specific, the breakdown by sub-sector clearly reveals the high electricity consumption of the wholesale and retail trade sector with 37% (Figure 2). (Feliter et al, 2010).

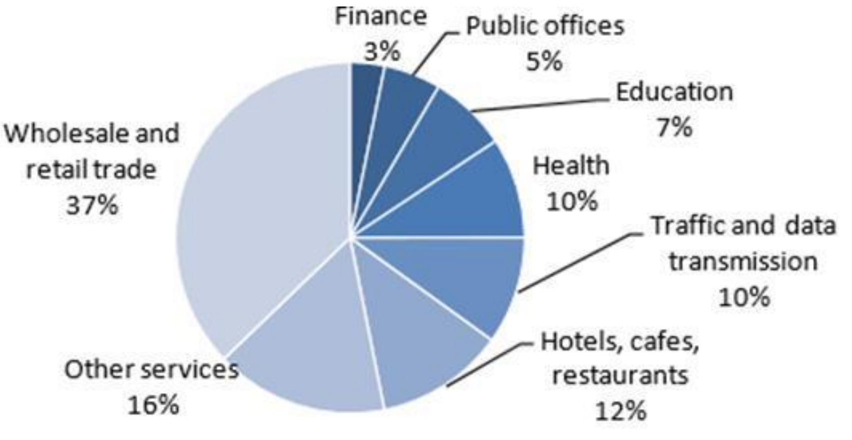


Figure 2: Electricity demand of the tertiary sector of the EU27+2 by sub-sector in 2007 (Source: Fleiter et al, 2010)

Based on the values regarding the sub-sector in which the shopping centres are included (around 10%), the potential to impact the interaction with the grid through measures aimed at improving energy efficiency of the buildings is significant.

Energy efficiency in shopping malls could be increased through the optimisation of the operation of the building (reduce the energy demand, local generation and storage) but also through improving the behaviour of the building users (both owners and tenants). Additionally, thanks to the large surfaces available and being a focal point for the community they could also provide useful services (i.e. electrical mobility).

Reducing the electricity demand is possible for example through passive measures (e.g., daylight and natural ventilation), the installation of high efficient lighting systems, appliances and HVAC systems but also through a well-established energy management system that operates the system at its maximum potential.

Increasing the local generation could even turn shopping centres from being mere consumers to become producers. This is possible if renewable energies are installed, such as photovoltaic, wind power, or combined heat and power systems (CHP). With this approach it is not only possible to increase the efficiency of the generation process, but to also avoid transmission and distribution losses.

Energy storage allows satisfying the shopping centre’s demand for a longer period of time from renewable energy systems storing energy during periods of overproduction and using it in underproduction periods when the building demand is higher than the renewable energy production. In the case of renewable energy storage, it is also possible to provide capacity to export power to the grid in periods of overproduction, if necessary. Another possibility is to store electricity from the on-site production/grid in valley periods in which the saturation of the grid and prices are lower and use it in peak periods with higher saturation and prices avoiding in this case disturbances in form of peak demand on the grid. Eventually the excess electricity could even be converted to different fuels (i.e., hydrogen) and used for a variety of purposes.

Control and management systems of the energy demand also play an important role in the interaction, allowing to manage in a suitable way the energy consumption/distribution of the building and trying to optimise the working conditions at every moment.

All these aspects related to the interaction between the shopping centres and the electrical grid are more detailed in the following chapters, where these potentials will be applied in different shopping centres depending on their own characteristics.

1.3 Characterisation of shopping mall energy profiles

The energy consumption depends largely on the type of shopping centre. There is a great disparity of facilities: shops, department stores, supermarkets, etc. In the case of small shops, there is a wide dispersion on the values of energy consumption per square meter, however, an approximate average value of 180 kWh/m^2 is estimated. For large (food-related or high tech) supermarkets and hypermarkets, this value rises to 327 kWh/m^2, and in shopping malls values between 118 and 333 kWh/m^2 are reached, the contribution of the thermal envelope being particularly important as well as the distribution and generation systems (Guía de auditorías energéticas en centros comerciales, 2010) .

There are also differences in shopping centres energy use and system solutions due to local outdoor climate, available energy sources, prices, national building regulations, traditions, etc. This influences both the absolute values and the consumption profiles.

Shopping malls have huge power needs, with typical long operating hours. They tend to have large lighting loads, high population density and, hence, a large air conditioning demand and ventilation loads, and large but fluctuating number of shops. There is also an apparent trend toward increasing glass surfaces and such design feature affects the energy balance of the building (Sofia Stensson et al, 2009).

Figure 3 represents the electricity consumption by sub-sector and energy services for Europe (EU27 + 2). For the wholesale and retail trade sector, the most important end-uses are Lighting, Electrical appliances, Ventilation and air-conditioning, and Refrigeration, which account for more than the 85% of the total electrical consumption.

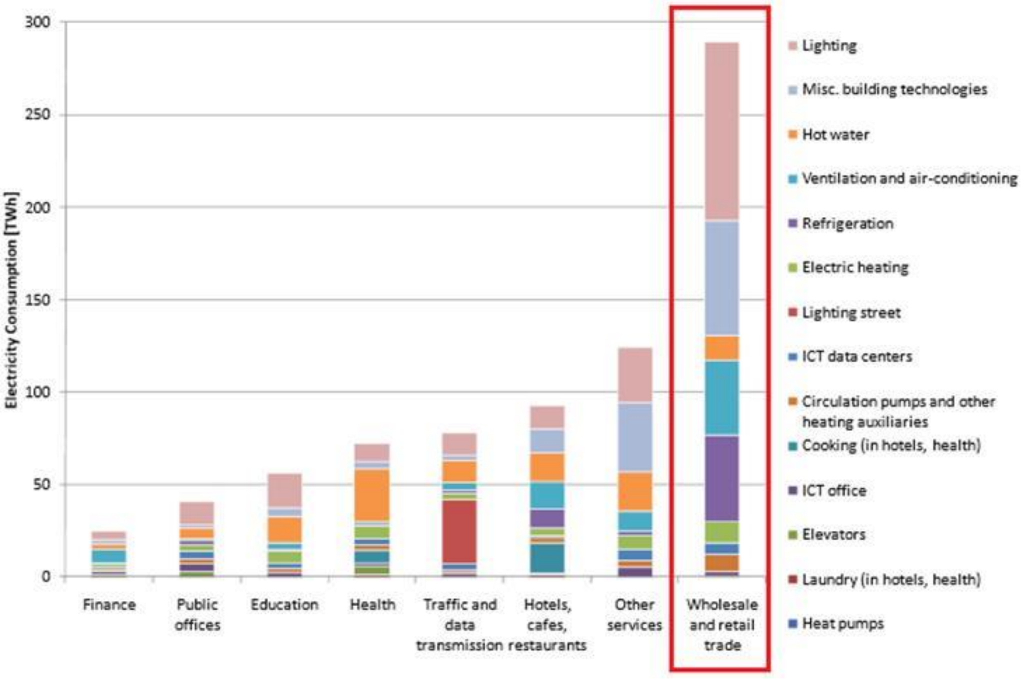
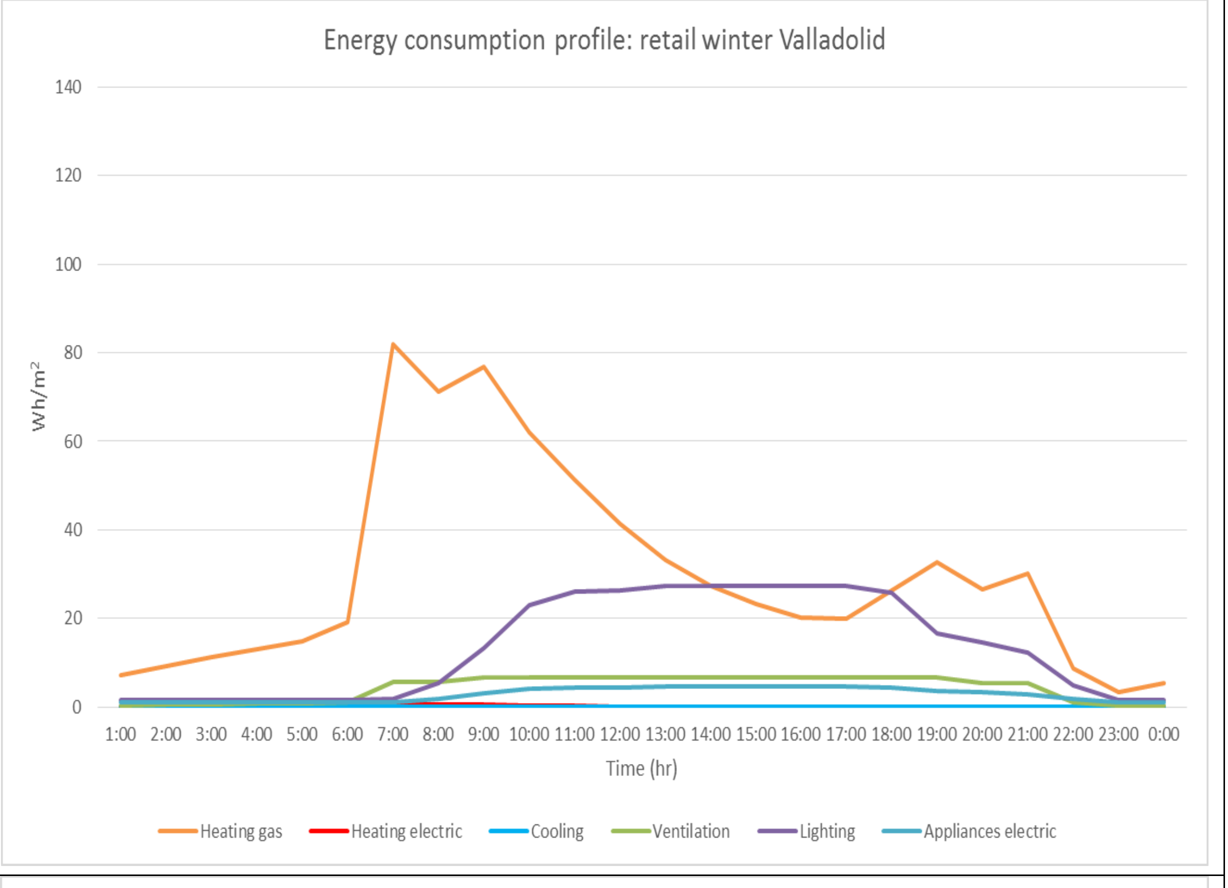


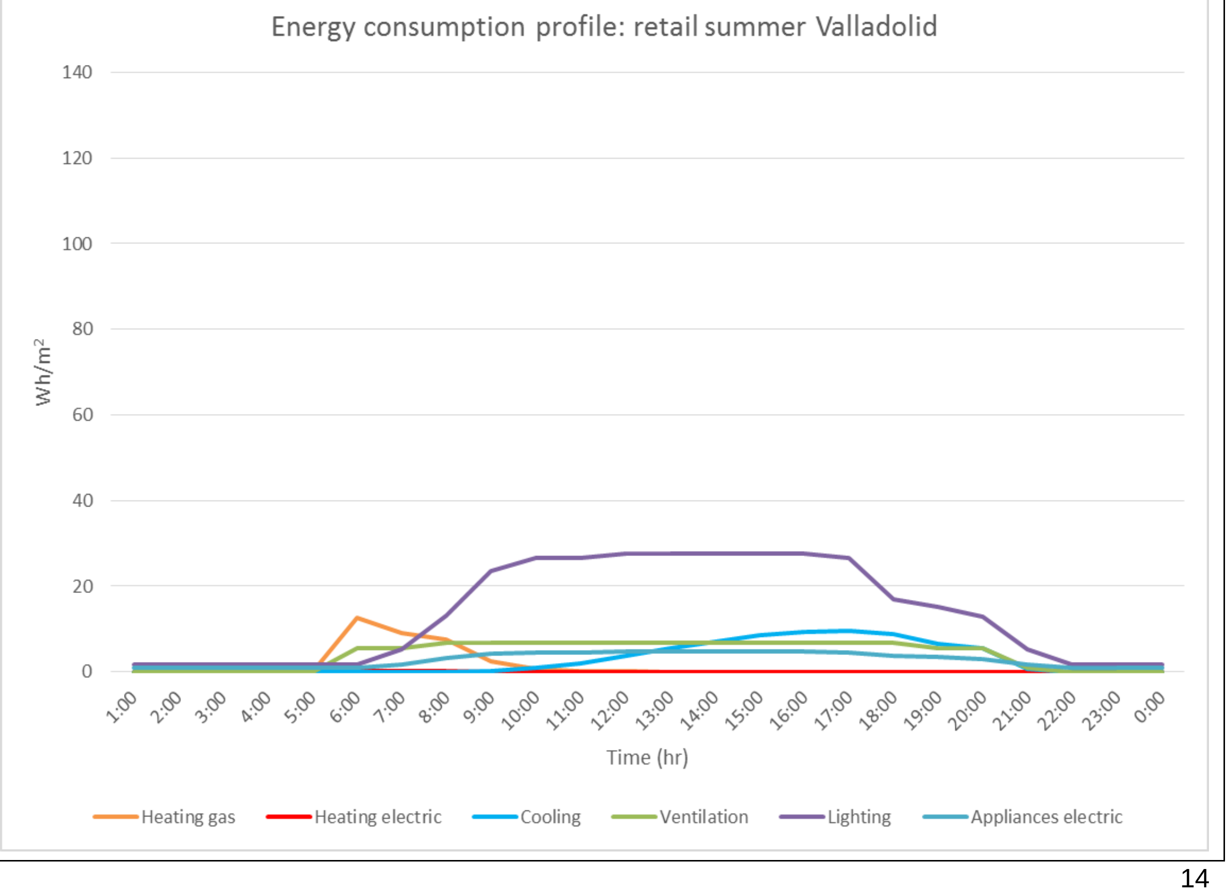
Figure 3: Electricity consumption by sub-sector and energy service for the EU27+2 (Source: Tobias Fleiter et al, 2010)

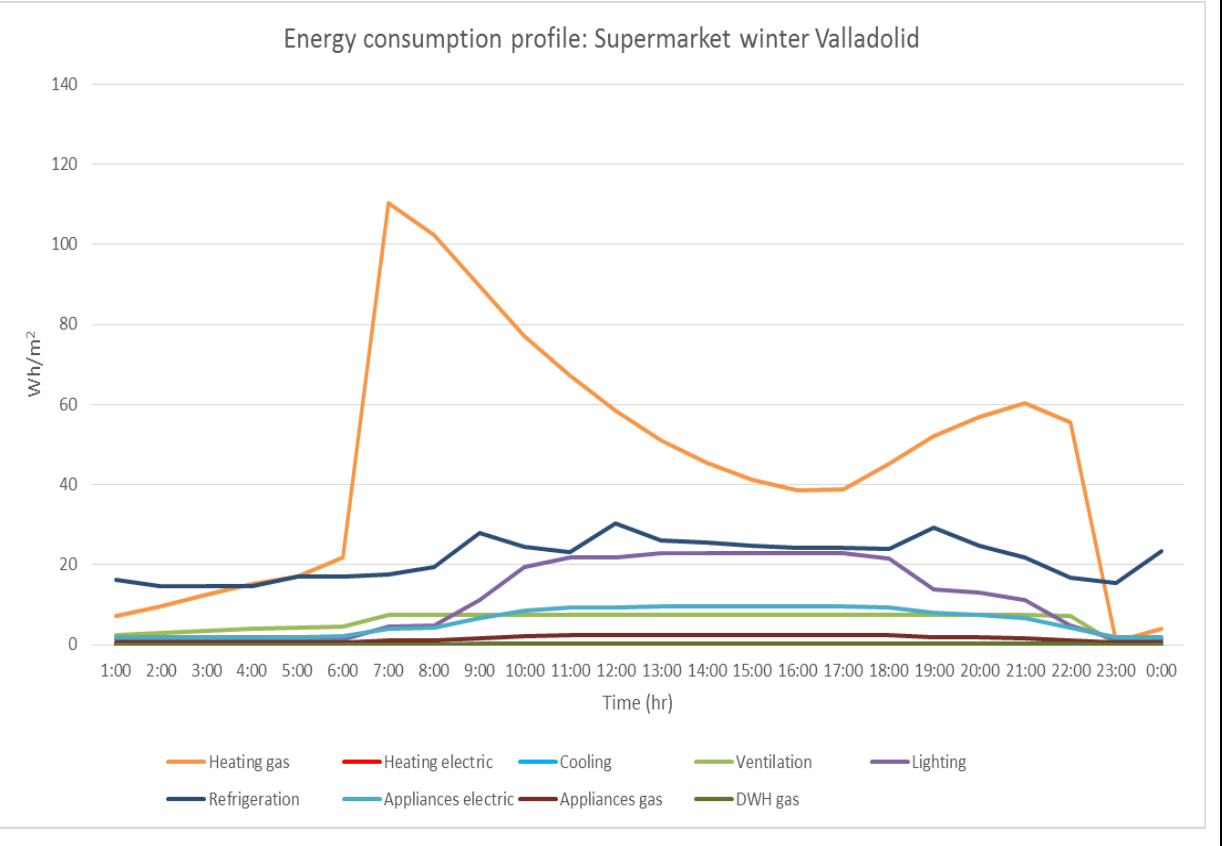
However, the profiles of these specific electricity uses can be quite different and are influenced also by the store type, the season and the climate. Table 1 shows typical energy consumption profiles by final end use for different seasons, climates (using the 10 locations of the reference buildings) and typologies (food and non-food store). These profiles were generated by running in EnergyPlus the reference building defined by the DOE (http://energy.gov/eere/buildings/existing-commercial-reference-buildings-constructed-or-after-1980) associated with the US climate most similar to the climate of interest. Such profiles generate typical energy behaviours for shopping malls in different contexts and allow understanding how possible modification strategies could impact these profiles, the match between demand and production and finally the building-grid interaction.

Table 1: Energy consumption profiles for shopping malls in different context.

Shopping Mall in Valladolid






Energy consumption profile: Supermarket winter Valladolid
140
120
100
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20
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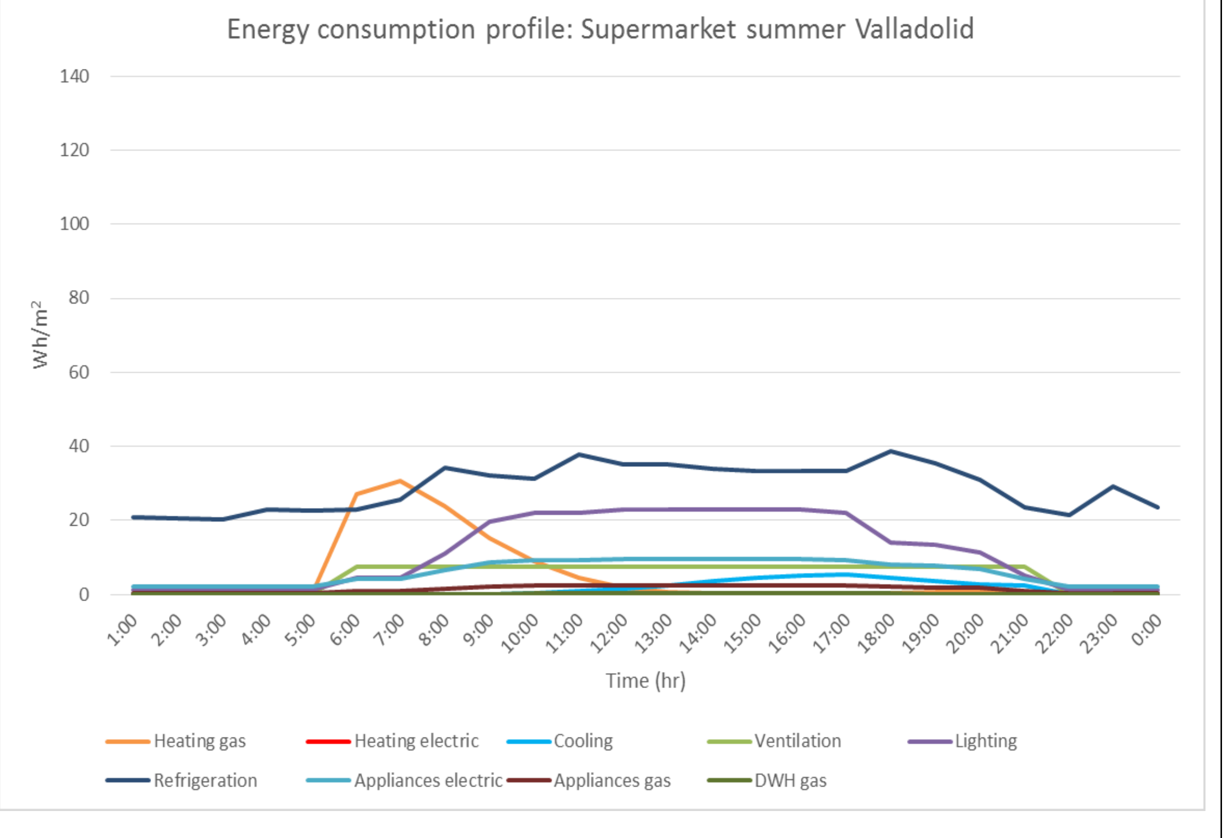
Wh/m²
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer Valladolid
140
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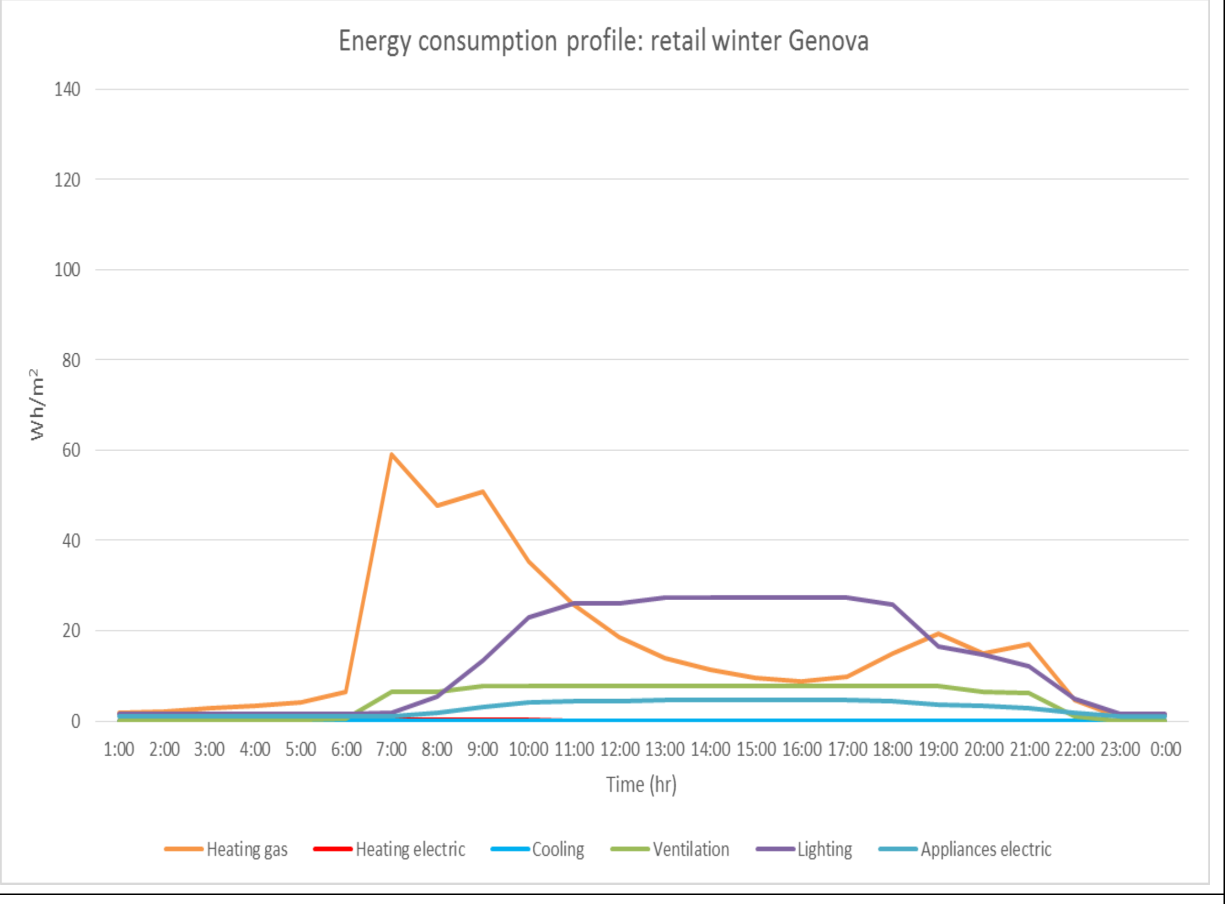
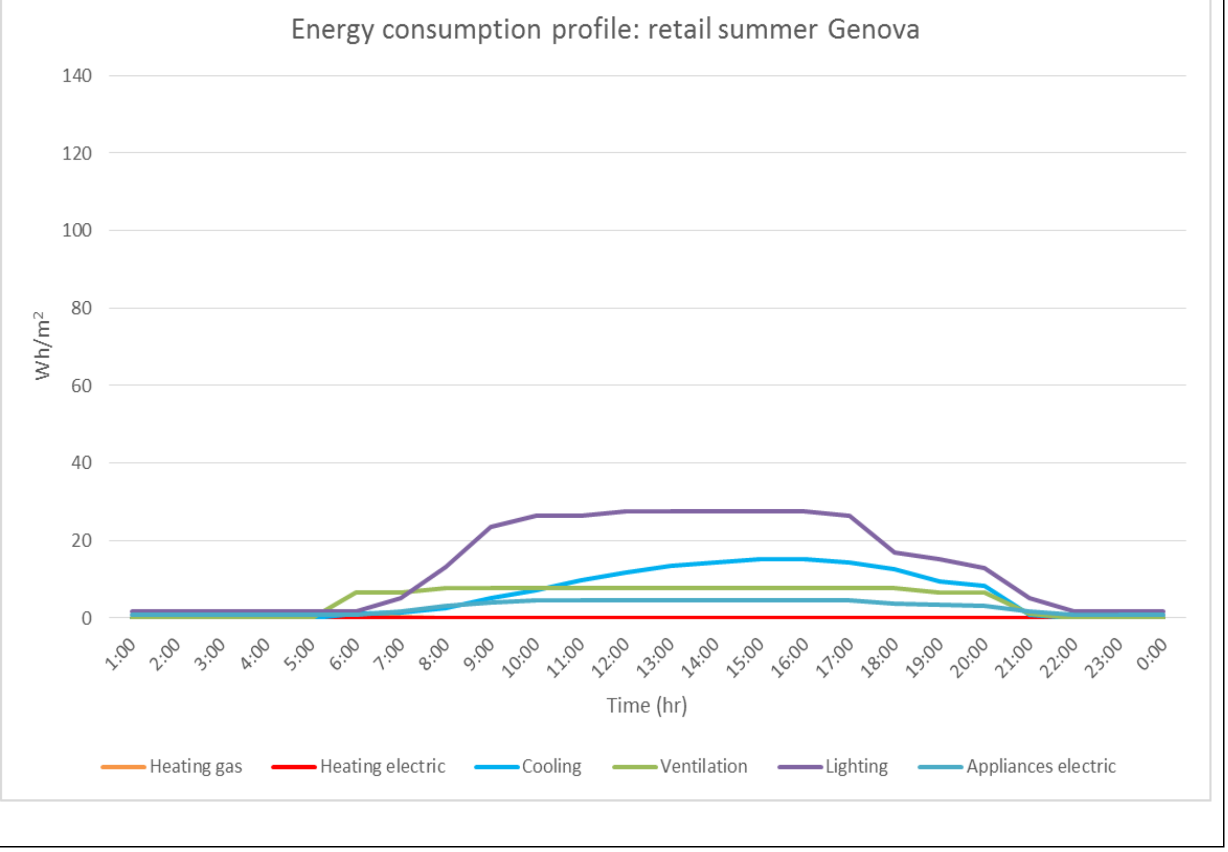
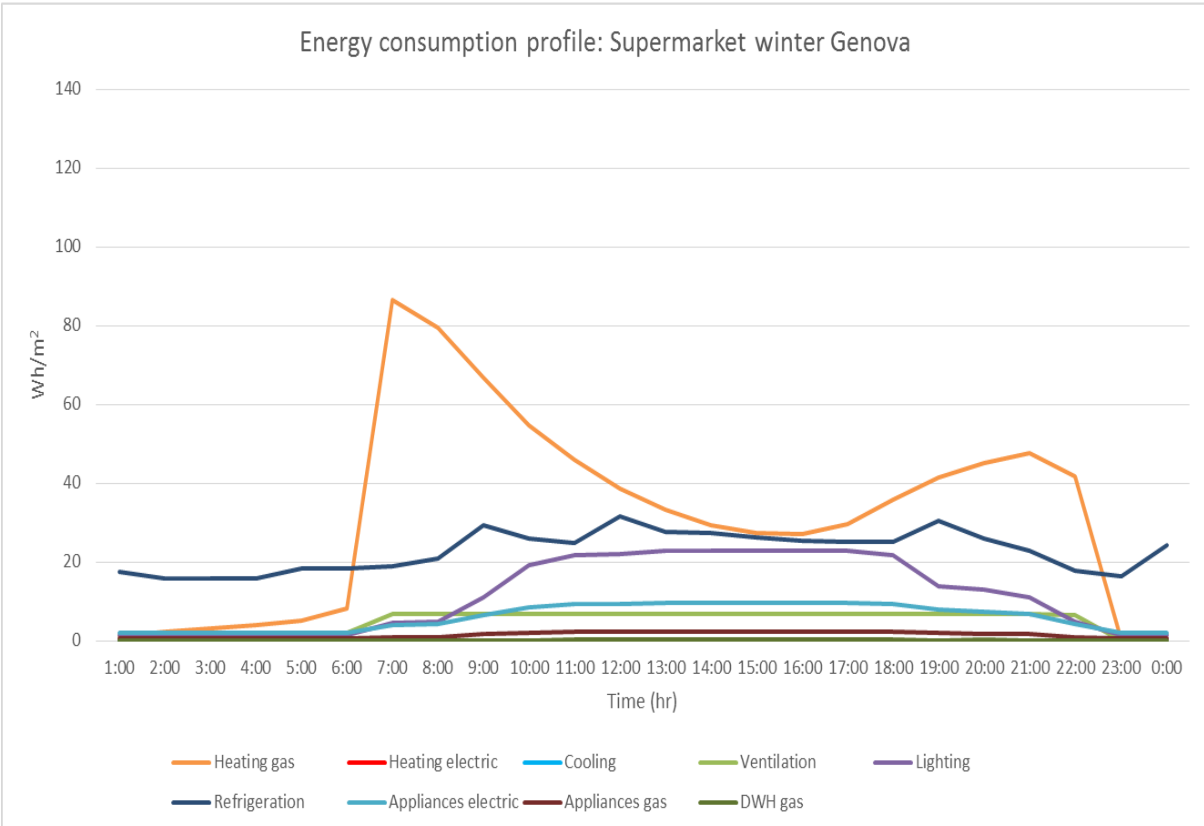
Wh/m²
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Genoa




Energy consumption profile: Supermarket winter Genova
140
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Wh/m²
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Time (hr)
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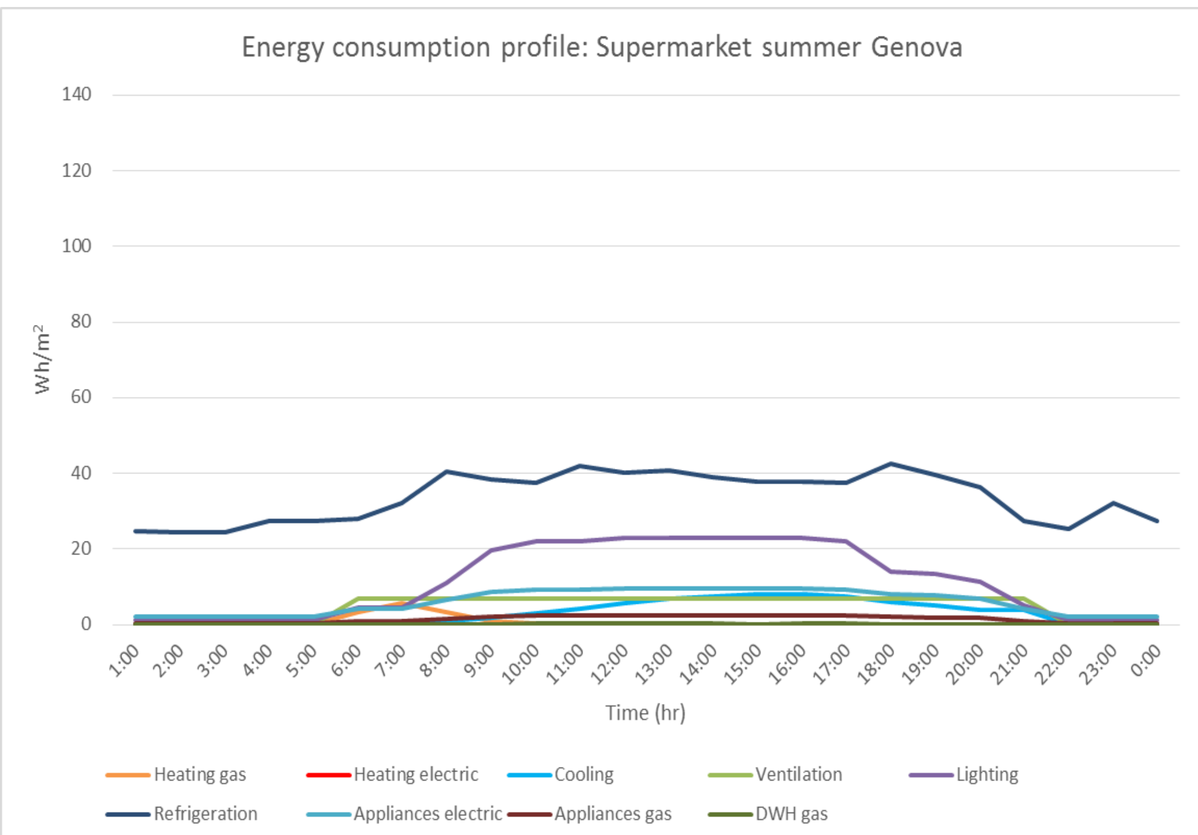
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas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Wh/m²
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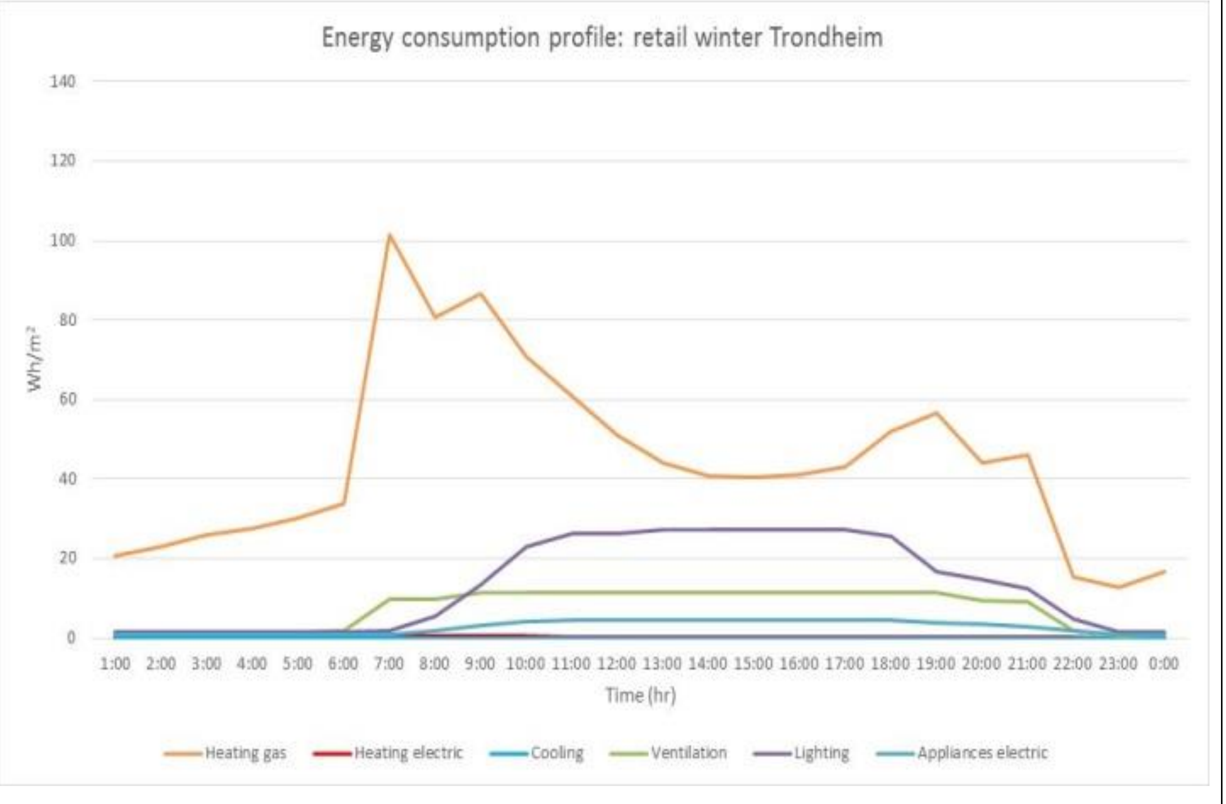
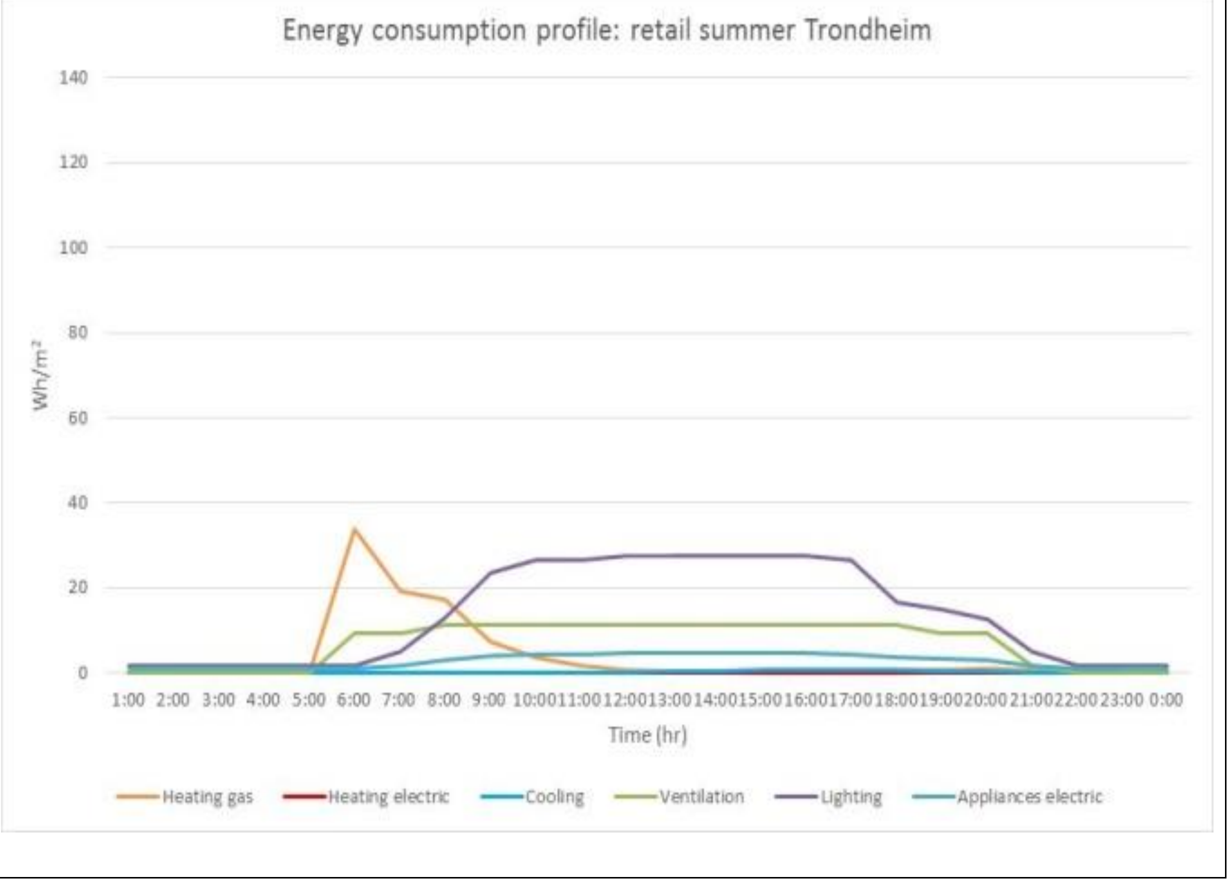
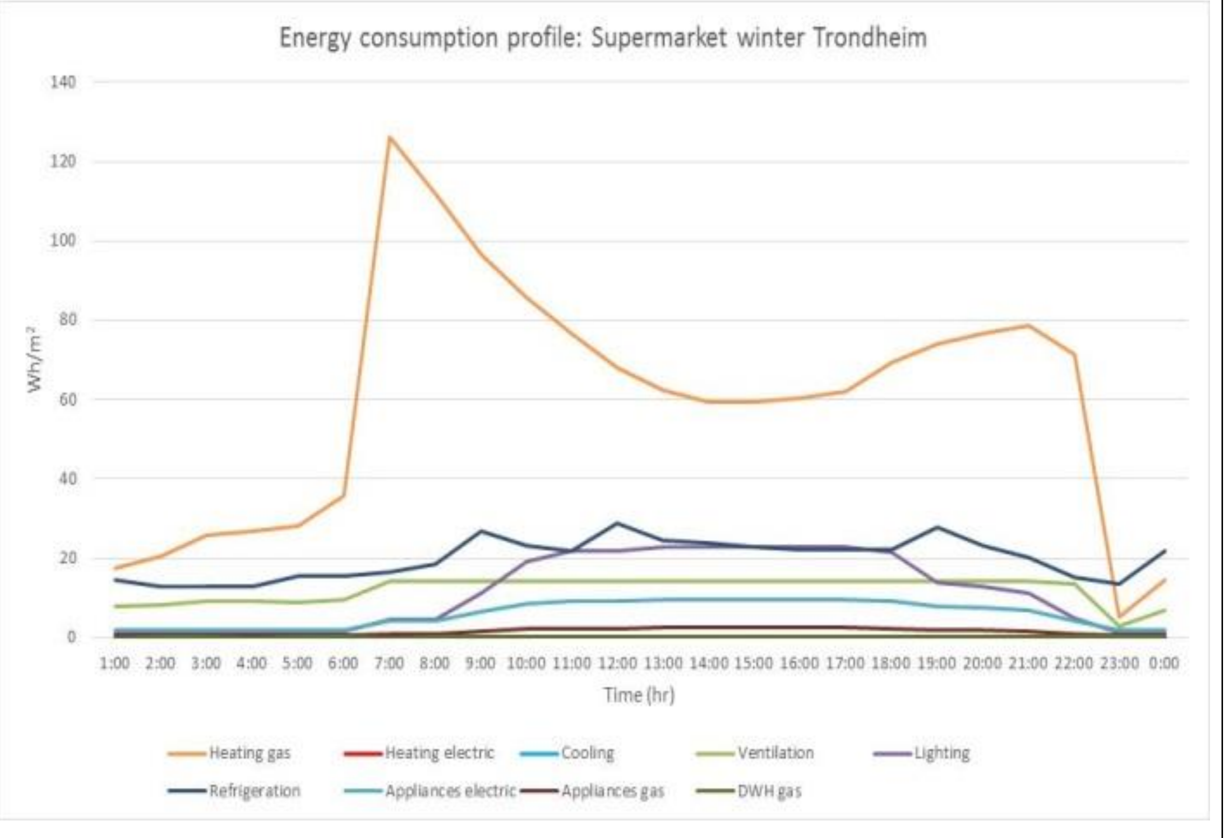
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Trondheim




Energy consumption profile: Supermarket winter Trondheim
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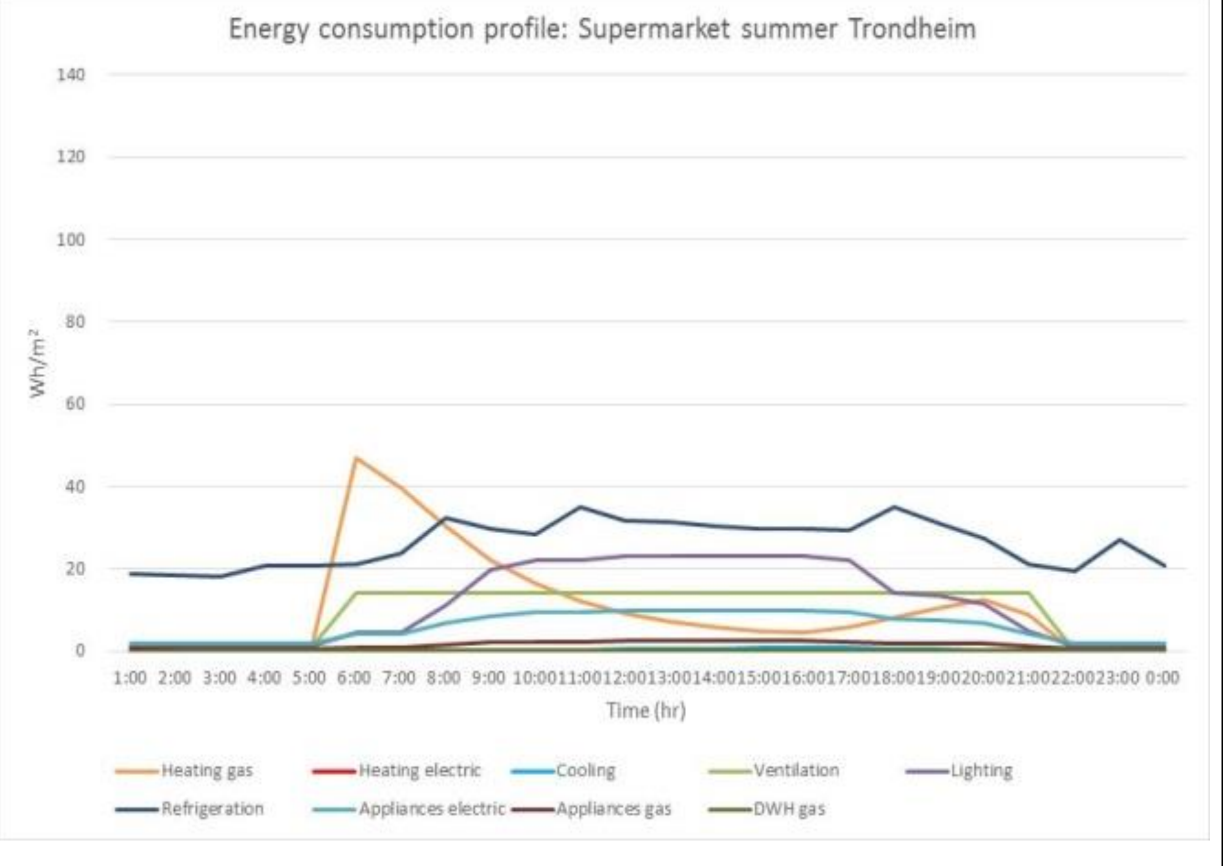
Wh/m²
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer Trondheim
140
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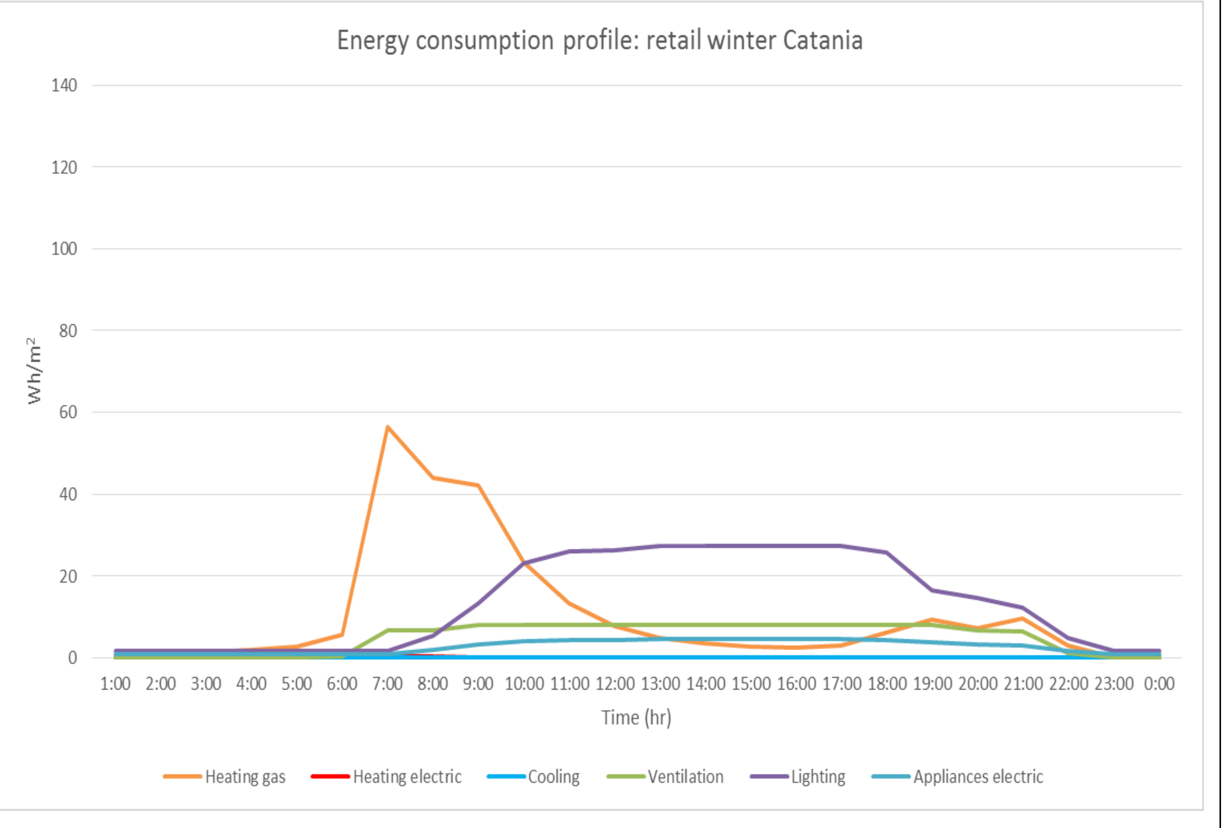
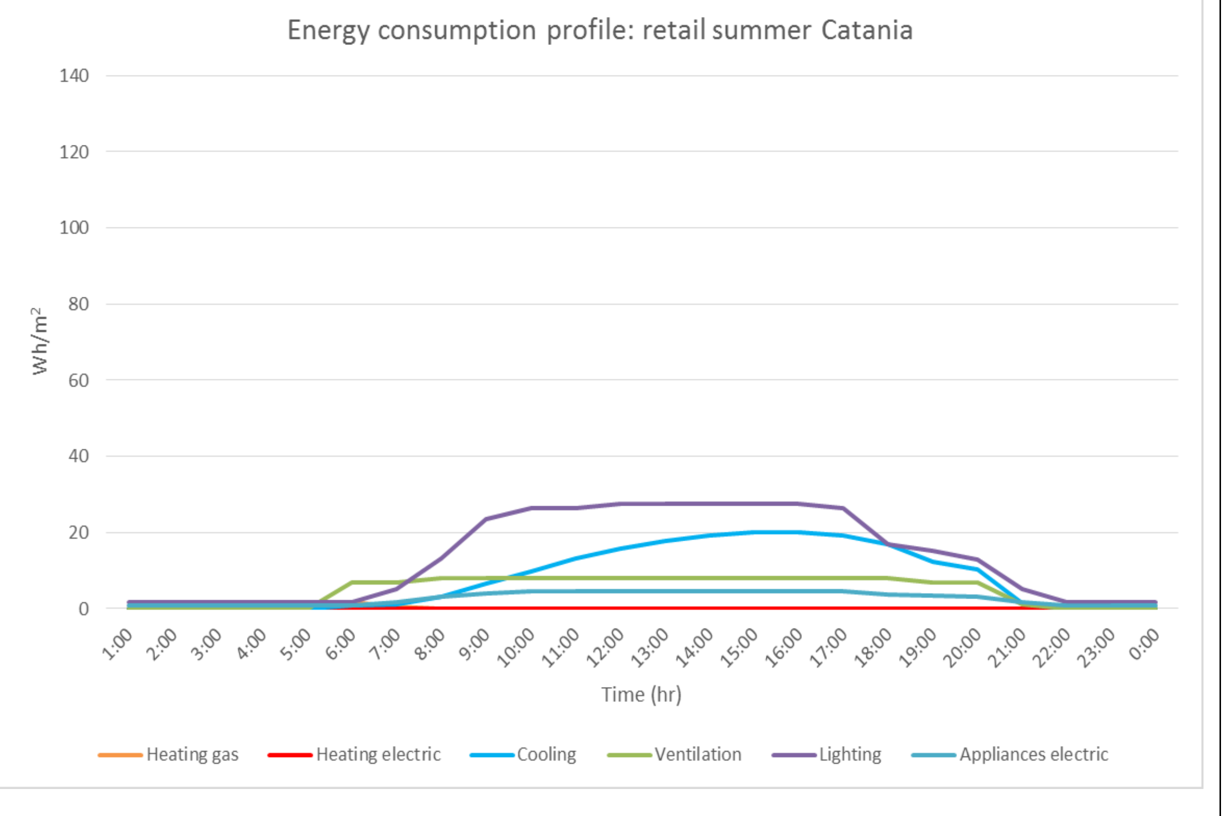
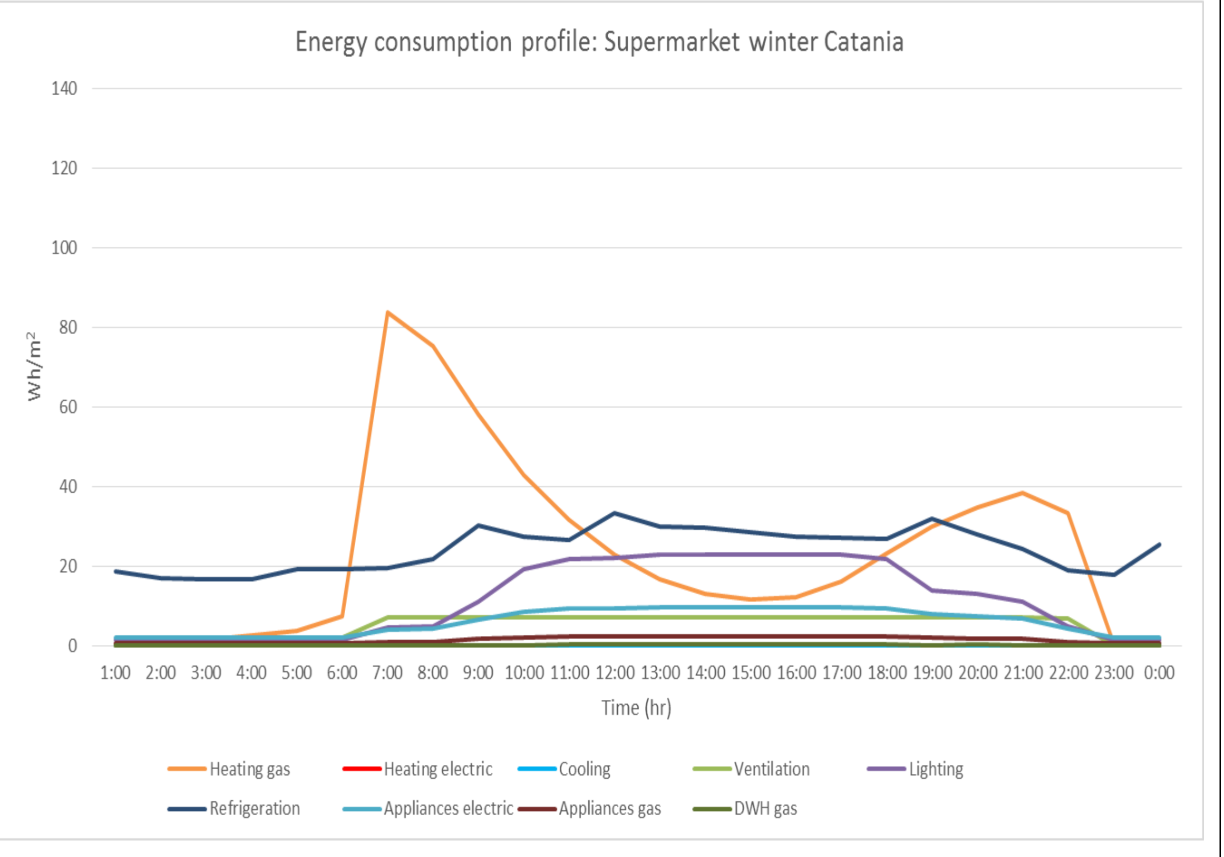
Wh/m²
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:0011:0012:0013:0014:0015:0016:0017:0018:0019:0020:0021:0022:0023:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Catania




Energy consumption profile: Supermarket winter Catania
Wh/m²
140
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60
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1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
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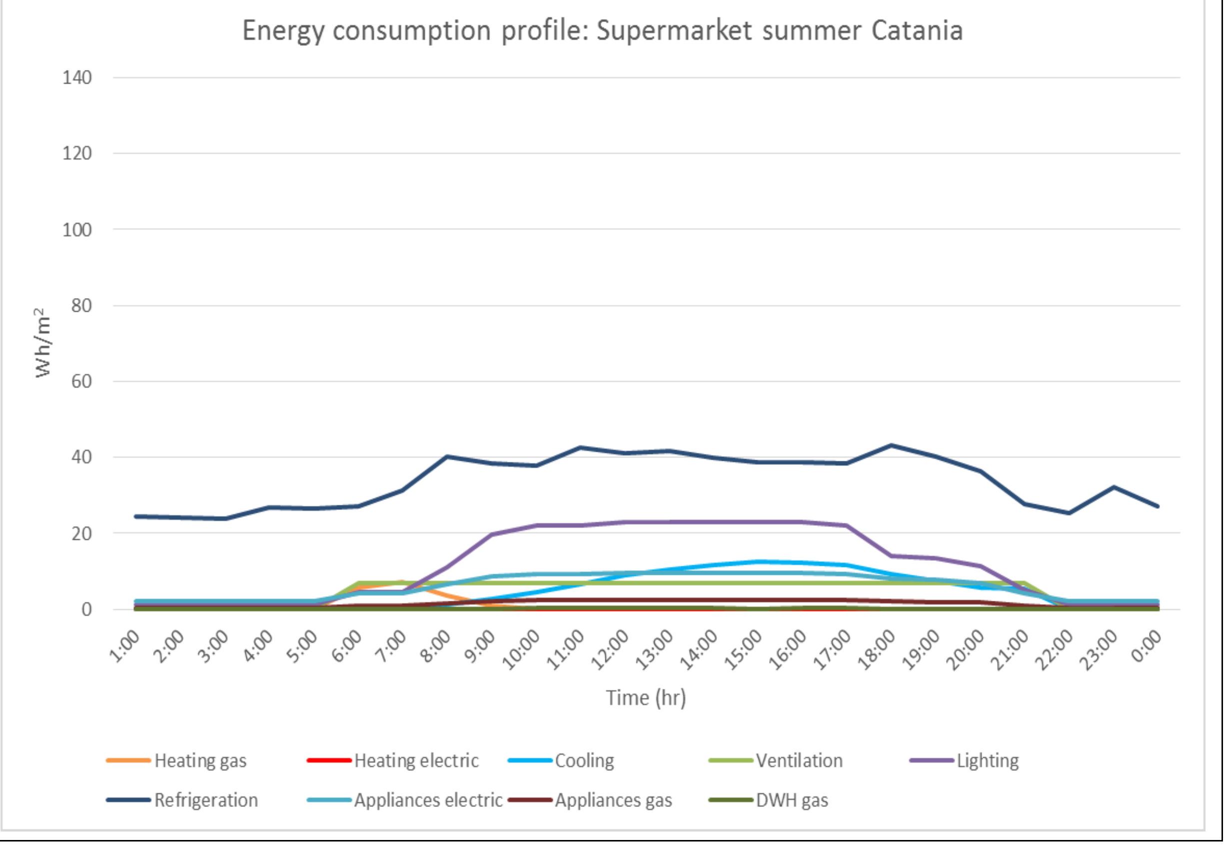
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer Catania
Wh/m²
140
120
100
80
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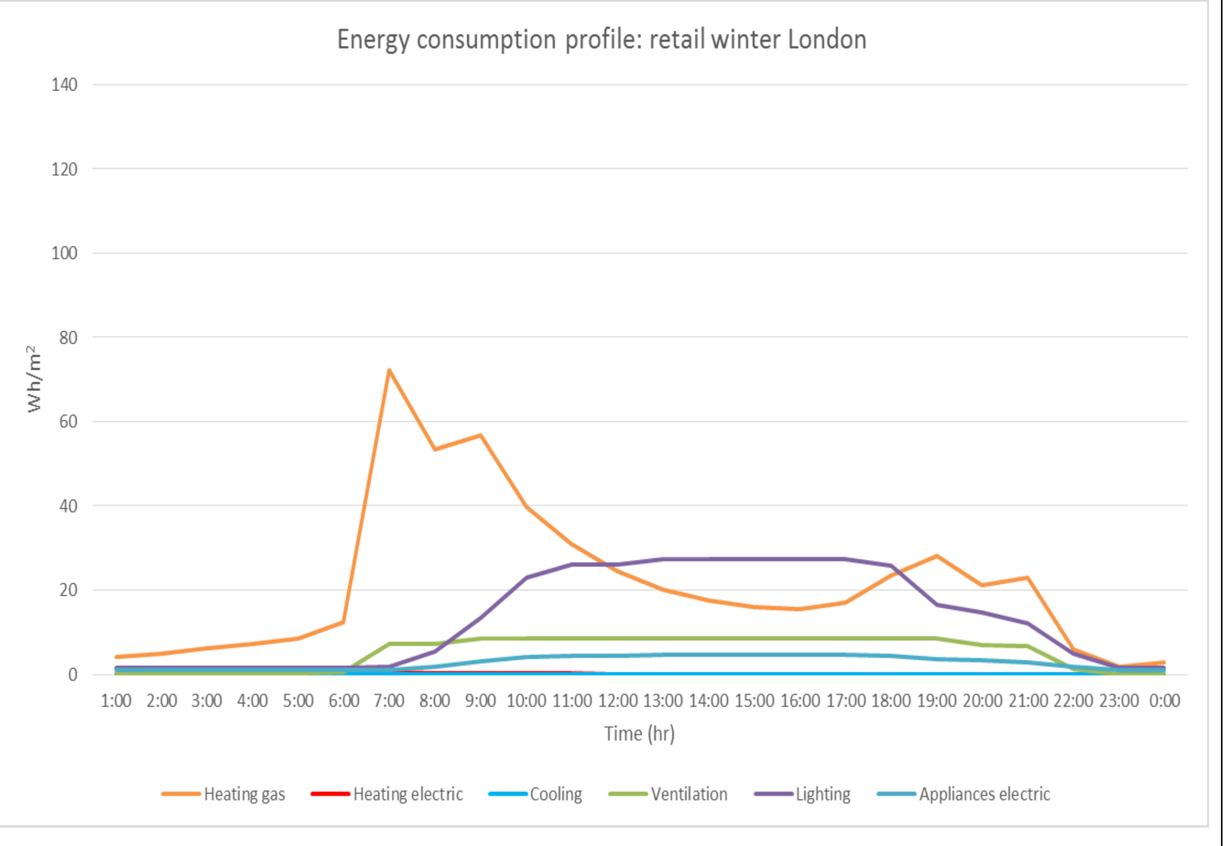
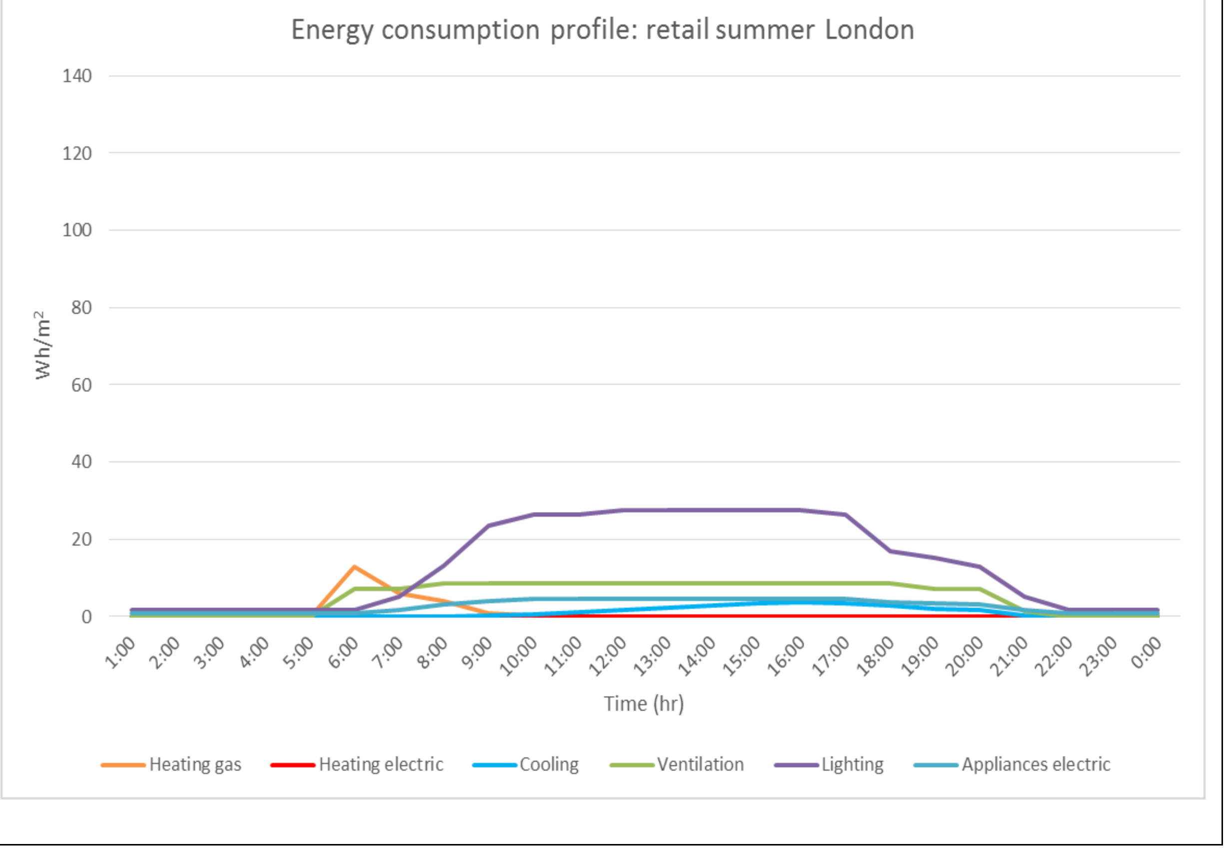
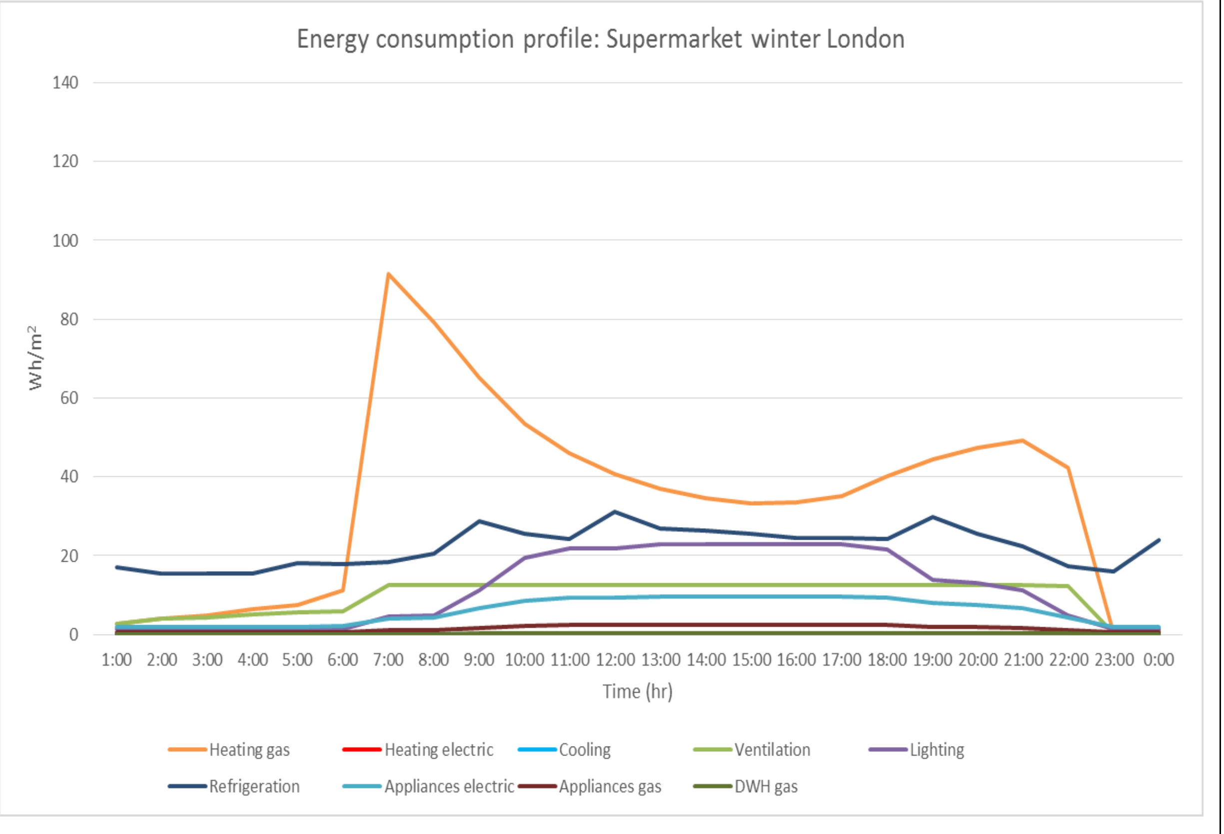
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in London




Energy consumption profile: Supermarket winter London
Wh/m²
140
120
100
80
60
40
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0
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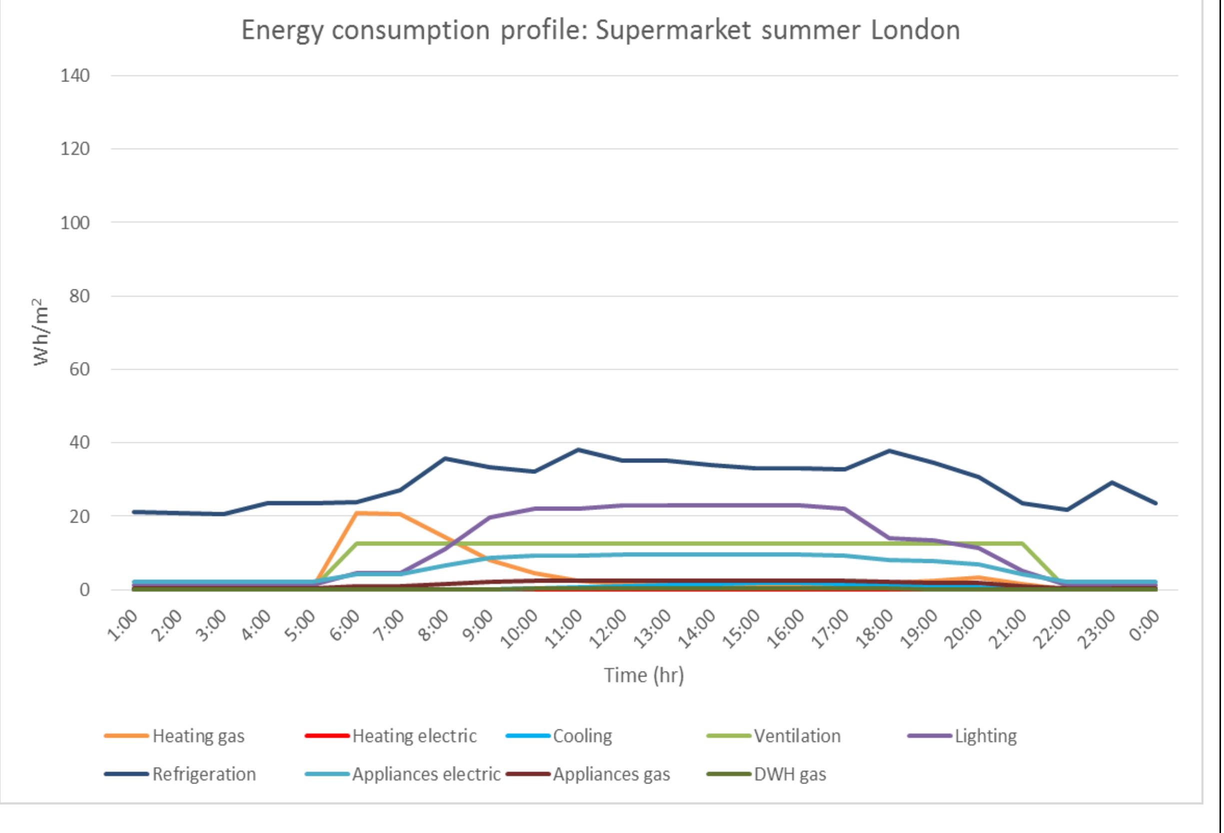
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer London
Wh/m²
140
120
100
80
60
40
20
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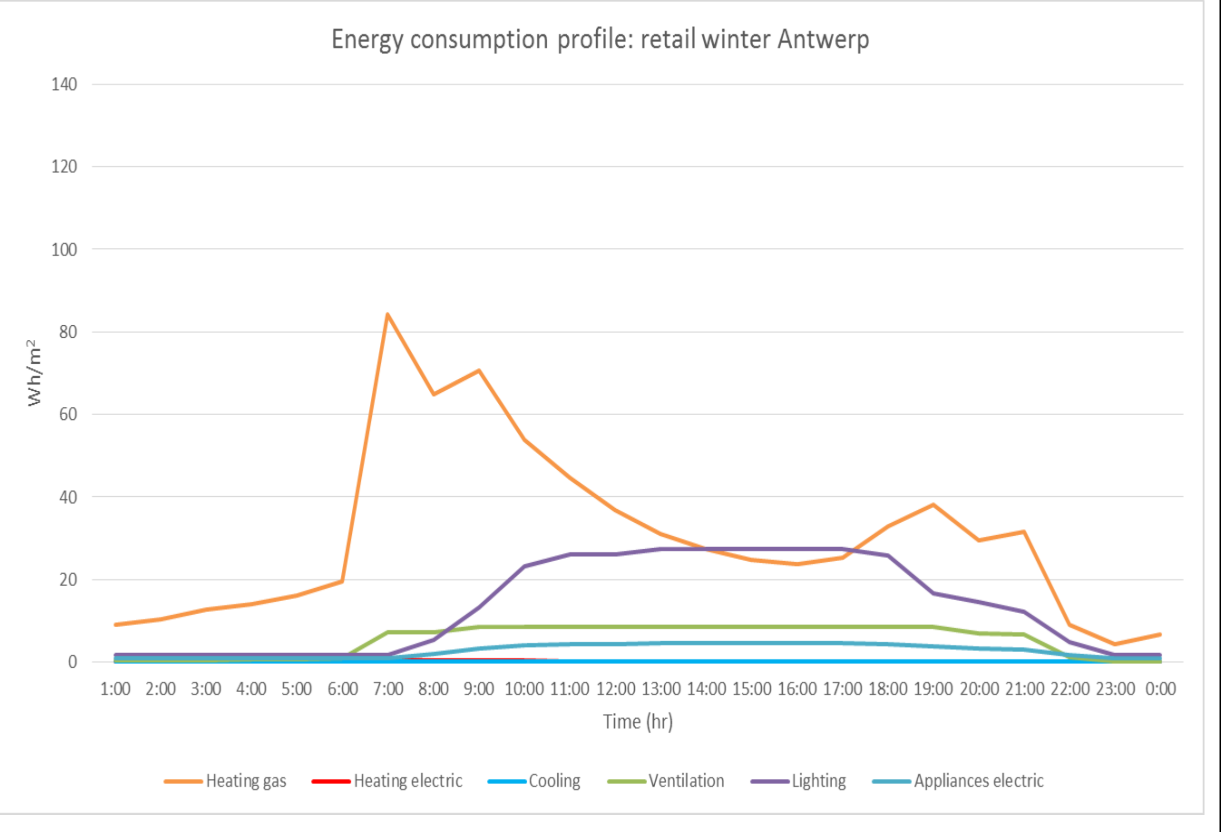
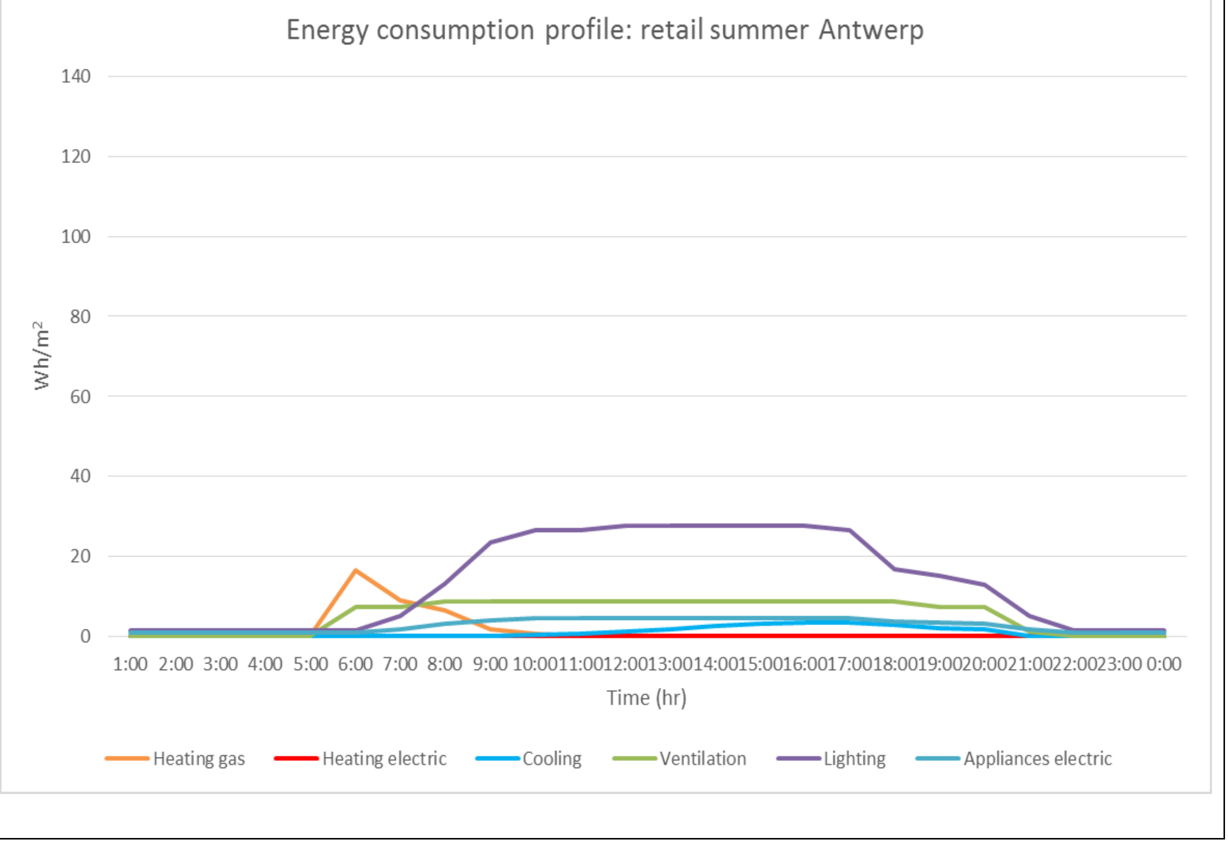
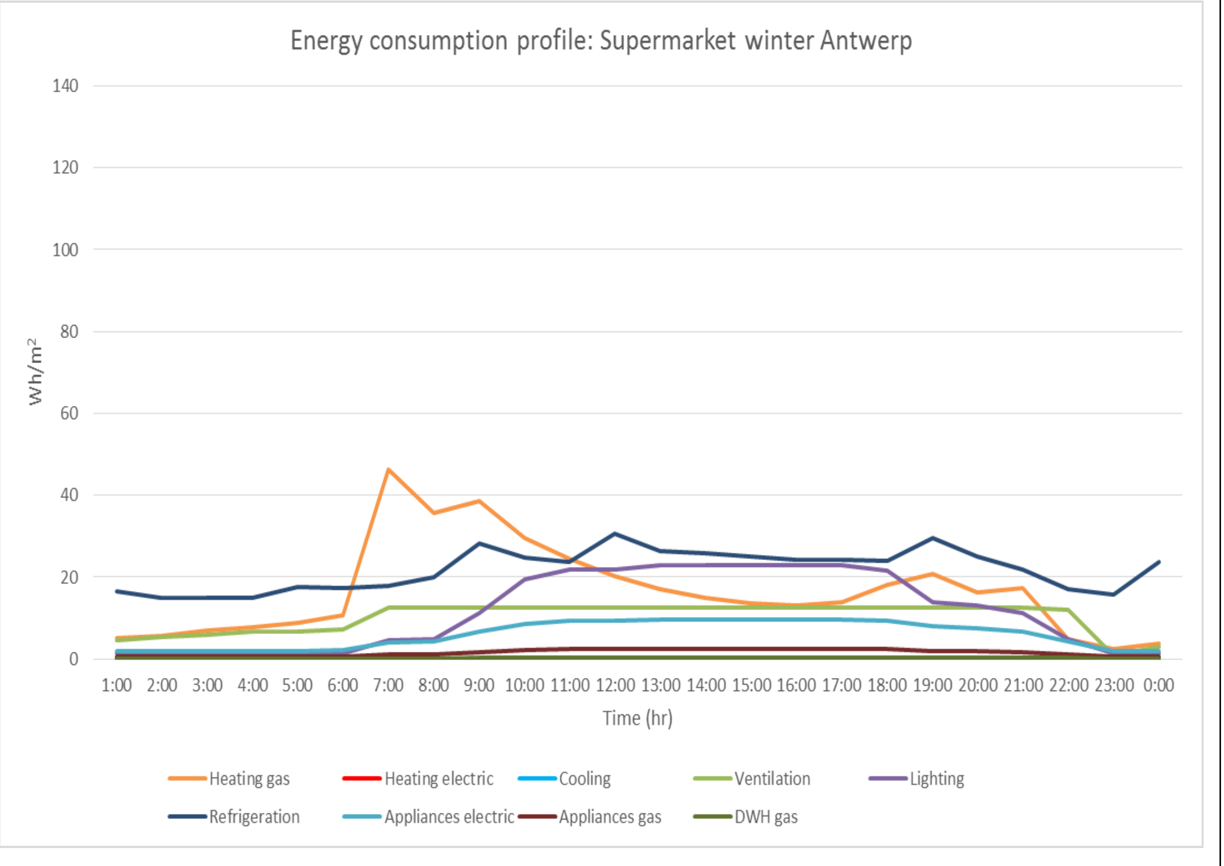
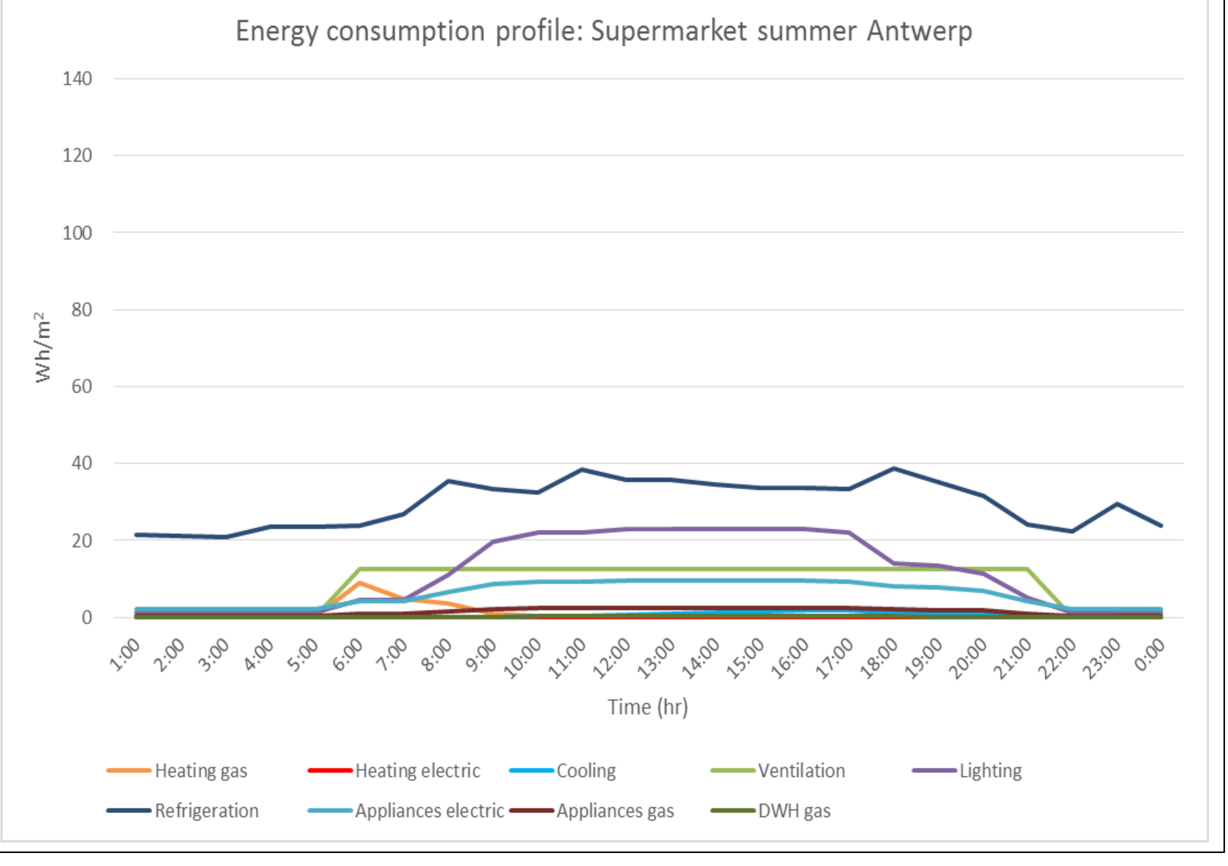
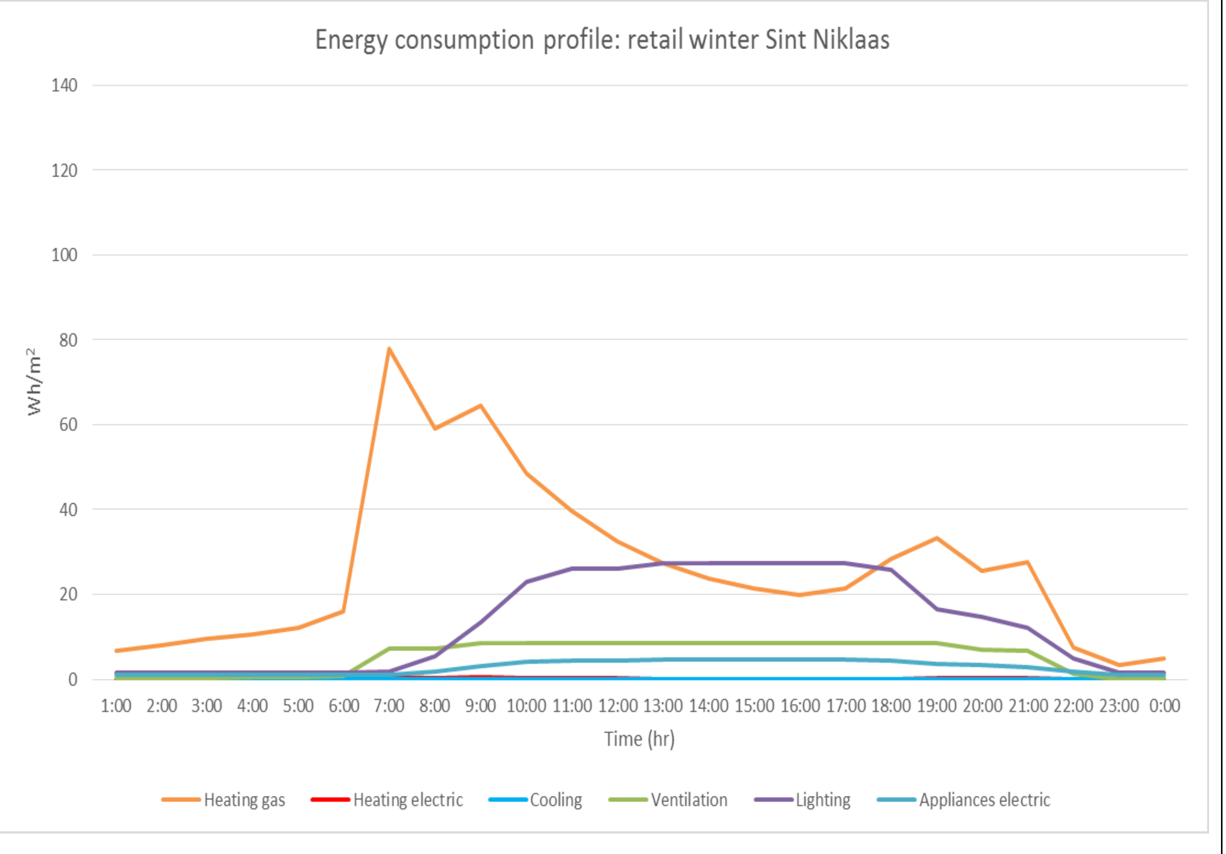
DWH gas

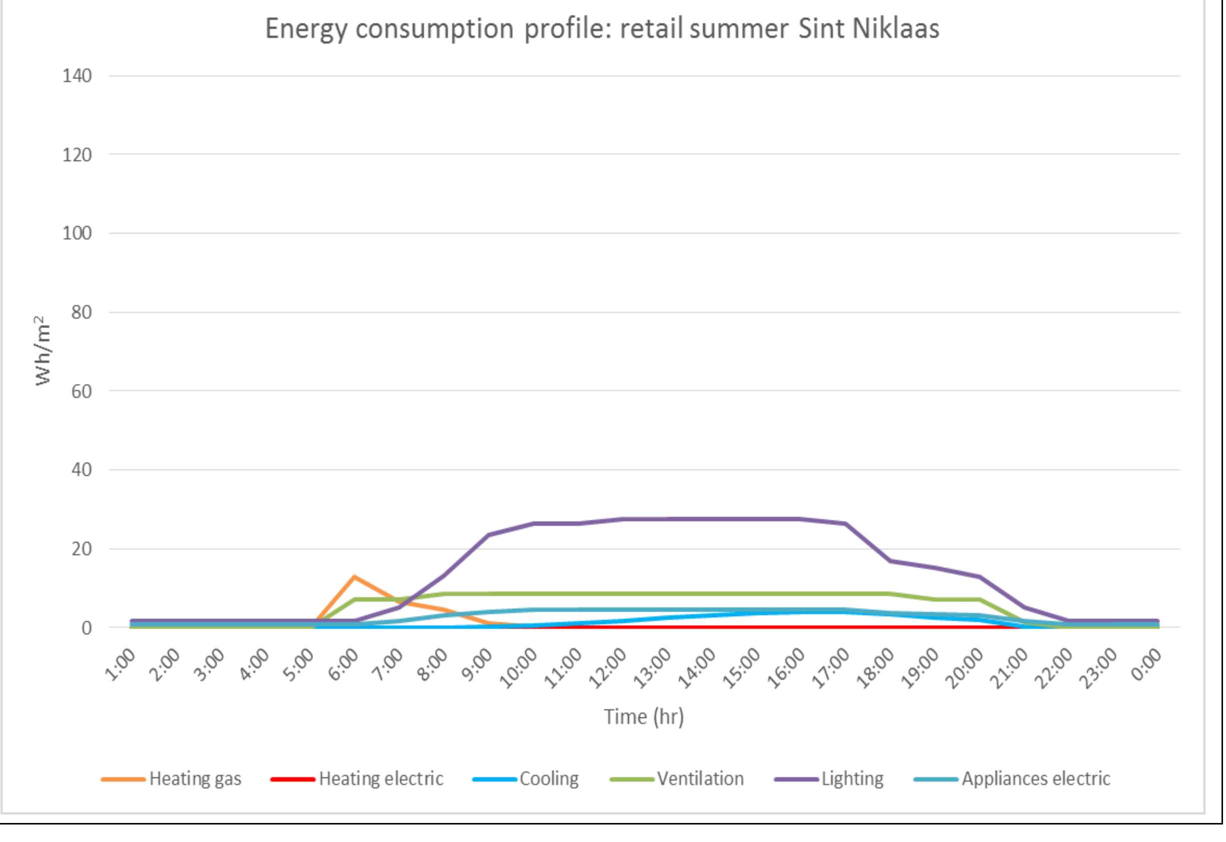
Shopping Mall in Antwerp



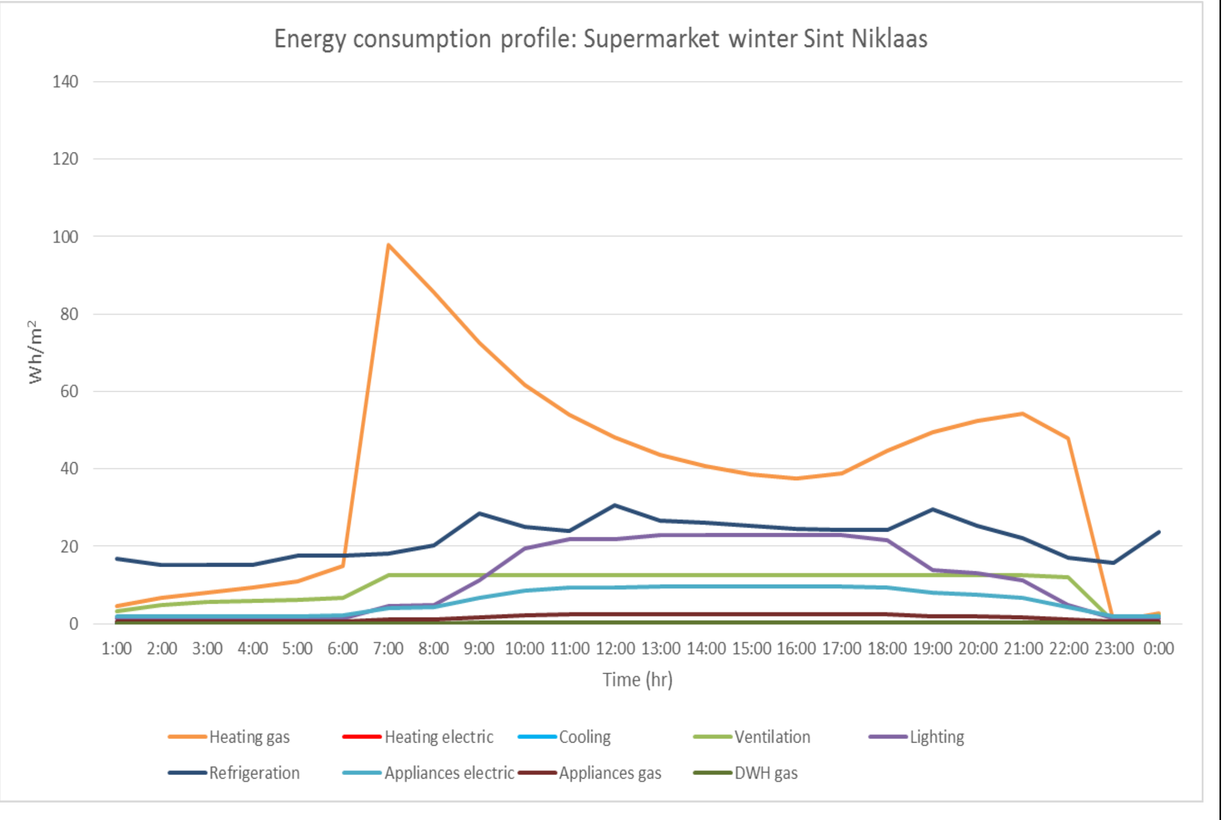

Energy consumption profile: Supermarket winter Antwerp
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

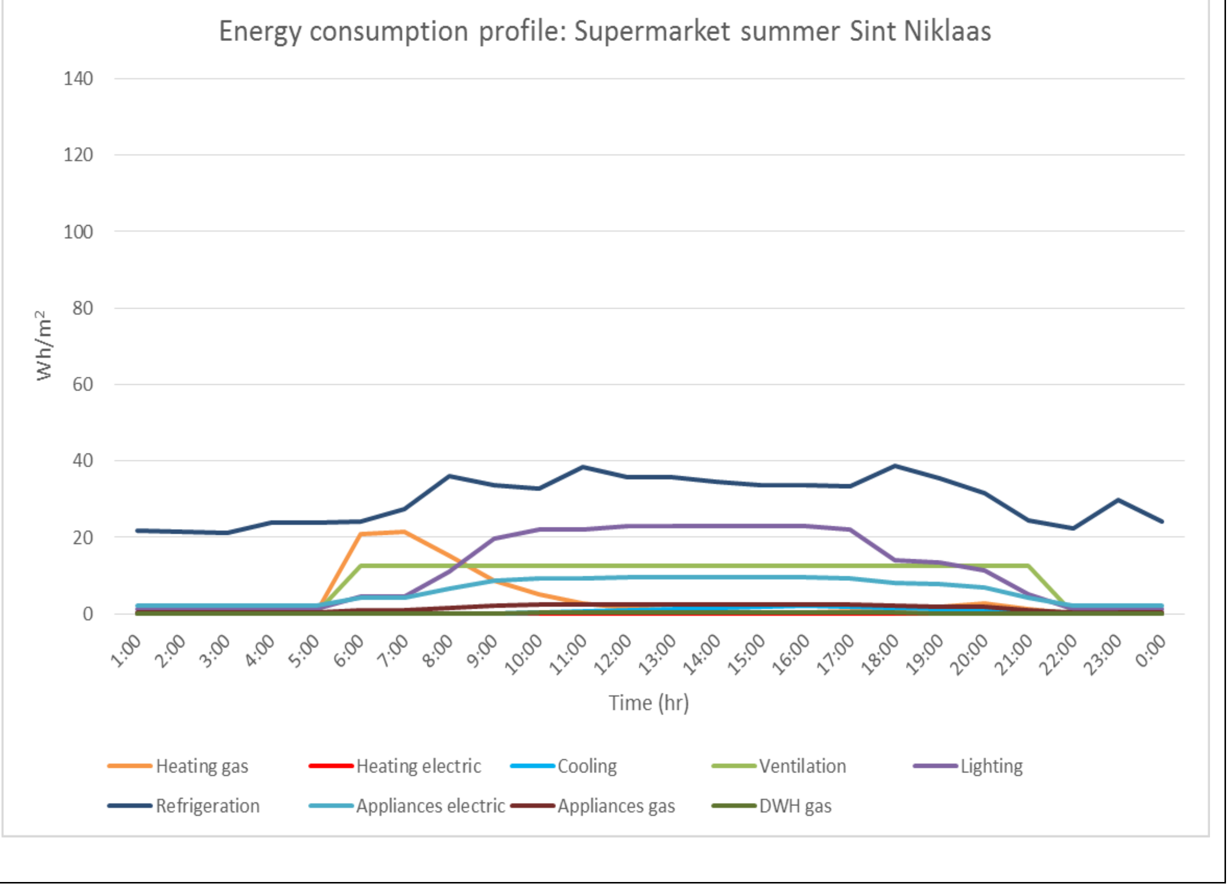

Energy consumption profile: Supermarket summer Antwerp
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Sint Niklaas

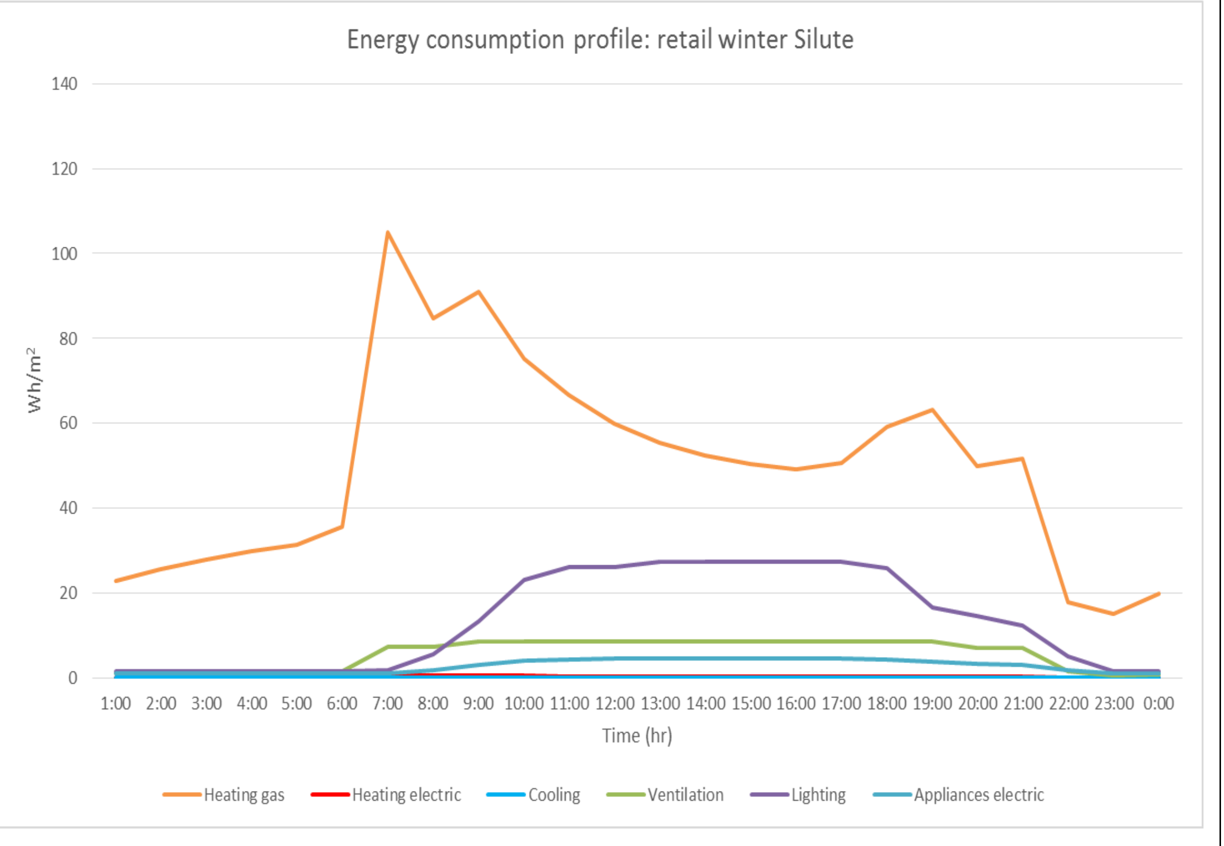


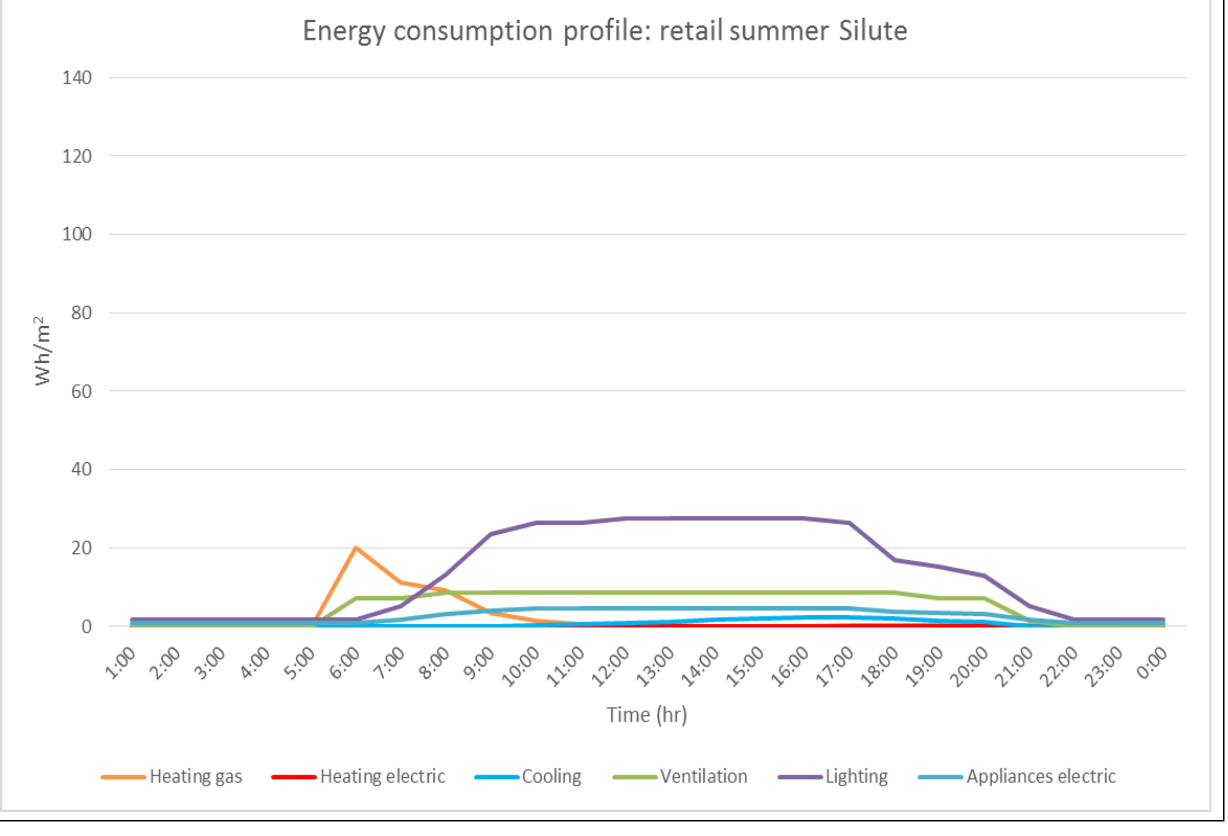


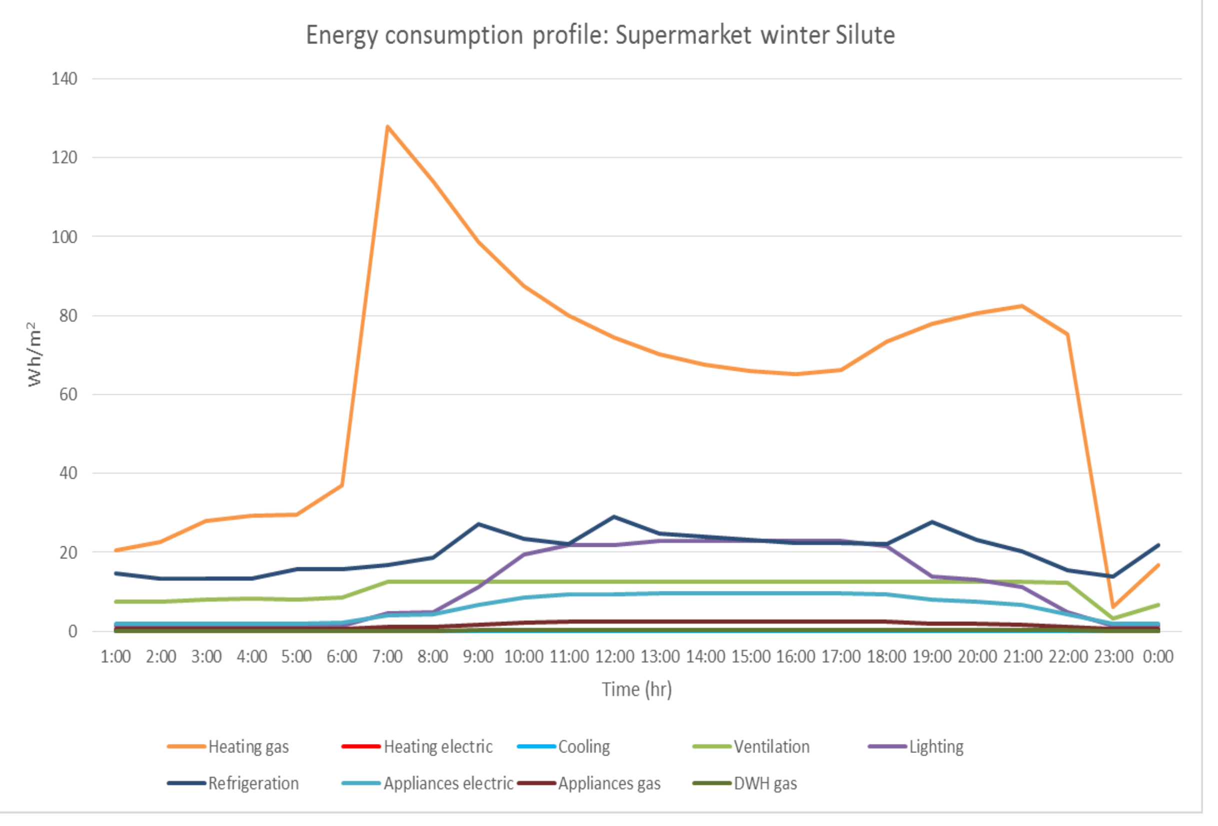

Energy consumption profile: Supermarket winter Sint Niklaas
Wh/m²
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

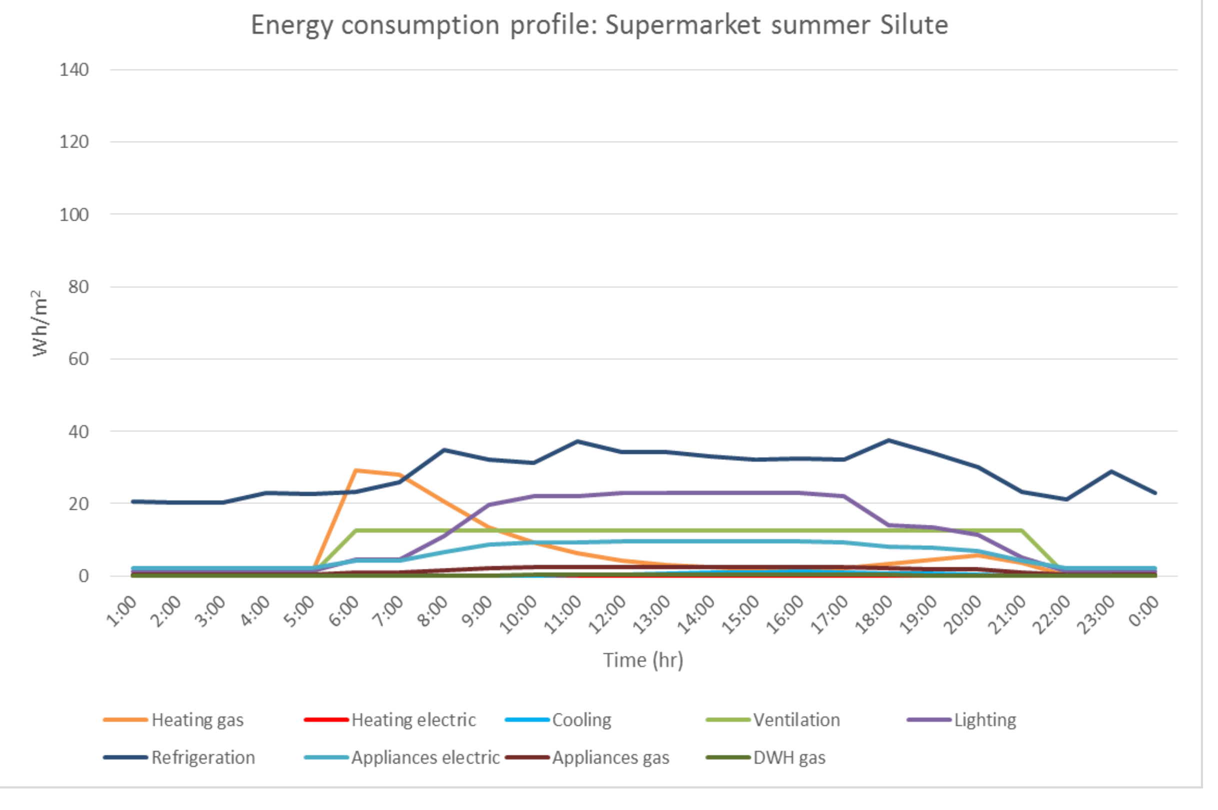

Energy consumption profile: Supermarket summer Sint Niklaas
Wh/m²
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Silute

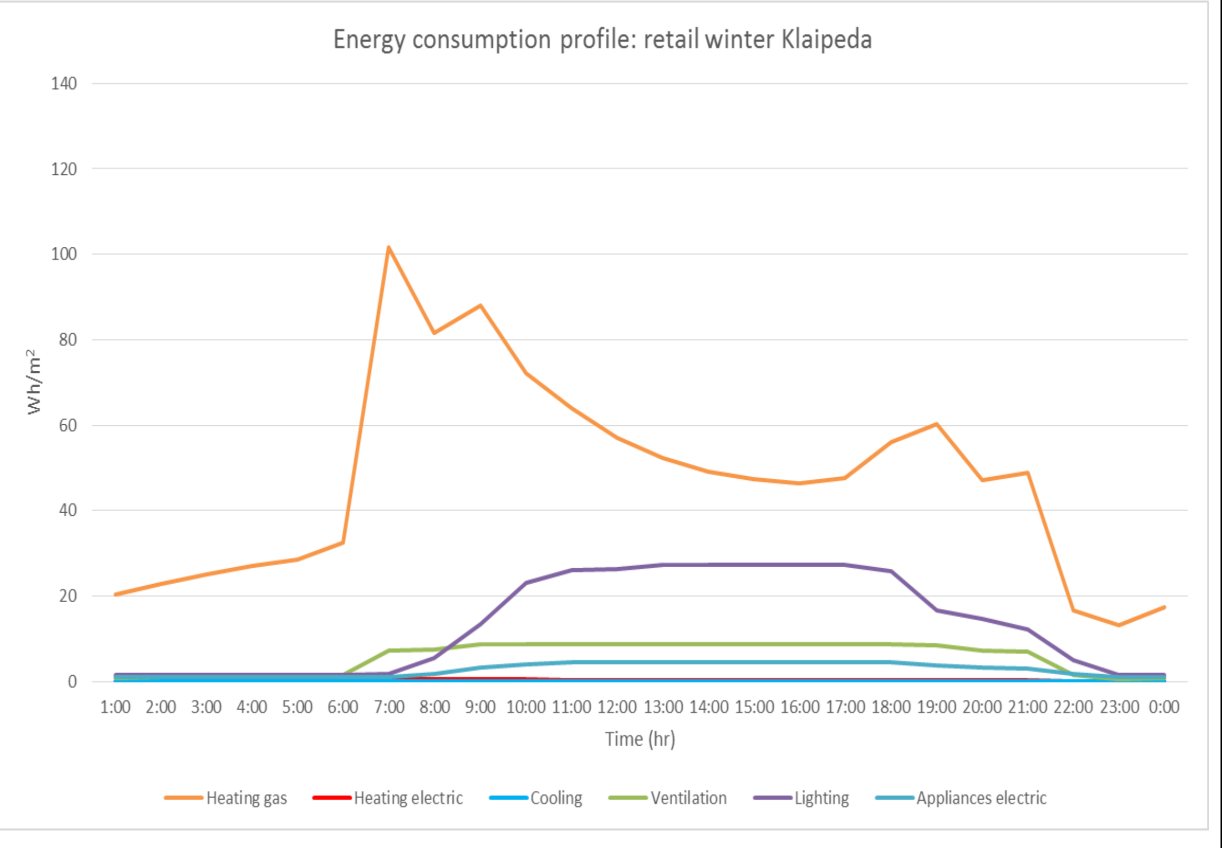


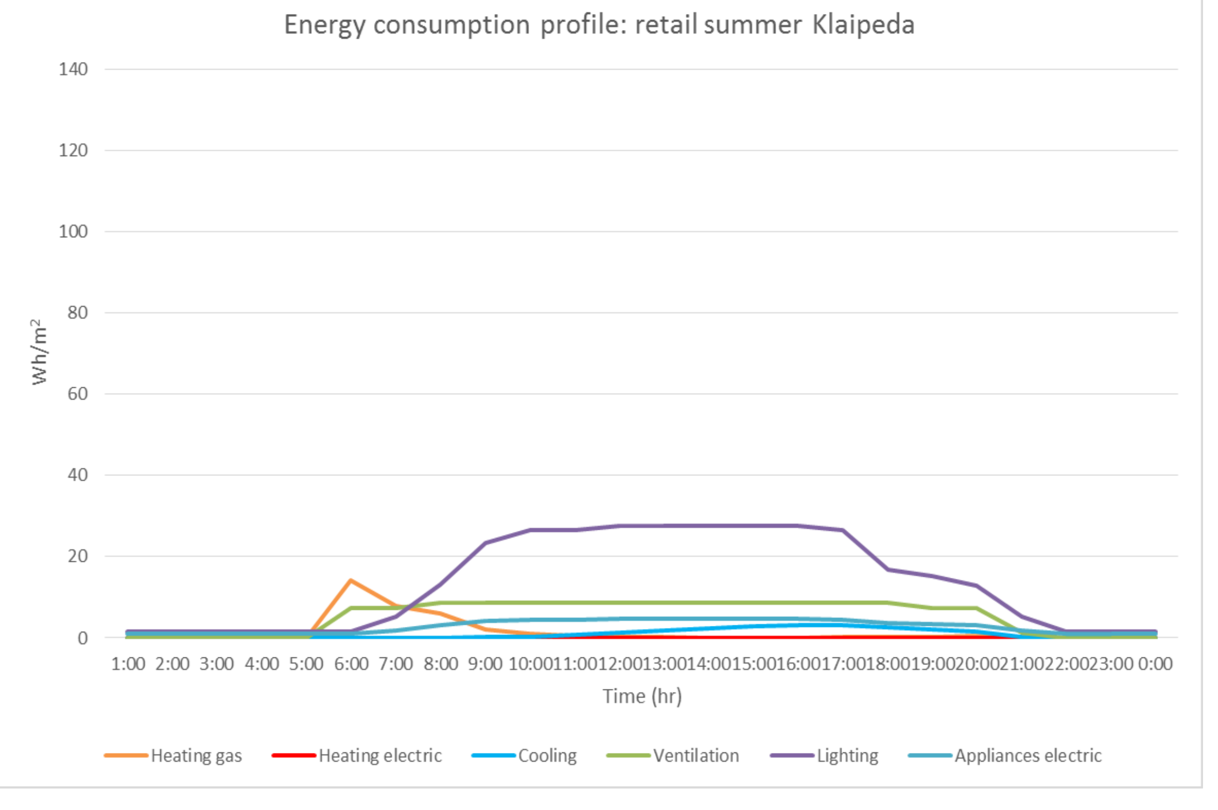


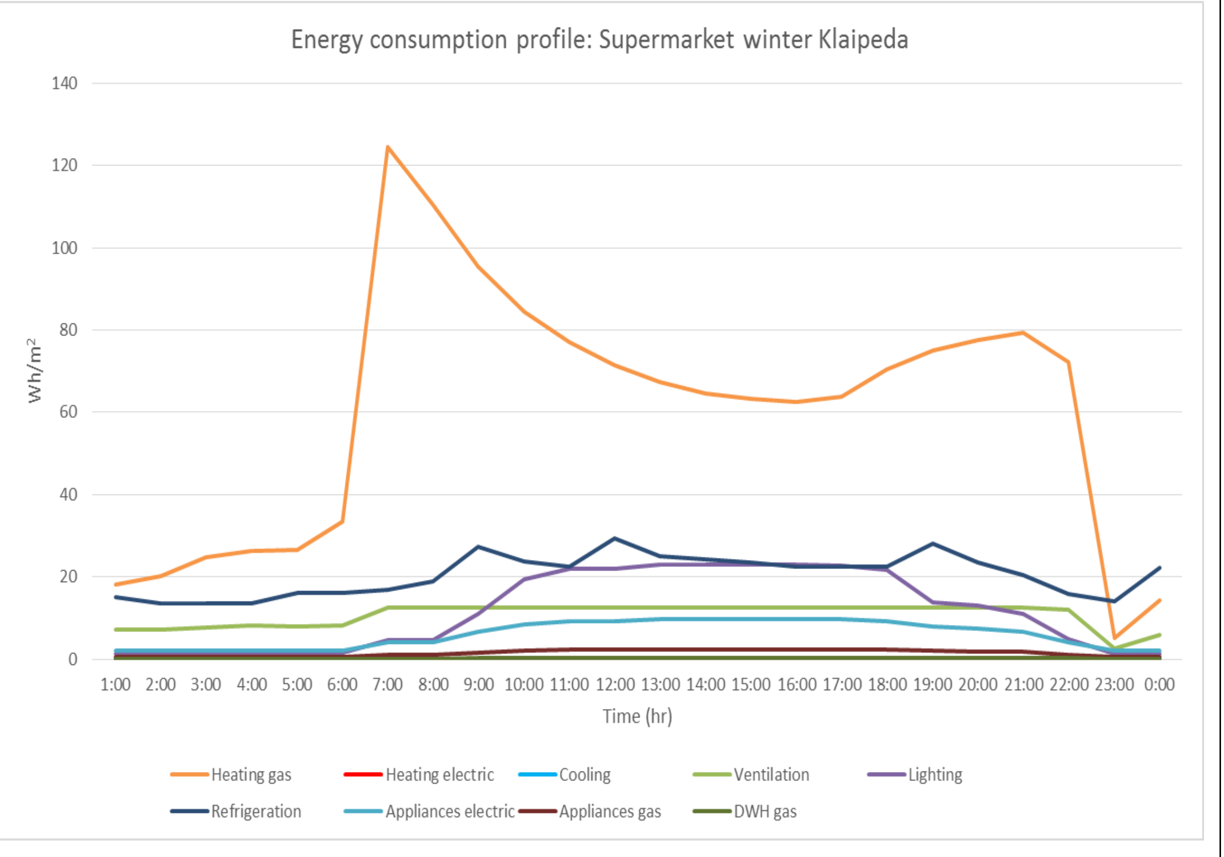

Energy consumption profile: Supermarket winter Silute
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

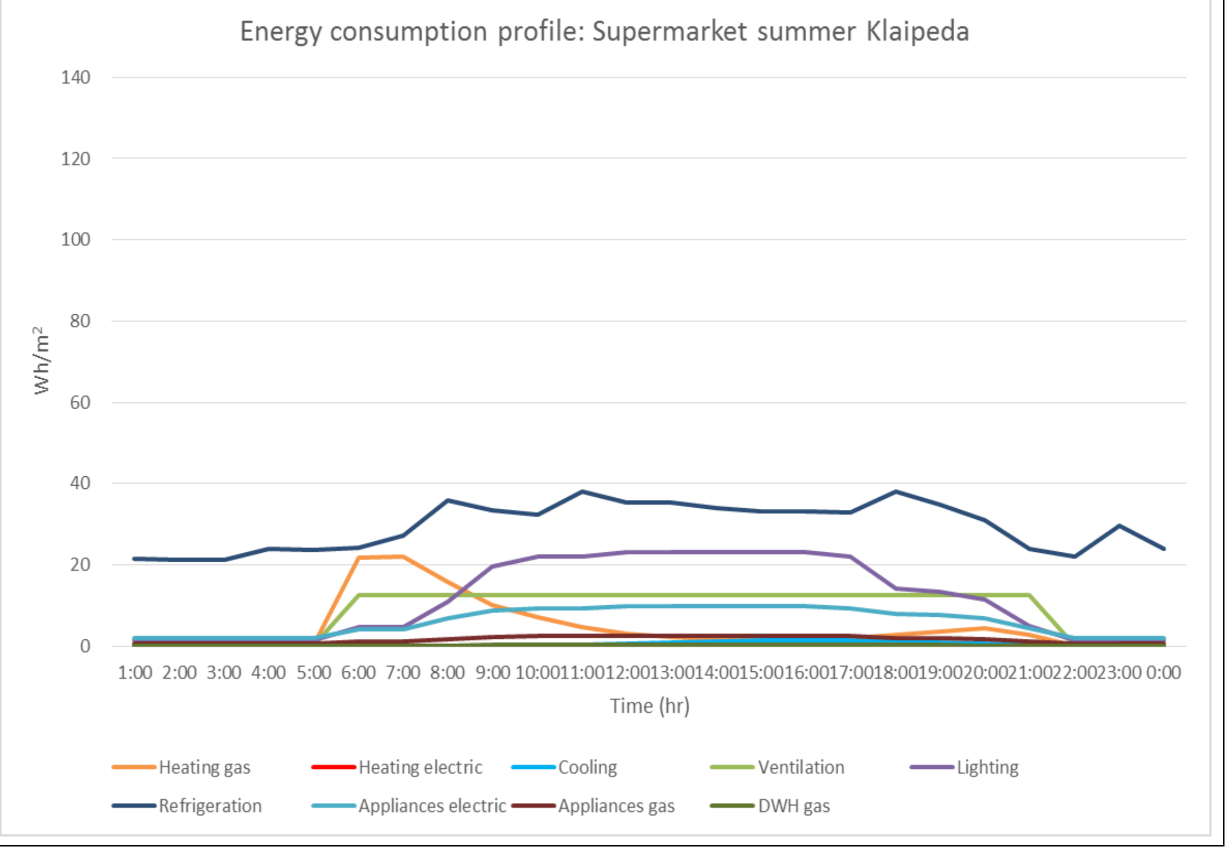

Energy consumption profile: Supermarket summer Silute
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

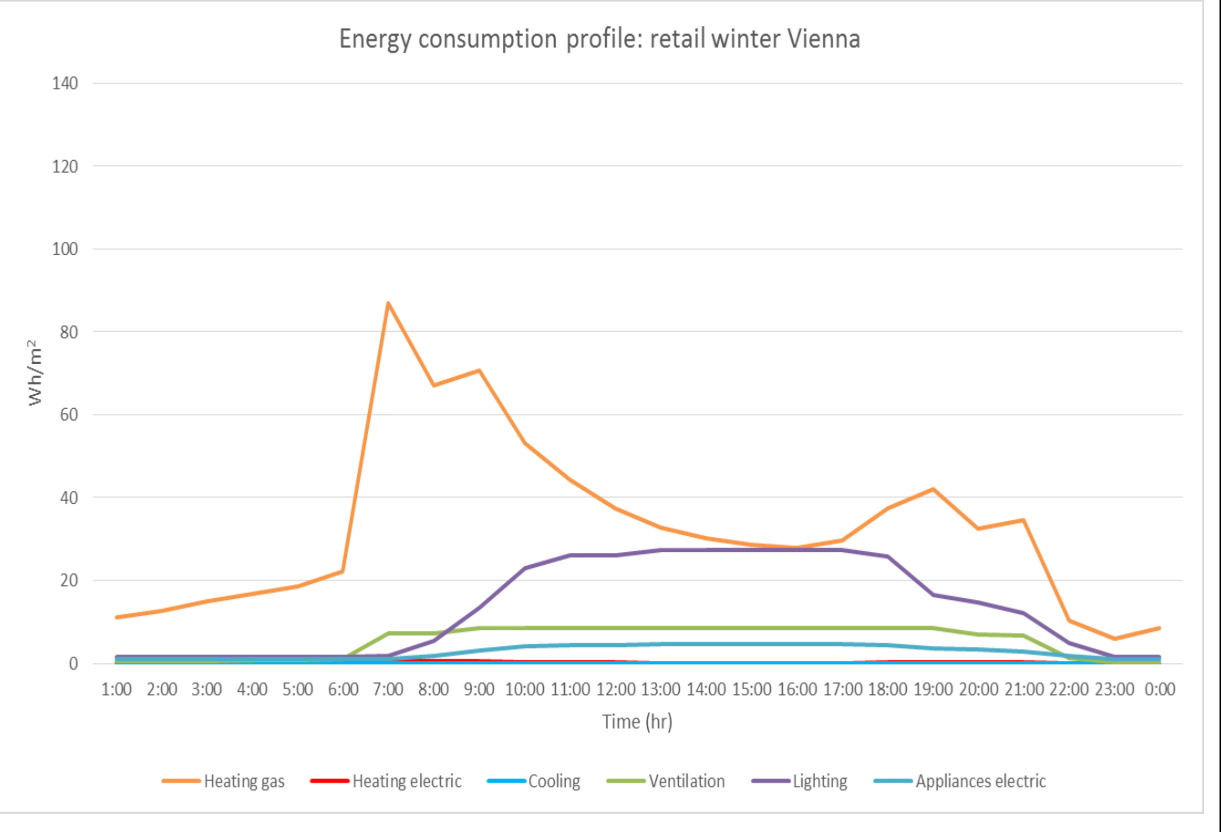
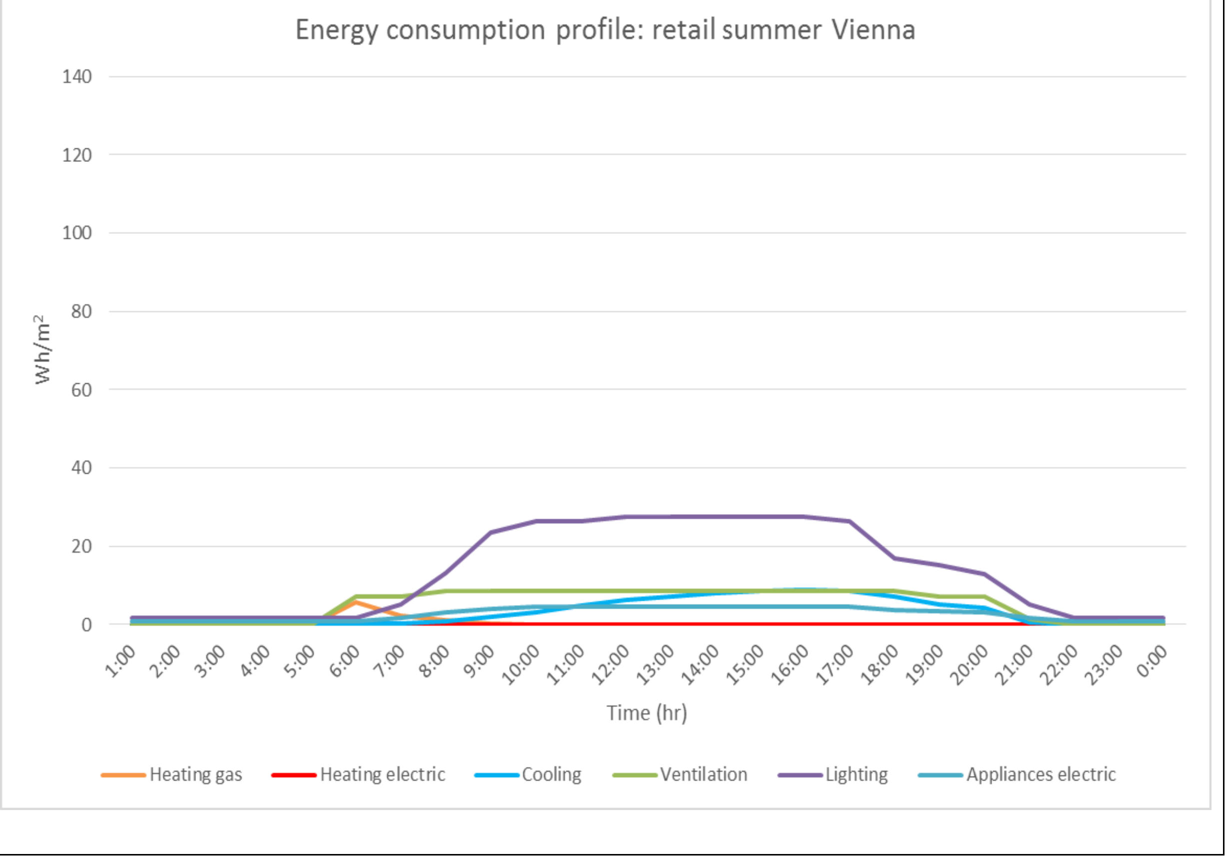
Shopping Mall in Klaipeda

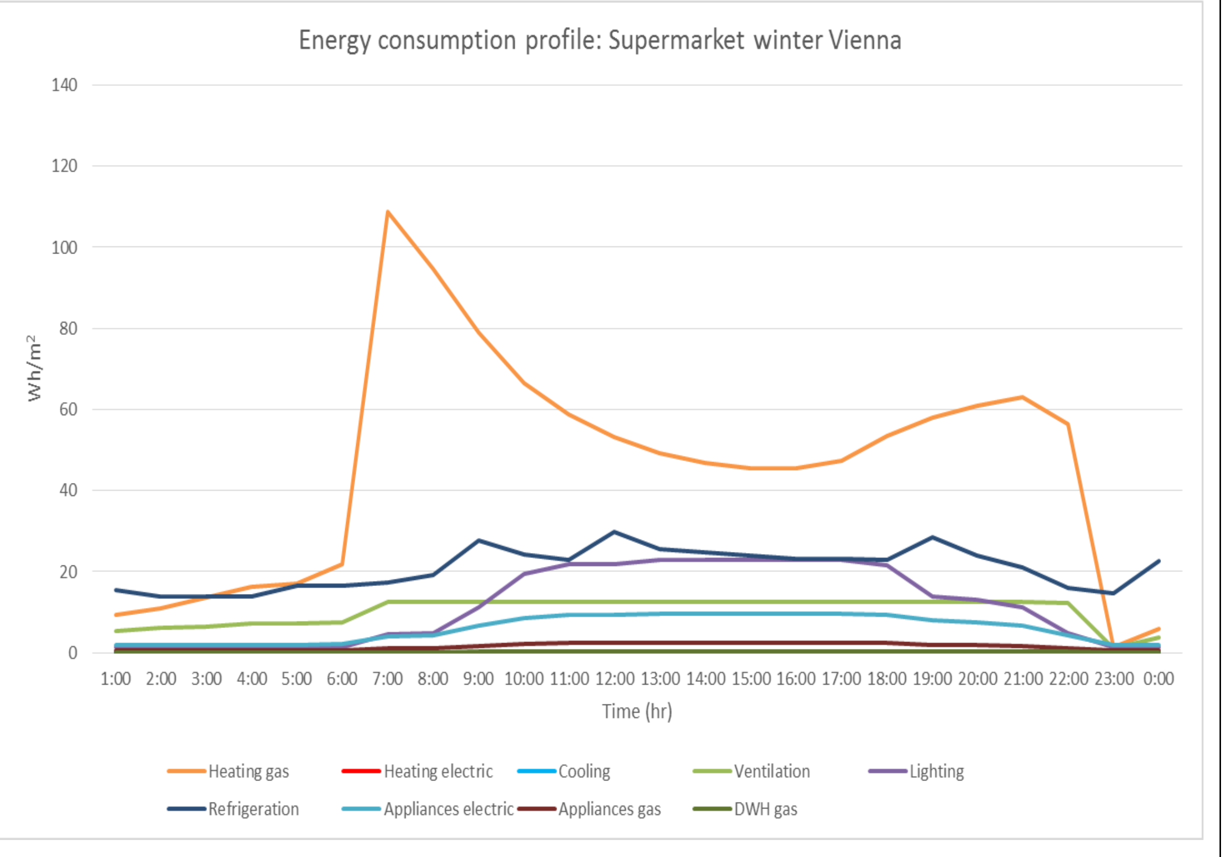


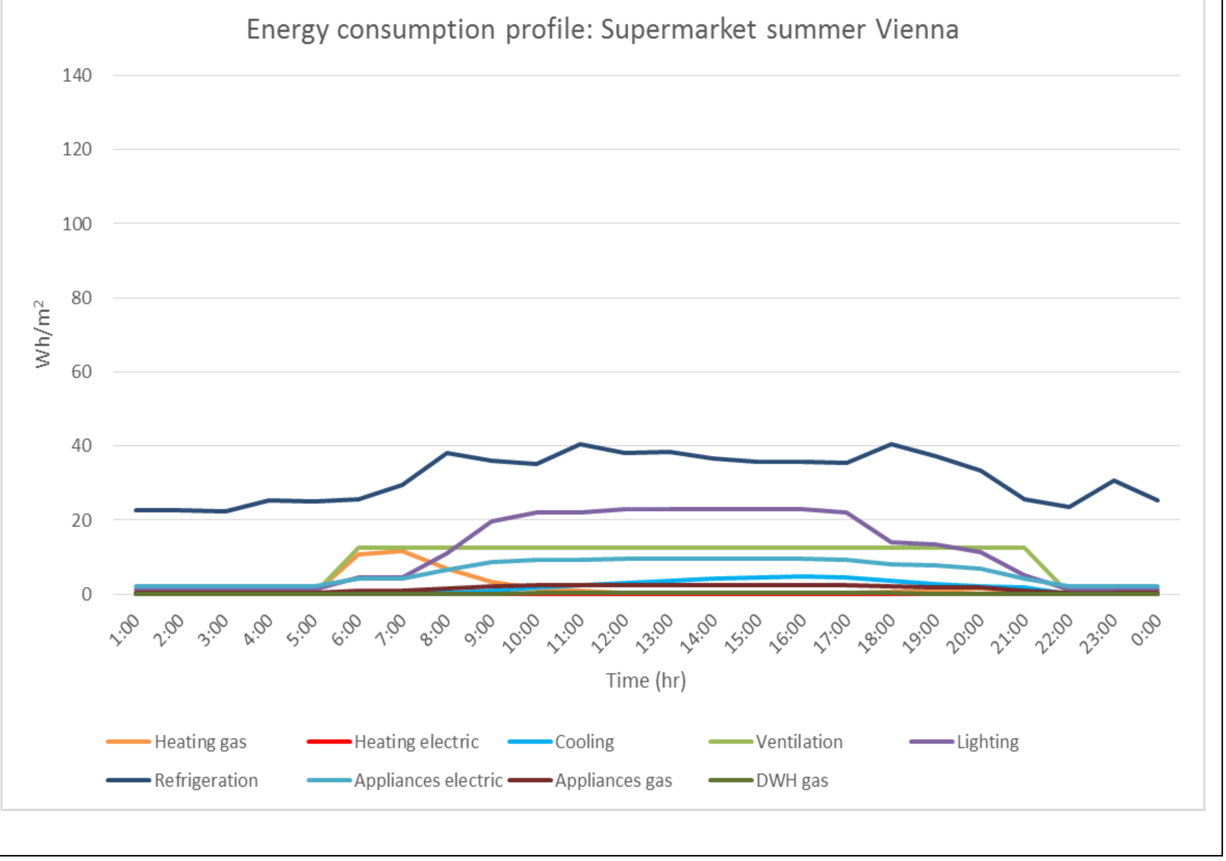



Energy consumption profile: Supermarket winter Klaipeda
Wh/m²
Time (hr)
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer Klaipeda
Wh/m²
Time (hr)
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:0011:0012:0013:0014:0015:0016:0017:0018:0019:0020:0021:0022:0023:00 0:00
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

Shopping Mall in Vienna




Energy consumption profile: Supermarket winter Vienna
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas


Energy consumption profile: Supermarket summer Vienna
Wh/m²
140
120
100
80
60
40
20
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time (hr)
Heating gas
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Appliances gas
DWH gas

In general, it is possible to see how electrical profiles for shopping malls in different climates are quite similar, although the absolute values vary significantly (e.g., heating demand for Trondheim vs Catania). Regarding the typology, the main difference is the presence of refrigeration in the supermarket sector, this being the most important service in terms of electrical consumption. The behaviour of the rest of the services is very similar (without taking into account refrigeration) regardless of the typology with the higher electrical consumptions in lighting, ventilation and electrical appliances respectively and the presence of cooling mainly in summer. Almost all the end-use consumptions follow similar profiles starting slightly before the centres' opening time (8 am) until closing time (10 pm). Some systems then have a night setback working at lower level.

1.4 Description of relevant aspects impacting the building-grid interaction

There are several aspects which are not linked to the building and grid but still may become constraints to exploit shopping malls to provide an energy service. Among others, the most important are:

- Climatology context:
  - Climate impact on loads
    - Thermal loads
    - Exploitation of natural resources (wind and light)
  - RES
    - Radiation
    - Peak sun hours
    - Average velocity of wind at 30 meters
- Urban context:
  - Type of urban context
  - Surrounding buildings
- Energy context:
  - Electricity profile and generation of the grid
  - Polices and tariff analysis

1.4.1 Climate context

The weather conditions affect the electricity consumption of shopping centres, as can be seen in Table 1. For example, during extremely hot summer periods, there is a tendency of increased electricity consumption because of the air conditioning equipment. On the other hand, in periods of strong cold, mainly in winter, there is an increase in power consumption as a result of heating equipment (especially if the equipment is electric). Favourable climates also increase the potential of exploitation of natural resources, therefore potentially favouring the use of natural ventilation and natural lighting, reducing the need for mechanical/artificial systems and consequently the electricity consumption and carbon footprint.

In many cases, there is a great opportunity to improve the energy behaviour of a shopping centre producing its own electricity through RES systems which takes advantage of the weather conditions, and thus reduce the dependency from the grid. For evaluating the capacities of shopping malls for incorporating RES, it is necessary to evaluate climate parameters. For PV systems, radiation and peak sun hours are critical elements. The solar radiation on the surface is fundamental to determine the potential production, and the time distribution; additionally, the solar radiation on each building surface is important to understand the shadow created by the surrounding elements. For wind turbines, the wind speed is the potential wind speed expected in a completely flat and open, typically specified 30 meters above the soil, independently of the roughness. However, attention must be paid to the fluctuation and variability of conditions.

1.4.2 Urban context

Three types of urban context are considered: urban context, suburban context and isolated context. Each location has got its own specific conditions that affect the expansion of the capacity of the grid and especially the use of renewable energies.

- Urban context: the network capacity is often saturated because of the need to ensure energy supply to all users of a city, which can limit the installation of new power generation sources. If the grid admits new energy power, it should be evaluated to see if the network has reached maximum capacity permitted for renewable power. Normatives usually fix limits to this type of energy in order to avoid quality problems in the network such as interruptions affecting energy availability due to the dependence on climate conditions and disturbances in the wave associated to the own facilities of RES. Furthermore, the installation of solar panels may be limited by the shading produced by the surrounding buildings. The application of wind turbines is restricted by the low wind speed achieved in cities and regulations.
- Suburban and isolated context: The installation of solar panels and wind turbines are suitable in this context thanks to the great availability of space as well as the excellent weather conditions (strong wind and no shading of buildings). In these locations, the installation of RES could cover the shopping mall's energy demand, especially for certain periods of time. In the case of isolated areas, which refer to small municipalities and industrial parks, the requirement for the installation of grid-connected renewable is the proximity of a network connection.

1.4.3 Energy context

The characterisation of the energy context of a specific location is useful to understand how the electricity is generated, what is the typical expected profiled time of abundance or scarcity of electricity, the legislative framework and the tariffs. This information is useful to suggest solutions for how shopping malls could provide potential services to the grid. Once the energy context is characterised, it is possible to evaluate investment in RES, storage, peak shaving, peak shifting that could be considered a service from the shopping mall to the grid while also be of benefit to the mall. The normative/legislative trajectory of each country, and even in each region, has conditioned the electricity profile of a location. This information can provide a general idea of the reliability of the business models around renewable energies.

2. Shopping centres – grid energy interaction parameters and performance indicators

A characterisation of the interaction between the buildings and grids can be very useful in an energy retrofitting process of a shopping centre. The challenge is to find a limited set of parameters and indicators that provide relevant information for application in these buildings in order to assess the saturation level of the original power supply facilities and identify technologies for covering the energy needs of buildings.
Parameters describe the interaction and involved elements' features, whilst performance indicators measure the quality level of such an interaction.

In the case of indicators, there are two main closely-related phenomena of interest: the interaction between the on-site generation and consumption and the resulting energy import from/export to the energy grid. The often used term load matching (LM) refers to the degree of agreement of the energy load and the on-site energy generation profiles. Grid interaction (GI) characterises the energy exchange between the building and the grid as well as the overall impacts of the grid. Collectively, the two aspects are called LMGI and they are clearly related.

Whereas indicators must be calculated, interaction parameters provide useful information directly from measuring equipment, plans or technical reports.

2.1 Relevant interaction parameters

In addition to the building-grid interactions, there are parameters focusing primarily on either the energy load or the supply that need to be considered and could be affected by shopping mall interconnection modifications. These parameters have been classified in three categories:

- Characteristics of the shopping centre defined by its consumption profile;
- Possibility of connection modification;
- Quality of energy supply.

Characteristics of the shopping centre defined by its consumption profile:

These parameters allow characterising the demand of a building.

- Electricity consumption [kWh/m^2 year]:
    - Total energy consumption.
    - Lighting consumption (in summer and winter)

- HVAC consumption (in summer and winter)
- Refrigeration consumption (in summer and winter)

Possibility of connection modification:

These parameters inform about the capacity of a building to incorporate renewable energies according to the possibilities of the own characteristics of the building.

- Available flat surface free of shadow for being covered by renewable facilities in a building/building surface already used.
- Peak sun hours.
- Average velocity of wind at 30 meters.

Quality of energy supply:

Indicators linked to the quality of the energy supply are compiled in the normative EN 50160 for being measured through grid analysers.

The quality of energy supply is characterised by two significant characteristics:

- Continuity of energy supply: this term refers to the availability of energy in quantity and necessity, so that the number of failures and supply interruptions is reduced. This aspect is related to the reliability of the system, both technically and planning production and transportation.
- Quality of the voltage wave: it is related to the characteristics of the wave supplied, which must be as similar as possible to a pure sine wave with the appropriate values of amplitude and frequency.

To test and validate the facilities' performance of facilities, the quality specifications need to be taken into account establishes the characteristics required for supply voltage by the general distribution network in low and medium voltage under the usual operating conditions.

Specifications are categorised in: Frequency, Amplitude, Waveform and Symmetry of the three phase voltage, whose reference values are defined in the normative. With these reference indexes, it is possible to identify anomalies in the facilities' behaviour or the possible interferences in the proper operation of the system.

According to this normative, the disturbances that influence in the electric energy supply are classified as follows:

- Variations in the wave amplitude which are produced by significant changes in the demand. Depending on the duration, they are named as interruptions, voltage dips or transient voltage surge.
- Voltage unbalance, which is linked usually to the emergence of negative sequence components and /or zero sequence fundamental frequency voltages in the network.

- Distortion of waveforms that occur when the wave forms of voltage and current differ in a purely sinusoidal due to the effect produced by the presence of harmonics.
- Voltage fluctuations and flicker (Flicker): asymmetric variations of the envelope stress. This phenomenon usually occurs by loads that experience continuous or rapid variations in stress.
- Frequency variations: deviations of the fundamental frequency of the system with respect to its nominal value. They occur by a sudden imbalance between production and consumption, being more important in isolated or weak systems, affecting condensers and inductances.

2.2 Relevant indicators

In the literature review, *Load matching and grid interaction indicators* (LMGI) have been described by Willis and Scott (2000), Colson and Nehrir (2009), Widén et al. (2009), Widén and Wäckelgård (2010), Castillo-Cagigal et al. (2010), Voss et al. (2010), Verbruggen et al. (2011), Lund et al. (2011), Salom et al. (2011) and Sartori et al. (2012).
IEA Task 40 is also focused on the analysis of load match and grid interaction indicators in net zero energy buildings.

The most relevant indicators of interaction are listed below, while in Annex 1 there is a more comprehensive list.

- Load Match Index
  It describes the degree of use of on-site energy generation related to the local energy demand. It is defined as the average value over the evaluation period of what fraction the energy load is covered by the generation.
  It is intended to describe the matching and a high load match means that a great fraction of the load is covered by the on-site generation, while a low value means that the generation covers only a small fraction of the demand. The simplest available formula is the following:

$$f_{load} = \frac{1}{N} \cdot \sum_{year} \min\left[1, \frac{g(t)}{l(t)}\right]$$

  Where f_{load} is the load match index, N is the number of samples (e.g., months, days), g(t) and l(t) are the energy generation and load over the period of interest.

- Grid Interaction Index
  The Grid Interaction index indicates the variability of the exchanged energy between the building and the grid within a year normalised by the maximum absolute value.

$$f_{grid} = STD\left(\frac{ne(t)}{max(|ne(t)|)}\right)$$

3. Characterisation of shopping centres and their interaction with the grid - Methodology for identification of capacities of these buildings as energy suppliers

This chapter illustrates the methodology applied in the current report for envisaging the capacities of reference buildings as well as the three demo-sites which are part of CommON*Energy* project to provide an energy supplier as well as quantify the impact in the grid produced by some of these solutions in case they were incorporated during a retrofitting process. First, the methodology involves a characterisation of shopping centres with respect to load profiles, climate, urban and energy contexts, among other aspects which condition the interaction between the buildings and grids.

The methodology consists of four steps:

1 Definition of parameters which characterise the building, the building context and the interaction of the building with grid.

- The characterisation of the reference buildings and the building context is based mainly on the parameters defined in Section 2.1. Most significant parameters have been included in a questionnaire delivered to the reference buildings' owners/managers (See Annex 3). This questionnaire intended to compile the relevant information about the building (size, type, and schedule and consumption profile), and the energy supply characteristics. It also included the grid capacity and evaluated the possibility for connection modification. The questions were analysed in detail in order to get suitable information from the minimum number of points in order to persuade owners/managers in its reply.
- For the characterisation of building-grid, it will consider indicators described in Section 2.2 (Load Match Index and Grid Interaction Index). In addition, for the Valladolid demo-case, an energy grid analyser was used for measuring the quality of supply electricity fed by the grid to the "Mercado del Val" building. This building is located in an urban context, the city centre, with a likely high degree of grid saturation. Therefore, it is assumed that this building represents the worst conditions, while the other reference buildings could have better conditions. Details can be found in Annex 2 "Quality of energy supply in Mercado del Val" and technical characteristics of the grid analyser (A2.1).

2 Characterisation of shopping centres by the analysis of the data collected through the questionnaires, obtaining also information about the quality of grid in the demo-case of Valladolid by means of grid analyser. Annex 7 shows general data from buildings aimed to this analysis, their environment context and electricity share of energy consumption.

3 Definition of possible energy scenarios and identification of the best solutions for each shopping centre. Once the diagnosis of shopping centres is done, it can identify constraints and potentials of buildings for being exploited as energy scenarios. Then, it is possible to propose a set of solutions according to the previous premises by each shopping centre (on site RES, Energy Storage, Peak Shaving and Energy Saving).

4 Evaluation of the impact that energy solutions would produce on the local grid in case they were applied in shopping centres through LMGI indexes. The procedure for this analysis consists of:

- Generation of generic energy profiles for each reference building/demo-site:
- Generic energy profiles of the current situation of the reference shopping centres using EnergyPlus were created based on simplified models of commercial buildings defined by U.S. Department of Energy (DOE) covering both retail and supermarket typologies (see: http://energy.gov/eere/buildings/existing-commercial-reference-buildings-constructed-or-after-1980) and locations (ten types of climatic conditions/weather files). Subsequently, typical days for three different seasons (summer, winter and middle-season) were generated. The profile is adjusted to the reference buildings' location once the climate characteristics of the places where they are located are introduced. Since profiles are shown in Wh/m^2, they will be adapted to the real surface of the supermarket and retail areas; these represented the baseline scenario.
- Evaluation of the energy generation and energy saving potential for the set of solutions proposed by each shopping centre:
  - The energy generation for RES solutions (PV and wind) was evaluated with TRNSYS. For the capacity of PV, the available surface of each building was taken into account as well as the climate and own restrictions of the building (shadow effect for surrounding buildings). For the case of the wind energy, the energy production was estimated taking into account a size of the turbine suitable to each building, the climate and the own restrictions of the building (e.g. location in urban context). The energy generation profile associated to the cogeneration is evaluated with EnergyPlus, assuming a 30% of efficiency is based on thermal efficiency.
  - The energy profile of buildings associated with the incorporation of efficient solutions (HVAC, Lighting, Envelope and Refrigeration) was calculated with EnergyPlus in line with the most ambitious settings defined with PHPP simulations (CommONEnergy deliverable 2.5), specifically.
    - <u>Envelope</u>
      - Reduce air changes to 0.6 hr^{-1}
      - Add night natural ventilation: 3hr^{-1}
      - Double insulation thickness
      - Modify window: U-value glazing=0,8;U-value frame=0,6

- Lighting
  - Reduce light density to 4.5 W/m^2 in shops and 3 W/m^2 for common areas (and others)
- HVAC
  - Modify Heating equipment efficiency to 95%
  - Modify Cooling equipment efficiency to COP=6
- Refrigeration
  - Reduce refrigeration power to 40% of initial installed power

- Calculation of Load Match and Grid Interaction Indexes (LMGI) for the baseline and the solutions with RES alone and with RES plus one of the energy efficiency measures at the time.
- Finally, based on the demand and generation profiles for the scenarios described above, an evaluation of the possible Energy Storage and Peak shaving solutions was discussed in some of the reference buildings and will be the basis for the detailed work in Task 4.3 "Load energy generation, grid interaction and storage".

Finally, a deeper analysis can include a study of policies and tariffs as boundary conditions for incorporating certain solutions in shopping centres as well as a more exhaustive evaluation of the quality of the grid in the proximity of the building. Annex 5 compiles the policies and normatives in countries where the CommON*Energy* demo-cases and reference buildings are located. This section also provides a description of the current situation of these countries, as a result of the application of normatives. Lastly, the electricity profile of these countries associated to the energy demand is shown in Annex 6. These figures can help to identify the peaks and valleys in the daily energy demand which must be accompanied by a specific study of the quality of the interconnection between the building and the electrical grid. The procedure is included in Annex 2.

4. Shopping mall potential services to the grid

Shopping centres have a high potential to supply grid services, reducing the impact on power demand through peak shavings of its demand curve or adaptation to the conditions of generation of the utilities, based on the classification of the demand or use of energy generated from renewable energy sources in moments of mismatch between energy supply and demand, either directly or from storage.

This potential is due to predictable consumption profiles linked with opening schedule as well as consumption peaks in period of maximum capacity for renewable solutions. Thus, this circumstance could be a potential driver for energy retrofitting since an economic benefit can be achieved for economic saving due to efficient measures but also for the payment related to the tariff linked with renewable energies in case it existed.

The selection of solutions to provide services to the grid (e.g., increase matching during lack of electricity or use electricity during time of excess) will be based on the characterisation of the building (available surface, energy consumption share and energy profile), environment context (climate, normative), grid capacity (current level of saturation and generation profile) and quality (non-existence of interferences in the proper operation of the system of energy supply) in order to detect the potential of building but also to note if the expansion of the capacity of the grid and especially to the use of renewable energies can produce stress for the grid.

A description of potential solutions to provide services to the grid is available in Annex 4 and divided in five categories: on-site RES, Energy Storage, Peak shaving of demand curve and Energy saving solutions.

- On site RES (A4.1)
    - Photovoltaic energy (A4.1.1)
    - Wind energy (A4.1.2)
    - Cogeneration (A4.1.3)
- Energy storage (A4.2)
    - Power
        - Backup power
        - Primary power
        - Hybrid H2-battery
    - Transport
        - Hydrogen refuelling station for customer
        - Hydrogen bus refuelling
        - Material handling vehicle refuelling
- Peak shaving of demand curve (A4.3)
    - Energy supply options

  - Shifting of loads using flexibility or system operation

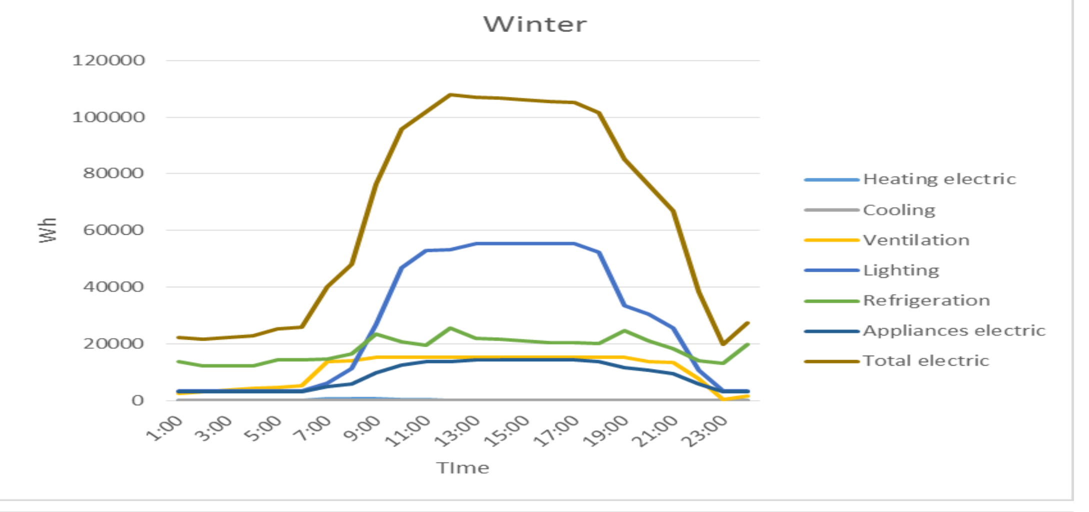
- Energy saving solutions (A4.4)
  - Envelope
    - Solar shading
    - Green integration
    - Reflective coating
    - Natural ventilation
  - Lighting
    - Daylight
    - Replacement of inefficient lighting equipment
    - Lighting control
  - HVAC systems
    - Energy efficiency equipment and components
    - Energy flux strategy and recovery
    - Equipment control and management
  - Refrigeration
    - Reduction of refrigeration heat gains
    - Reduction of refrigeration heat load
    - General setting and operation rules

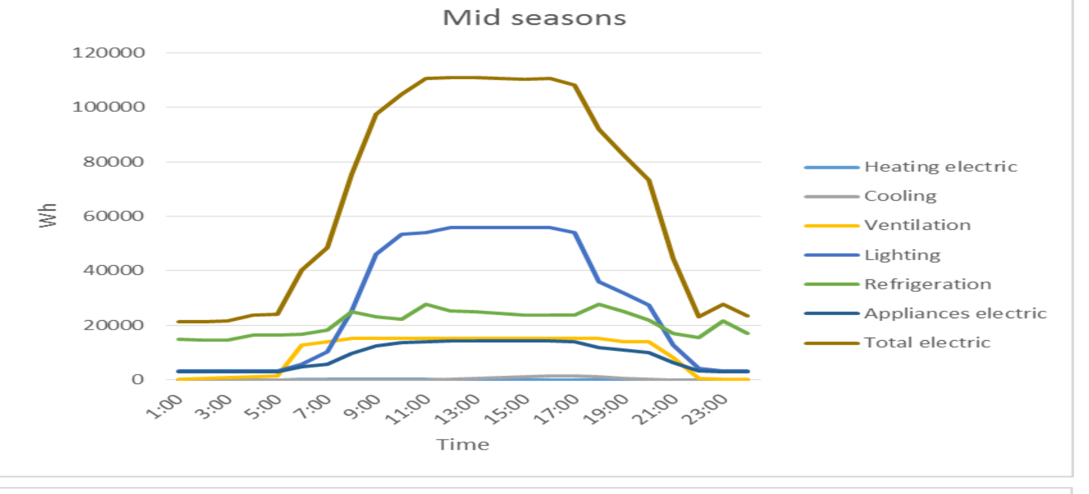
Based on the assessment of the context, the demand and the generation profiles, potential services of reference shopping centres involved in CommON*Energy* are identified below.

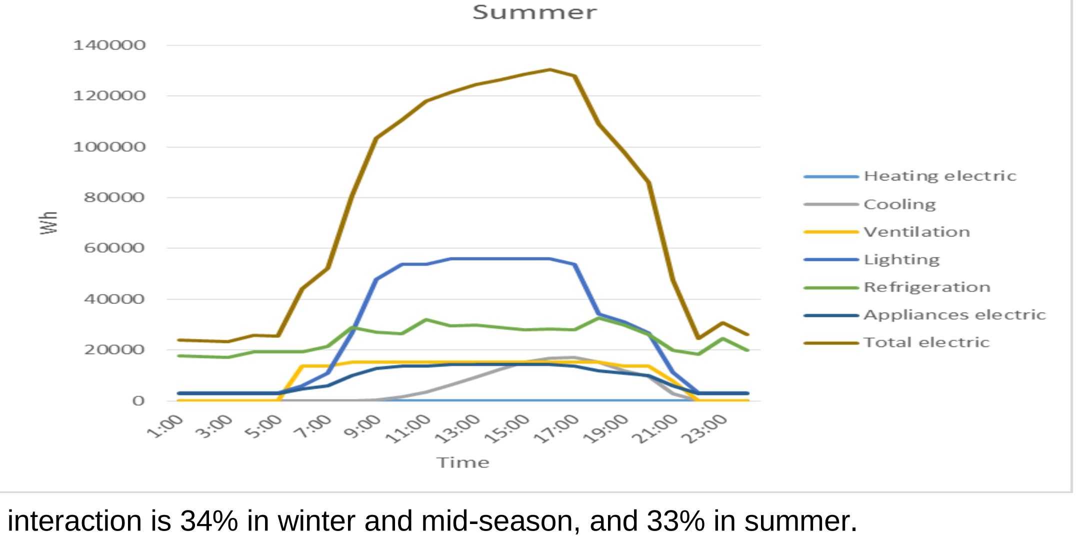
4.1 Reference SC in VALLADOLID based on MERCADO DEL VAL

LOAD PROFILES (BASE CASE)

Total Surface: 2,168 m^2 (Supermarket area: 844,5 m^2)







The grid interaction is 34% in winter and mid-season, and 33% in summer.

POTENTIALS
• The electricity demand of the "Mercado del Val" is mainly due to the lighting, HVAC systems (radiant floor fed by air/water heat pumps) and the energy consumption of the refrigerators used for the conservation of the products. This gives an idea of where it is possible to act to reduce the shopping centre's electricity consumption. • The demand profile shows a clear correlated character with the timetable during the market working day. Thus, the highest values are produced from 9:00 to 16:00, although there is a minimum consumption mainly due to the refrigerators outside of working hours. • The cooling systems are old and undersized because, following the air temperature analysis and the users' and clients' comments, the comfort levels are not reached a lot of times. Furthermore, the low airtightness, owing to the building status, causes elevated energy consumption and it is a constraint for achieving the comfort conditions. • Existing lighting systems are old and non-efficient in contrast to the modern lamps and luminaires in the marketplace. • There is no energy management system for programming the control strategies so as to deal with the energy management. • The results of the analysis of the main electrical parameters in the supply indicate the lack of network quality problems, during the metering period. • Elevated reactive energy consumption has been detected, as well as low values of cosPhi, because of the lack of reactive energy consumption compensation. This penalises the bills from the supplier. • Great values in the harmonics 5 and 7 have been detected due to non-linear loads (luminaires, fans…). This could influence the quality of the grid in terms of disturbances. • There are no renewable systems for the electricity generation connected to the distribution grid of the market which affects regulations regarding the renewable installation typical to each distribution line. • The urban environment and the presence of buildings in the surroundings limit the installation of photovoltaics and wind turbines. Besides that, the historical character of the building is a determinant factor too. However, high levels of radiation make solar panels a potential solution for this building.
SOLUTIONS
On-site RES
Installation of a photovoltaic system which could be placed over the roof and oriented to the South-East whose shadow factor is not critical. Moreover, due to architectural and aesthetic restrictions, photovoltaic tiles could also be considered. Anyway, without considering the final placement, the photovoltaic generation profile is suitable for the demand profile of the building because the photovoltaic generation peaks coincide with the market demand peaks. Mini-wind system, in combination with the photovoltaic, minimises the electrical consumption. It is important to note that this system presents great troubles with the installation both at aesthetic

level and urban environment noise. Therefore, although from the energy point of view it is feasible; from the functional one it is almost discarded.

Below are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity on the grid will be reduced.

Photovoltaic installation

Mercado del Val is considered a heritage building which makes the integration of renewable facilities difficult. Therefore, installing photovoltaic roof tiles with a power density of 112 W/m^2 has been considered.

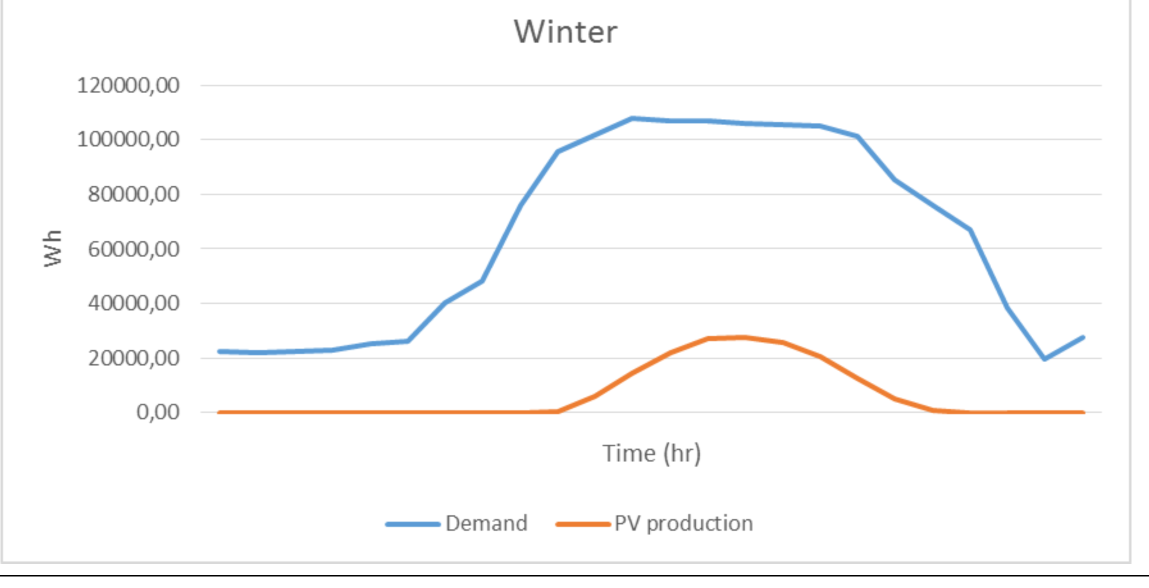
For the simulation in TRNSYS of the photovoltaic installation, a surface free of shadows of approximately 865 m^2 has been considered with an inclination of 30º and a deviation of 30 degrees respect to the south.

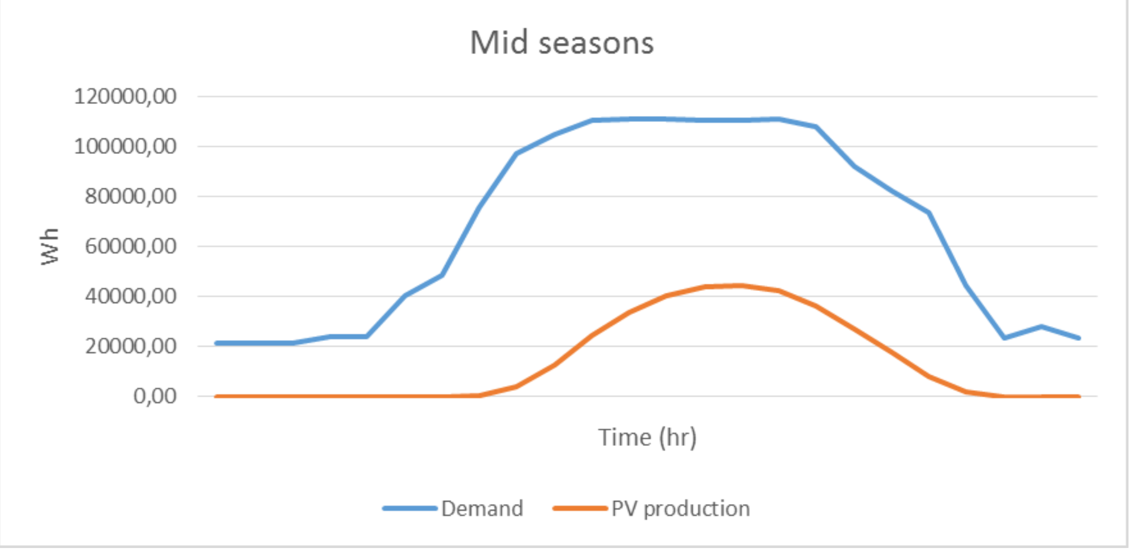
Table 2 show the results for the hourly energy production for the different seasons:

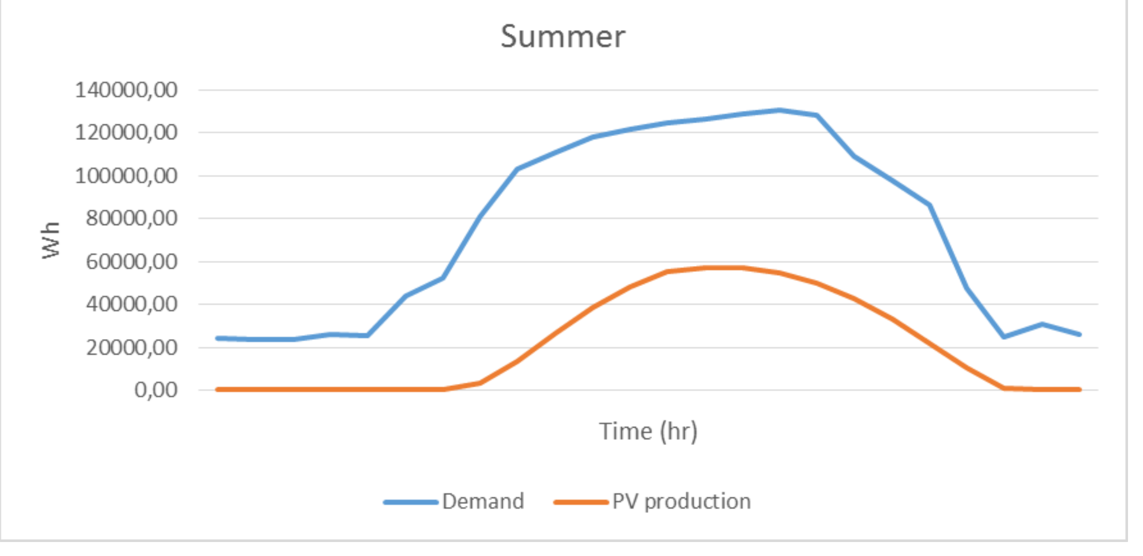
Table 2: Hourly energy production in Wh by season for the photovoltaic installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0	0	0	0	0	0	0	0	0	446	6,152	14,359
Summer	0	0	0	0	0	0	0	3,035	13,468	26,392	38,269	48,398
Mid-season	0	0	0	0	0	0	0	530	3,994	12,913	24,218	33,560
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	22,163	26,923	27,766	25,704	20,517	12,660	5,221	617	0	0	0	0
Summer	55,085	57,172	56,991	54,441	49,929	42,728	33,458	21,934	10,149	1,021	0	0
Mid-season	40,533	44,110	44,375	42,211	36,058	27,180	17,804	8,210	1,754	30	0	0

By overlapping the PV production (according to the 865 m^2) with the load profile curves for the different seasons developed before, we obtain the following figures:







With these values, we obtain that the load match during the winter days is approximately 6%, mid-seasons 13% and in the summer days 19%. The grid interaction that indicates the variability in the import from the grid is 30%, 24%, 30% for winter, mid-season, summer respectively.

Wind Power installation

A wind power installation has also been considered with a low power turbine of 20 kW, which allows its easy energetic integration in the system as well as its operation with low wind velocities.

Figure 4 shows the evolution of the power produced by the wind turbine through simulation in TRNSYS. It is possible to appreciate how it is not possible to reach the highest power, with a large variation in the power from one day to another.

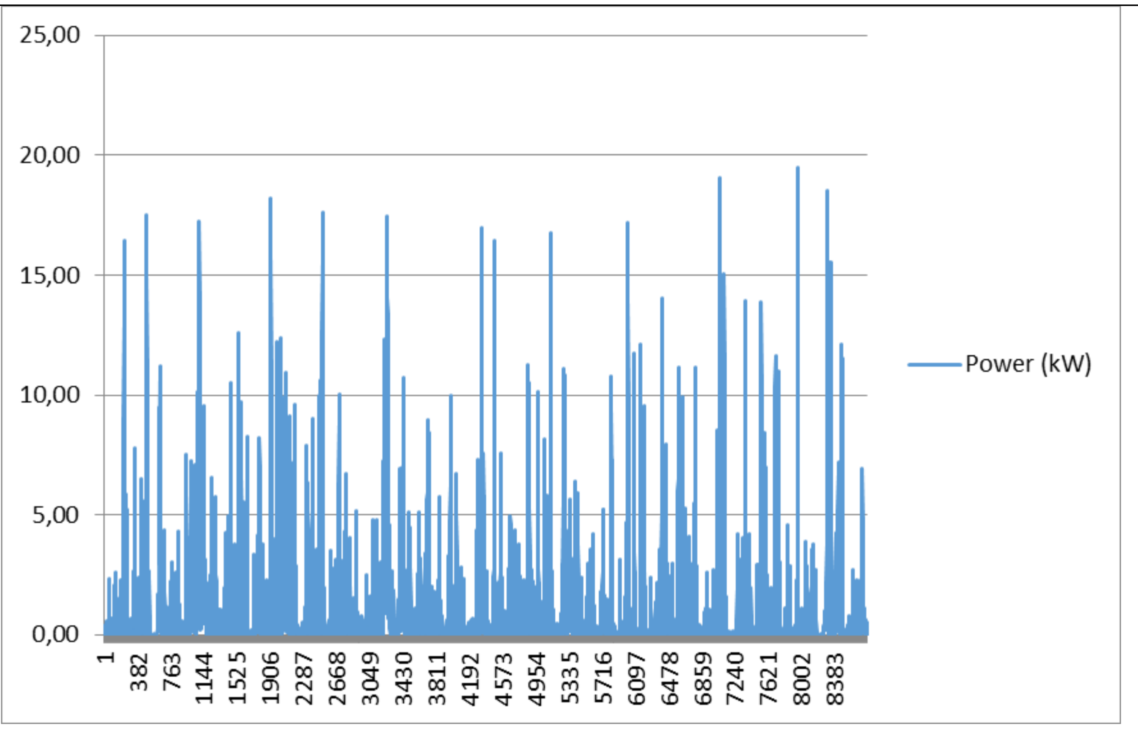


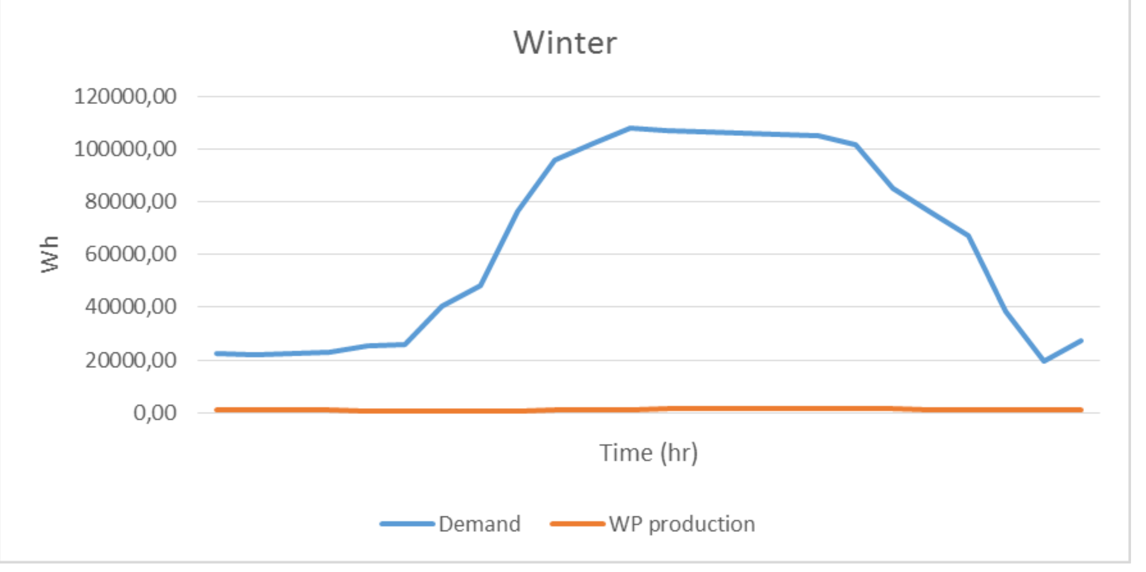
Figure 4: Evolution of power produced by the wind turbine.

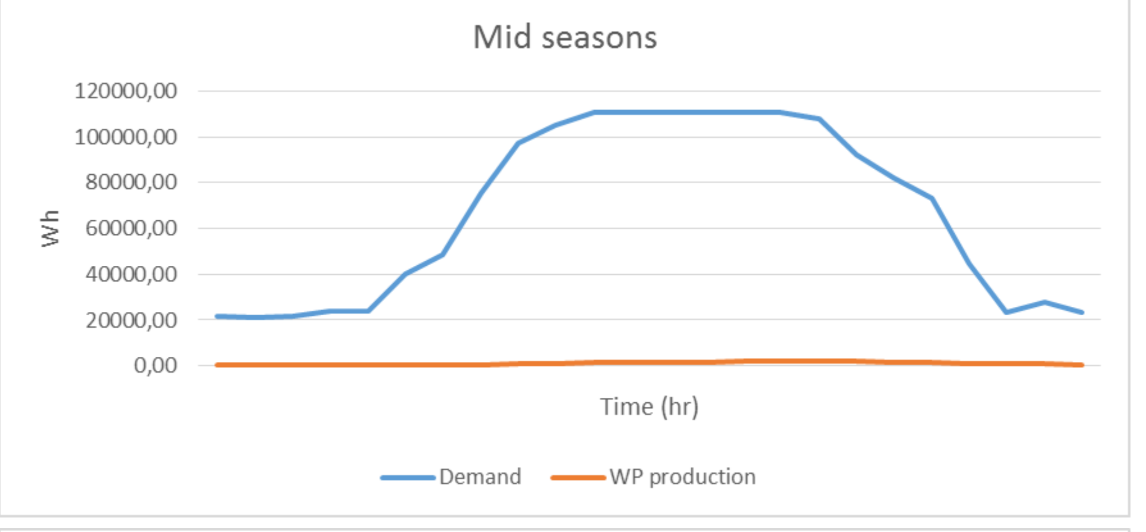
Table 3 shows the results for the hourly energy production for the different seasons:

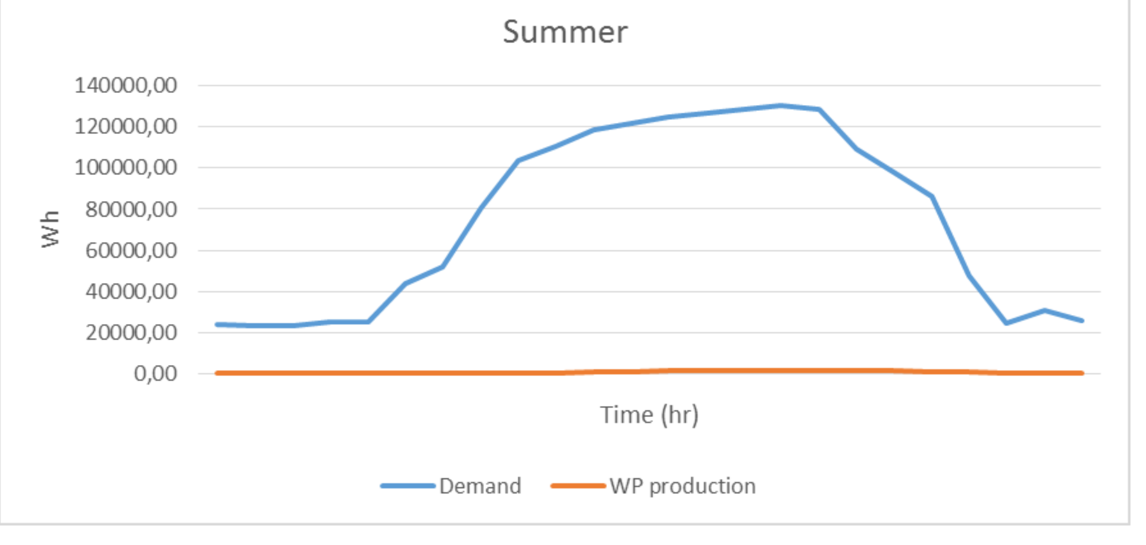
Table 3: Hourly energy production in Wh by season for the wind power installation

Time	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**	**12:00**
Winter	1,005	996	833	921	805	691	661	639	796	1,010	1,081	1,126
Summer	664	575	424	535	518	427	335	323	392	555	891	1,242
Mid-season	648	590	469	531	490	561	556	598	739	973	1,240	1,440
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	1,326	1,406	1,418	1,434	1,336	1,342	1,343	1,268	1,130	976	987	989
Summer	1,565	1,835	1,969	2,028	2,057	2,025	1,749	1,357	1,026	830	770	724
Mid-season	1,529	1,717	2,015	2,115	2,191	2,168	1,772	1,343	1,004	879	735	658

By overlapping the WP production (according to the 20 kW power turbine) with the demand curves for the different seasons, we obtain the following figures:



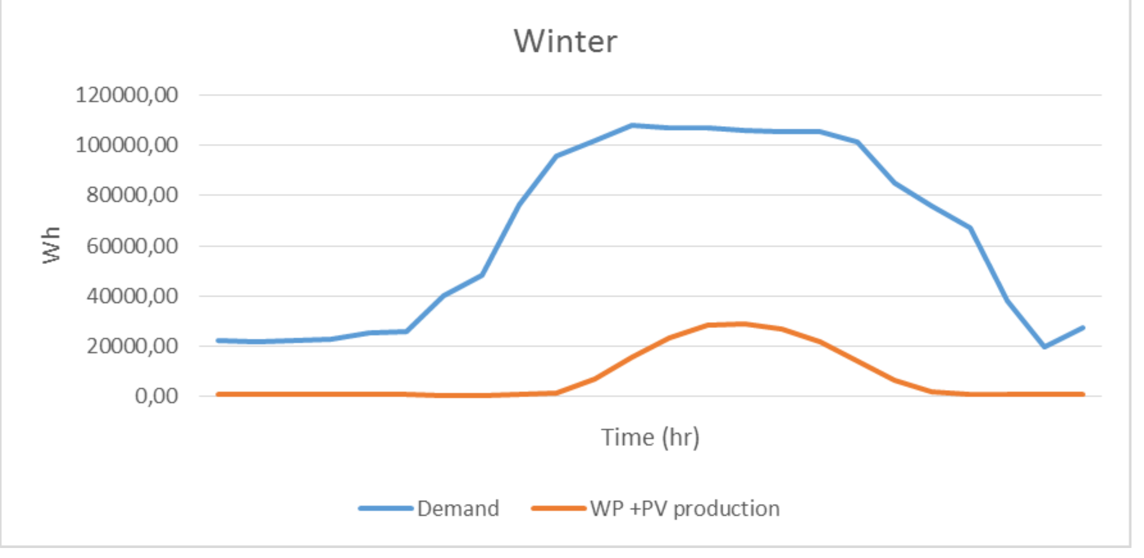


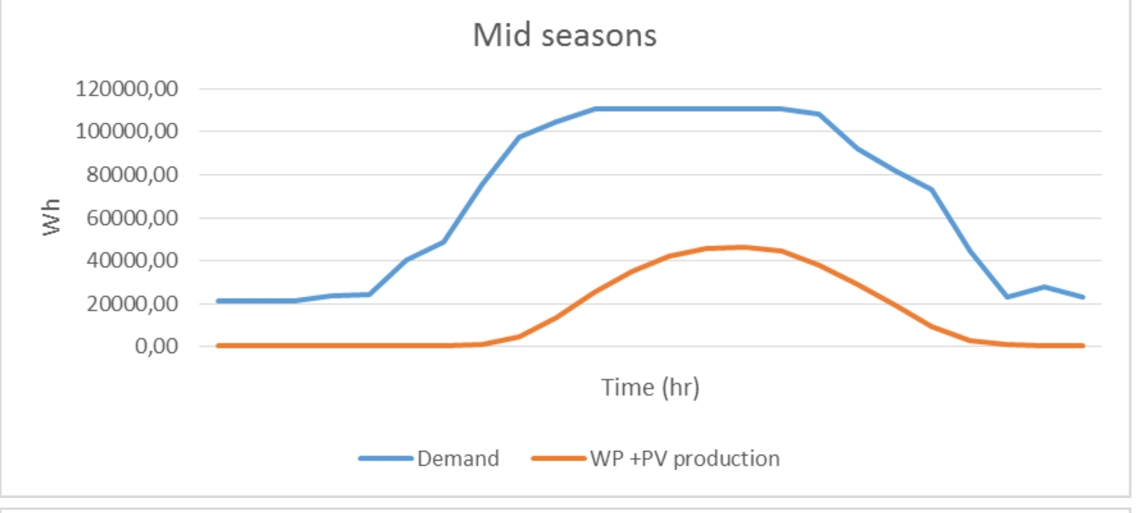


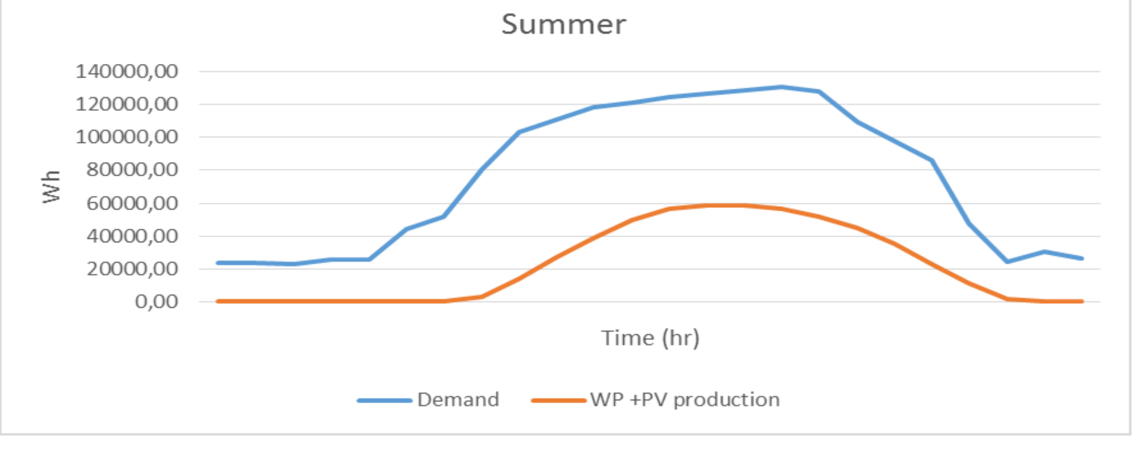
With these values, we obtain that the load match is extremely low (2%) throughout the seasons, while the Grid Interaction is 34%.

Photovoltaic installation + Wind Power installation

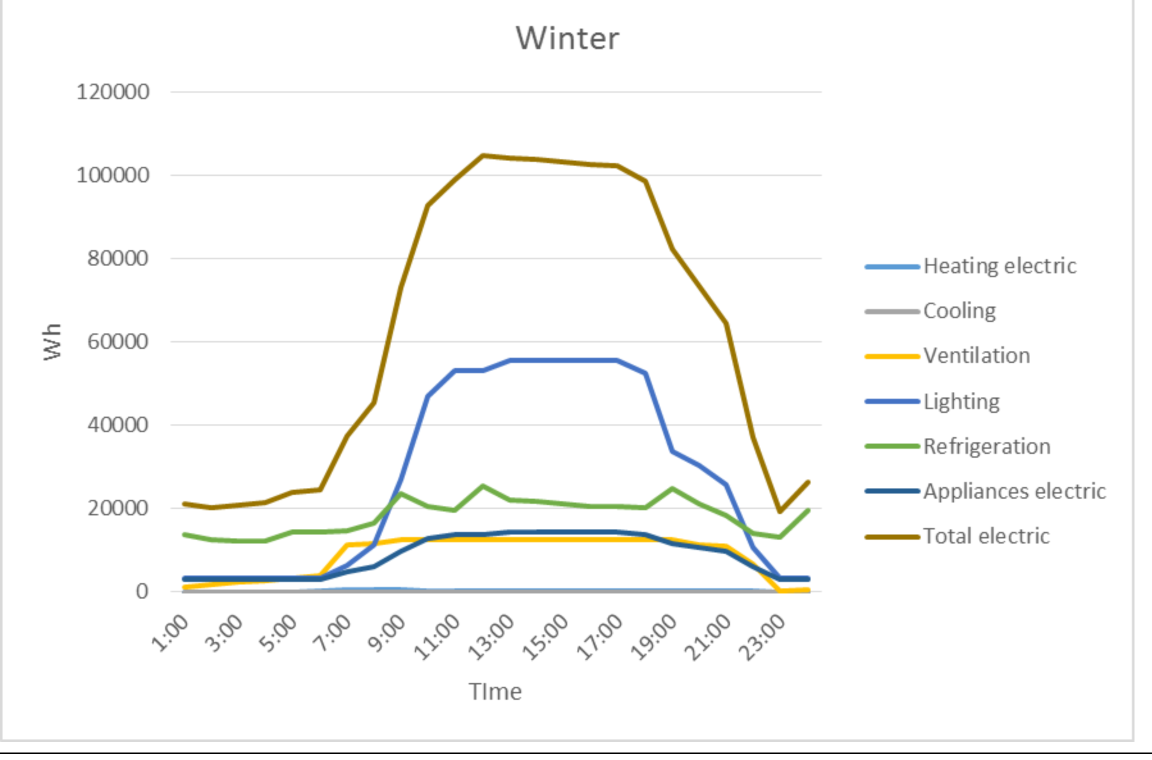
If both RES solutions are considered at the same time, we obtain the following figures:

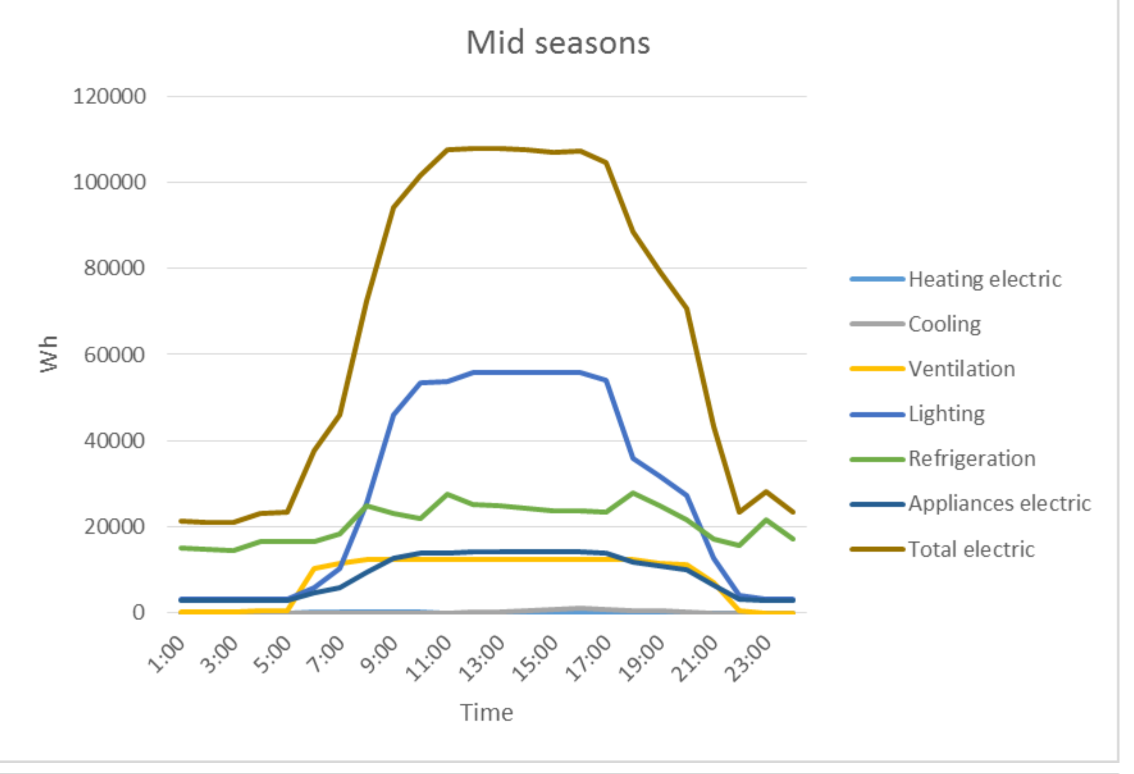


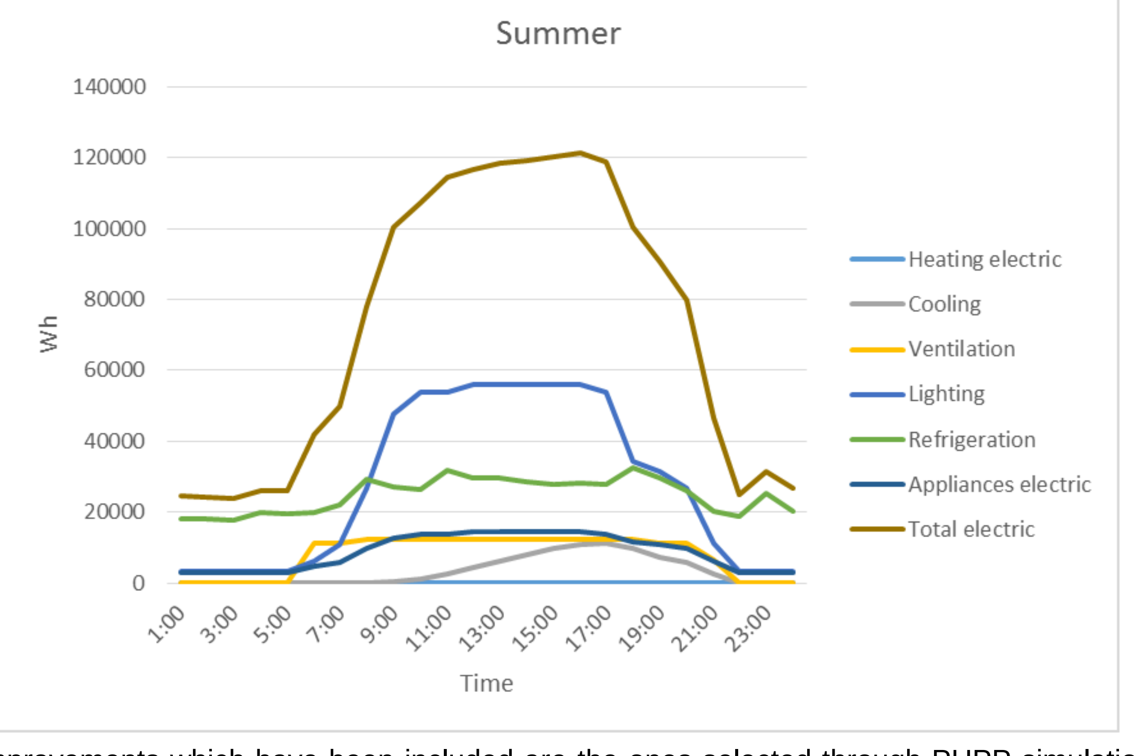




In this case, the load match is increased to 9% in winter, 15% in mid-seasons and 20% in summer. Concerning the interaction with the grid, the values are 31% in winter, 24% in mid seasons and 30% in summer.

Energy saving
Envelope Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, taking into account the HVAC systems are electrical ones, because the losses could be decreased. If improvements in the envelope are included in this building, we obtain the following load profiles: 



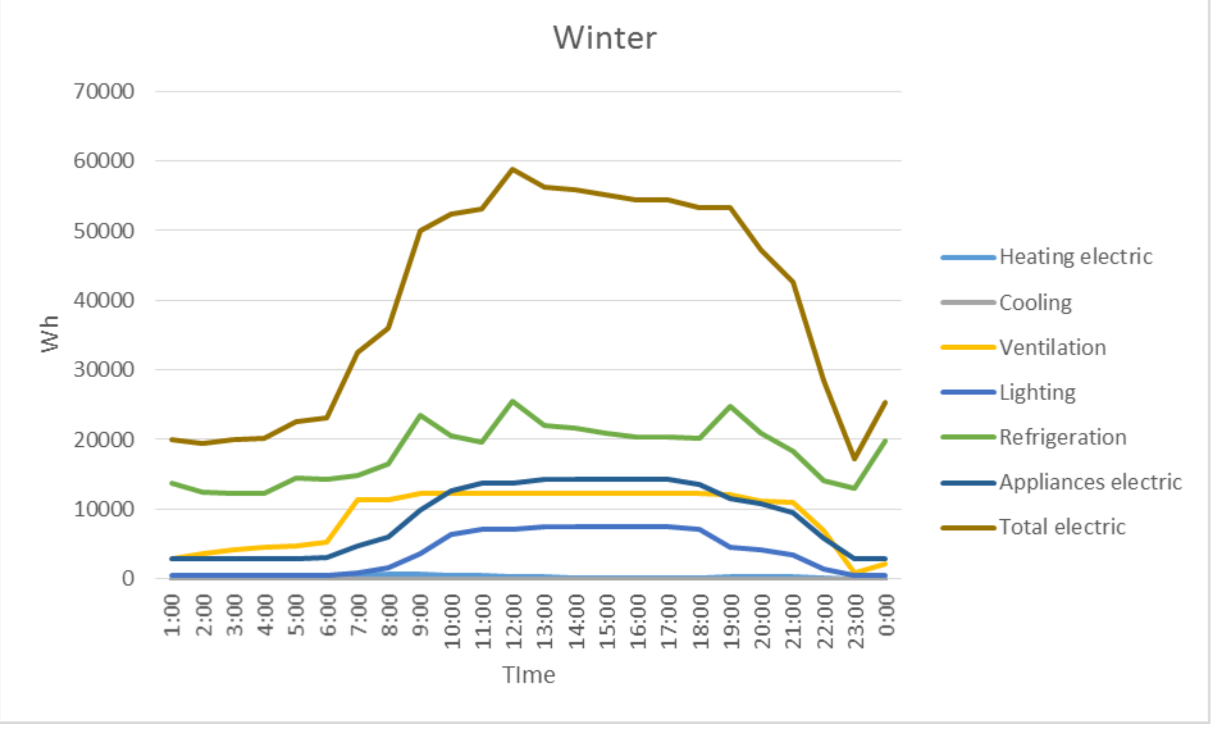


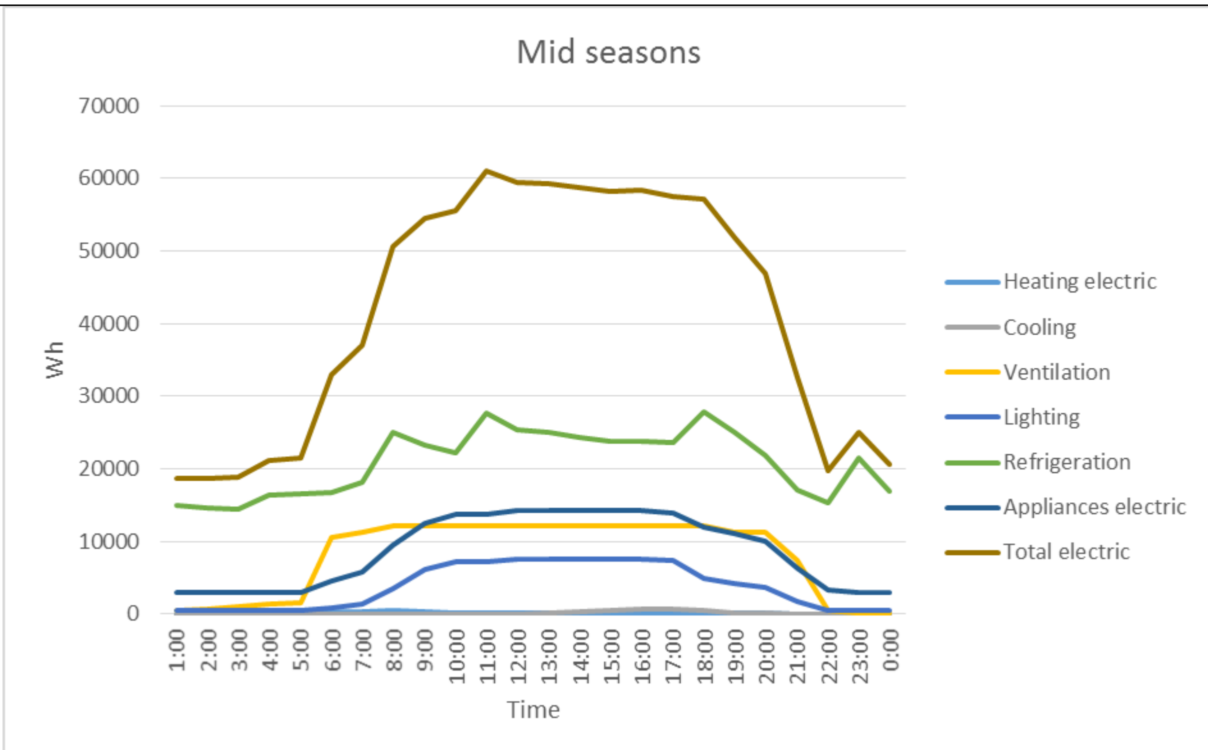
The improvements which have been included are the ones selected through PHPP simulations in CommON*Energy* report D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems to not have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

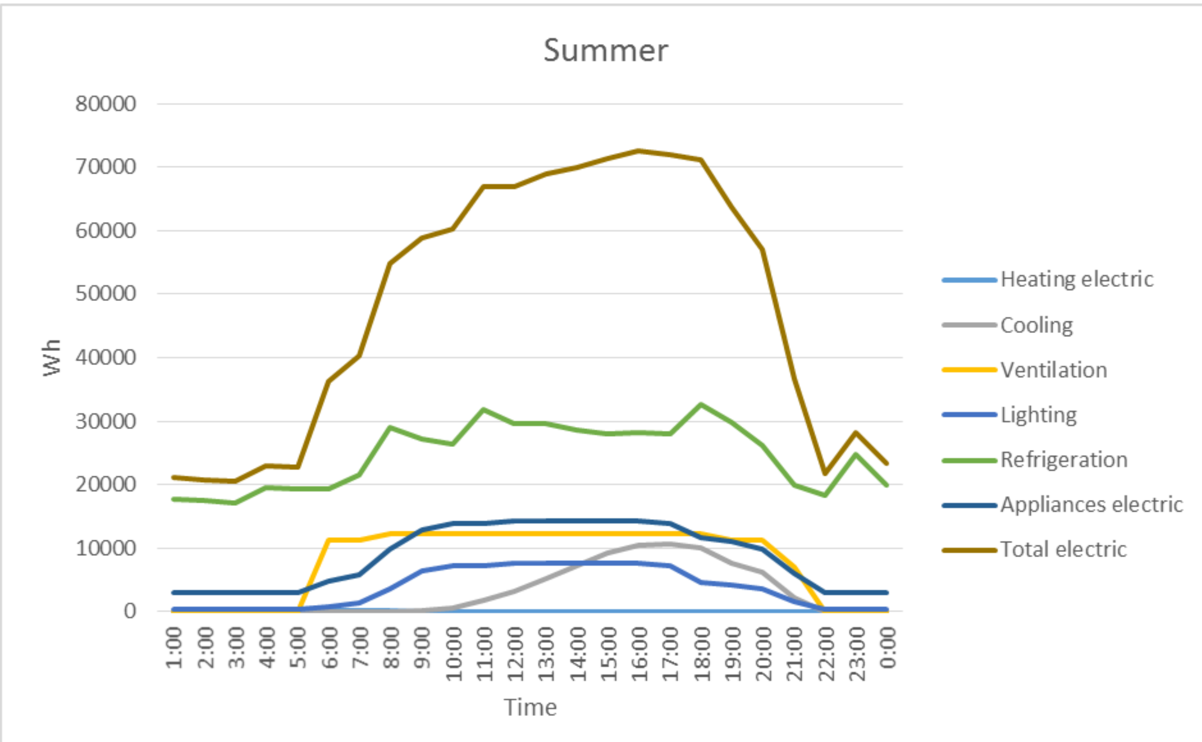
Lighting

Existing luminaries and lighting systems stand in for new equipment more efficient and with higher performance. The installation of electrical ballast and control equipment for the luminosity which allow dimmer regulation so as to adjust the lux level according to the indoor and outdoor conditions, as well as the comfort parameters in order to decrease the consumption when enough daylight.

The improvements in terms of lighting are shown in the following load profiles. These improvements are also based on PHPP simulations developed in D2.5 taken the most effective solution in terms of energy efficiency (From D2.5: V1, Reduce light density to 3 W/m^2 for common areas (and others) and 4.5 W/m^2 in shops).



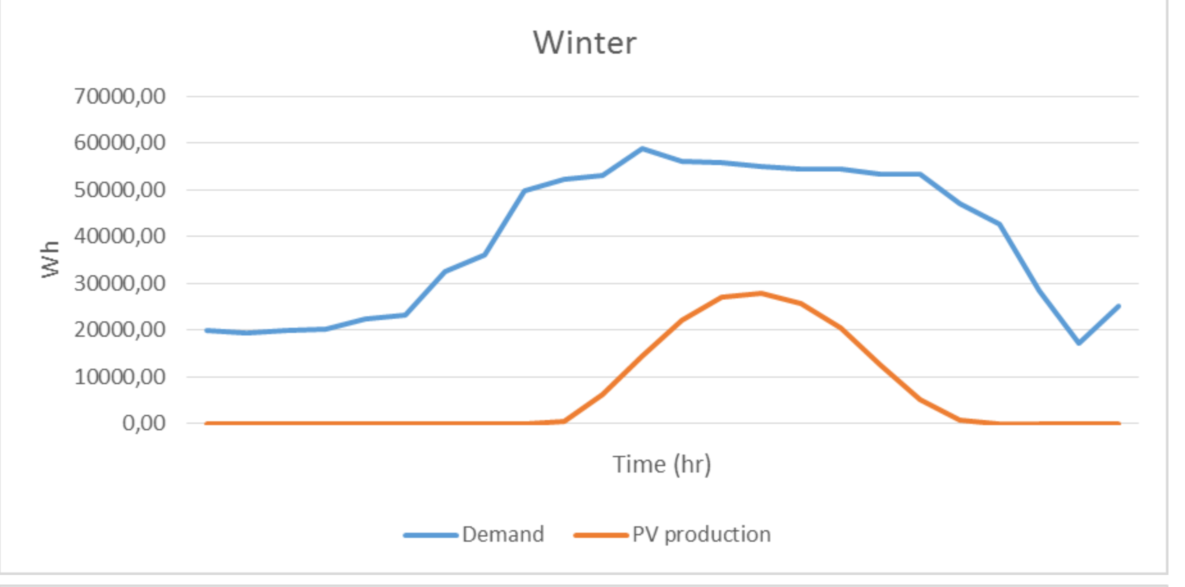


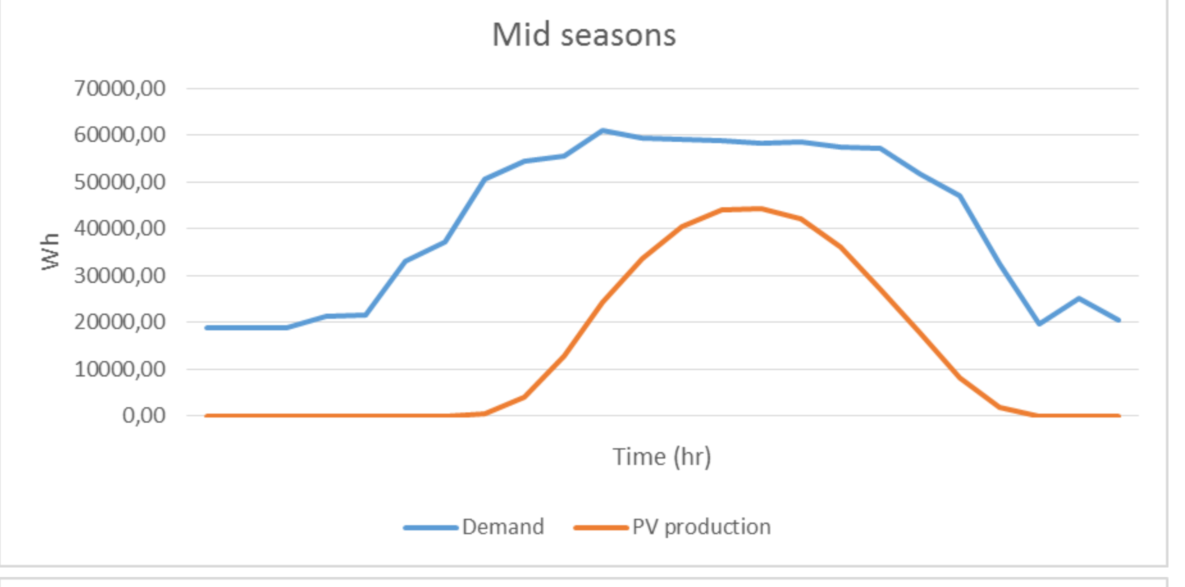


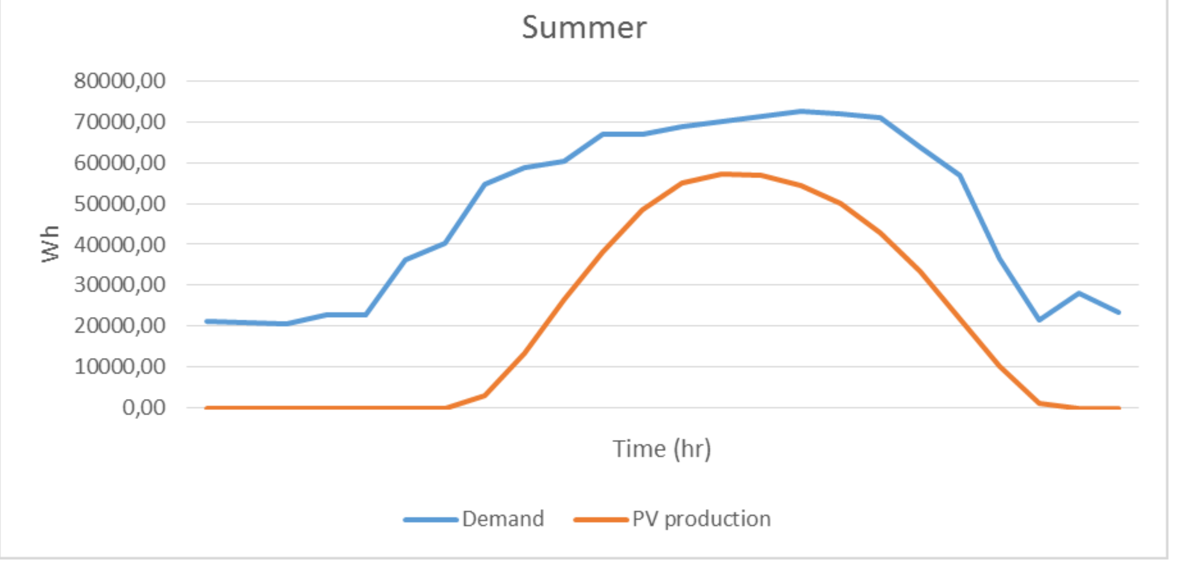
In this case, the grid interaction is reduced from 34% (winter), 34% (mid-season) and 33% (summer) in the base case to 26% (winter), 28% (mid-season) and 29% (summer) with improvement in terms of lighting.

Lighting + PV

As the lighting solution seems to be a suitable solution, the idea is to combine it with the PV solution proposed before in order to calculate a new load match index.


Winter
70000,00
60000,00
50000,00
40000,00
30000,00
20000,00
10000,00
0,00
Wh
Time (hr)
Demand
PV production


Mid seasons
70000,00
60000,00
50000,00
40000,00
30000,00
20000,00
10000,00
0,00
Wh
Time (hr)
Demand
PV production


Summer
80000,00
70000,00
60000,00
50000,00
40000,00
30000,00
20000,00
10000,00
0,00
Wh
Time (hr)
Demand
PV production

With these values we obtain that the load match during the winter days is approximately 12%, mid-seasons 24% and in the summer days 32% and the grid interaction is 21%, 25% and 20% for winter, mid-season, summer respectively.

Quality of the grid

From the information we have obtained through the quality analysis of the interaction between the building and the grid in Mercado del Val with the Grid Analyser we have identified the following as possible solutions. More information about this analysis is in Annex 2.

Installation of harmonics filters in order to remove the circulating harmonics 5 and 7, which could decrease the perturbations created in the grid.

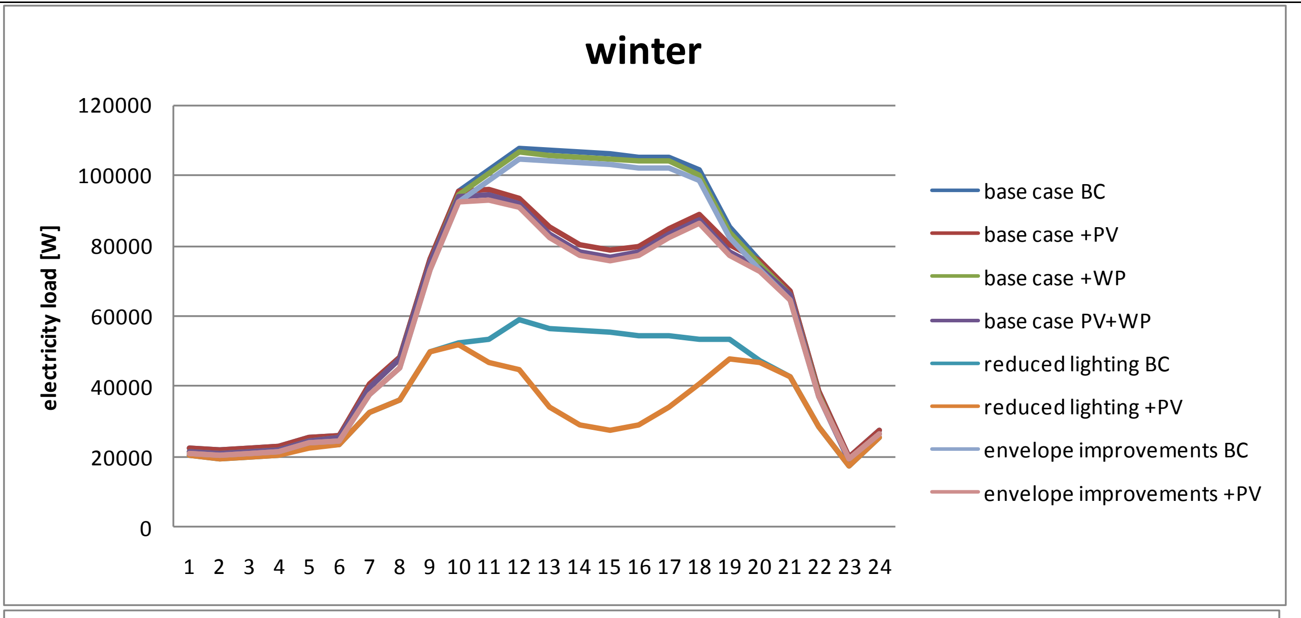
Installation of compensation equipment for the consumed energy by the system. It could be carried out either in the supplier, which implies fewer loads in the distribution grid, or in the main consumption points, if possible, of this kind of energy that would also reduce the energy flows along the distribution circuits.

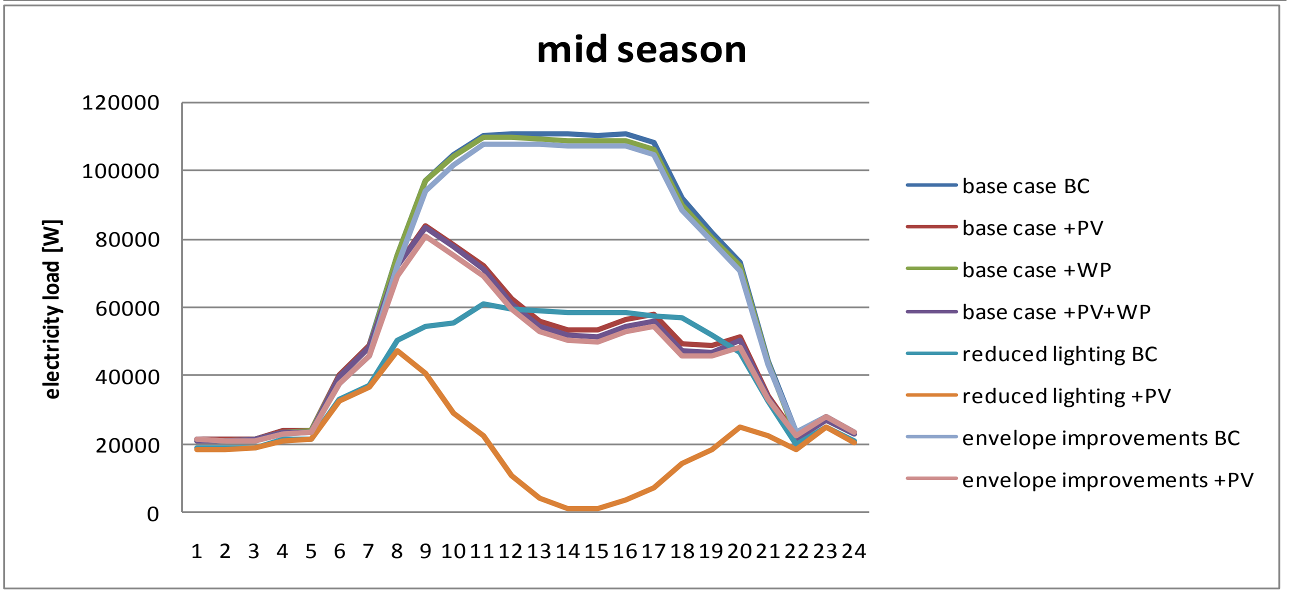
Summary

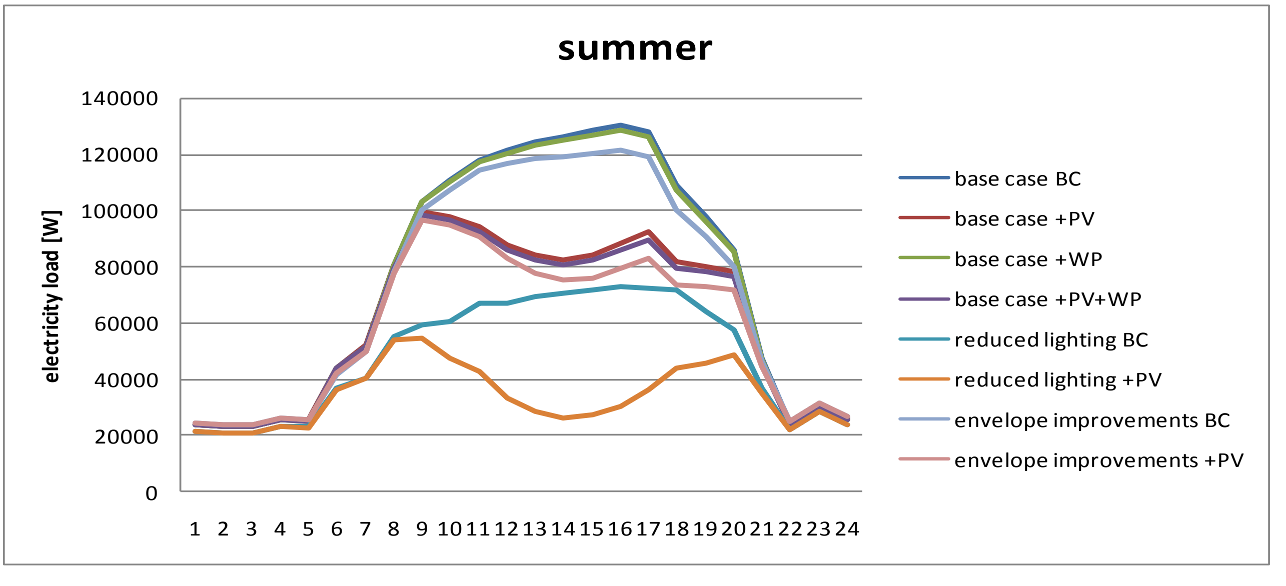
		Base case (BC)			Reduced lighting (LG)	Envelope improvements (EN)
		+PV	+WP	+PV+WP	+PV	+PV
LMavg	winter	6%	2%	9%	12%	7%
	midseason	13%	2%	15%	24%	14%
	summer	19%	2%	20%	32%	20%
GI	winter	30%	34%	31%	21%	31%
	midseason	24%	34%	24%	25%	23%
	summer	30%	34%	30%	20%	28%

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + LG	BC + EN	BC+ PV + WP	BC + LG + PV	BC + EN + PV
Winter	3 %	0 %	7 %	0 %	3 %	12 %	3 %
Mid – season	11 %	0 %	6 %	0 %	11 %	9 %	11 %
Summer	4 %	0 %	5 %	0 %	4 %	13 %	6 %


winter
electricity load [W]
120000
100000
80000
60000
40000
20000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case PV+WP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV

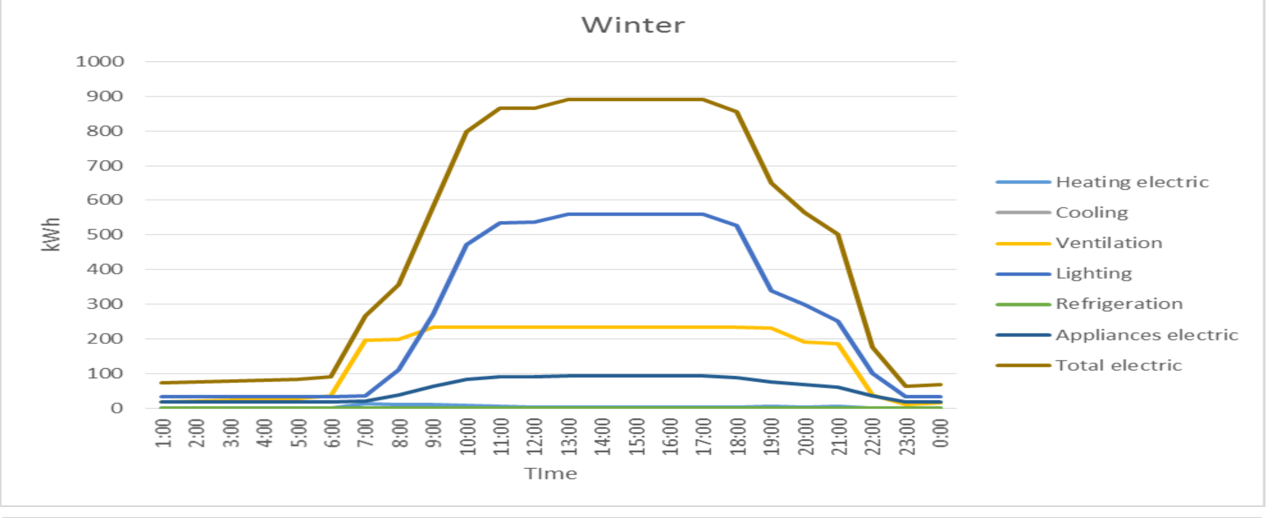

mid season
electricity load [W]
120000
100000
80000
60000
40000
20000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV

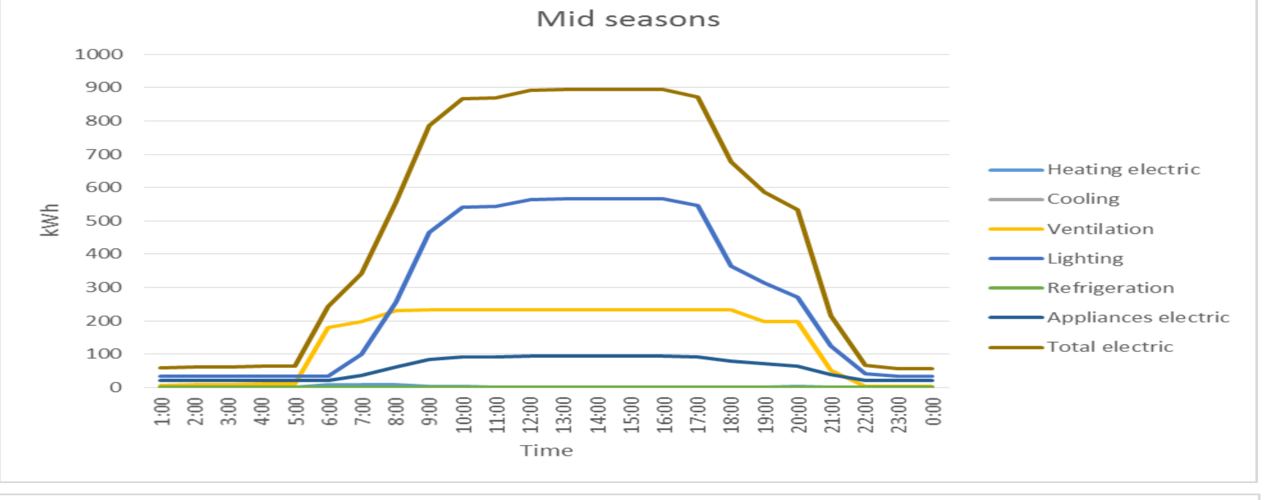

summer
electricity load [W]
140000
120000
100000
80000
60000
40000
20000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV

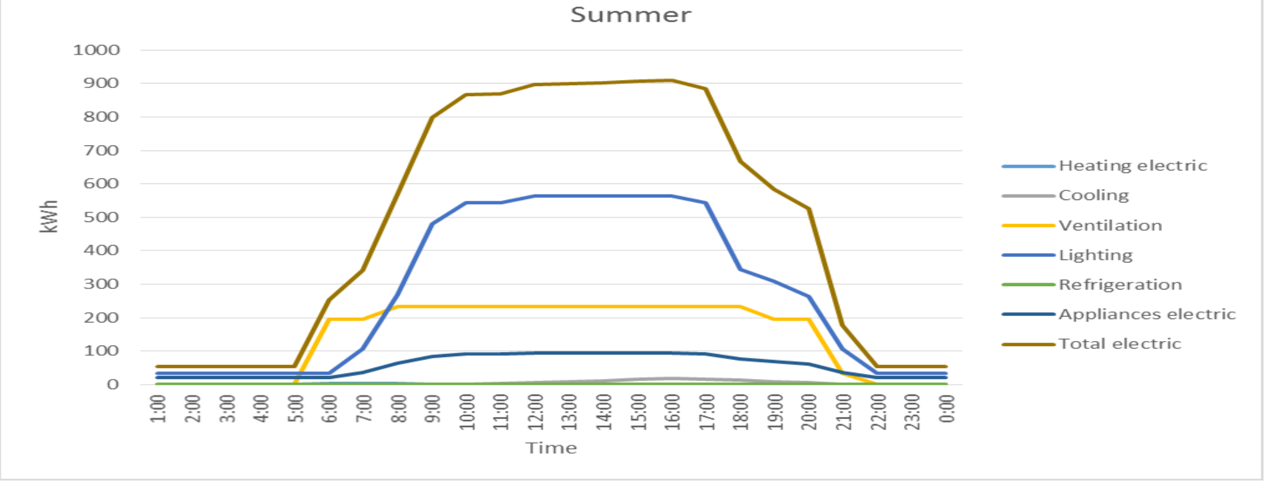
4.2 Reference SC in TRONDHEIM based on CITY SYD

LOAD PROFILES (BASE CASE)

Total Surface: 20,500 m^2 (no supermarket)







The grid interaction is 40% in winter, and 41% in summer and mid-season.

POTENTIALS

- The electricity demand of shopping malls in Trondheim is mainly due to lighting and appliances and HVAC. This gives an idea in where the potential lies to reduce the electricity consumption of the shopping centre.
- The demand profile shows a clear correlated character with the timetable during the working hours. Thus, the highest values are produced from 9:00 to 16:00, although there is a minimum consumption mainly due to lighting and appliances outside working hours.
- There are no renewable systems for the electricity generation connected to the distribution grid of the market which affect regulations with regards to the renewable installation typical to each distribution line.
- The urban environment and the presence of mainly low-rise buildings in the surroundings favour the installation of the photovoltaic and possibly wind turbines.

SOLUTIONS

On site RES

Installation of a photovoltaic system which could be placed over the roof and oriented horizontally. Anyway, without considering the final placement, the photovoltaic generation profile is suitable for the demand profile of the building because the photovoltaic generation peaks coincide with the market demand peaks.
Mini-wind system, in combination with the photovoltaic, minimises the electrical consumption. It is important to note that this system presents great troubles with the installation both at aesthetic level and urban environment noise. Therefore, although from the energy point of view it is feasible; from the functional one it is almost discarded.

Below there are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity from the grid will be reduced.

Photovoltaic installation

For Trondheim, an installation of photovoltaic roof tiles with a power density of 112 W/m^2 has been considered. The installed power was assumed to 500kWp.

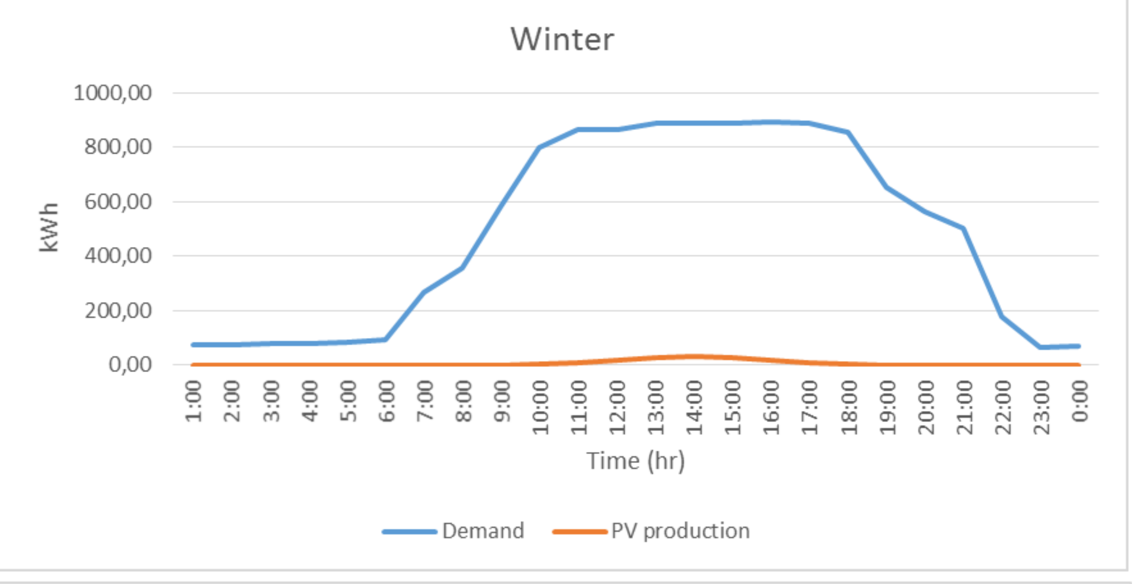
For the simulation in TRNSYS of the photovoltaic installation, a surface free of shadows of approximately 4500 m^2 has been considered with a deviation of 0 degrees respect to the south.

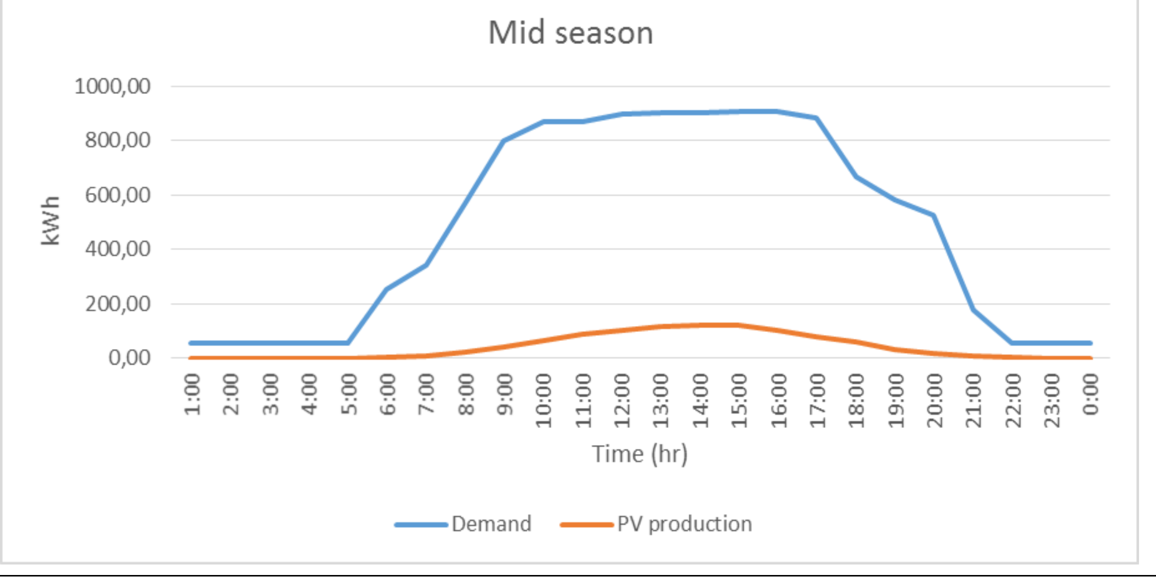
Table 4 shows the results for the hourly energy production for the different seasons:

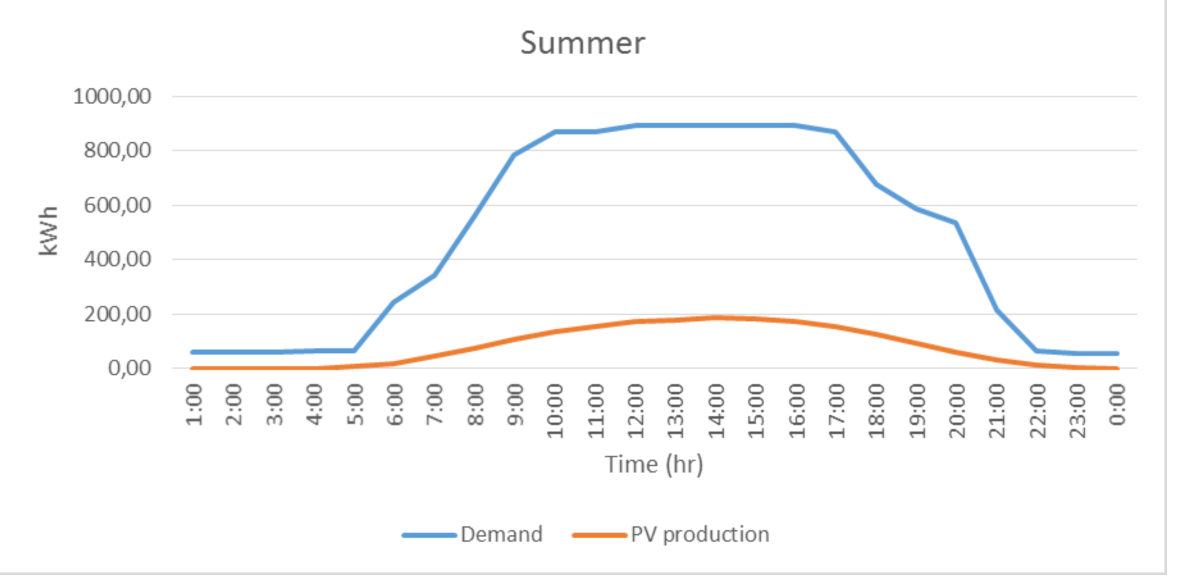
Table 4: Hourly energy production in kWh by season for the photovoltaic installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	7.7	17.5
Summer	0.0	0.0	0.0	0.0	0.6	3.2	9.7	22.3	41.9	66.1	87.3	103.7
Mid-season	0.0	0.0	0.0	0.1	6.3	19.5	44.1	75.2	105.6	135.1	155.5	174.7
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	27.7	30.7	28.7	17.0	8.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Summer	115.7	119.3	119.0	102.6	80.7	58.0	33.5	15.5	5.9	1.5	0.0	0.0
Mid-season	177.9	185.8	182.5	170.4	154.6	126.9	94.4	61.3	32.4	12.9	2.7	0.0

By overlapping the PV production (according to 500kWp) with the load profile curves for the different seasons developed before we obtain the following figures:







With these values we obtain that the load match during the winter days is approximately 1%, mid-seasons 5% and in the summer days 13%. The grid interaction that indicates the variability in the import from the grid is 39%for winter, and 40% for mid-season and summer respectively.

Wind Power installation

A wind power installation has also been considered with a low power turbine of 150 kW, which allows its easy energetic integration in the system as well as its operation with low wind velocities.

Figure 5 shows the evolution of the power produced by the wind turbine through simulation in TRNSYS. It is possible to appreciate how it is not possible to reach the highest power, existing a large variation in the power from one day to another.

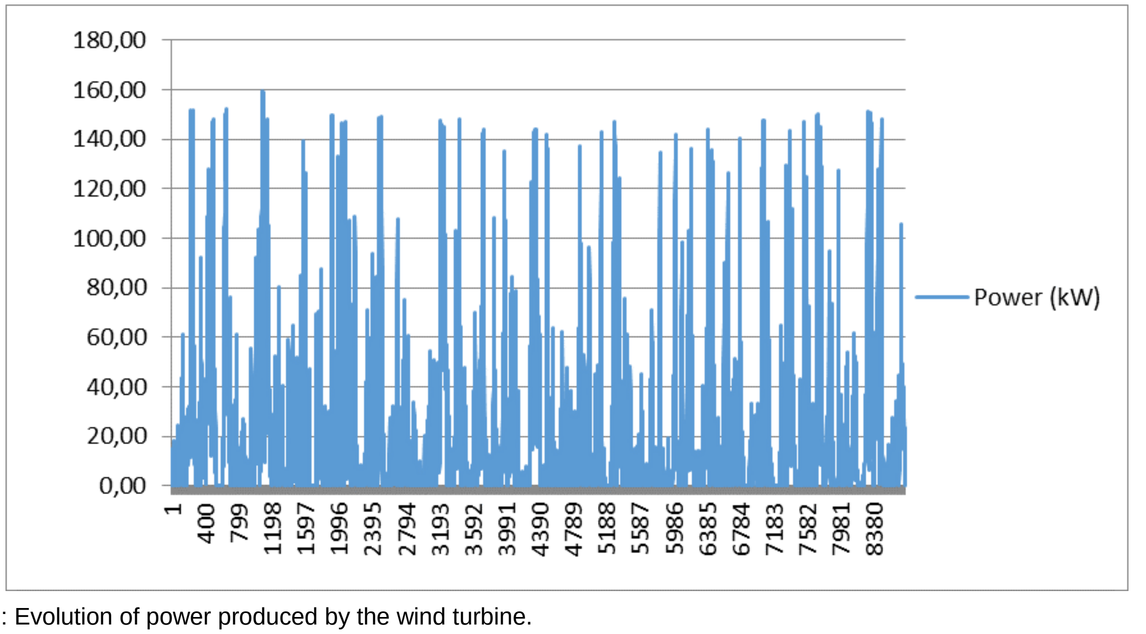


Figure 5: Evolution of power produced by the wind turbine.

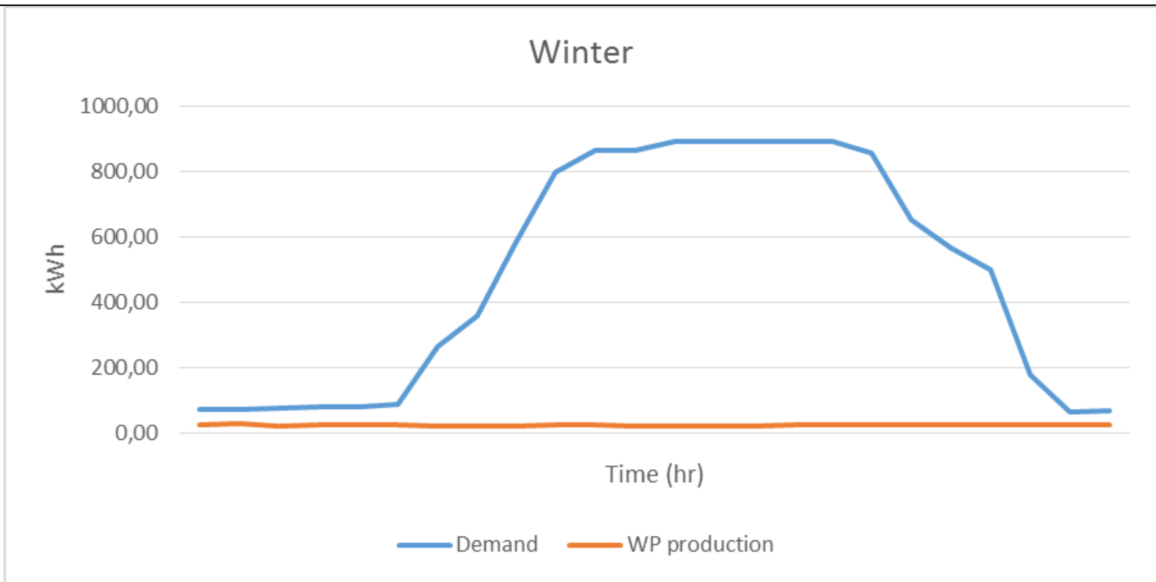
Table 5 shows the results for the hourly energy production for the different seasons:

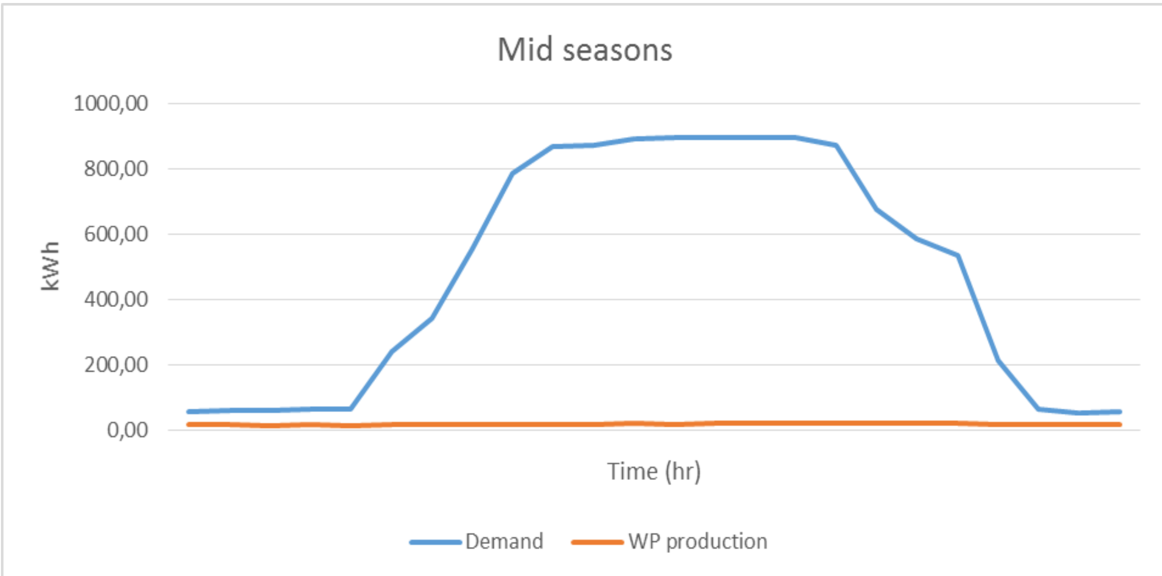
Table 5: Hourly energy production in kWh by season for the wind power installation

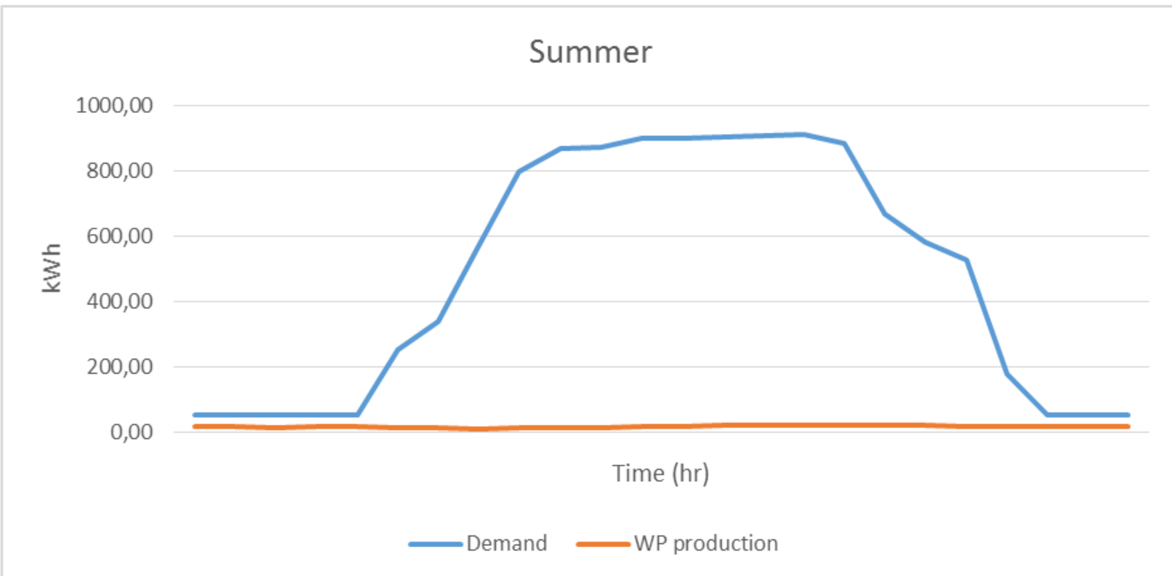
Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	28.0	28.4	22.5	26.4	26.0	25.2	24.2	23.3	24.3	25.1	24.4	22.9
Summer	18.3	17.9	14.3	18.3	16.3	16.6	17.2	17.3	18.2	19.0	20.4	20.8
Mid-season	17.7	16.5	13.6	18.9	17.8	15.4	13.6	12.6	13.2	14.5	16.5	18.6
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	23.3	23.4	23.7	24.8	24.9	25.8	26.3	27.2	27.5	26.2	26.7	27.2
Summer	20.2	21.0	22.6	23.2	23.6	23.8	22.7	21.0	20.0	19.6	18.4	17.6
Mid-season	20.2	21.6	22.8	22.0	21.2	21.5	21.3	20.4	20.0	19.7	19.3	18.4

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons, we obtain the following figures.

With these values we obtain that the load match for winter is 15%, 12% in mid-season and 13% in summer. Grid Interaction is 41% in winter and mid-season and 42% in summer.

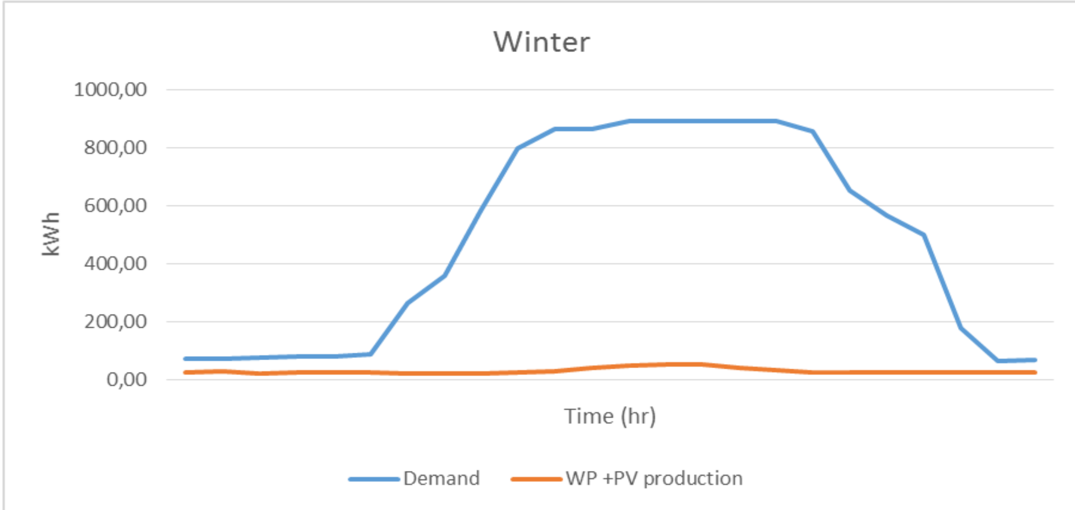

Winter
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
WP production

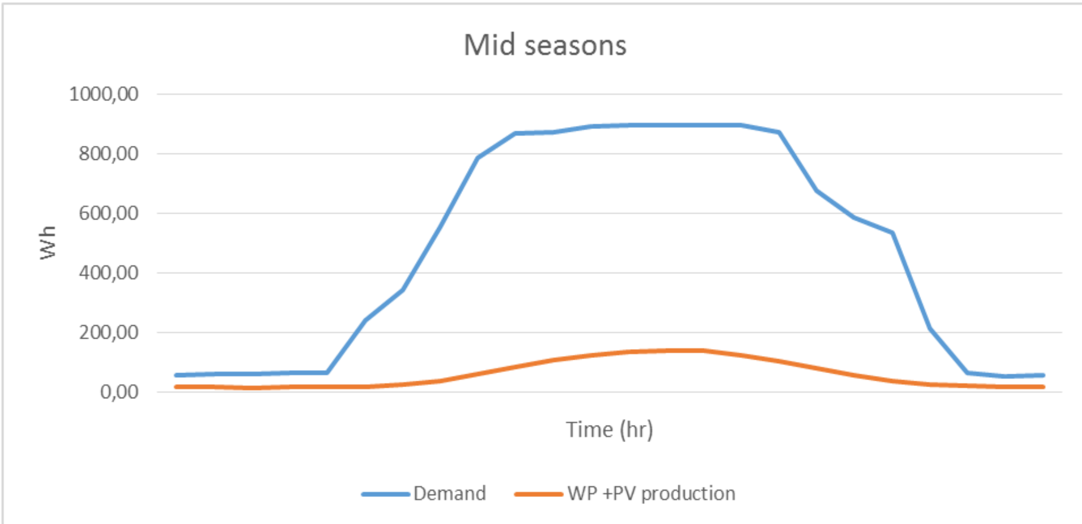

Mid seasons
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
WP production

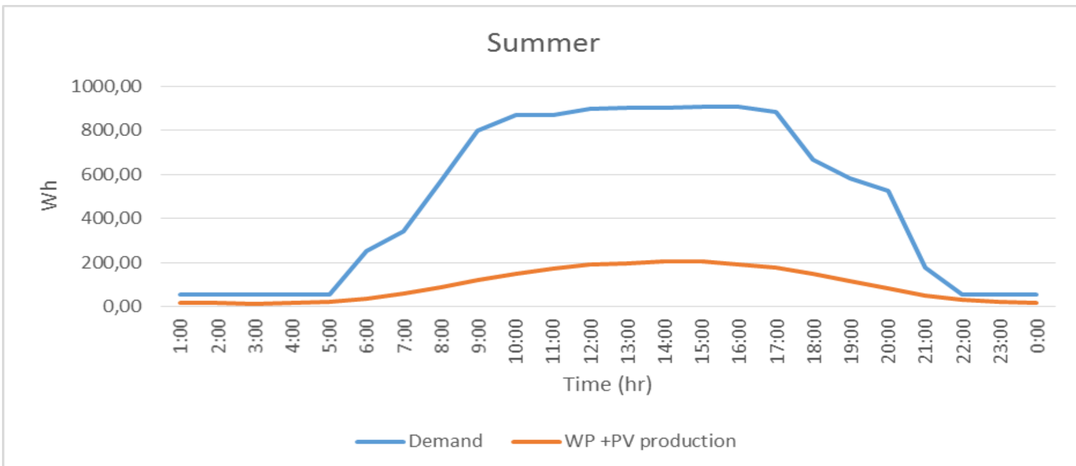

Summer
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
WP production

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time, we obtain the following figures:







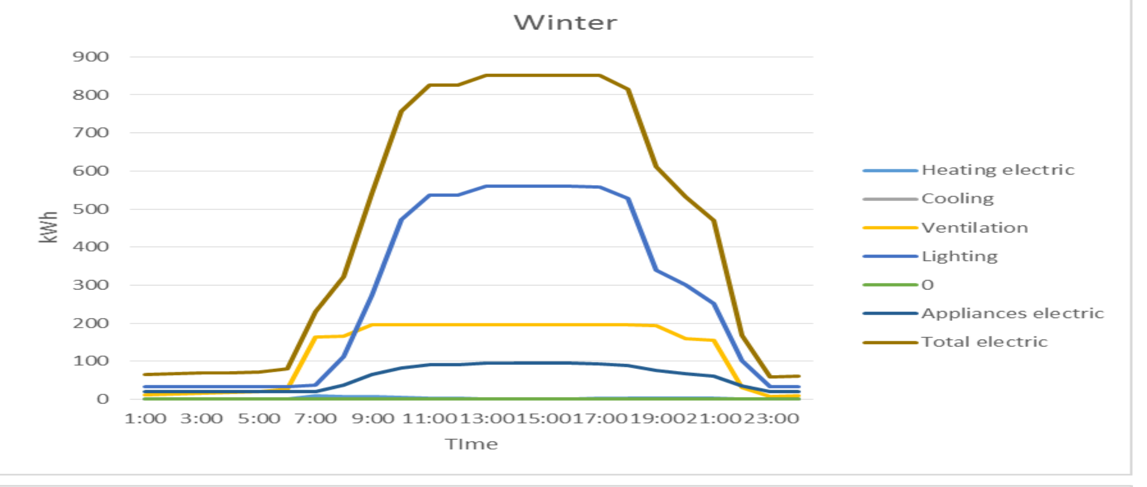
In this case, the load match is increased to 15% in winter, 17% in mid-seasons and 26% in summer, concerning the interaction with the grid the values are 41% in winter and mid-seasons and 42% in summer.

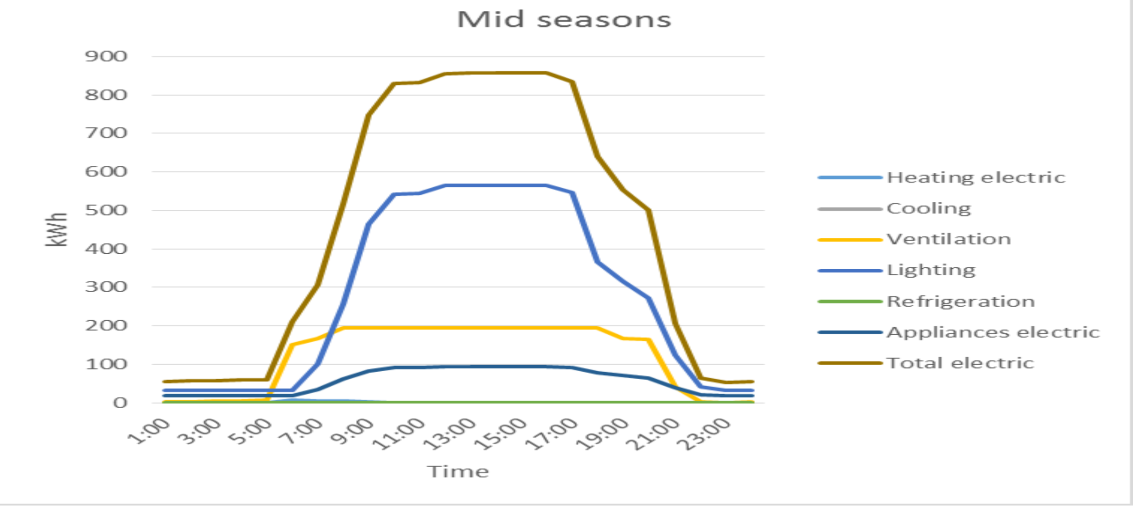
Energy saving

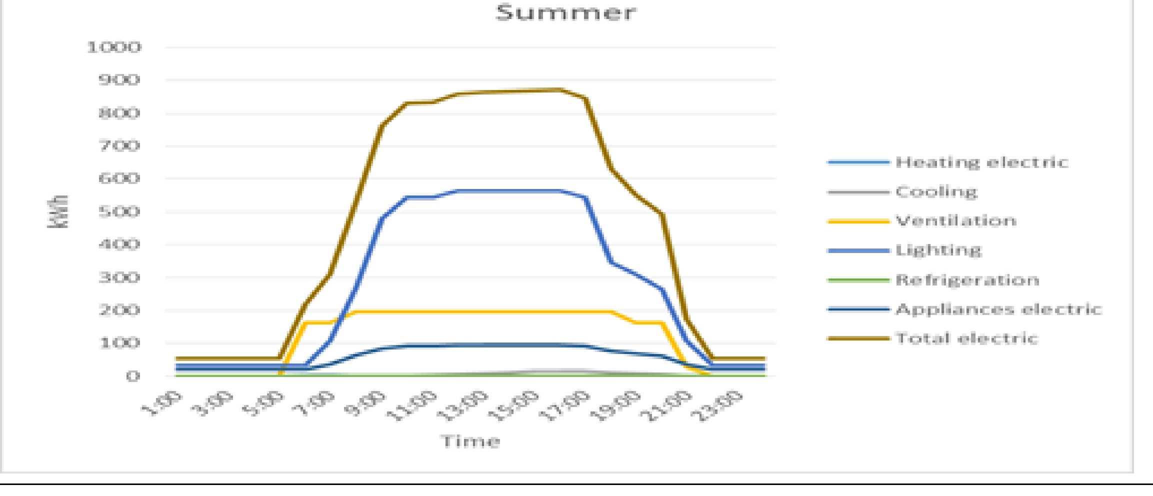
Envelope

Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, taking into account the HVAC systems are electrical ones, because the losses could be decreased.

If improvements in the envelope are included in this building, we obtain the following load profiles:





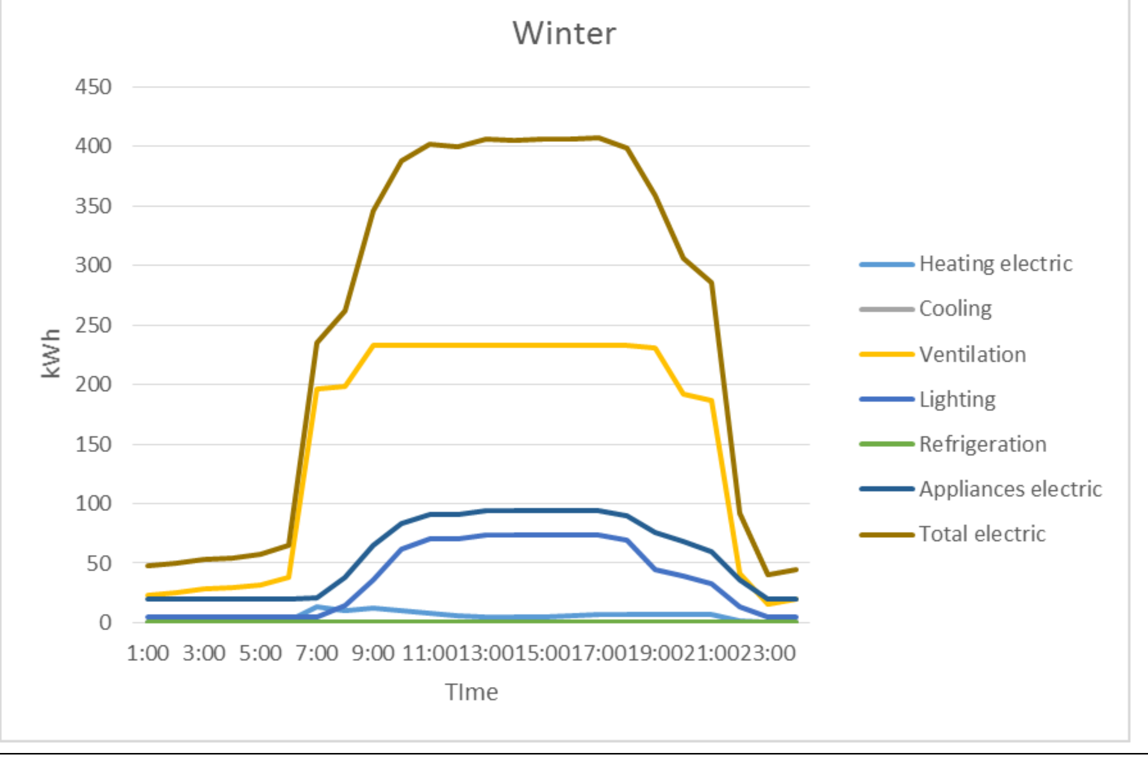


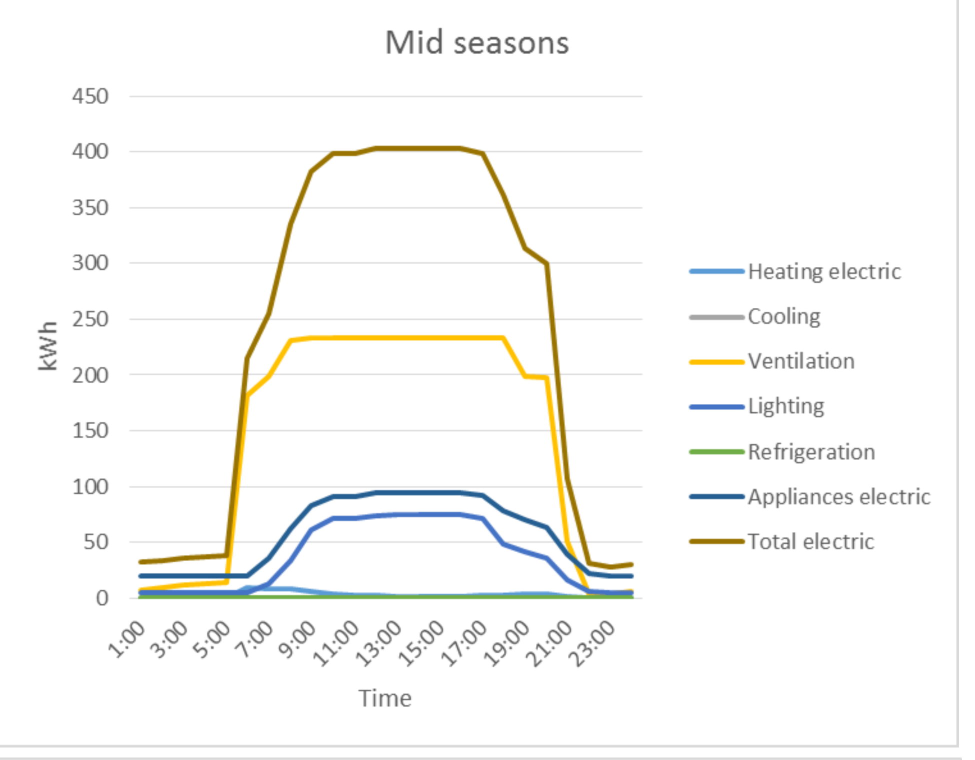
The improvements which have been included are the ones selected through PHPP simulations in the CommON*Energy* report D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems not to have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

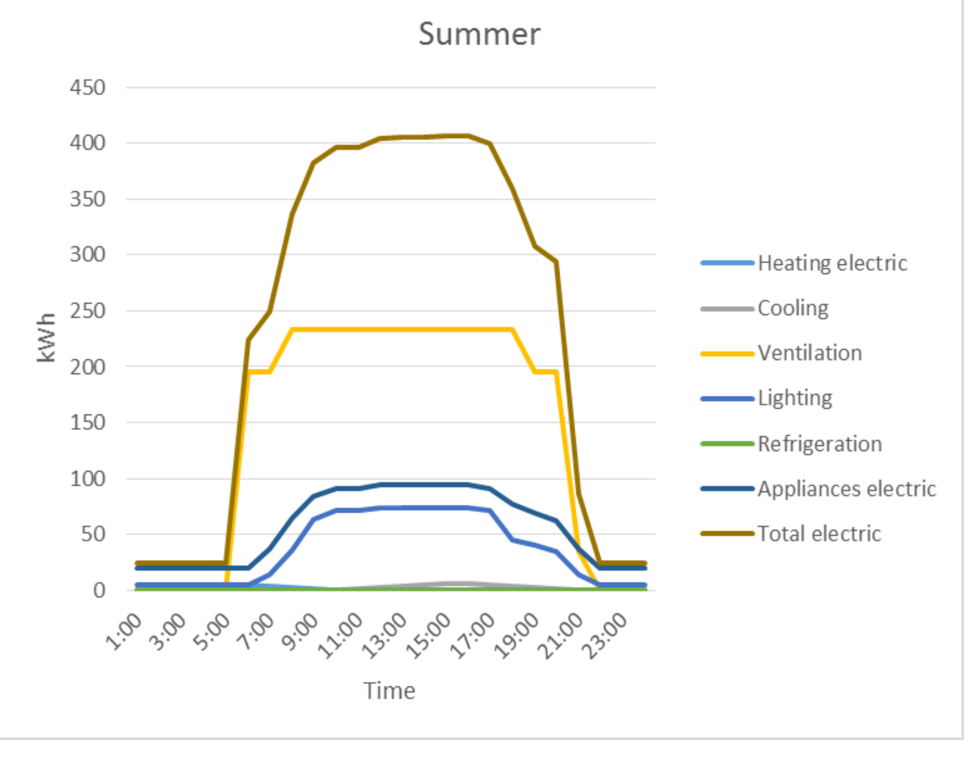
Lighting

Existing luminaries and lighting systems stand in for new equipment more efficient and with higher performance. The installation of electrical ballast and control equipment for the luminosity which allow dimmer regulation so as to adjust the lux level according to the indoor and outdoor conditions, as well as the comfort parameters in order to decrease the consumption when enough daylight.

The improvements in terms of lighting are shown in the following load profiles. These improvements are also based on PHPP simulations developed in the CommON*Energy* report D2.5 taken the most effective solution in terms of energy efficiency (From D2.5: V1, Reduce light density to 3 W/m^2 for common areas (and others) and 4.5 W/m^2 in shops).



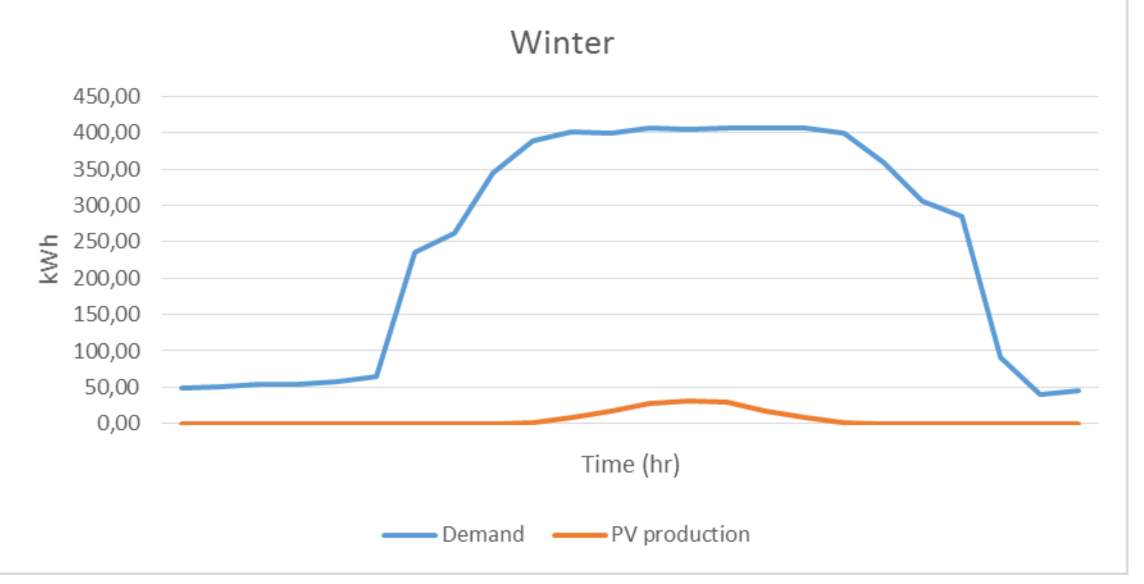


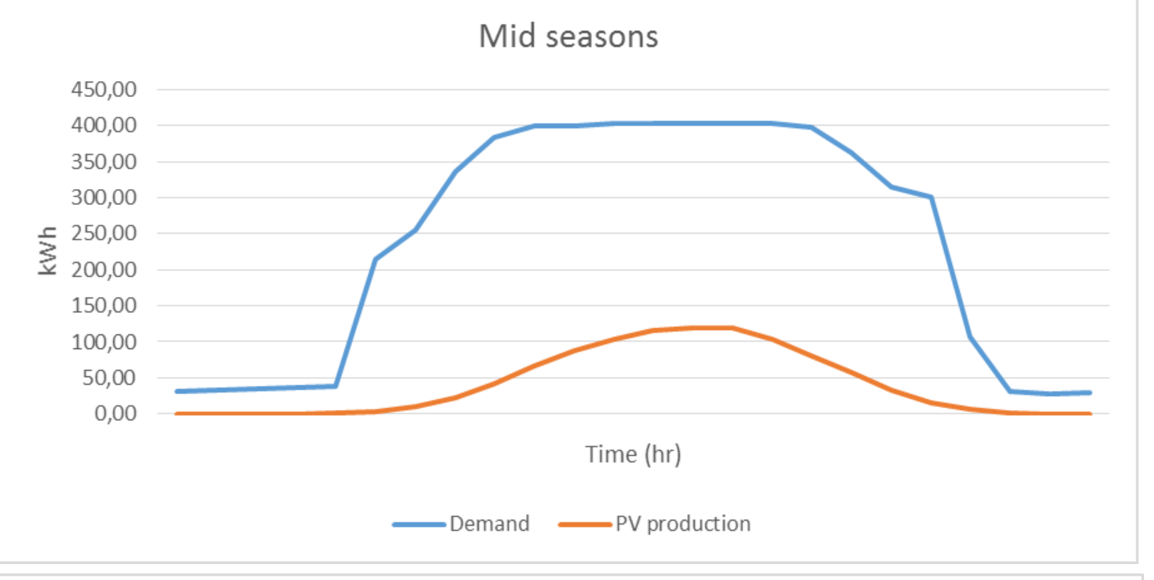


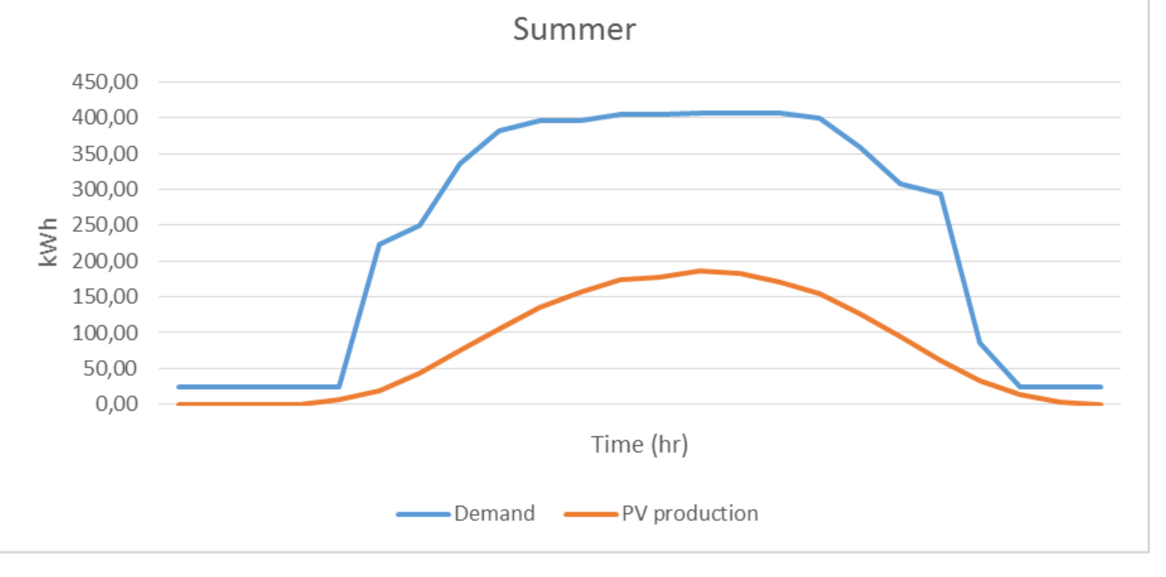
In this case, the grid interaction is reduced to 39% in winter, and 41% in mid-season and 42% in summer with an improvement in terms of lighting.

Lighting + PV

As the lighting solution seems to be a suitable solution, the idea is to combine it with the PV solution proposed before in order to calculate a new load match index.


Winter
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
kWh
Time (hr)
Demand
PV production


Mid seasons
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
kWh
Time (hr)
Demand
PV production


Summer
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
kWh
Time (hr)
Demand
PV production

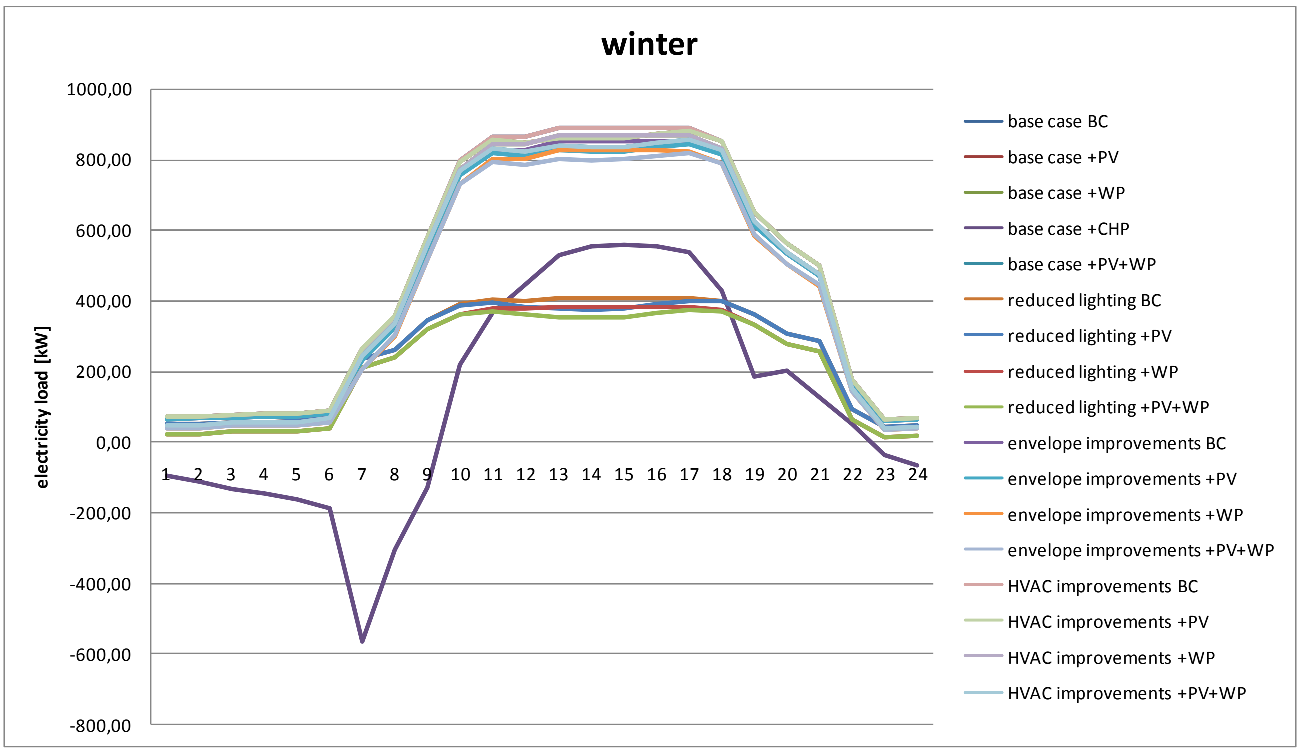
With these values we obtain that the load match during the winter days is approximately 1%, mid-seasons 11% and in the summer days 26% and the grid interaction is 38% for winter, mid-season, and summer respectively.

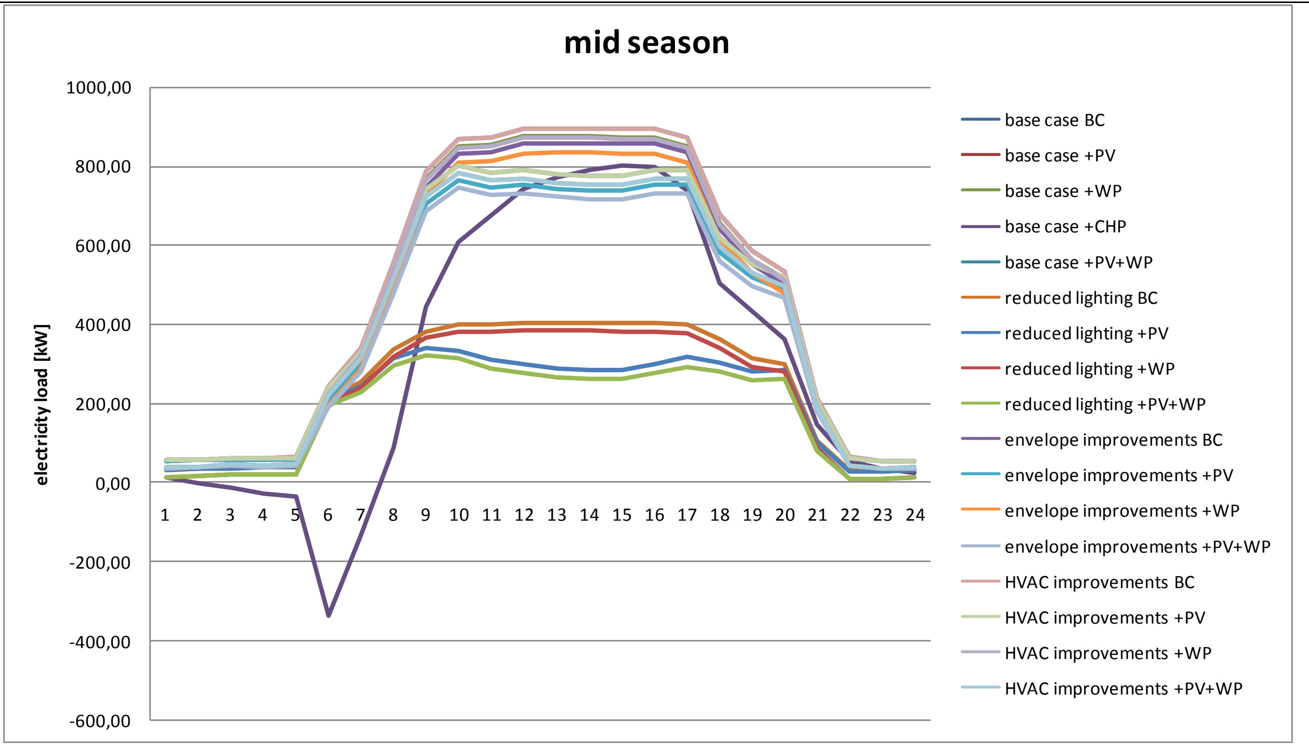
Summary

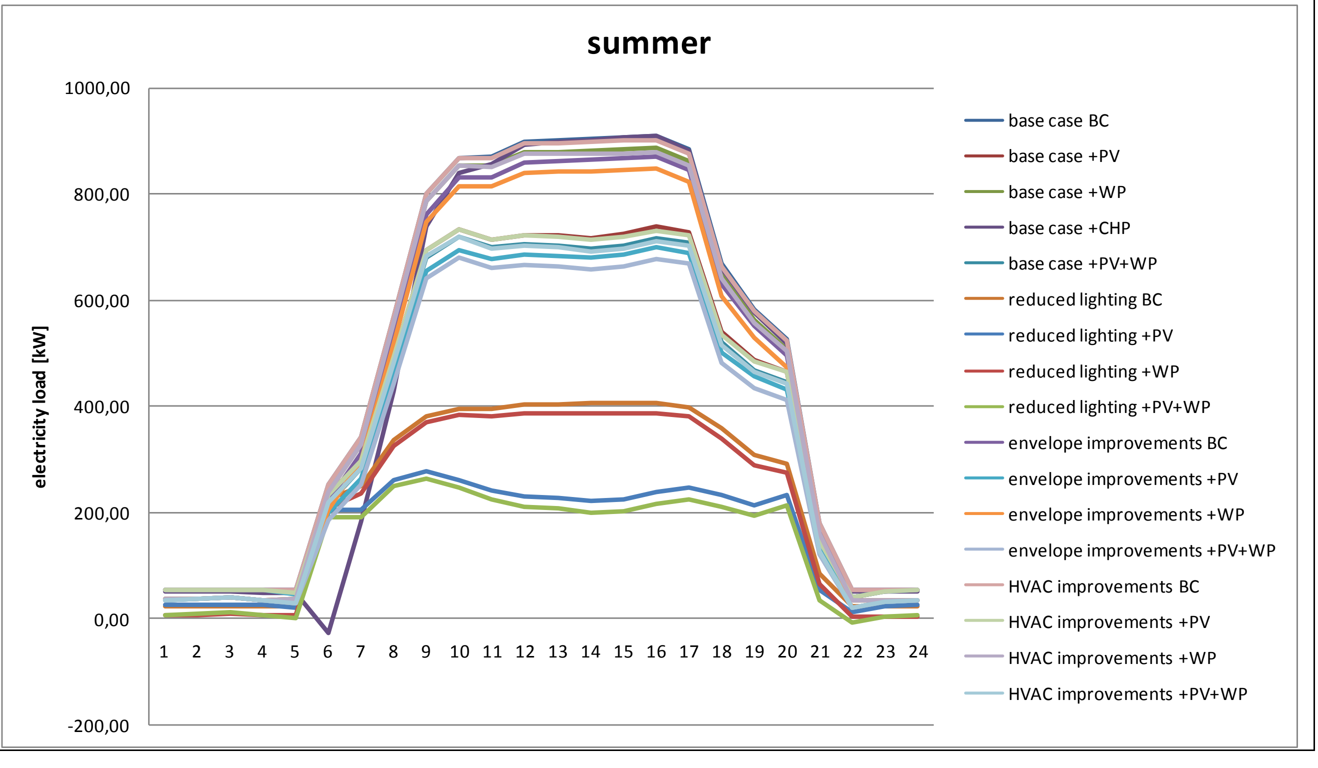
		base case (BC)			Reduced lighting (LG)		Envelope improvements (EN)		HVAC improvements	
		+PV	+WP	+CHP	+PV	+PV+WP	+PV	+PV+WP	+PV	+PV+WP
LMavg	winter	0.7 %	14.7 %	138.5 %	1.5 %	24.5 %	0.7 %	17.0 %	0.7 %	15.3 %
	midseason	5.3 %	12.1 %	9.3 %	11.0 %	46.9 %	12.9 %	25.5 %	12.3 %	24.2 %
	summer	12.6 %	13.4 %	66.2 %	26.0 %	39.9 %	5.5 %	19.2 %	5.3 %	18.8 %
GI	winter	39.3 %	40.9 %	57.6 %	38.2 %	40.9 %	39.6 %	40.9 %	39.3 %	40.6 %
	midseason	40.0 %	41.3 %	45.3 %	37.6 %	39.3 %	40.0 %	40.8 %	40.0 %	40.8 %
	summer	40.5 %	41.6 %	41.7 %	37.9 %	39.8 %	40.3 %	41.4 %	40.6 %	41.3 %

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + LG	BC + EN	BC + HVAC	BC + PV + WP	BC + CHP	BC + LG + PV	BC + LG + PV + WP	BC + EN + PV	BC + EN + PV + WP	BC + HVAC + PV	BC + HVAC + PV + WP
Winter	0.4 %	-1.2 %	0.9 %	-0.3 %	0.0 %	-0.9 %	-17.9 %	1.6 %	-1.2 %	0.1 %	-1.2 %	0.4 %	-0.9 %
Mid – season	0.5 %	-0.7 %	-0.3 %	0.0 %	0.0 %	-0.3 %	-4.8 %	2.9 %	1.2 %	0.5 %	-0.3 %	0.5 %	-0.3 %
Summer	0.2 %	-0.9 %	-0.9 %	0.1 %	-0.1 %	-0.9 %	-1.1 %	2.7 %	0.8 %	0.3 %	-0.7 %	0.1 %	-0.7 %



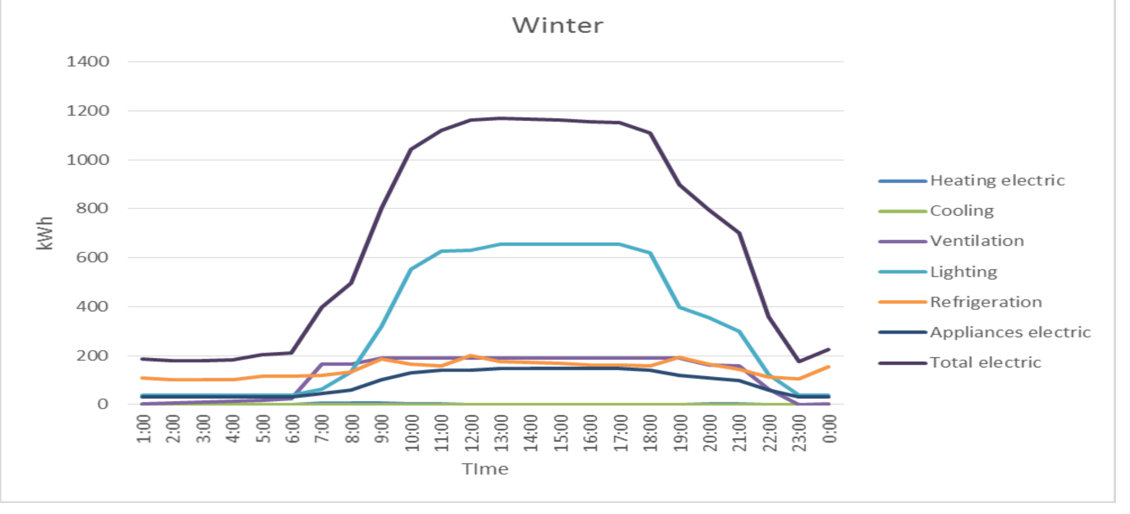

mid season
1000,00
800,00
600,00
400,00
200,00
0,00
-200,00
-400,00
-600,00
electricity load [kW]
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

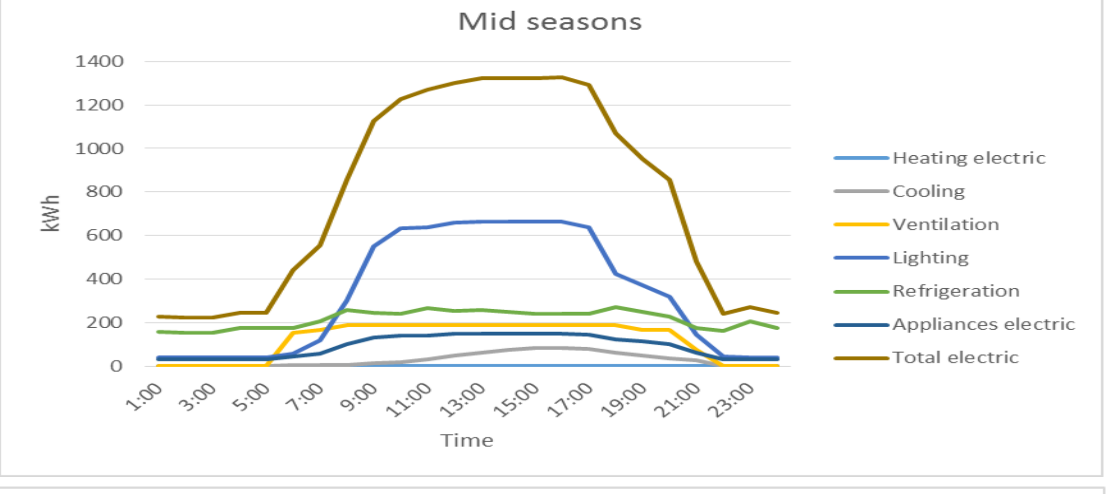

summer
1000,00
800,00
600,00
400,00
200,00
0,00
-200,00
electricity load [kW]
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

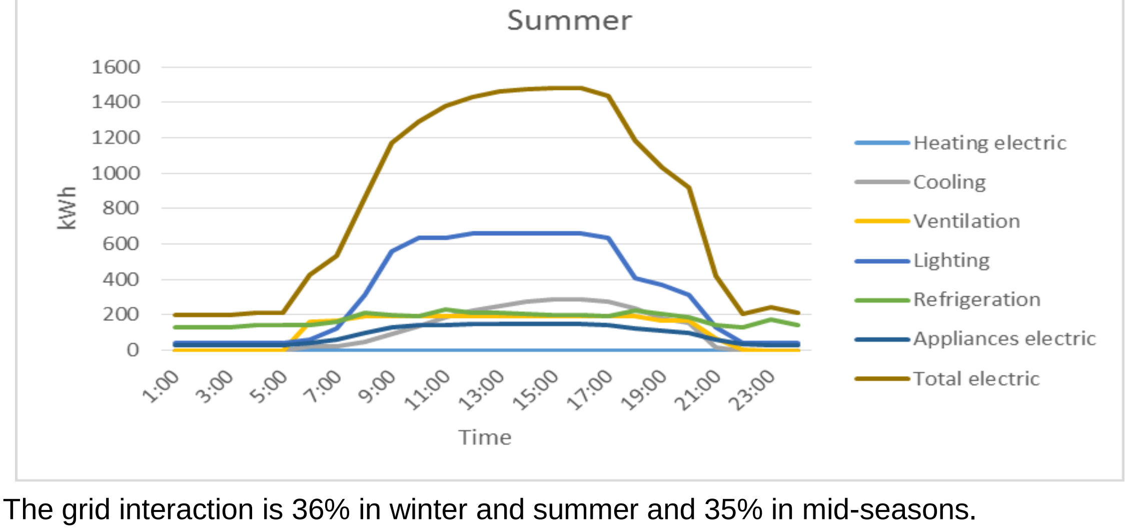
4.3 Reference SC in GENOA based on Ex Officine Guglielmetti

LOAD PROFILES (BASE CASE)

Total Surface: 25,048 m^2 (Supermarket area: 6,352 m^2)

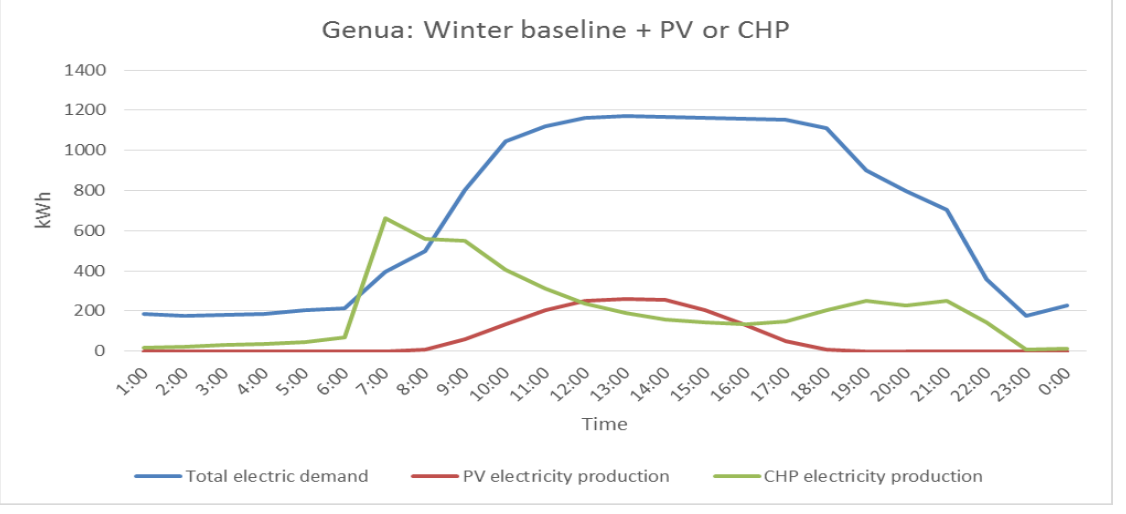


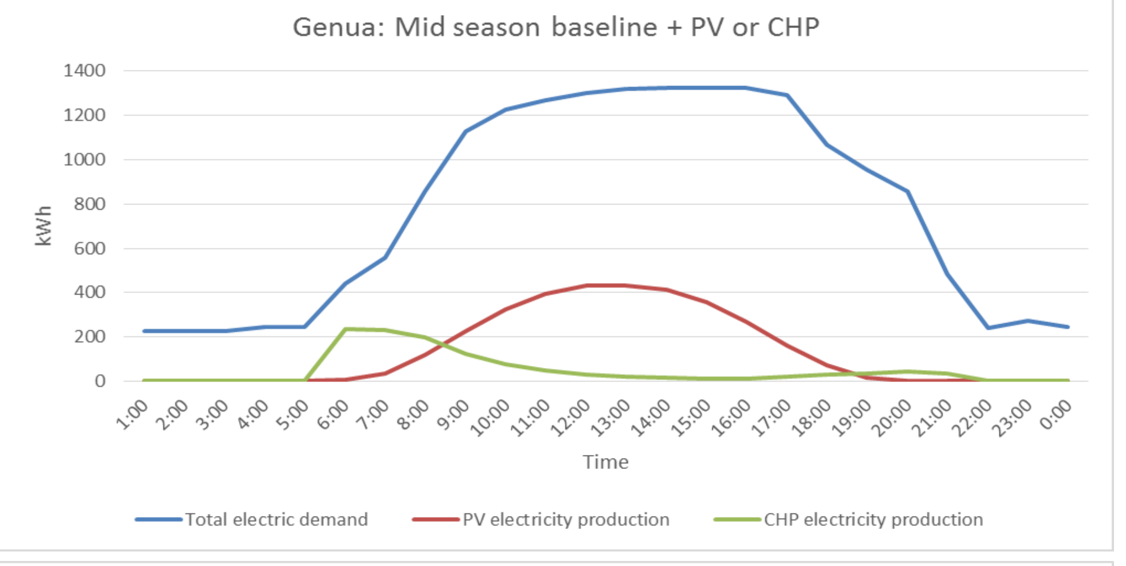


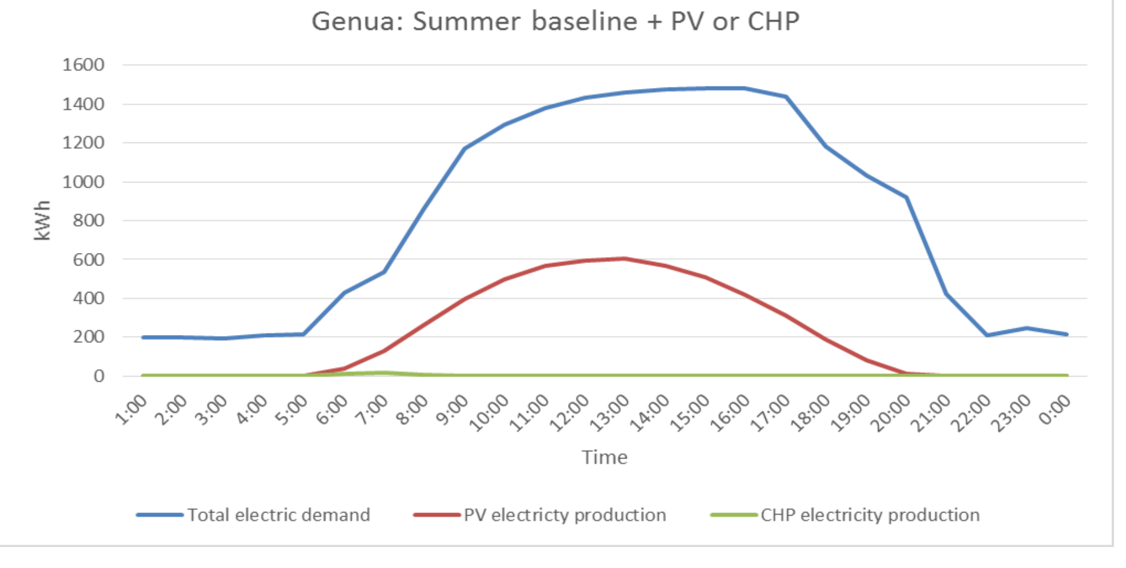


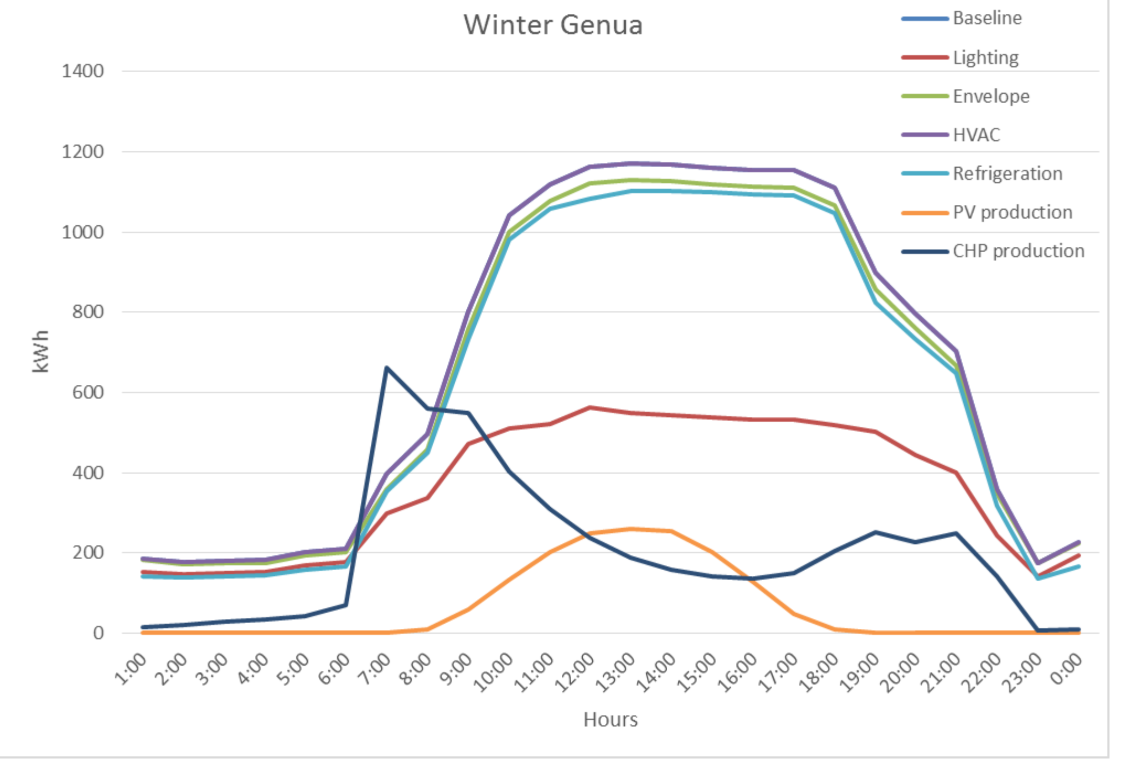
The grid interaction is 36% in winter and summer and 35% in mid-seasons.

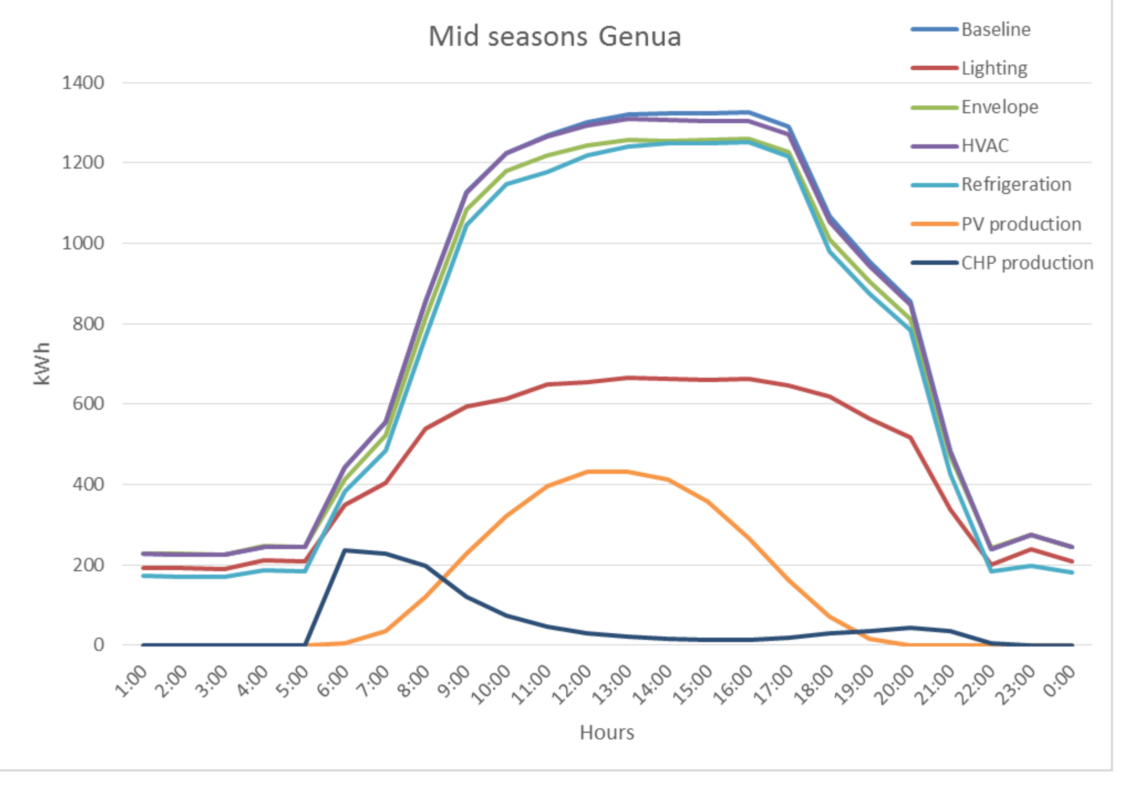
POTENTIALS
• The energy consumption of the Genova demo-case is dominated by lighting, which accounts for 43% of the buildings' predicted consumption. • Following lighting, the consumption is equally distributed between refrigeration and HVAC. • All these services, even lighting, consume more in the summer months. • The electricity demand profiles for each month indicates correlation with seasons as well as opening hours of the building: - Daily: the consumption peaks are reached during the central hours of the days, towards the mid-morning (i.e. 10 AM) during the winter months and in the early afternoon (3 PM) during the summer months. The summer peak is associated with the peak in cooling and refrigeration needs - Monthly: there is a strong correlation with the month of the year. During the summer months, the consumptions are approximately 15% higher mainly due to the elevated electricity cooling need. The months with the highest and lowest consumptions are July and December. • Assessing the present building situation we noticed: - Limited exploitation of daylight and consequent elevated reliance on standard artificial lights; in addition to the increased electrical needs for lights, this also leads to, for the majority of the year, increased thermal needs associated with cooling. Limited recovery of wasted heat and cold due to only partial integration of different systems and thermal fluxes. - Limited exploitation of RES on the roof surface due to parking needs. - Limited integrated management of loads based on setting and control strategies. - Absence of management to optimise loads and on-site RES generation profiles to optimise the self-consumption or take advantage of favourable tariff conditions (e.g., use grid electricity when cheaper, use store electricity when grid electricity is more expensive), also exploiting storage.
SOLUTIONS
On-site RES
Two types of RES can be considered: installation of PV on the roof and the installation of CHP. The figures below show the total electricity demand and production for the 1) installation of PV on 90% of the roof or 2) the CHP installation. For the PV installation the hourly load match (LM) ranges from 6% in winter to 17% in the summer months with higher LM during the central hours of the day (peak at noon). For the CHP, the situation is the opposite with the LM that ranges from 0 in summer to 29% in winter. Additionally, the electricity generated by the CHP exceeds the demand during the winter morning (7 and 8 AM).

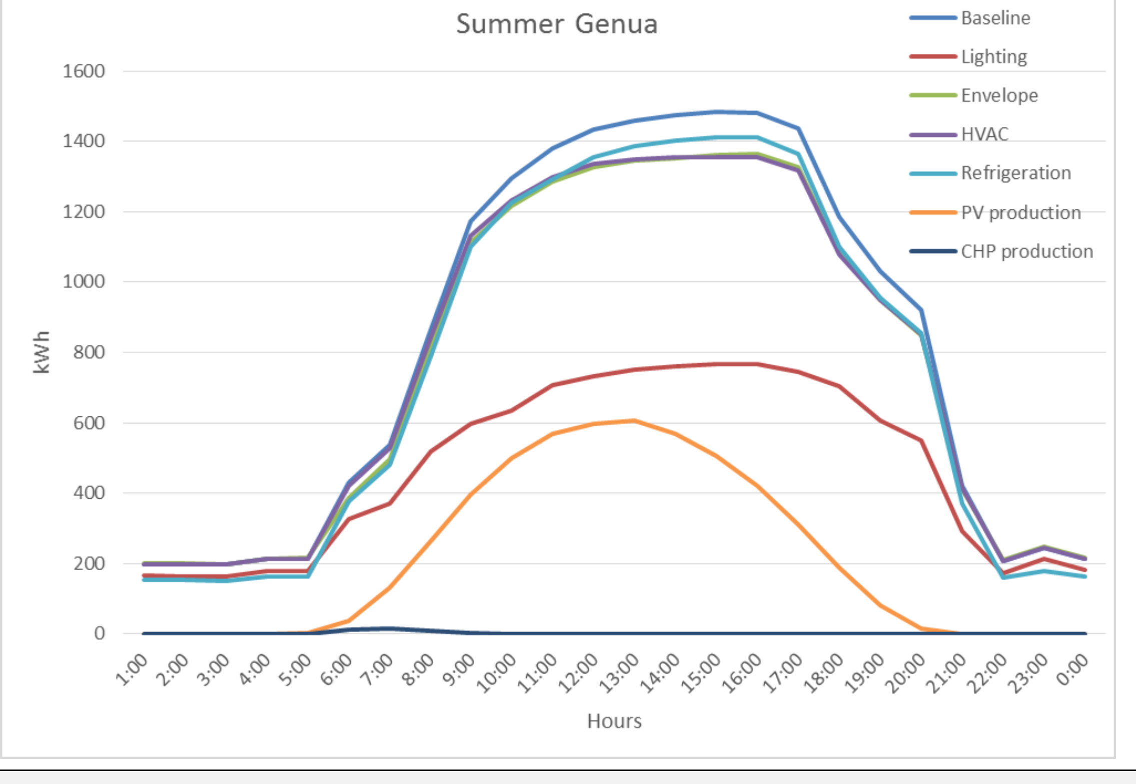

Genua: Winter baseline + PV or CHP
kWh
1400
1200
1000
800
600
400
200
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time
Total electric demand
PV electricity production
CHP electricity production


Genua: Mid season baseline + PV or CHP
kWh
1400
1200
1000
800
600
400
200
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time
Total electric demand
PV electricity production
CHP electricity production


Genua: Summer baseline + PV or CHP
kWh
1600
1400
1200
1000
800
600
400
200
0
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Time
Total electric demand
PV electricty production
CHP electricity production

Energy saving solutions
In order to improve self-consumption, several energy efficiency measures were considered. They focus on envelope, lighting, HVAC and refrigeration. The figures below show the hourly electric demand profile for the different seasons. The greatest reduction is achieved with the reduction of lighting, leading to a consumption of 46% lower than the base case in winter, 43% in mid-season and 42% in summer. If these energy efficiency measures are coupled with RES solutions (e.g., PV or CHP), the load match (LM) as calculated for the base case with RES is modified. Specifically, while for most solutions the impact is minimal, for lighting (the most impacting solution) it is quite noticeable and LM becomes 12% in winter and 32% in summer for the OV installation. For the installation of CHP for the base case the LM is opposite, with the greatest value for the winter when the CHP is operated. The LM ranges from 0% in summer to 29% in winter. Additionally, it is worth noticing that in the early morning in winter there is an excess production following the heating demand (and the CHP operation). This excess electricity could be injected into the grid, stored in a battery for later use, given to costumer to charge their vehicles .convert into hydrogen. The decision will depend mainly on the tariff available and the objective of the shopping centre (e.g., their interest for an marketing action). 


Mid seasons Genua
Baseline
Lighting
Envelope
HVAC
Refrigeration
PV production
CHP production
kWh
0
200
400
600
800
1000
1200
1400
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Hours

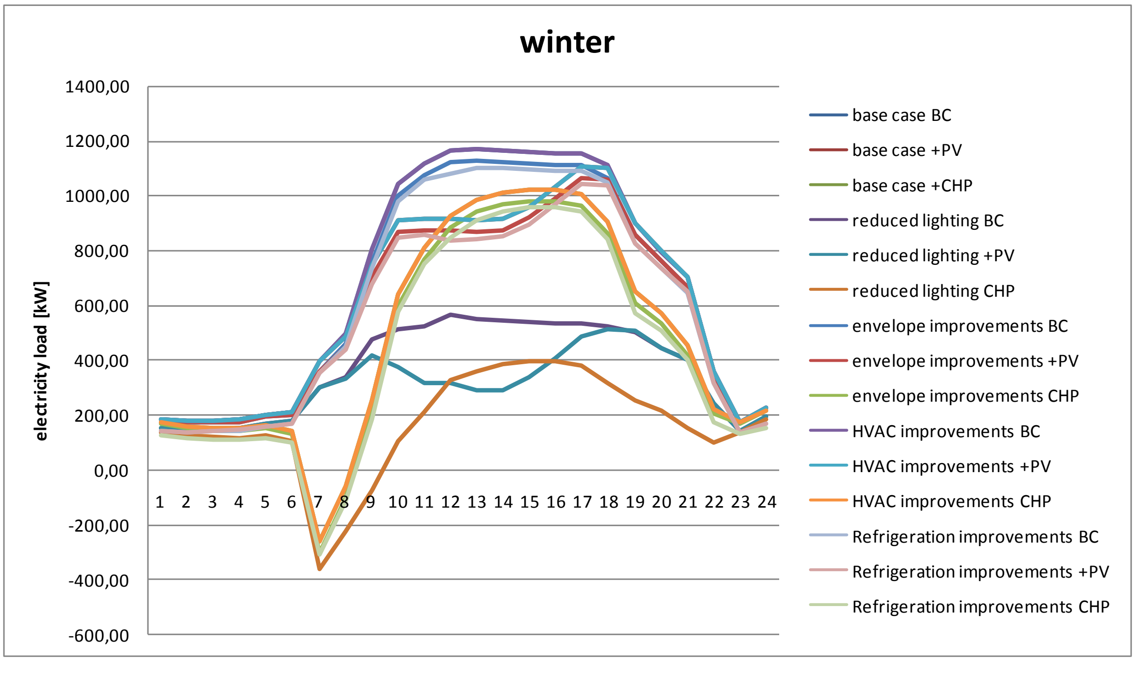

Summer Genua
Baseline
Lighting
Envelope
HVAC
Refrigeration
PV production
CHP production
kWh
0
200
400
600
800
1000
1200
1400
1600
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Hours

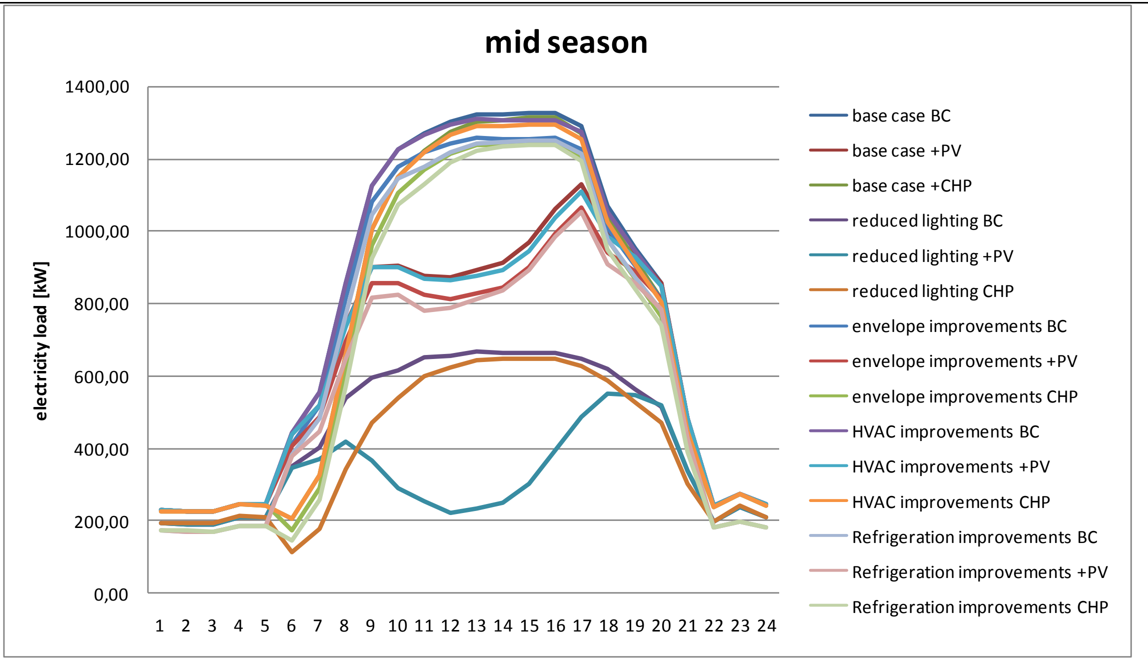
Summary

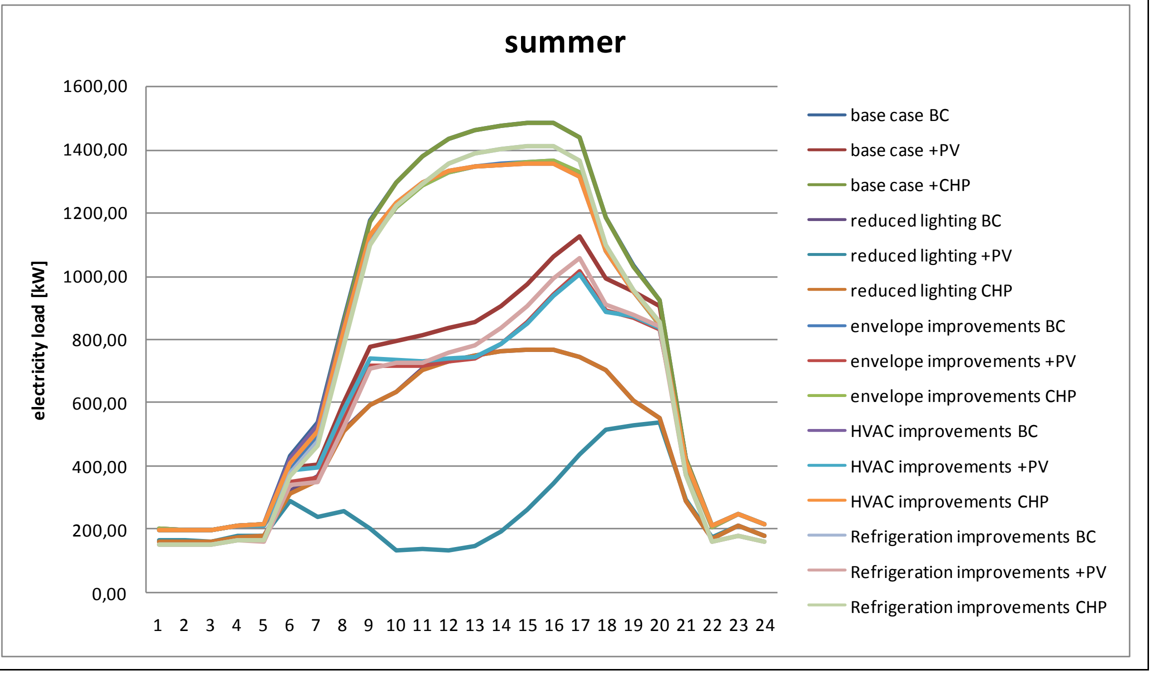
		Base case (BC)		Reduce lighting (LG)		Envelope improvement (EN)		HVAC improvement		Refrigeration improvement (RF)	
		+PV	+CHP	+PV	+CHP	+PV	+CHP	+PV	+CHP	+PV	+CHP
LMavg	winter	5,8 %	28,7 %	12,2 %	42,7 %	6,0 %	29,6 %	5,8 %	28,7 %	6,2 %	31,3 %
	midseason	11,0 %	7,0 %	21,3 %	10,5 %	11,5 %	7,4 %	11,1 %	7,0 %	11,8 %	7,9 %
	summer	17,0 %	0,3 %	31,9 %	0,4 %	18,4 %	0,3 %	18,2 %	0,3 %	18,2 %	0,3 %
GI	winter	32,2 %	39,4 %	23,9 %	47,2 %	31,9 %	39,9 %	32,2 %	39,4 %	33,1 %	41,0 %
	midseason	29,4 %	35,5 %	21,6 %	30,8 %	28,7 %	35,4 %	29,4 %	35,6 %	30,6 %	36,9 %
	summer	30,2 %	36,4 %	23,8 %	32,4 %	28,9 %	36,0 %	29,1 %	36,3 %	31,1 %	37,4 %

Grid Interaction improvement

Season	BC + PV	BC + CHP	BC + LG	BC + EN	BC + HVAC	BC + RF	BC + LG + PV	BC + LG + CHP	BC + EN + PV	BC + EN + CHP	BC + HVAC + PV	BC + HVAC + CHP	BC + RF + PV	BC + RF + CHP
Winter	3.9 %	-3.3 %	6.1 %	0.0 %	0.0 %	-1.2 %	12.1 %	-11.1 %	4.1 %	-3.9 %	3.9 %	-3.3 %	3.0 %	-4.9 %
Mid – season	5.7 %	-0.4 %	5.3 %	0.2 %	0.0 %	-1.3 %	13.5 %	4.3 %	6.4 %	-0.3 %	5.7 %	-0.5 %	4.5 %	-1.8 %
Summer	6.2 %	0.0 %	4.1 %	0.4 %	0.1 %	-1.0 %	12.5 %	4.0 %	7.5 %	0.3 %	7.3 %	0.1 %	5.2 %	-1.0 %



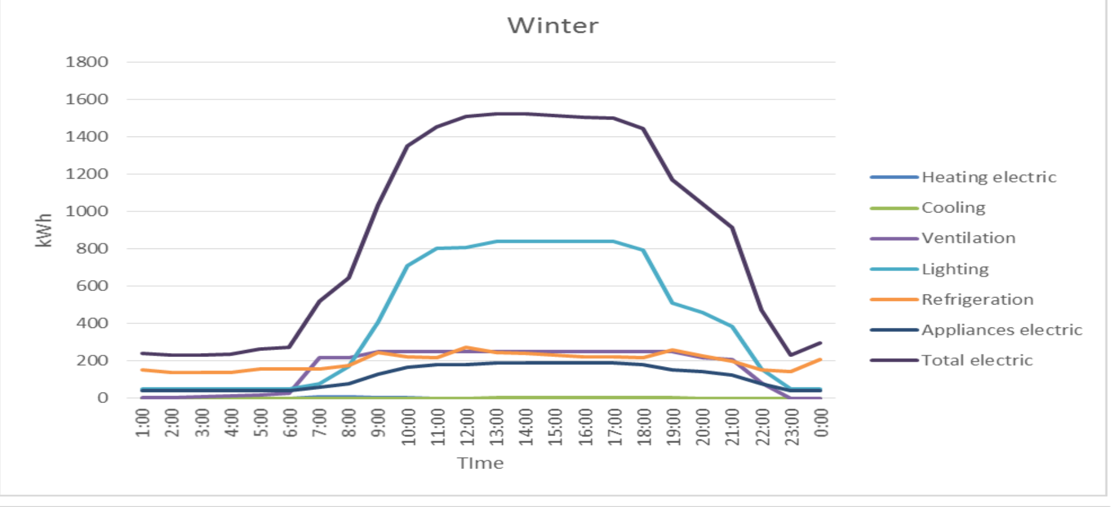

mid season
electricity load [kW]
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
reduced lighting CHP
envelope improvements BC
envelope improvements +PV
envelope improvements CHP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements CHP
Refrigeration improvements BC
Refrigeration improvements +PV
Refrigeration improvements CHP

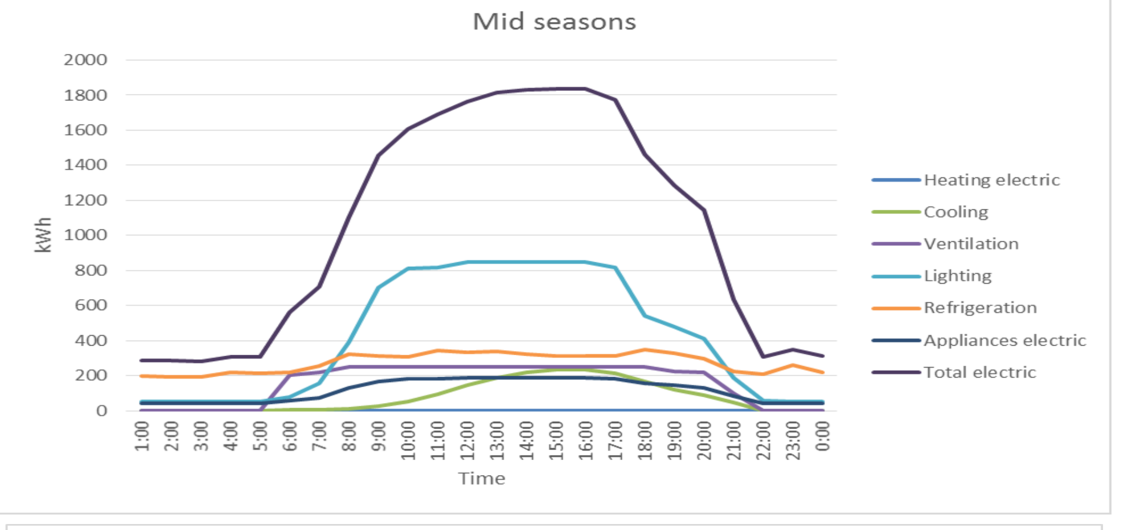

summer
electricity load [kW]
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
reduced lighting CHP
envelope improvements BC
envelope improvements +PV
envelope improvements CHP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements CHP
Refrigeration improvements BC
Refrigeration improvements +PV
Refrigeration improvements CHP

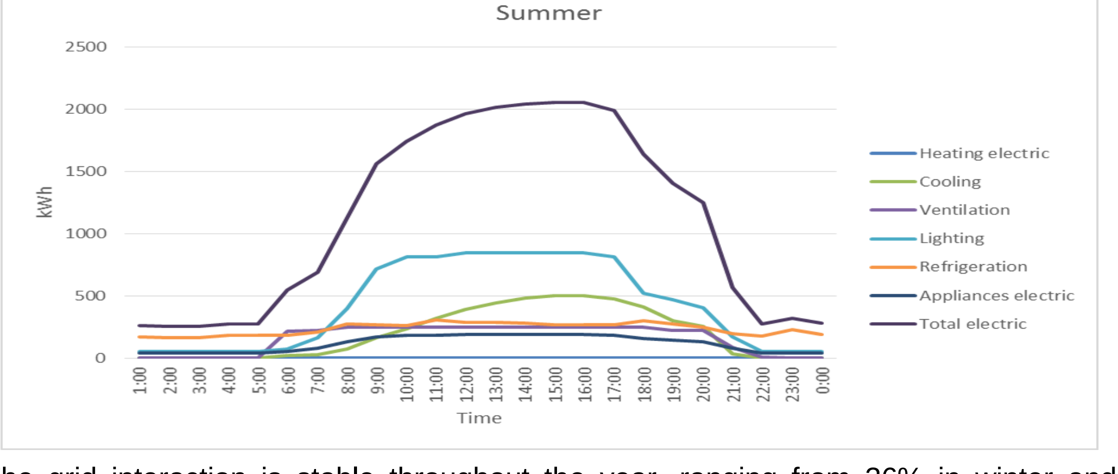
4.4 Reference SC in CATANIA based on KATANE

LOAD PROFILES (BASE CASE)

Total Surface: 32,089 m^2 (Supermarket area: 8,106 m^2)







The grid interaction is stable throughout the year, ranging from 36% in winter and summer and 35% in mid-seasons.

<table>
<tr><th>POTENTIALS</th></tr>
<tr><td>

The energy consumption of the Catania demo-case is dominated by lighting that accounts for 41% of the buildings predicted consumption.
Following lighting, the consumption is equally distributed between refrigeration and HVAC.
All these services, even lighting, have greater consumptions in the summer months.
The electricity demand profiles for each month indicates correlation with season as well as opening hours of the building.

Daily: the consumption peaks are reached during the central hours of the days, toward the early afternoon (i.e., 2 PM) during the winter months and in the later afternoon (4 PM) during the summer months. The summer peak is associated with the peak in cooling and refrigeration needs.
Monthly: there is a strong correlation with the month of the year. During the summer months the consumptions are approximately 20% higher mainly due to the elevated electricity cooling need. The months with the highest and lowest consumptions are July and December.

Assessing the present building situation we noticed:

Envelope: structural elements could be improved including wall and window transmittance, exploitation of daylight, use of natural/hybrid ventilation
Active:

BMS to control and manage conditions (e.g., setting, presence, lux level) and energy fluxes (including improved efficiencies in the heat recovery system)
Improved refrigeration systems
Efficient artificial lighting systems

Load management: management of loads and generation matching (also with batteries) to increase self-consumption and take advantage of favourable tariffs
RES: limited exploitation of on-site RES that should be considered (e.g., PV, solar thermal collectors or min-wind turbine).

</td></tr>
<tr><th>SOLUTIONS</th></tr>
<tr><th>On-site RES</th></tr>
<tr><td>Two types of RES can be considered: installation of PV on the roof and the installation of CHP. The figures bellow show the total electricity demand and production for the 1) installation of PV on 90% of the roof or 2) the CHP installation. For the PV installation the hourly load match (LM) ranges from 10% in winter to 20% in the summer months with higher LM during the central hours of the day (peak at noon). For the CHP, the situation is the opposite with the LM that ranges from 0 in summer to 21% in winter. Additionally, the electricity generated by the CHP exceeds the demand during the winter morning (7 and 8 AM).</td></tr>
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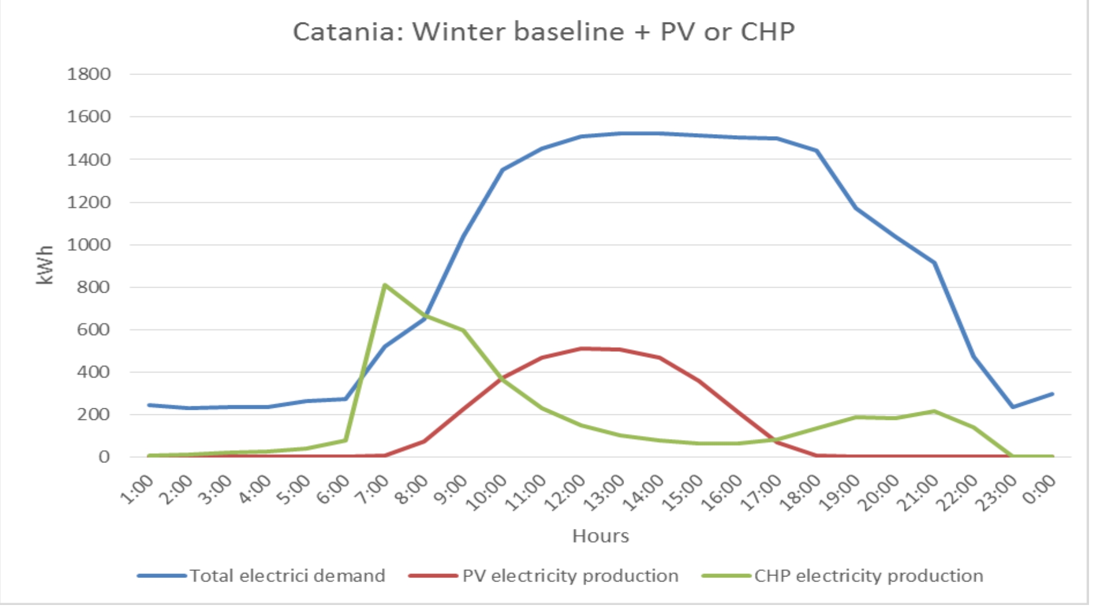
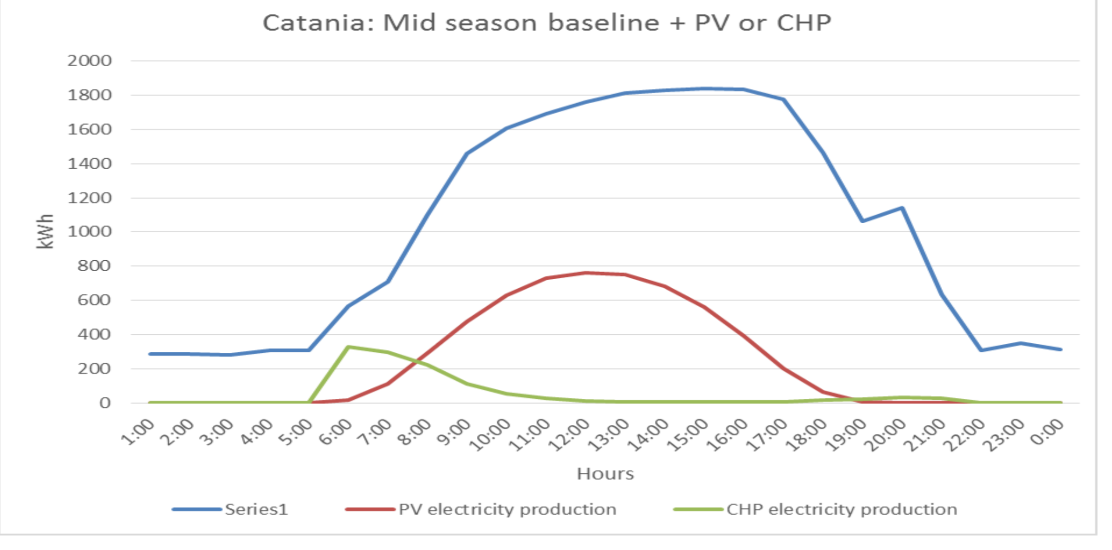
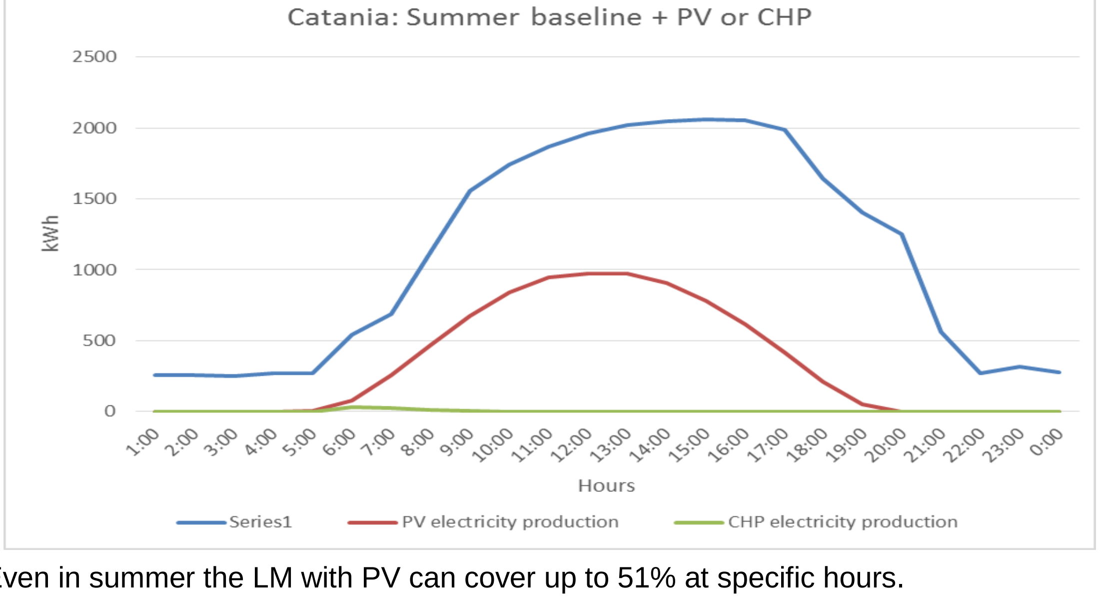
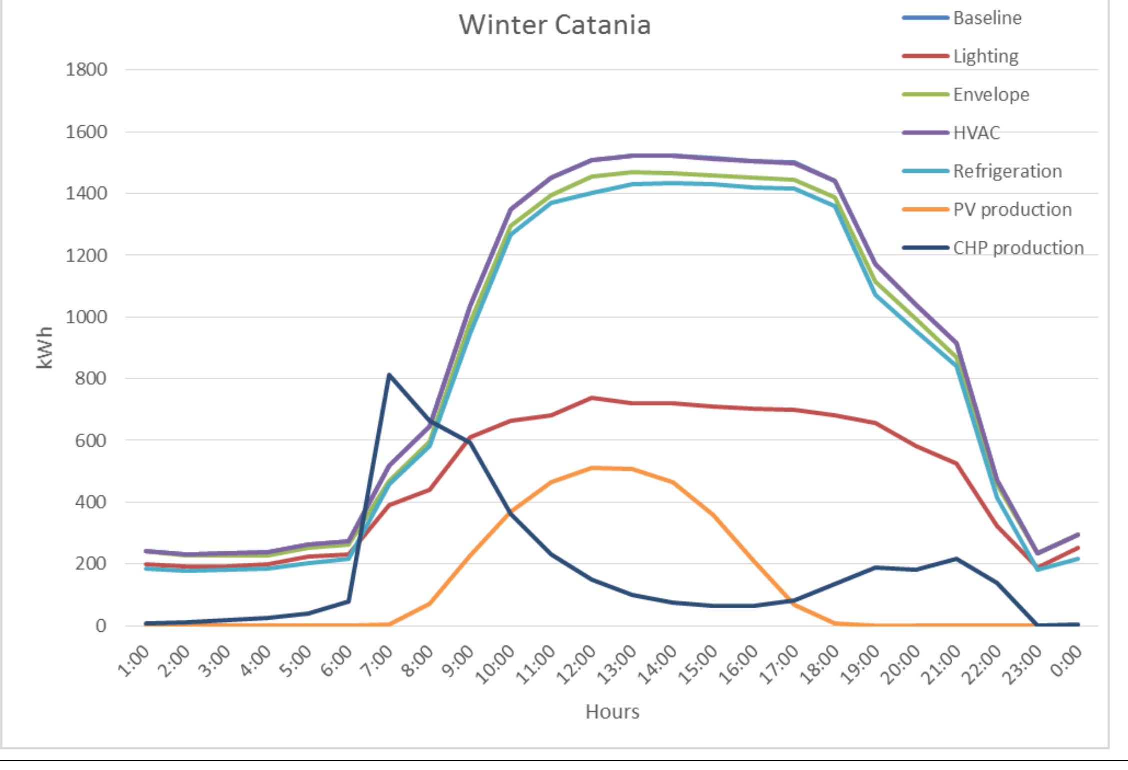


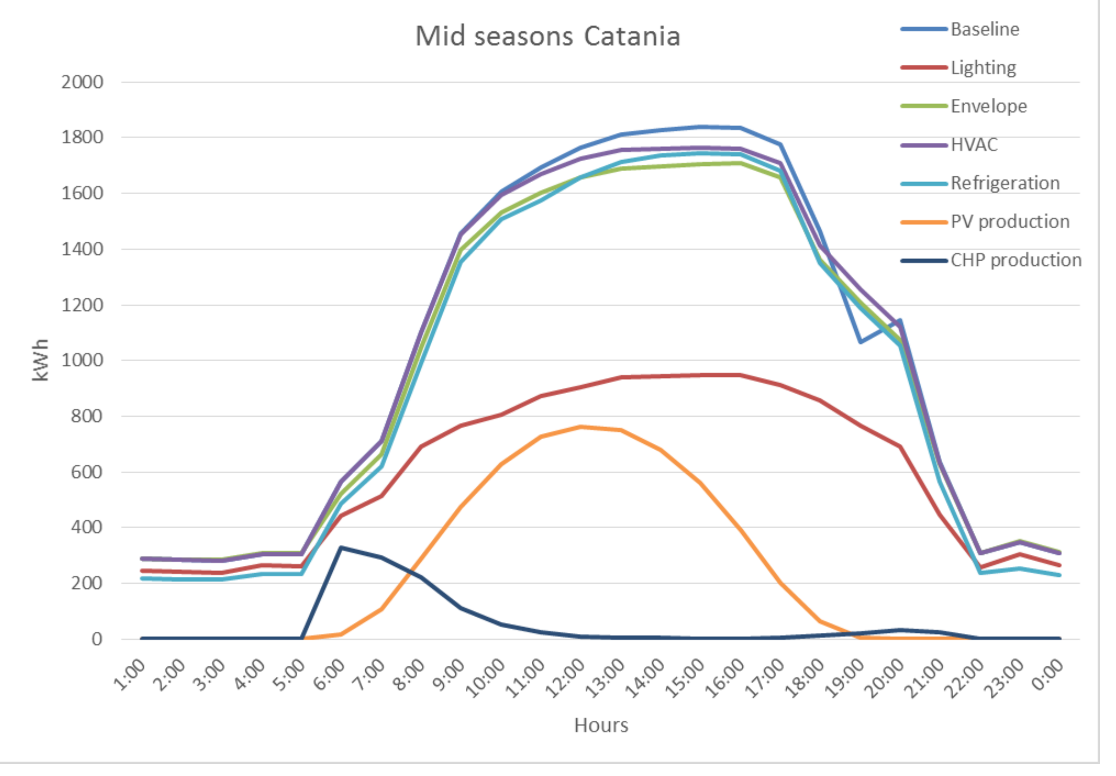


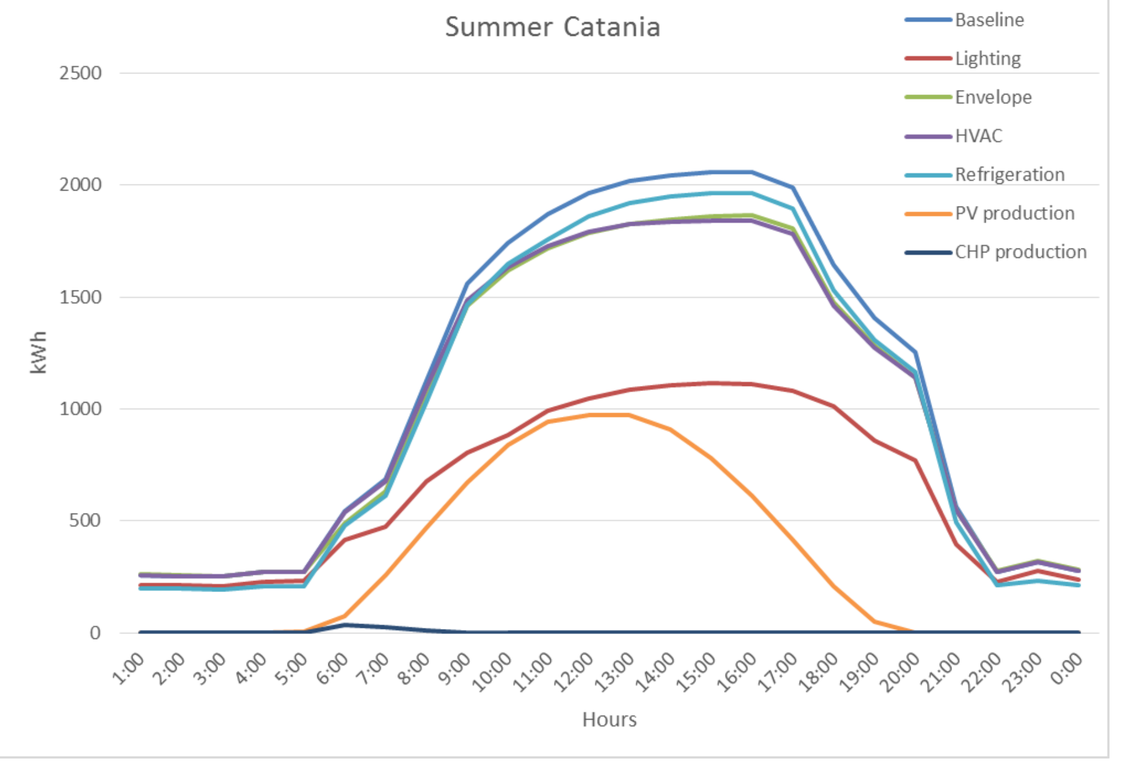


Even in summer the LM with PV can cover up to 51% at specific hours.

Energy saving solutions
The figures below show the hourly electric demand profiles for the different energy efficiency measures and the electricity production for PV and CHP for the different seasons. As can be seen the greatest reduction is achieved with the lighting scenario, leading to a consumption 45% lower than the base case in winter, 41% in mid-season and summer. If these energy efficiency measures are coupled with RES solutions (e.g., PV or CHP), the load match (LM) as calculated for the base case with RES increases. Specifically, while for most energy efficiency solutions the impact is minimal, for lighting it is quite noticeable and LM becomes 20% in winter and 36% in summer for the PV installation (compared to 10% and 20% for the baseline). For the installation of CHP to the base case the LM has the opposite behaviour, with the greatest value for the winter when the CHP is operated. The LM ranges from 0% in summer to 21% in winter. During the winter months we observed an overproduction during the early morning, accounting for approximately 312 kWh. This excess electricity could be injected into the grid, stored in a battery for later use, given to costumers to charge their vehicles or converted into hydrogen for transportation. The decision will depend mainly on the tariff available and the objective of the shopping centre (e.g., their interest for a marketing action).




Mid seasons Catania
Baseline
Lighting
Envelope
HVAC
Refrigeration
PV production
CHP production
kWh
0
200
400
600
800
1000
1200
1400
1600
1800
2000
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Hours


Summer Catania
Baseline
Lighting
Envelope
HVAC
Refrigeration
PV production
CHP production
kWh
0
500
1000
1500
2000
2500
1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Hours

Interesting possibilities associated with storage exists:

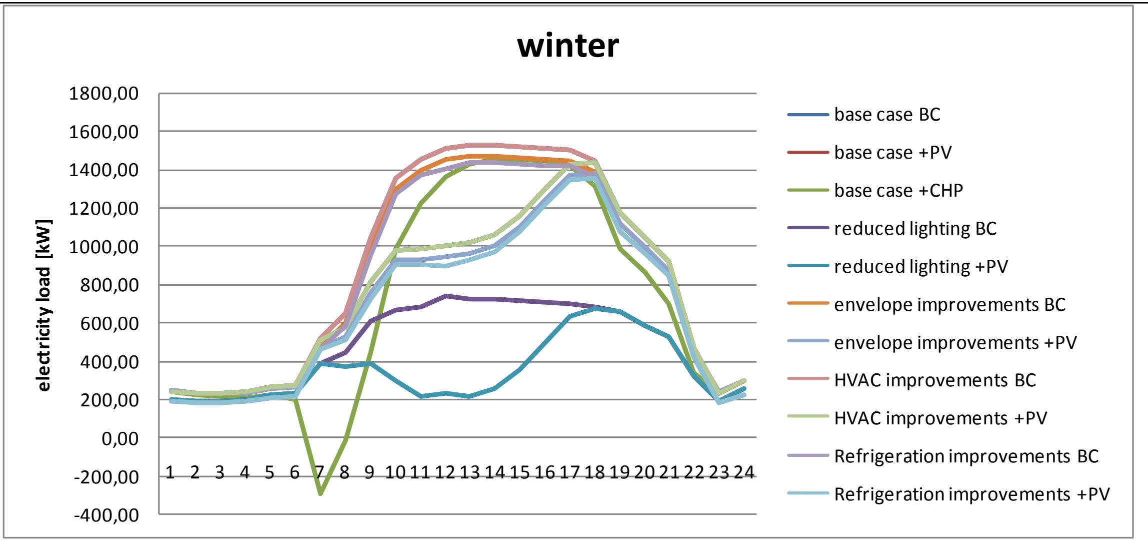
- Power: The UPS should be coupled with the on-site RES. This system could also be enlarged to serve an additional function as primary power: take advantage of time-varying prices or improve self-consumption by storing energy during period of low-price/great production and use it during period of scarcity.
- Transport: electricity produced could be used to refuel shopping mall MHV or costumer's cars, therefore partially reducing the carbon emissions since this vehicle will operate with carbon neutral electricity. Providing free charging station for costumer will likely increase the shopping mall consumption but will provide an appreciated service for the citizen
- Heat: RES-electricity could be converted to hydrogen for heat generation. The heat could be generated via a catalytic boiler or, with greater impact, a CHP. However, considering the yearly electricity load and production profiles and the systemic scarcity of electricity in Sicily carrier conversation could be carefully considered.

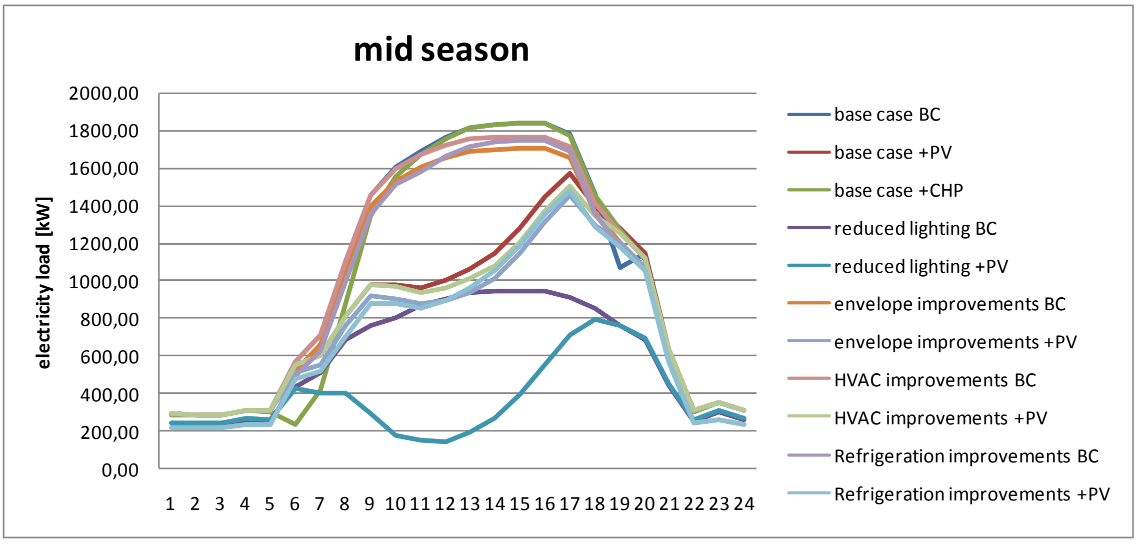
Summary

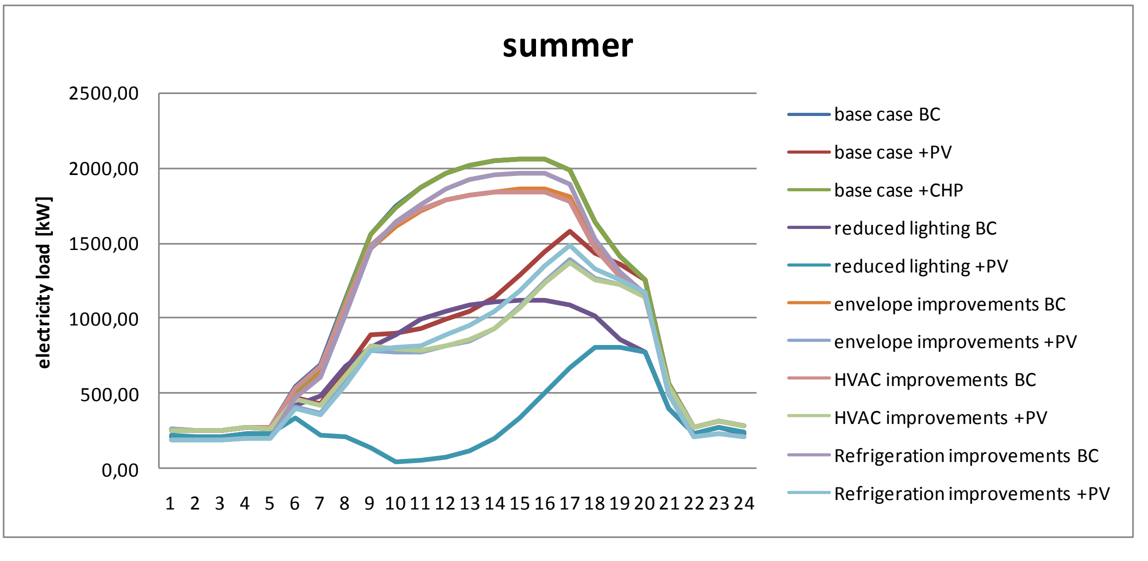
		Base case (BC)		Reduce lighting (LG)	Envelope improvement (EN)	HVAC improvement	Refrigeration improvement (RF)
		+PV	+CHP	+PV	+PV	+PV	+PV
LMavg	Winter	9,7 %	20,9 %	19,7 %	10,2 %	9,7 %	10,4 %
	Mid-season	14,5 %	6,0 %	27,4 %	15,4 %	14,8 %	15,6 %
	Summer	20,2 %	0,5 %	36,4 %	22,0 %	21,8 %	21,5 %
GI	Winter	29,7 %	39,3 %	24,2 %	29,4 %	29,7 %	30,5 %
	Mid-season	27,7 %	35,9 %	24,8 %	26,7 %	27,4 %	28,7 %
	Summer	29,4 %	36,6 %	28,6 %	28,0 %	28,0 %	30,3 %

Grid Interaction improvement

Season	BC + PV	BC + CHP	BC + LG	BC + EN	BC + HVAC	BC + RF	BC + LG + PV	BC + EN + PV	BC + HVAC + PV	BC + RF + PV
Winter	6.3 %	-3.3 %	5.9 %	0.1 %	0.0 %	-1.2 %	11.8 %	6.6 %	6.3 %	5.5 %
Mid-season	7.2 %	-1.0 %	4.6 %	0.1 %	-0.3 %	-1.3 %	10.2 %	8.3 %	7.6 %	6.2 %
Summer	7.1 %	-0.1 %	3.4 %	0.4 %	0.2 %	-0.9 %	7.8 %	8.4 %	8.5 %	6.2 %


winter
electricity load [kW]
1800,00
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
-200,00
-400,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

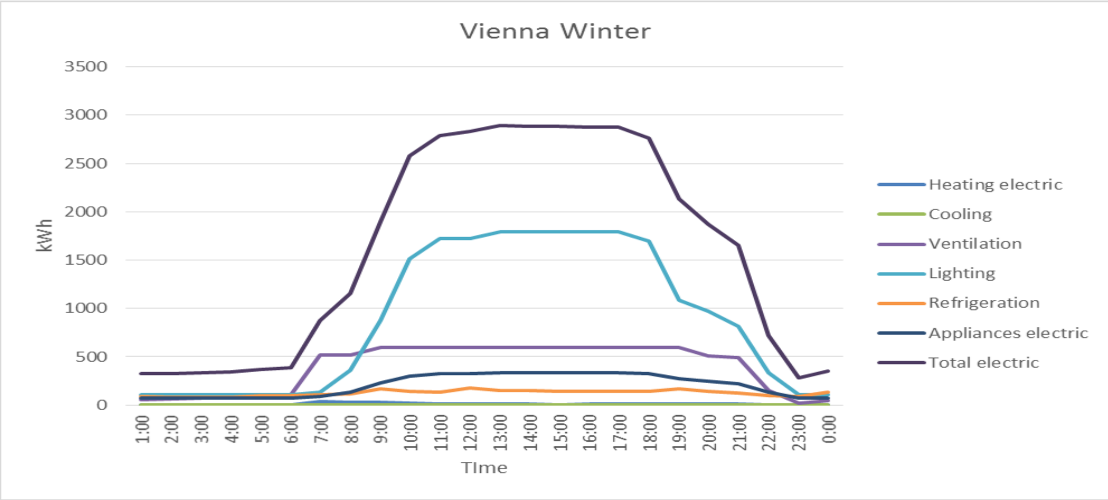

mid season
electricity load [kW]
2000,00
1800,00
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

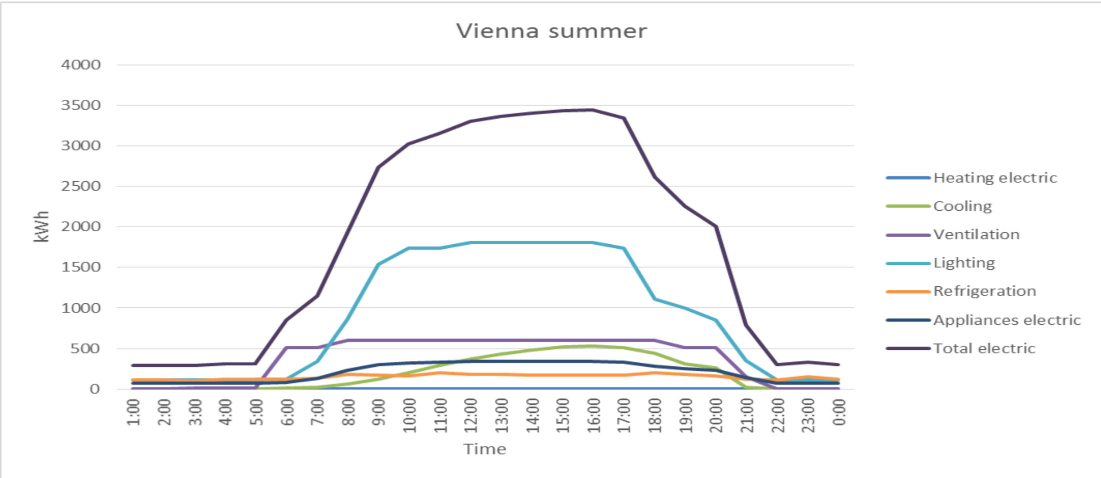

summer
electricity load [kW]
2500,00
2000,00
1500,00
1000,00
500,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

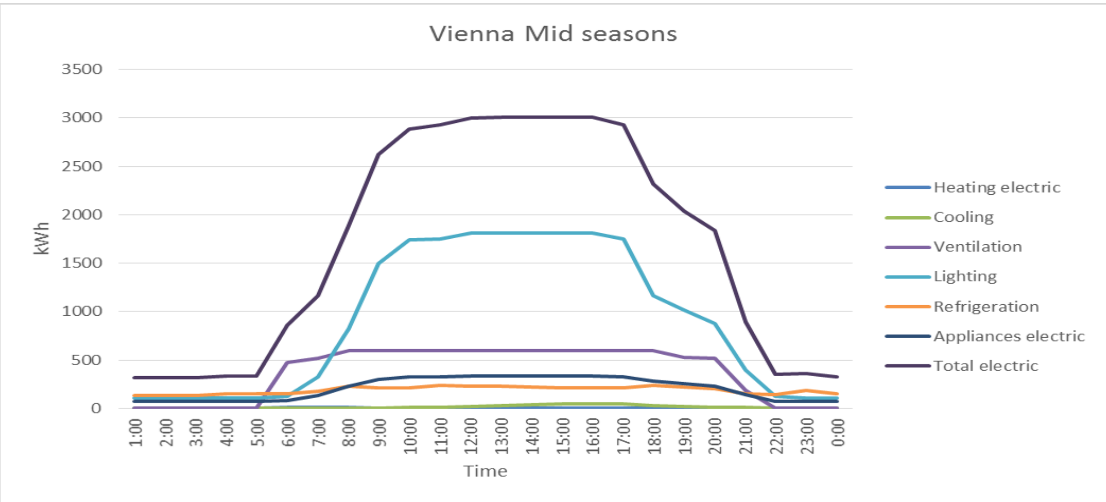
4.5 Reference SC in VIENNA based on DONAUZENTRUM

LOAD PROFILES (BASE CASE)

Total Surface: 66,734 m^2 (Supermarket area: 5,985 m^2)

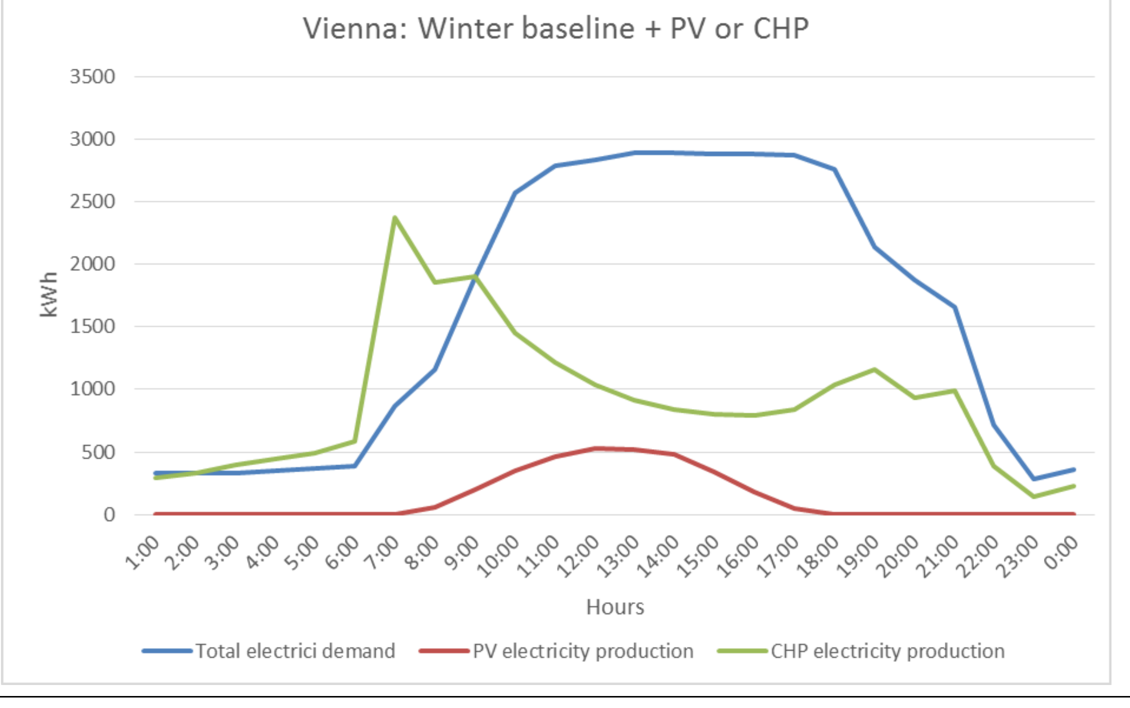


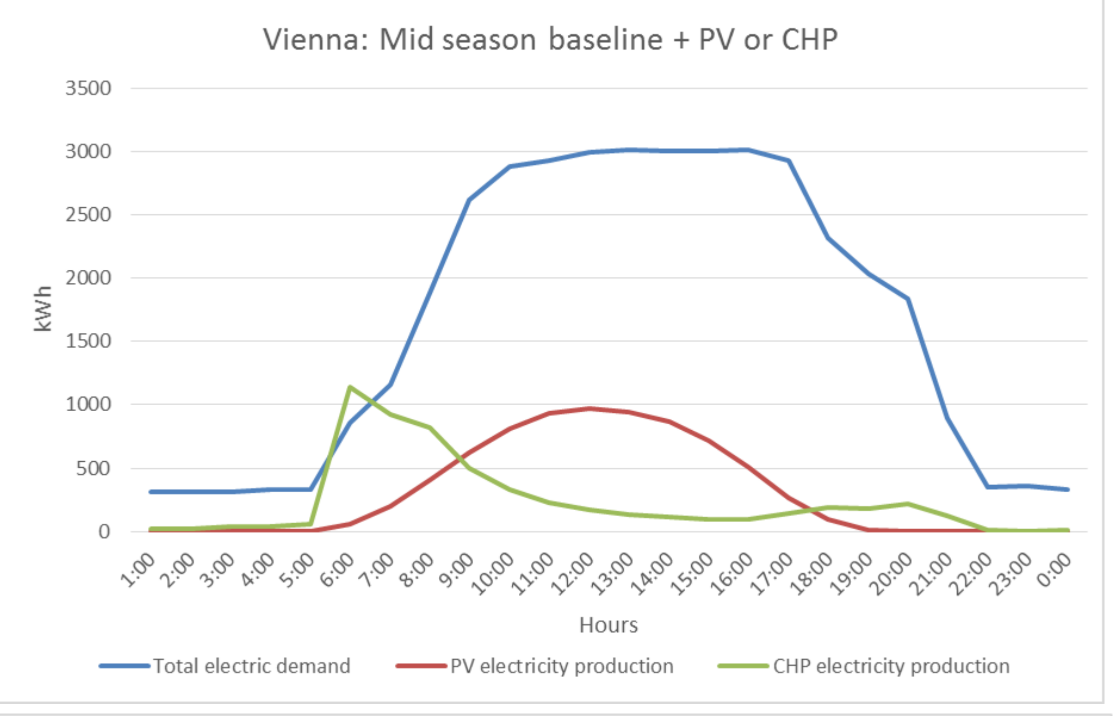


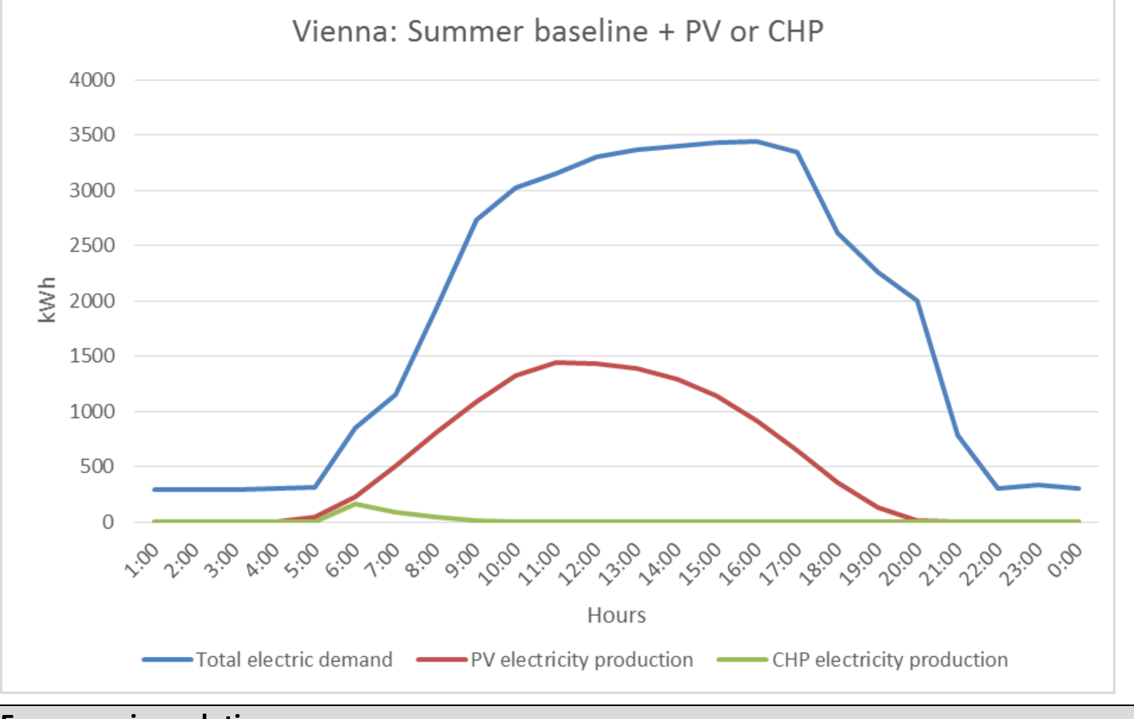


The grid interaction is approximately 38-39% in the different seasons.

POTENTIALS
Based on the analysis of the real building (Donauzentrum), we identified the following potentials: • Lack of load management and batteries to increase self-consumption and exploit tariff time dependent prices. • Not complete exploitation of available roof space for RES production, as can be seen in section 3.2.5. PV panels and solar thermal could be added to generate electricity and/or heat. • Increase of summer T setpoint (currently set at 22º C)
SOLUTIONS
On-site RES
Two types of RES can be considered: installation of PV on the roof and the installation of CHP. The figures below show the total electricity demand and production for the 1) installation of PV on 90% of the roof or 2) the CHP installation. For the PV installation the hourly load match (LM) ranges from 5% in winter to 20% in the summer months with higher LM during the central hours of the day (peak at noon). For the CHP, the situation is the opposite with the LM that ranges from 1 in summer to 64% in winter. Such a high load match is due to the elevated heating demand of a shopping centre located in Vienna, calling for a great degree of CHP use. Indeed, in winter, CHP electricity production exceeds the demand from 2 to 9 AM. Even during the mid-seasons there are times (early morning, i.e., 6 AM) in which production exceeds demand. The possible strategies to use this excess electricity depend on the specific energy tariff for the SC. Possibilities are: store in a battery, feed it to the electricity grid, convert into hydrogen, charging of electrical vehicles.







Energy saving solutions

When the energy efficiency measures are considered, the greatest demand reduction is observed for the lighting scenario. In order to improve self-consumption several energy efficiency measures were considered. They focus on envelope, lighting, HVAC, refrigeration. The figures below show the hourly electric demand profile for the different seasons. As can be seen the greatest reduction is achieved with the reduction of lighting, leading to a consumption of 47% lower than the base case, while for all the other solutions the reduction is minimal (i.e, <5%).

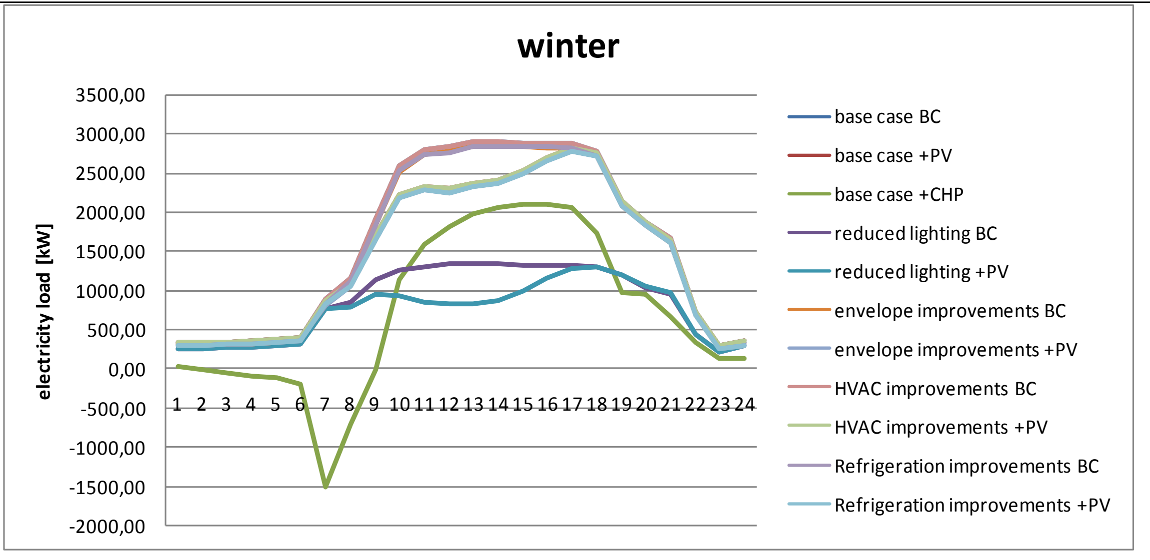
When these energy efficiency solutions are coupled with RES solutions (e.g., PV or CHP), the load match (LM) as calculated for the base case with RES is modified. Specifically, while for most solutions the impact is minimal, for lighting (the most impacting solution) is quite noticeable and LM becomes 10% in winter and 37% in summer for the PV installation.

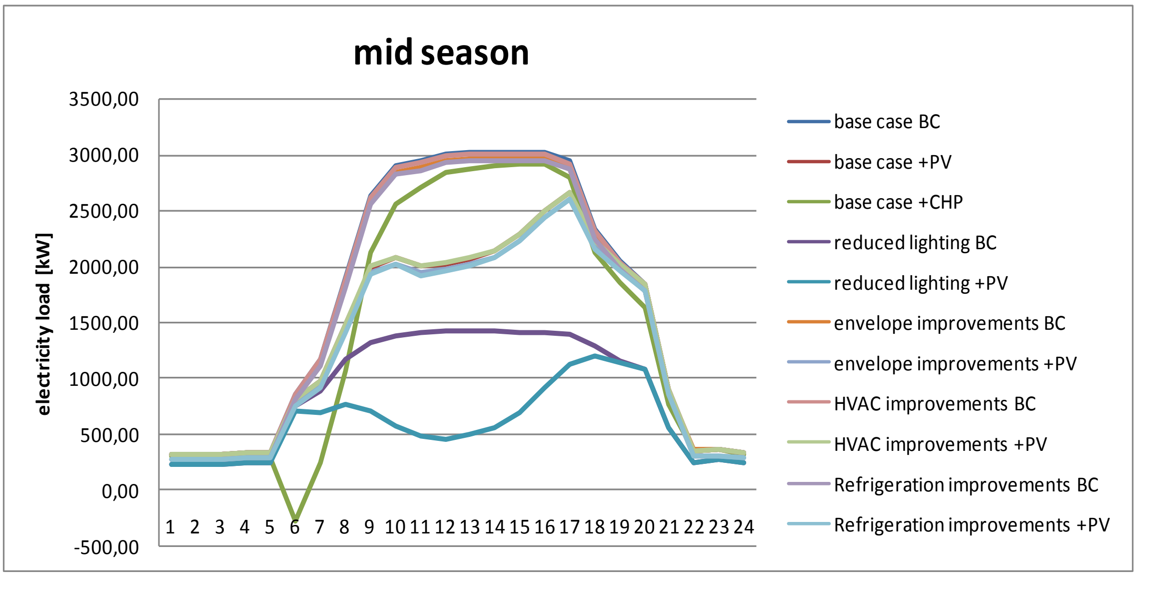
Summary

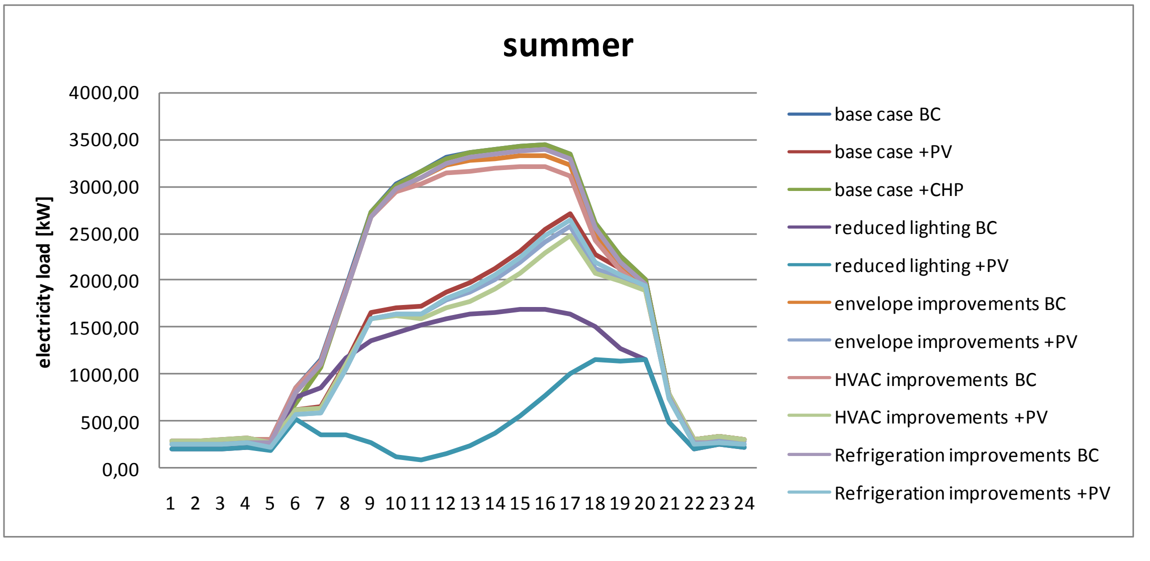
		Base case (BC)		Reduce lighting (LG)	Envelope improvement (EN)	HVAC improvement	Refrigeration improvement (RF)
		+PV	+CHP	+PV	+PV	+PV	+PV
LMavg	winter	5,0 %	64,2 %	10,2 %	5,1 %	5,0 %	5,1 %
	midseason	11,6 %	16,2 %	22,9 %	11,8 %	11,6 %	11,9 %
	summer	20,0 %	1,3 %	37,4 %	20,6 %	20,8 %	20,6 %
GI	winter	34,5 %	49,0 %	28,9 %	34,6 %	34,5 %	34,9 %
	midseason	32,6 %	40,2 %	27,0 %	32,4 %	32,6 %	33,1 %
	summer	32,5 %	38,7 %	30,3 %	32,2 %	31,9 %	32,9 %

Grid Interaction improvement

Season	BC + PV	BC + CHP	BC + LG	BC + EN	BC + HVAC	BC + RF	BC + LG + PV	BC + EN + PV	BC + HVAC + PV	BC + RF + PV
Winter	3.7 %	-10.8 %	2.8 %	-0.1 %	0.0 %	-0.5 %	9.4 %	3.6 %	3.7 %	3.3 %
Mid – season	6.0 %	-1.6 %	2.0 %	0.1 %	0.0 %	-0.6 %	11.5 %	6.2 %	5.9 %	5.5 %
Summer	6.0 %	-0.2 %	1.9 %	-0.1 %	-0.2 %	-0.4 %	8.2 %	6.3 %	6.6 %	5.6 %

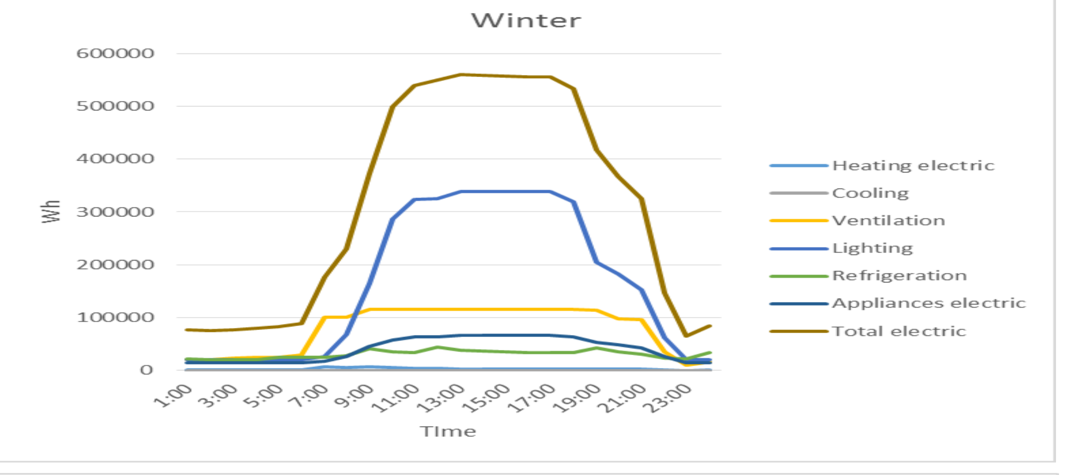

winter
electricity load [kW]
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
-500,00
-1000,00
-1500,00
-2000,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

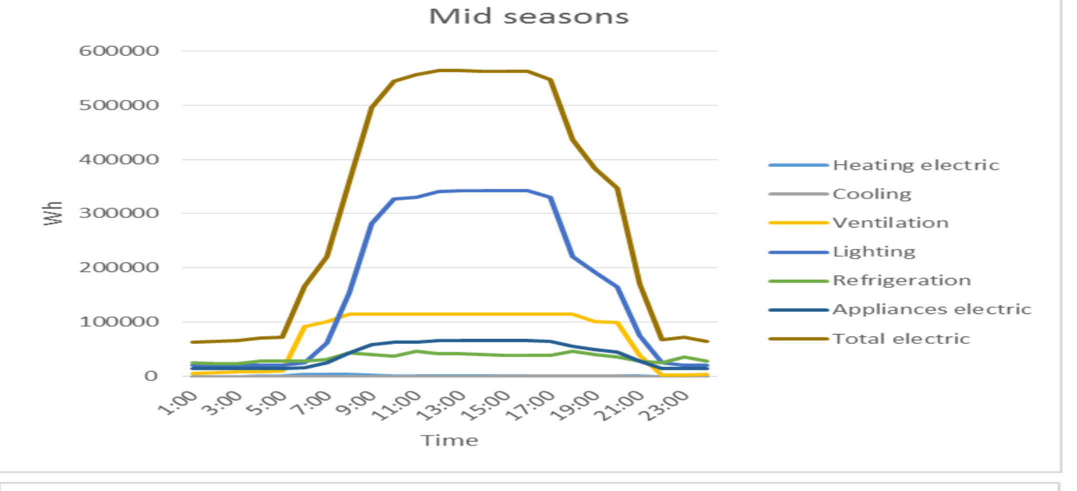

mid season
electricity load [kW]
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
-500,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

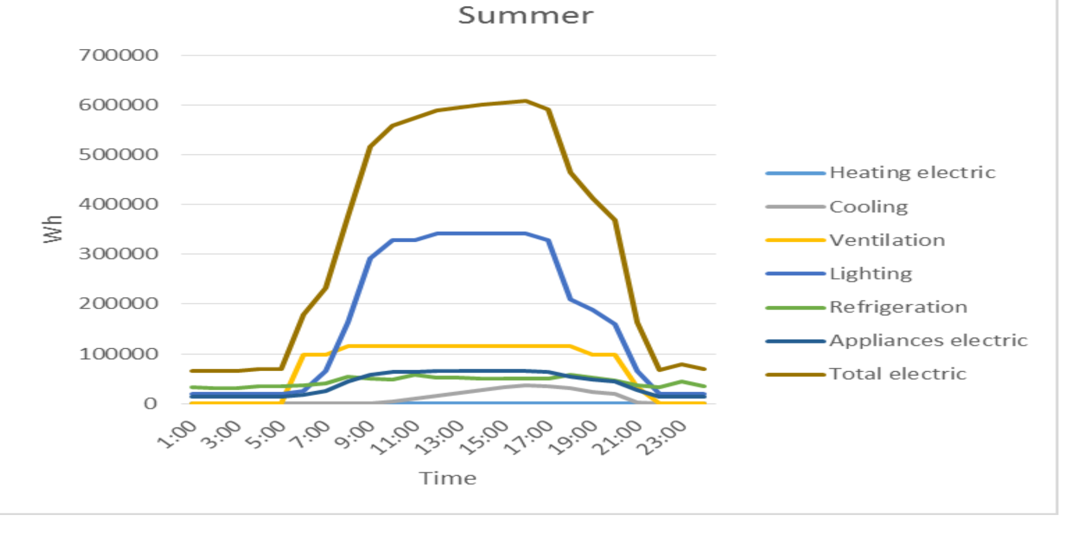

summer
electricity load [kW]
4000,00
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +CHP
reduced lighting BC
reduced lighting +PV
envelope improvements BC
envelope improvements +PV
HVAC improvements BC
HVAC improvements +PV
Refrigeration improvements BC
Refrigeration improvements +PV

4.6 Reference SC in KLAIPEDA based on STUDLENDAS

LOAD PROFILES (BASE CASE)
Total Surface: 12,647 m² (Supermarket area: 1,500 m²)







The grid interaction is 37% in winter, and 38% in mid-season and summer.

POTENTIALS
• The electricity demand of "Studlendas" is mainly because of the lighting, HVAC systems and the energy consumption of the refrigerators used for the conservation of the products. • It is possible to install a PV system, due to the climatologic conditions (Irradiation ~ 1,300 kWh/m^2) and the surface available on the roof (~ 3,000 m^2). The photovoltaic generation profile is suitable for the demand profile of the building because the photovoltaic generation peaks coincide with the market demand peaks. • It is possible to install a wind turbine system, due to the climatologic conditions (wind speed ~ 5 – 6 m/s and without buildings surrounding the shopping mall) and the surface available on the roof (~ 3,000 m^2).

SOLUTIONS

On-site RES

Installation of photovoltaic system which could be placed over the roof and oriented to the South-East.

Mini-wind system, in combination with the photovoltaic, minimises the electrical consumption.

Below there are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity will be reduced.

Photovoltaic installation

The first thing that has been done is an assessment of the optimum operation tilt.

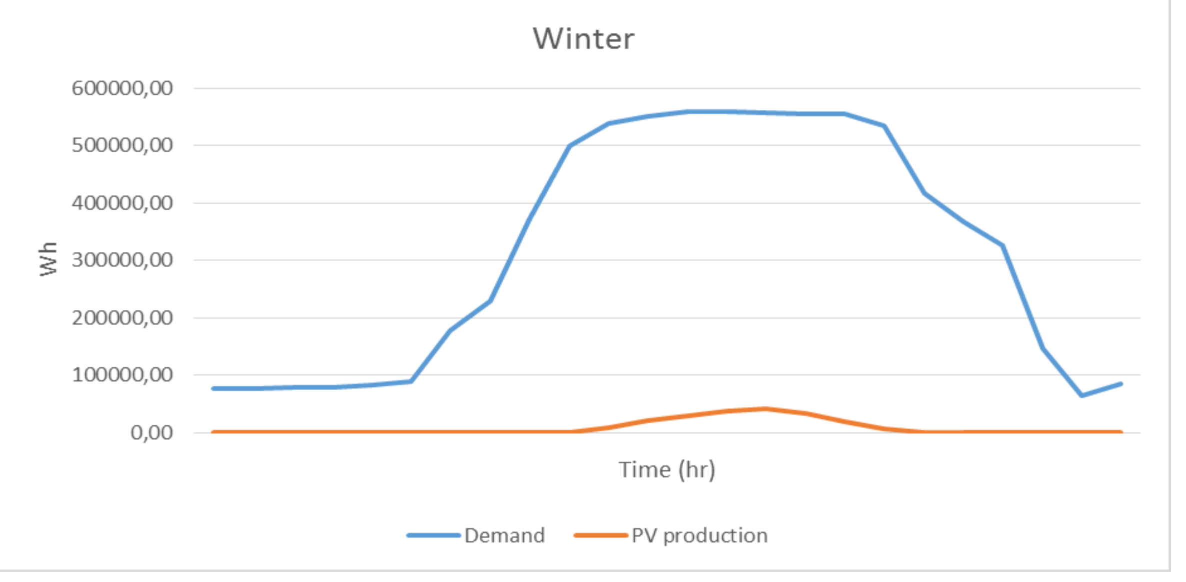
For the assessment of both wind and photovoltaic production, a dynamic simulation in TRNSYS has been performed, considering a photovoltaic installation of panels with 112 W/m^2, with a surface free of shadows of approximately 3,000 m^2, with an inclination of 35º oriented to the South.

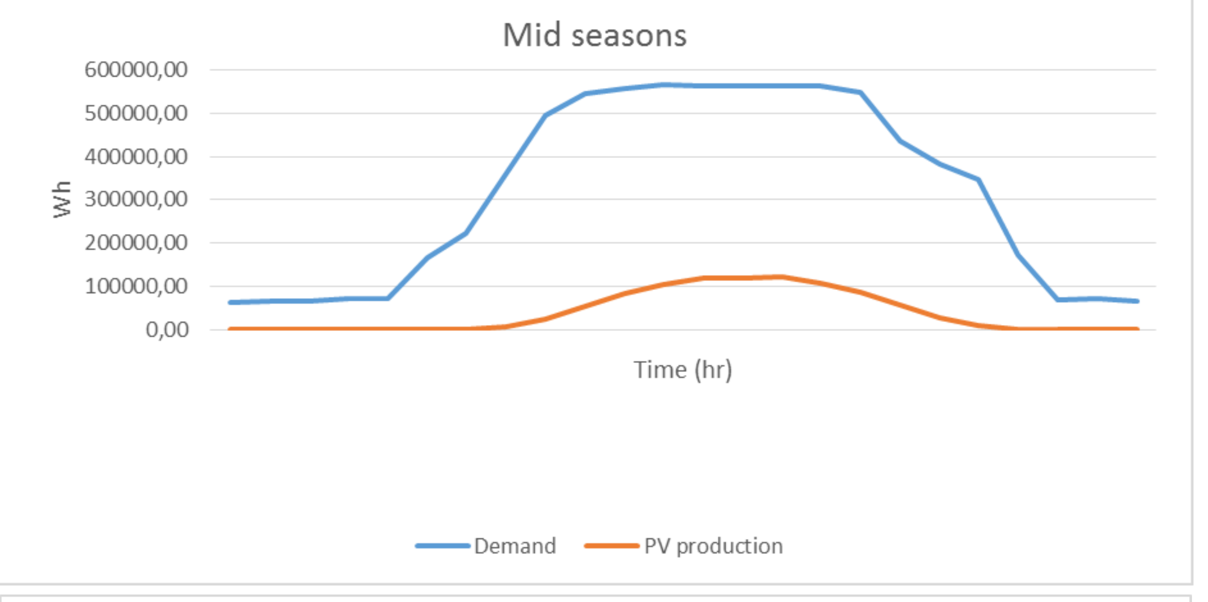
Table 6 shows the results for the hourly energy production for the different seasons:

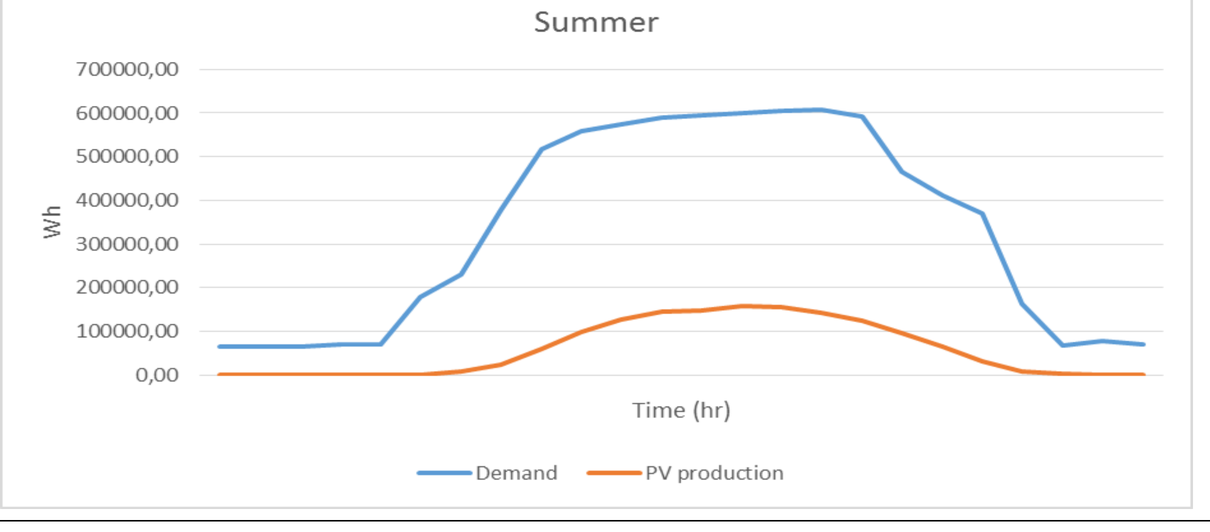
Table 6: Hourly energy production in Wh by season for the PV installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0	0	0	0	0	0	0	0	0	974	9,022	19,818
Summer	0	0	0	0	0	1,390	8,213	24,272	60,399	97,717	126,644	146,028
Mid-season	0	0	0	0	0	60	1,599	6,889	25,565	54,702	83,223	105,361
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	29,915	36,338	41,796	32,749	18,838	5,883	205	0	0	0	0	0
Summer	148,274	15,8148	155,634	143,494	123,555	96,077	65,770	31,283	9,242	2,269	0	0
Mid-season	118,268	120,074	121,124	105,868	85,791	57,199	28,151	8,417	1,822	52	0	0

By overlapping the PV production (according to the 3,000 m^2) with the demand curves for the different seasons developed before for Studlendas we obtain the following figures:







With these values we obtain that the load match during the winter days is approximately 1%, 7% during mid-seasons and in the summer days 11%. The grid interaction that indicates the variability in the import from the grid is 37%, 35%, 37% for winter, mid-season, summer respectively which is relatively constant. The reduction in terms of grid interaction regarding the base case is almost insignificant with a little variation during mid-season (38% in the base case) and in summer (38% in the base case).

Wind turbine installation

A wind turbine installation has been considered with a nominal power of 150 kW.
Through Energy Plus data and the power curve of the wind turbine the annual electricity production can be estimated.
Figure 6 shows the evolution of the power produced by the wind turbine. It is possible to appreciate how a large variation exists in the power from one day to another.

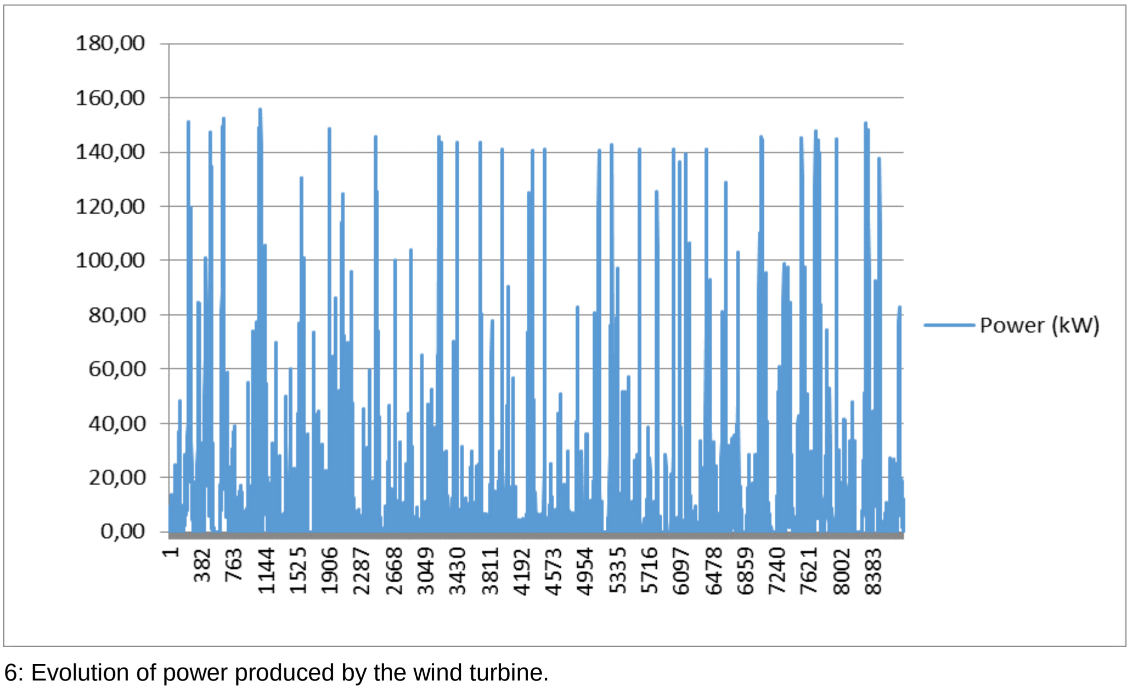


Figure 6: Evolution of power produced by the wind turbine.

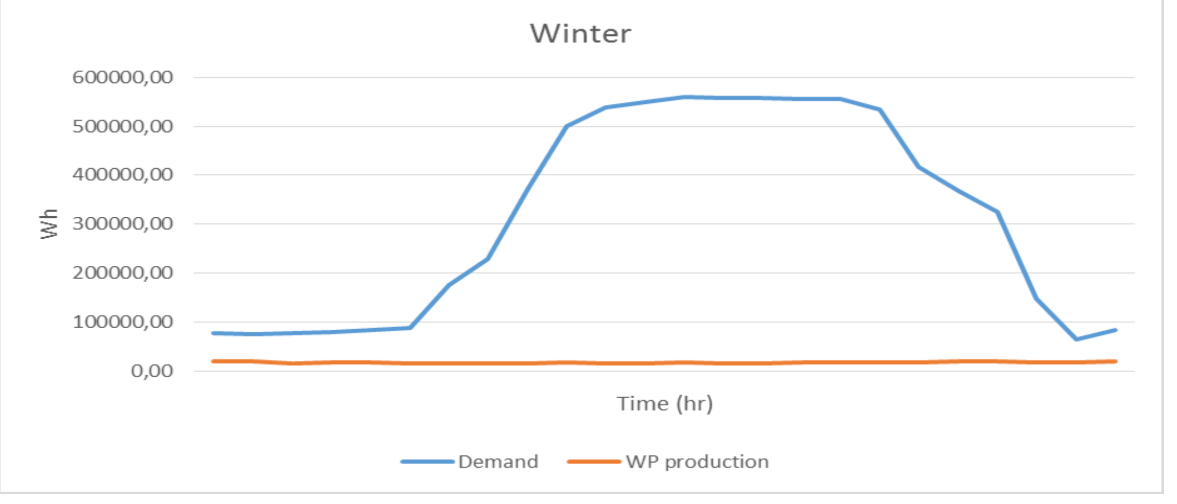
Table 7 shows the results for the hourly energy production for the different seasons:

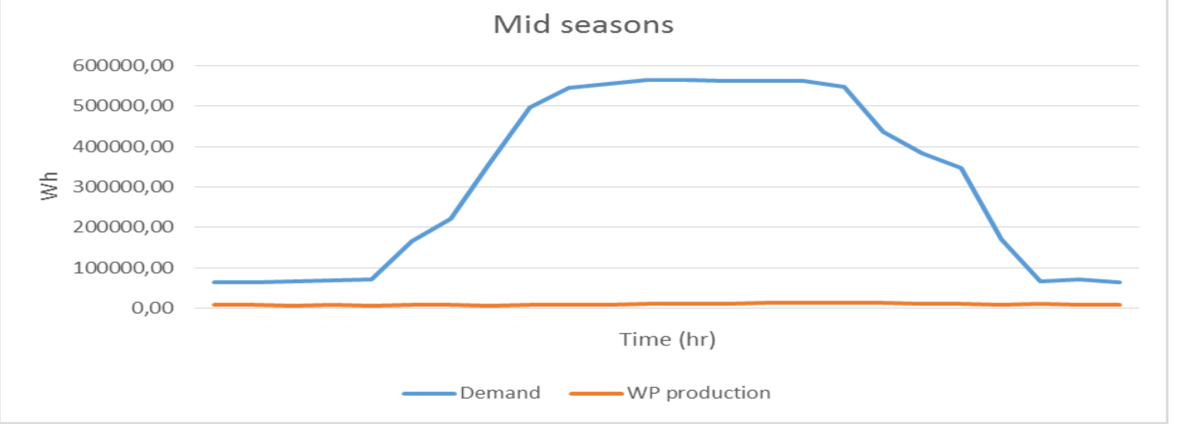
Table 7: Hourly energy production in Wh by season for the WP installation

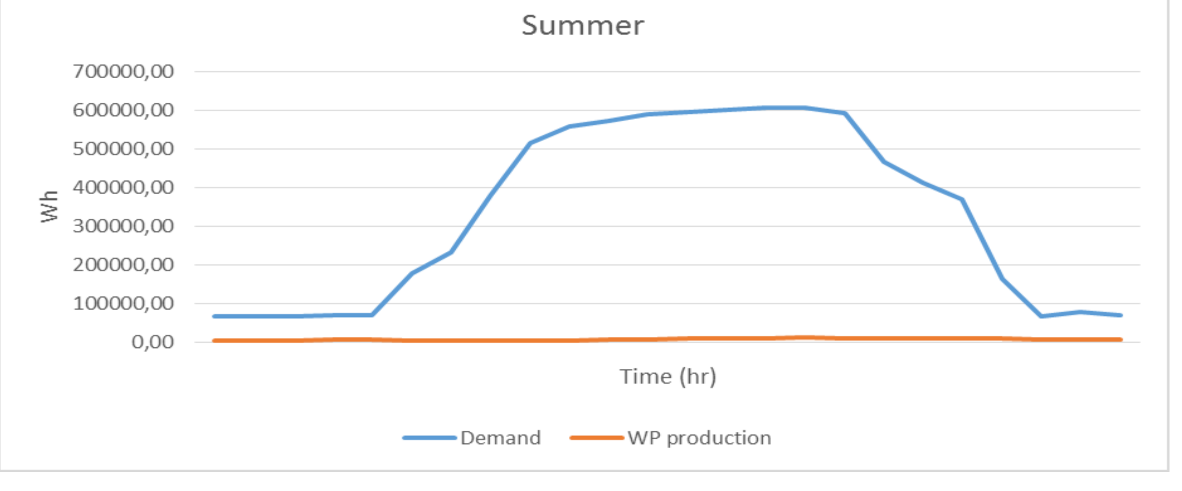
Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	19,715	19,832	15,761	17,563	17,197	16,271	15,458	14,437	15,879	17,419	16,178	15,189
Summer	4,251	3,464	2,530	5,331	5,594	3,935	2,435	1,830	2,853	4,415	6,304	7,129
mid season	9,218	8,288	7,371	8,157	6,807	7,937	7,846	7,390	8,159	8,665	9,298	10,522
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	16,327	16,109	15,962	17,114	16,519	17,491	17,736	18,890	19,123	17,515	17,860	18,658

Summer	7,654	9,036	9,406	10,473	10,213	9,718	8,558	9,589	8,523	6,620	5,415	5,280
Mid-season	10,529	11,172	12,592	12,682	12,947	12,851	11,581	11,032	9,685	10,050	9,173	8,858

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons we obtain the following figures:



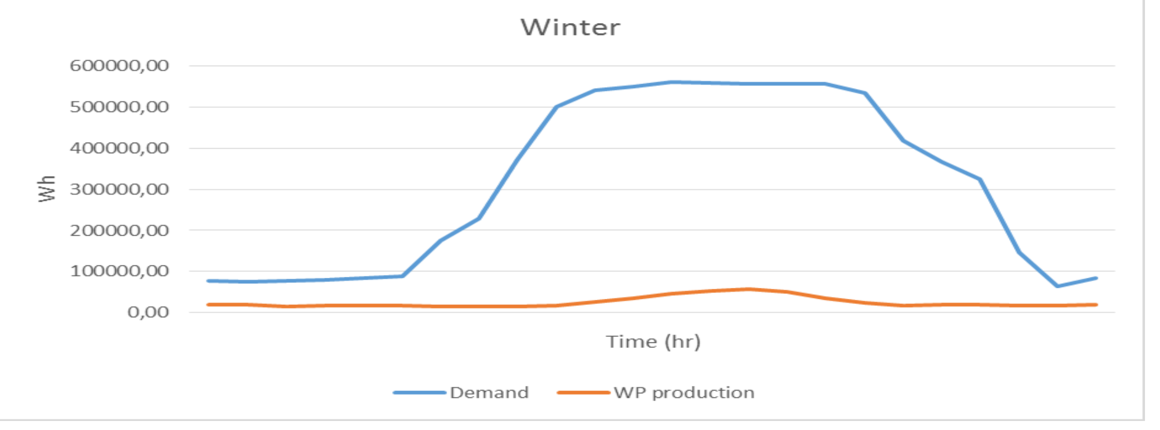


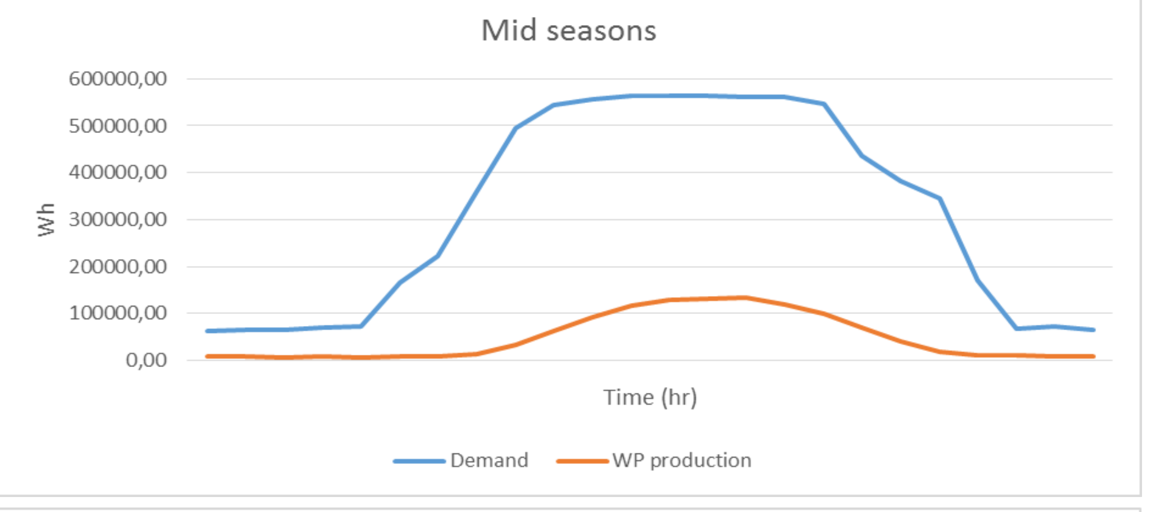


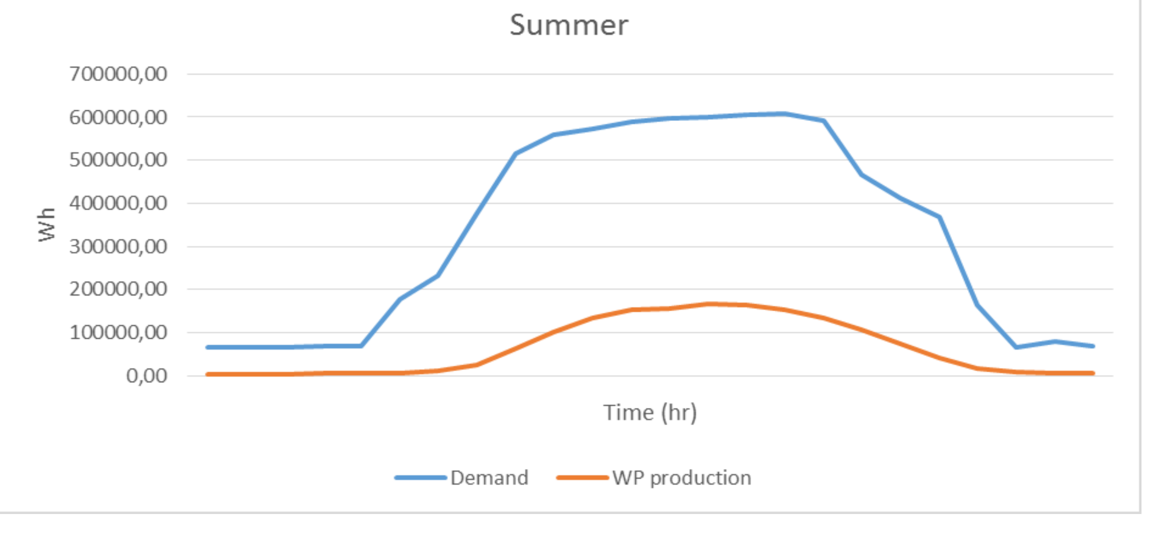
With these values we obtain that the load match during the winter days is 11%, 6% during mid-seasons and 3% in the summer days. The grid interaction is 38% throughout all the seasons.

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time, we obtain the following figures:







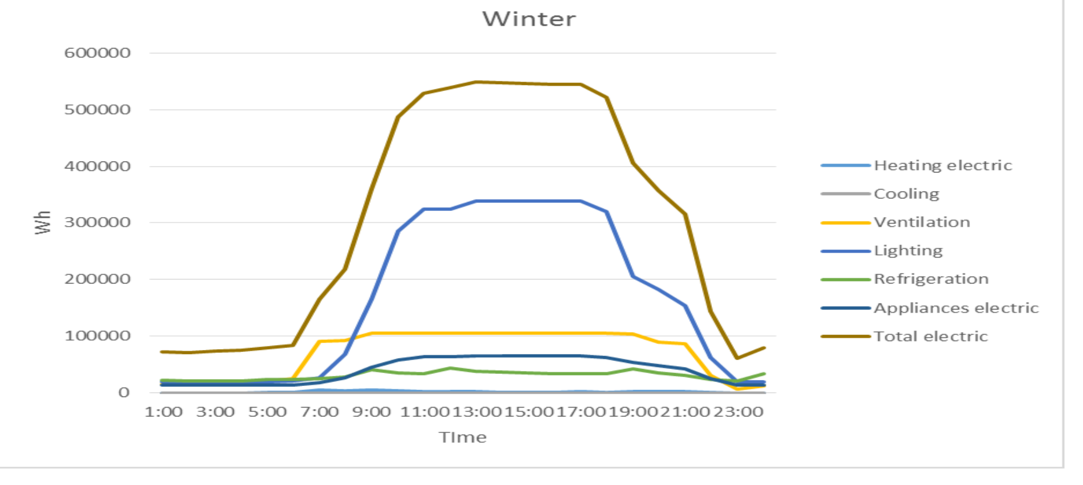
In this case, the load match is increased to 12% in winter, 13% in mid-seasons and 14% in summer, concerning the interaction with the grid the values are 38% in winter, 35% in mid

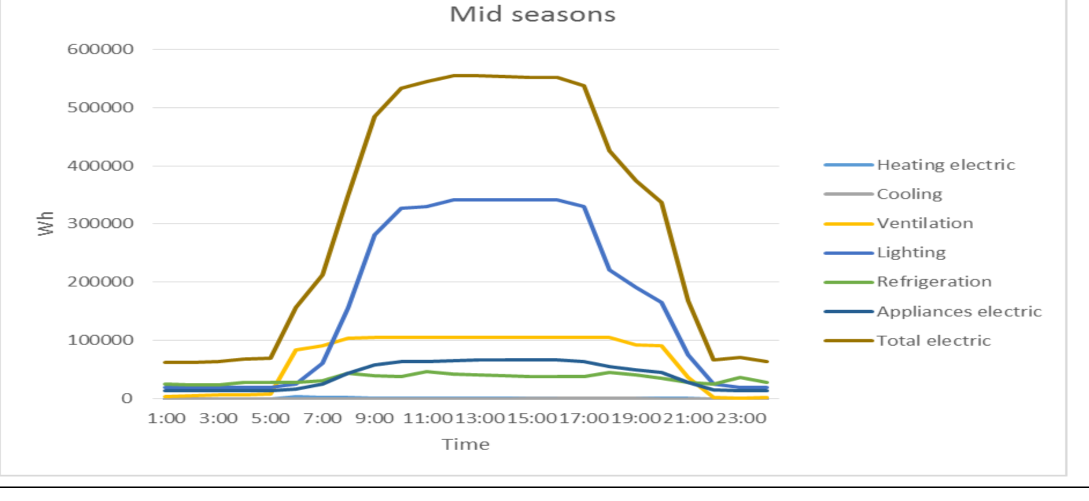
seasons and 38% in summer.
Energy saving

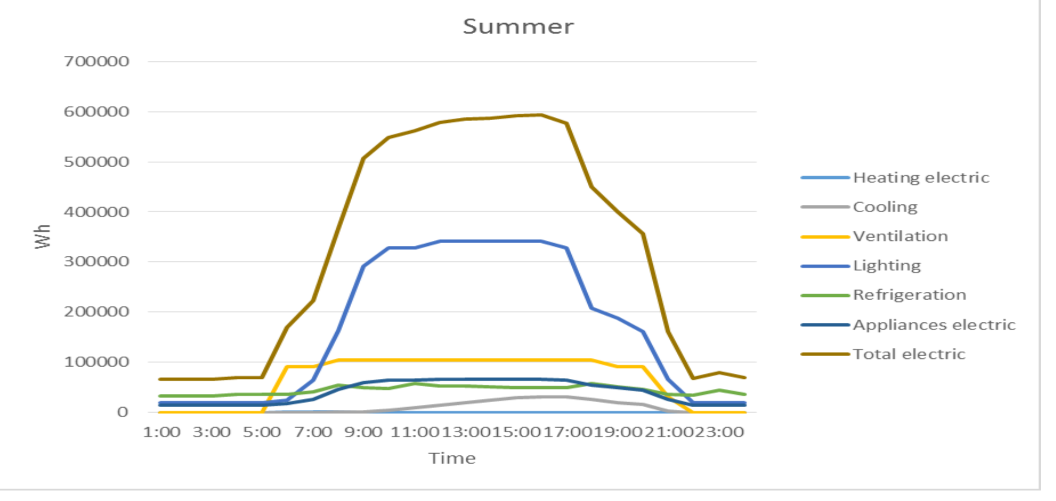
Envelope

Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, because the losses could be decreased.

If improvements in the envelope are included in this building, we obtain the following load profiles:



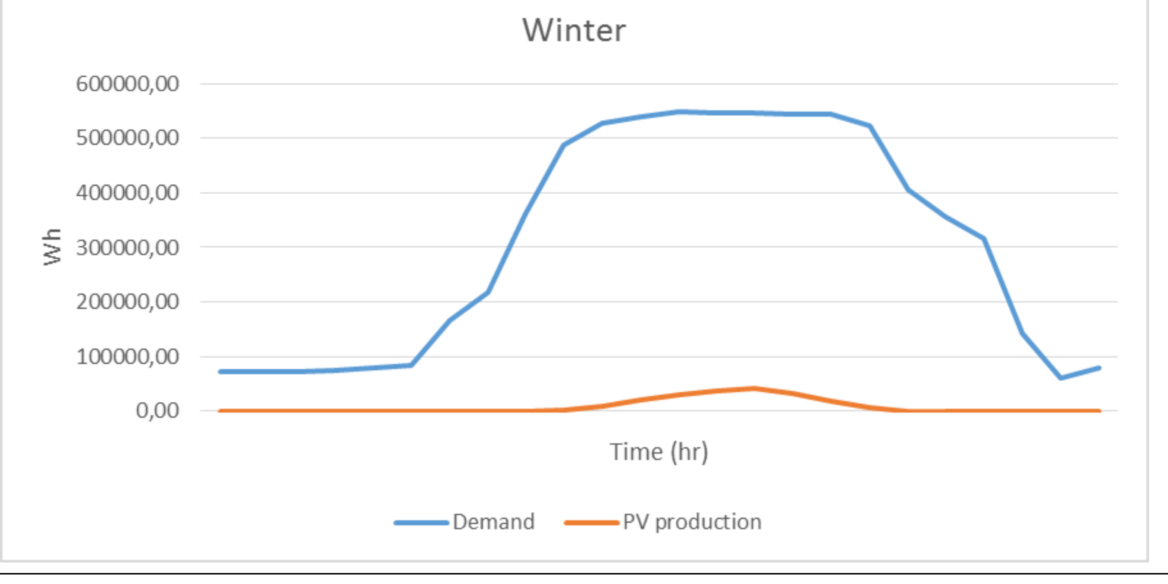


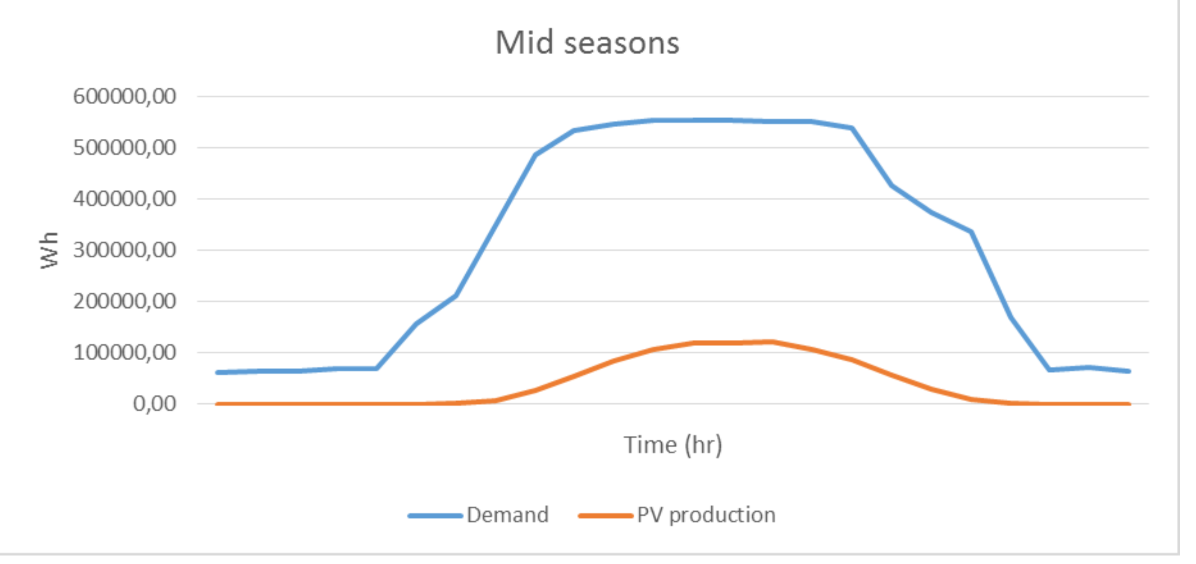


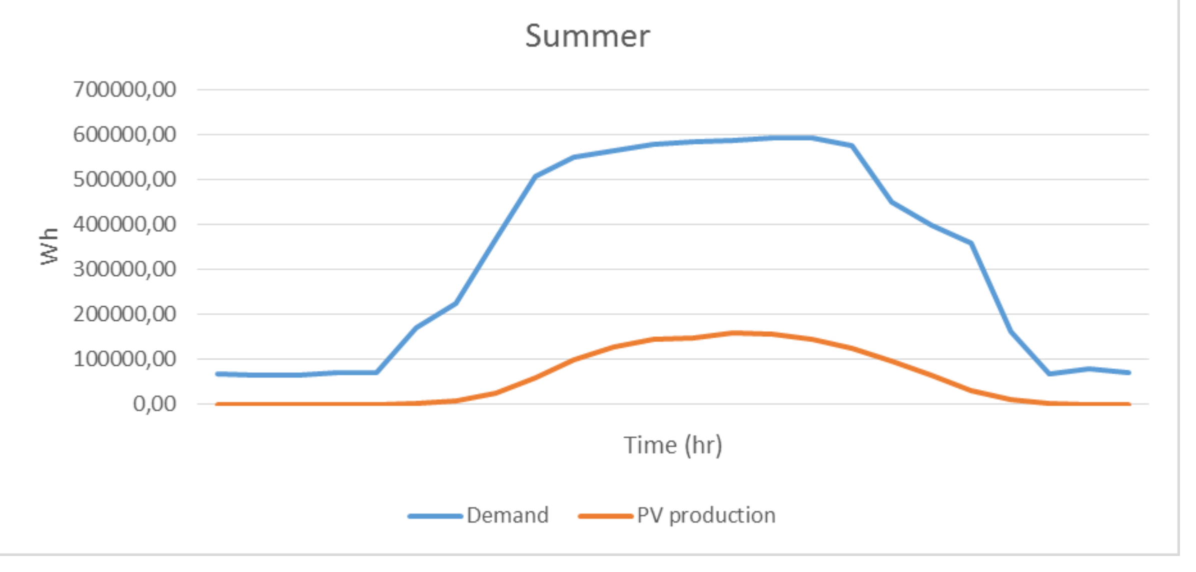
The improvements which have been included are the ones selected through PHPP simulations in D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems to not have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

Envelope + PV

Although we have seen that improvements in the envelope seems to not have a significant improvement in terms of grid interaction, the idea is to combine it with the PV solution described before with the idea to calculate the new Load Match index.







With these values we obtain that the load match during the winter days is approximately 1%, 7% during mid-seasons; 11% in the summer days and the grid interaction is 37%, 35% and 37% for winter, mid-season and summer respectively.

If we compare these values with those obtained only using PV, we can appreciate that the values do not present significant differences.

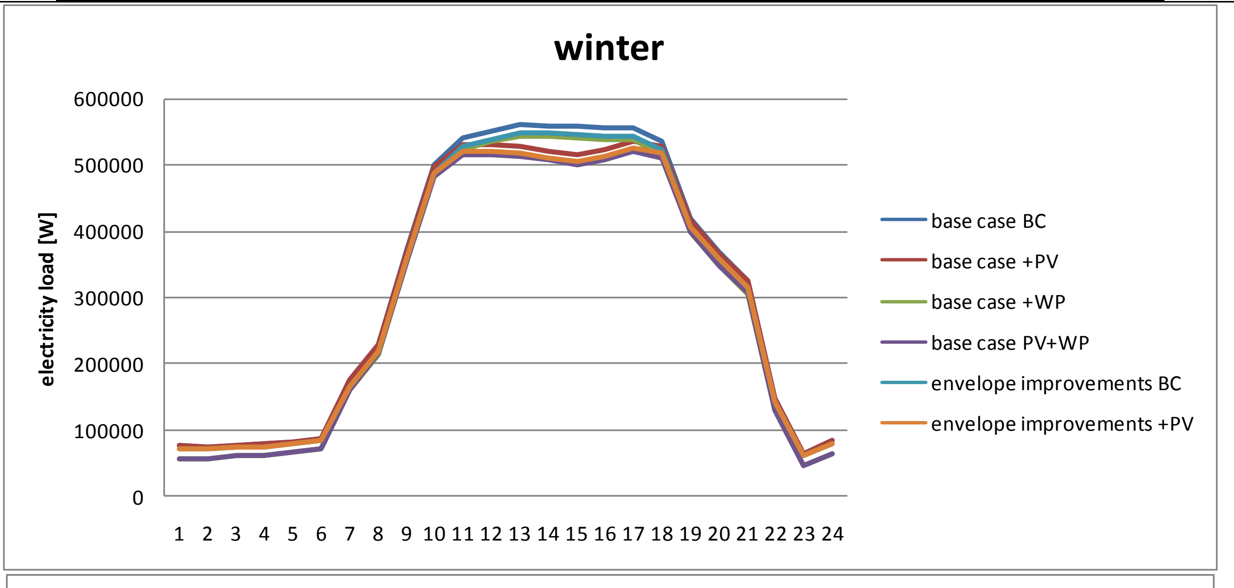
Summary

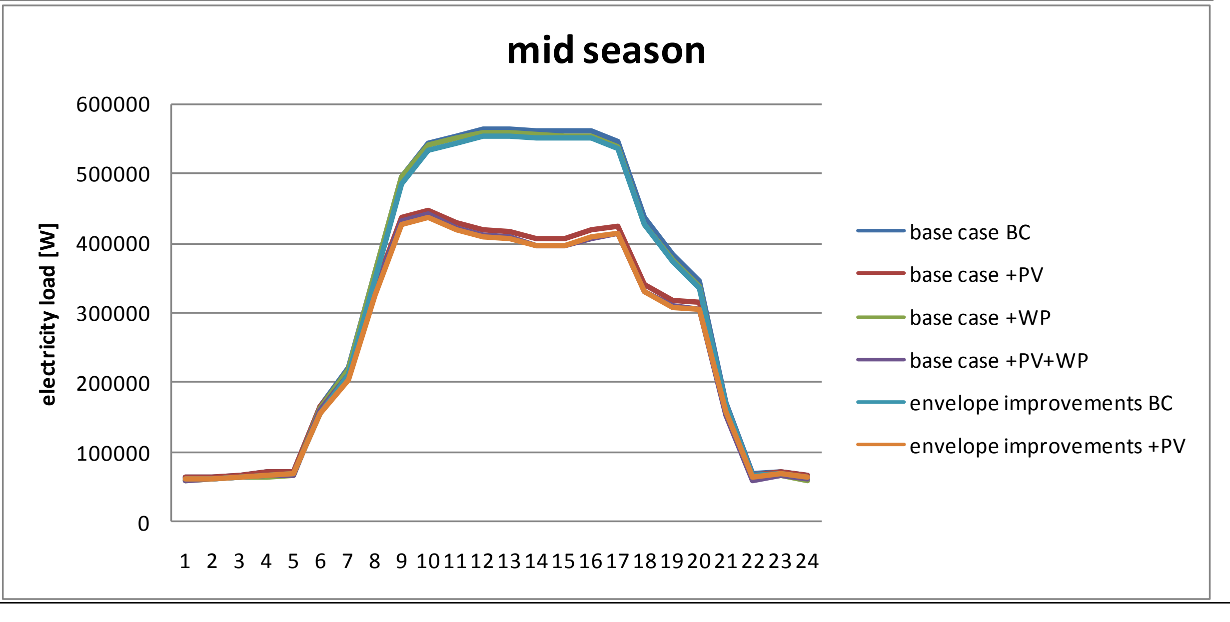
		Base case (BC)			Envelope improvements (EN)
		+PV	+WP	+PV+WP	+PV
LMavg	winter	1%	11%	12%	1%
	Mid-season	7%	6%	13%	7%
	summer	11%	3%	14%	11%
GI	winter	37%	38%	38%	37%

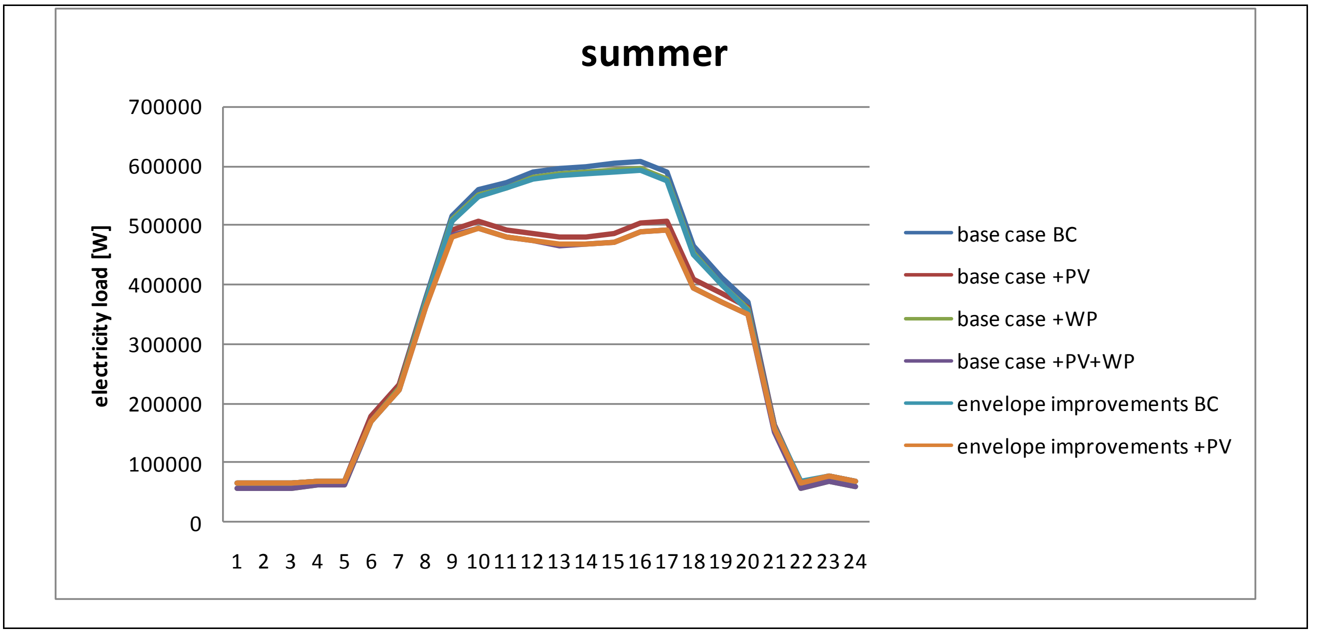
Mid-season	35%	38%	35%	35%
summer	37%	38%	38%	37%

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + EN	BC+ PV + WP	BC + EN + PV
Winter	0%	-1%	0%	-1%	0%
Mid-season	3%	0%	0%	3%	3%
Summer	0%	-1%	0%	0%	1%



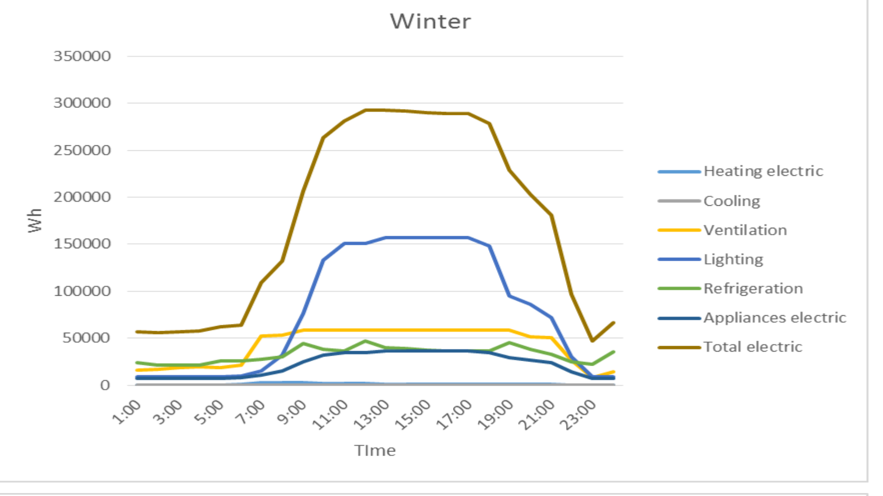


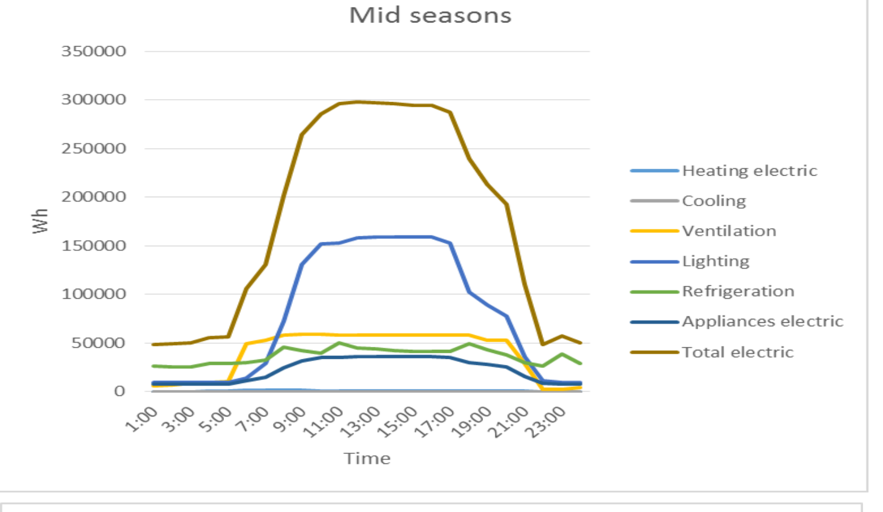

summer
electricity load [W]
700000
600000
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +PV+WP
envelope improvements BC
envelope improvements +PV

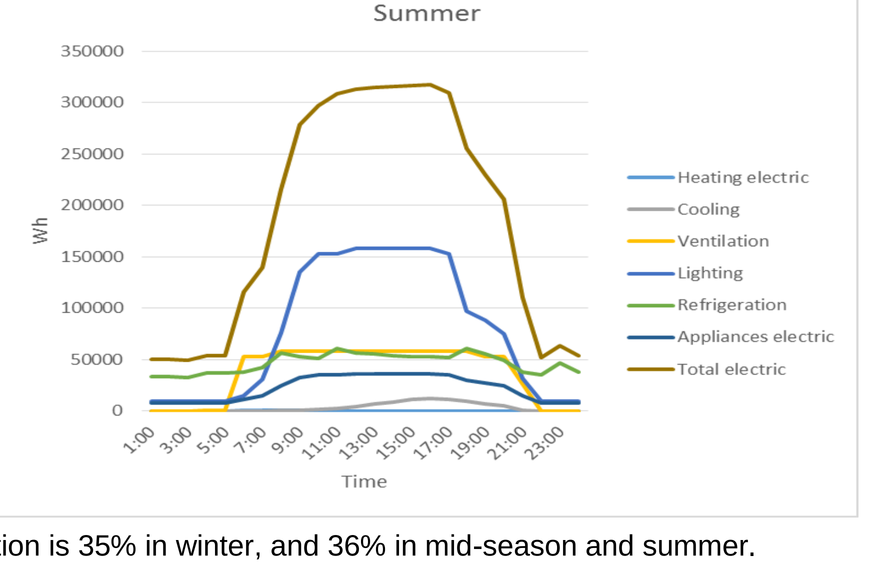
4.7 Reference SC in SILUTE based on PAMARYS

LOAD PROFILES (BASE CASE)

Total Surface: 6,020 m^2 (Supermarket area: 1,625 m^2)







The grid interaction is 35% in winter, and 36% in mid-season and summer.

POTENTIALS

- The electricity demand of the "Pamarys" is mainly due to the lighting, HVAC systems and the energy consumption of the refrigerators used for products' conservation.
- It is possible to install a PV system, due to the climatologic conditions (Irradiation ~ 1,300 kWh/m^2) and the surface available on the roof (~ 1,500 m^2). The photovoltaic generation profile is suitable for the demand profile of the building because the photovoltaic generation peaks coincide with the market demand peaks.
- It is possible to install a wind turbine system, due to the climatologic conditions (wind speed ~ 5 – 6 m/s and without buildings surrounding the shopping mall) and the surface available on the roof (~ 1,500 m^2).

SOLUTIONS

On-site RES

Installation of a photovoltaic system which could be placed over the roof and oriented to the South-East. Mini-wind system, in combination with the photovoltaic, minimising the electrical consumption.

Below are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity will be reduced.

Photovoltaic installation

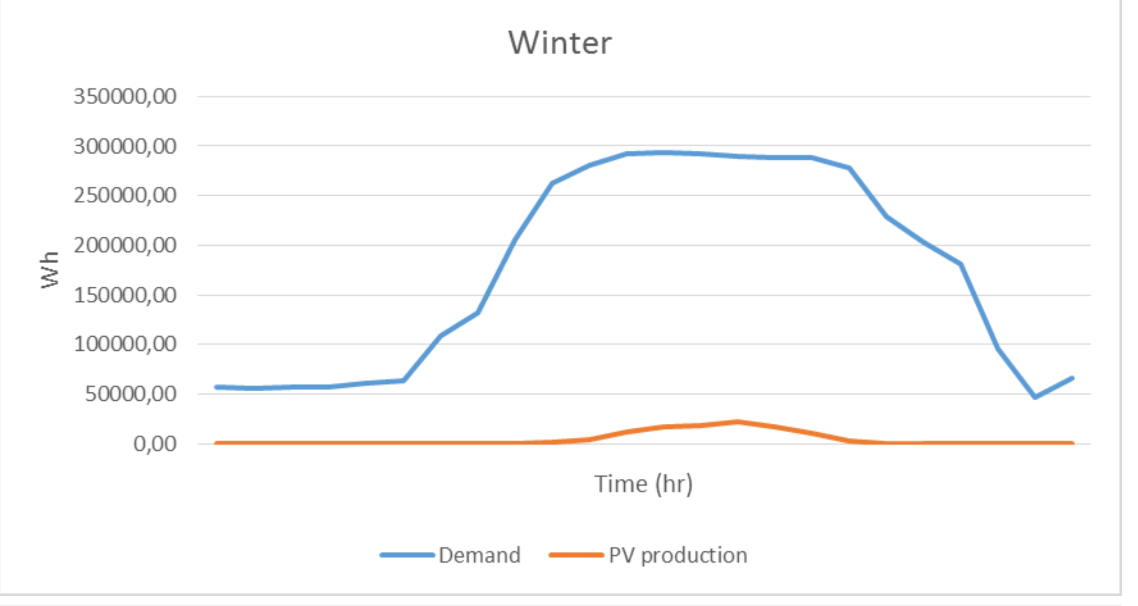
For the simulation in TRNSYS of the photovoltaic installation, has been considered a surface free of shadows of approximately 1,500 m^2, with an inclination of 35º oriented to the South.

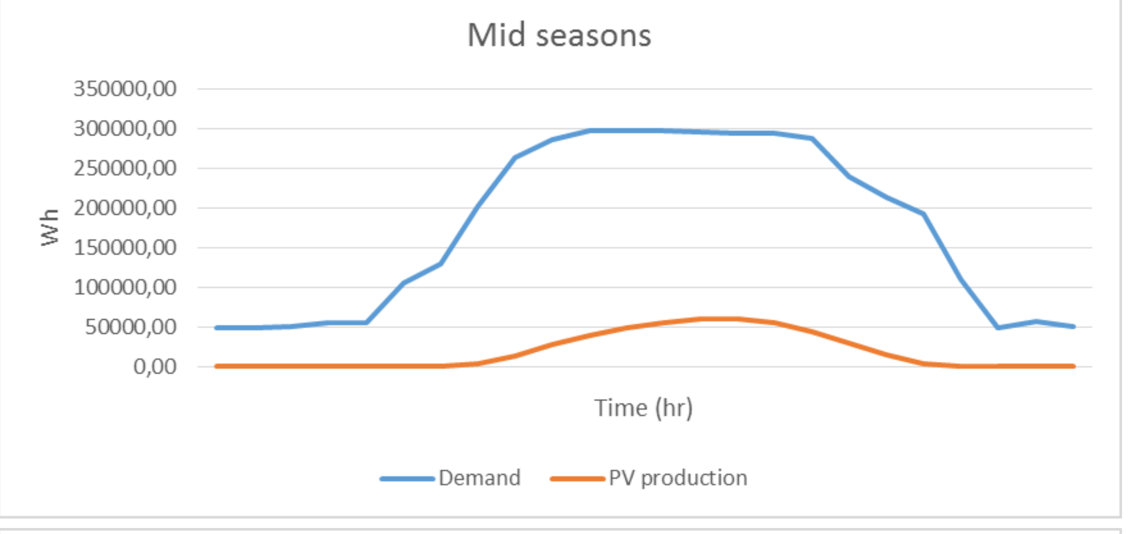
Table 8 shows the results for the hourly energy production for the different seasons:

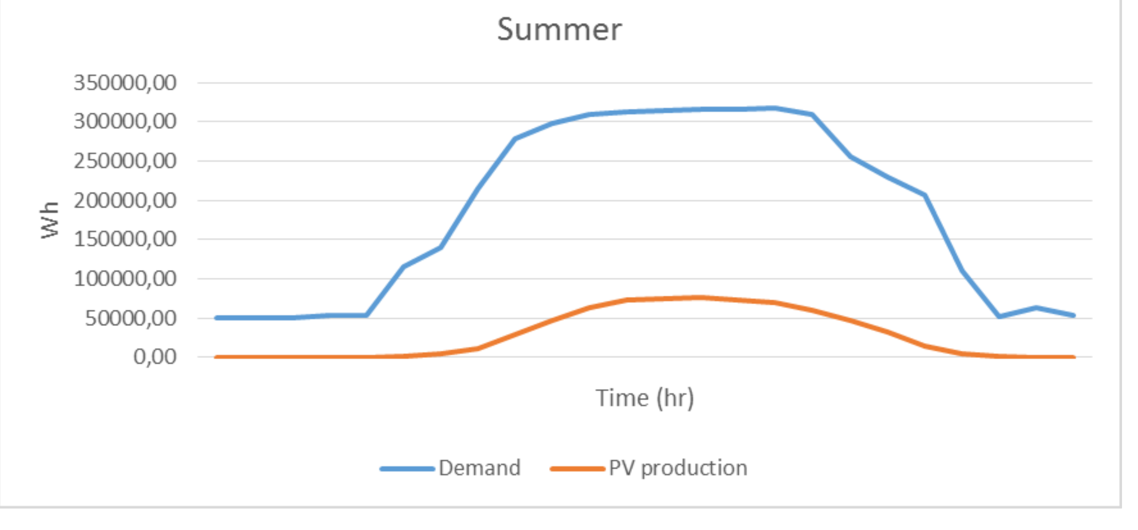
Table 8: Hourly energy production in Wh by season for the PV installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0	0	0	0	0	0	0	0	3	1,066	4,502	11,628
Summer	0	0	0	0	0	598	4,104	11,635	28,063	47,135	63,027	73,041
Mid-season	0	0	0	0	0	45	858	3,580	12,938	27,835	39,759	49,482
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	17,098	18,511	22,486	17,661	10,728	3,076	126	0	0	0	0	0
Summer	74,930	75,602	72,552	69,245	60,355	47,430	31,940	14,784	3,897	1,051	0	0
Mid-season	55,860	60,219	61,146	55,554	44,869	29,064	14,599	3,895	768	22	0	0

By overlapping the PV production (according to the 1,500 m^2) with the demand curves for the different seasons developed before specifically for Pamarys we obtain the following figures:


Winter
350000,00
300000,00
250000,00
200000,00
150000,00
100000,00
50000,00
0,00
Wh
Time (hr)
Demand
PV production


Mid seasons
350000,00
300000,00
250000,00
200000,00
150000,00
100000,00
50000,00
0,00
Wh
Time (hr)
Demand
PV production


Summer
350000,00
300000,00
250000,00
200000,00
150000,00
100000,00
50000,00
0,00
Wh
Time (hr)
Demand
PV production

With these values we obtain that the load match during the winter days is approximately 2%, 7% during mid-seasons and 10% in the summer days. The grid interaction that indicates the variability in the import from the grid is 34%, 33%, 35% for winter, mid-season, summer respectively which is relatively constant. The reduction in terms of grid interaction regarding to the base case is 1% in winter and summer, and 3% in the mid-season.

Wind turbine installation

A wind turbine installation has been considered with a nominal power of 150 kW.
Through Energy Plus data, and the power curve of the wind turbine the annual electricity production can be estimated.

Figure shows the evolution of the power produced by the wind turbine. It is possible to appreciate how there is a large variation in the power from one day to another.

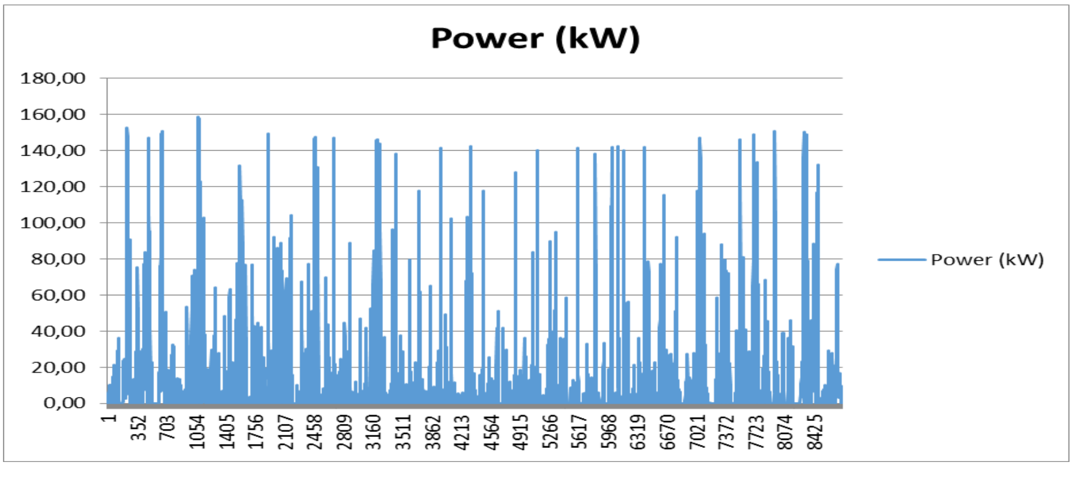


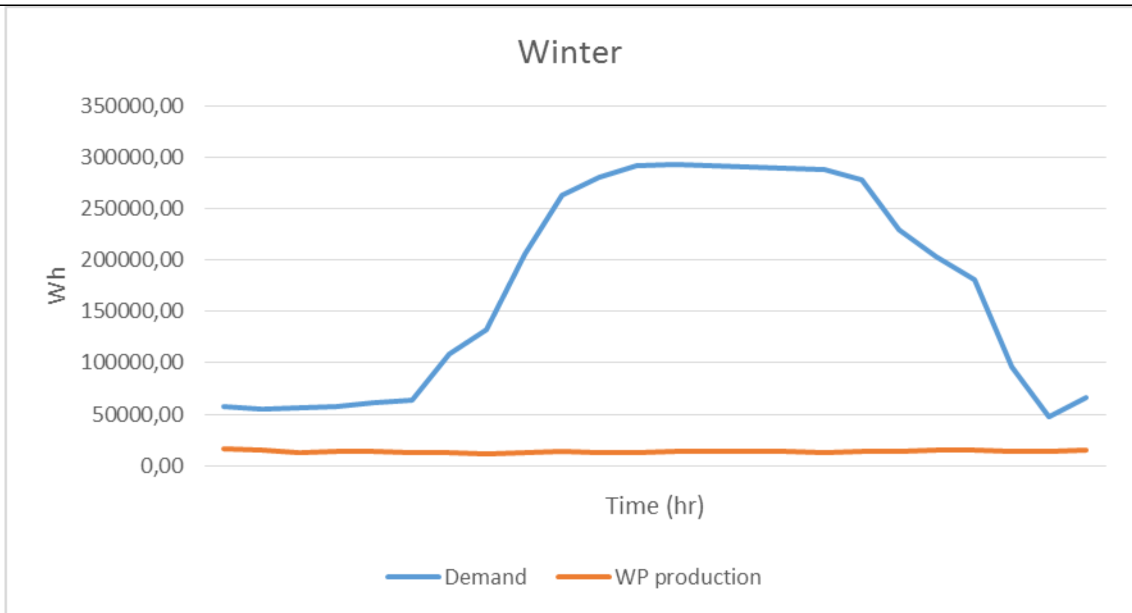
Figure 7: Evolution of power produced by the wind turbine

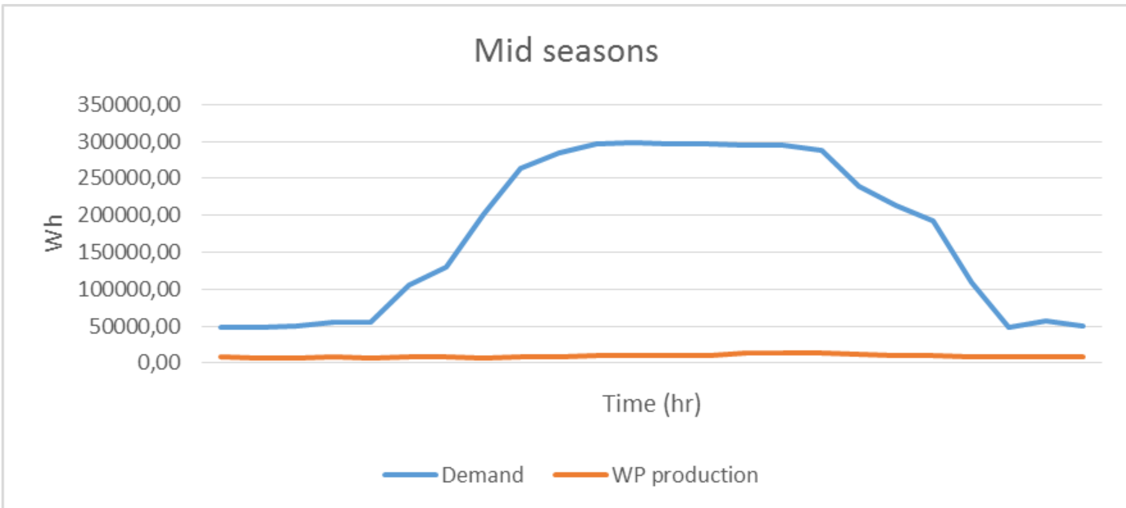
Table 9 shows the results for the hourly energy production for the different seasons:

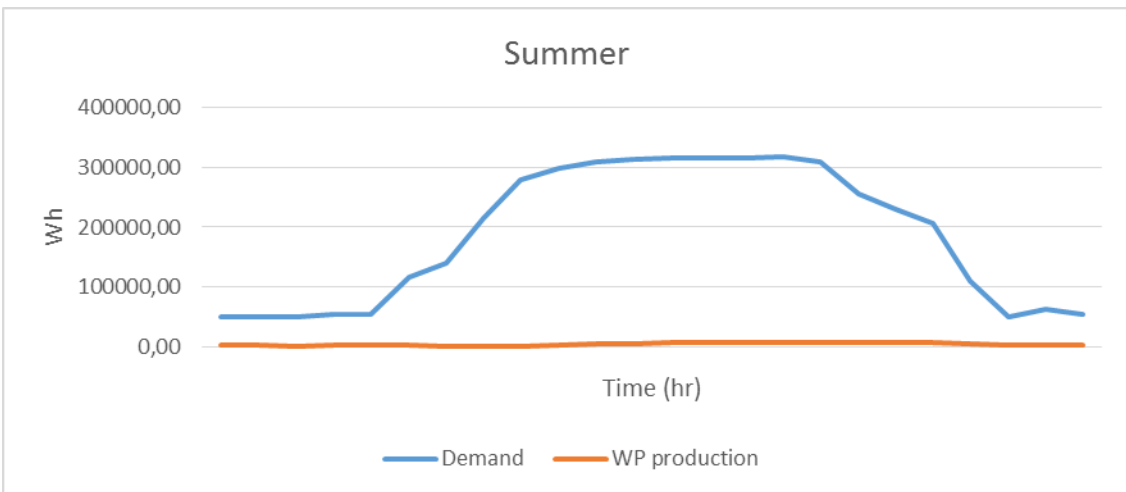
Table 9: Hourly energy production in Wh by season for the WP installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	15,758	15,704	12,696	13,963	13,878	12,953	12,197	11,386	12,496	13,971	12,890	12,248
Summer	3,487	2,916	2,131	4,080	4,556	2,948	1,457	1,174	2,121	3,798	5,368	6,616
mid season	8,711	7,225	6,593	7,998	6,462	7,692	7,593	7,325	8,273	9,095	9,660	10,368
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	13,351	13,547	13,268	13,886	12,989	13,593	14,414	15,691	15,461	14,111	14,483	14,843
Summer	6,927	7,610	7,414	8,861	8,694	7,484	7,095	7,699	6,665	4,606	4,398	4,440
mid season	10,110	10,897	12,795	12,861	13,153	12,676	10,864	10,251	8,964	9,301	8,282	8,374

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons we obtain the following figures:



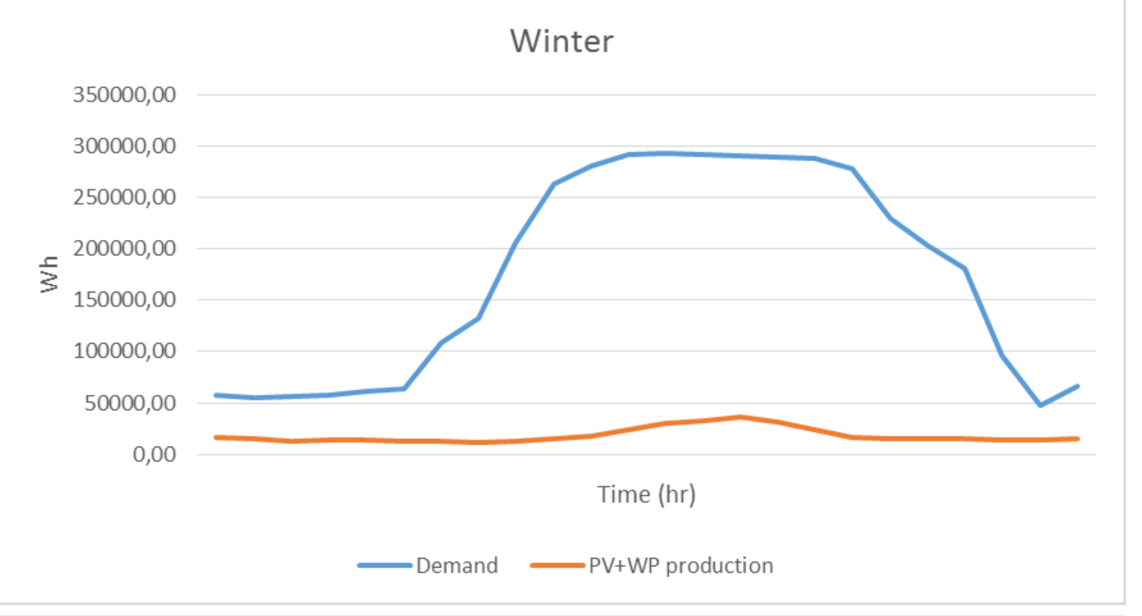


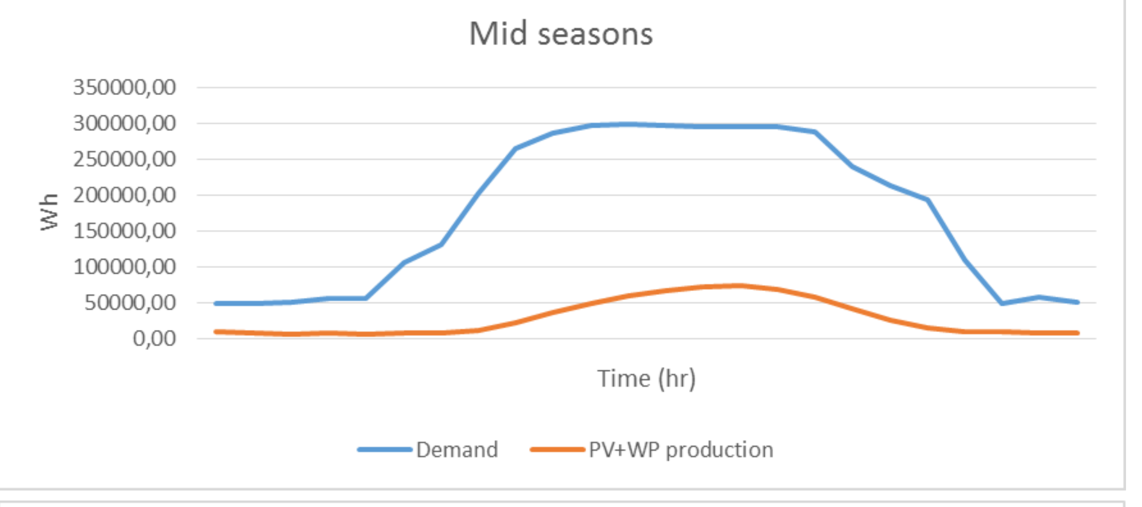


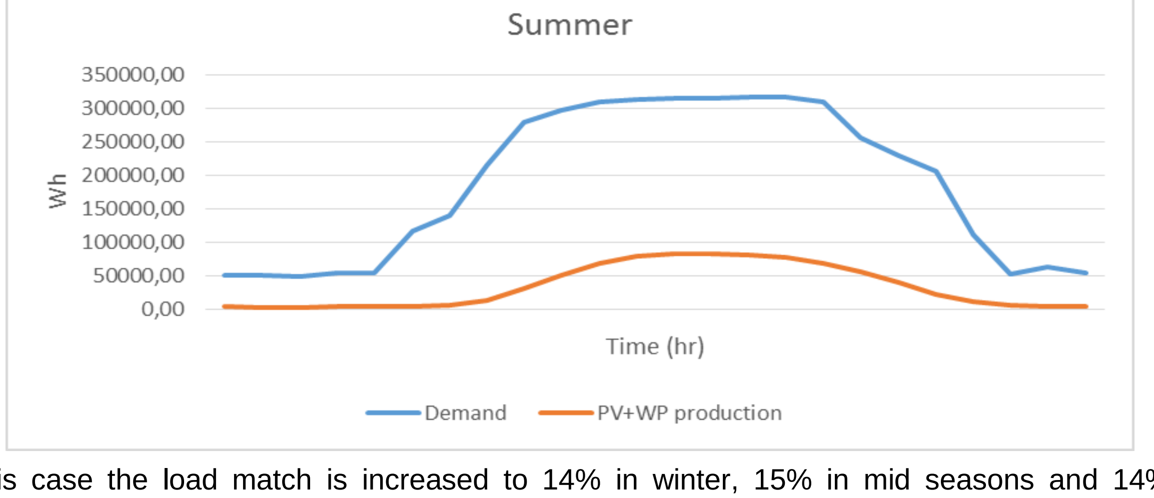
With these values we obtain that the load match during the winter days is 13%, mid-seasons 8% and in the summer days 4%. The grid interaction that indicates the variability in the import from the grid is 36%, 36% and 37% for winter, mid-season and summer respectively.

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time we obtain the following figures:

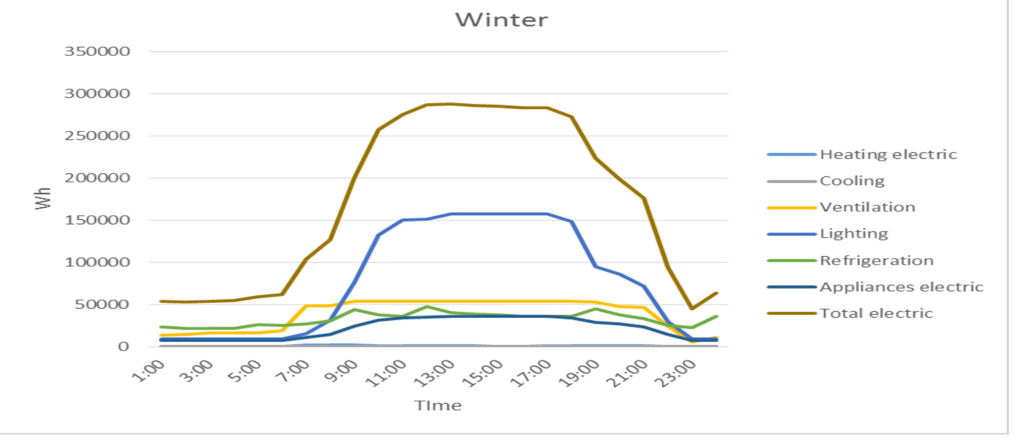


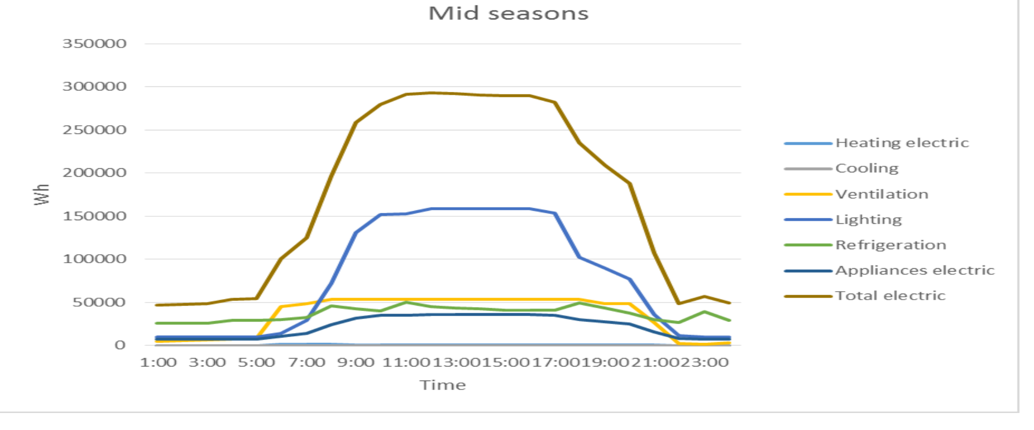


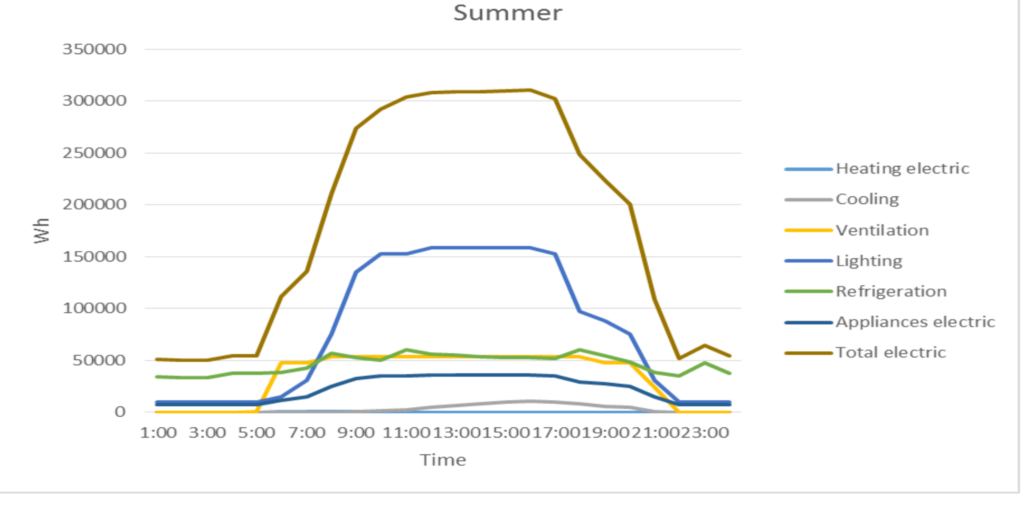


In this case the load match is increased to 14% in winter, 15% in mid seasons and 14% in summer, concerning the interaction with the grid the values are 36% in winter, 33% in mid seasons and 35% in summer.

Energy shaving
Envelope Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, because the losses could be decreased. If improvements in the envelope are included in this building, we obtain the following load profiles:



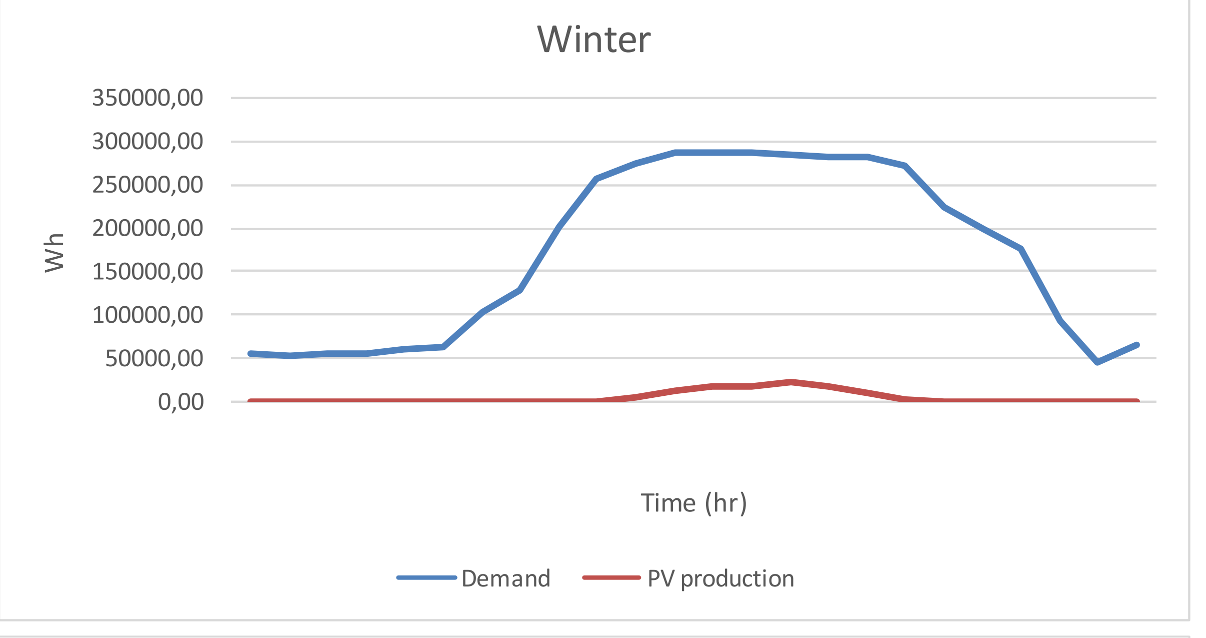


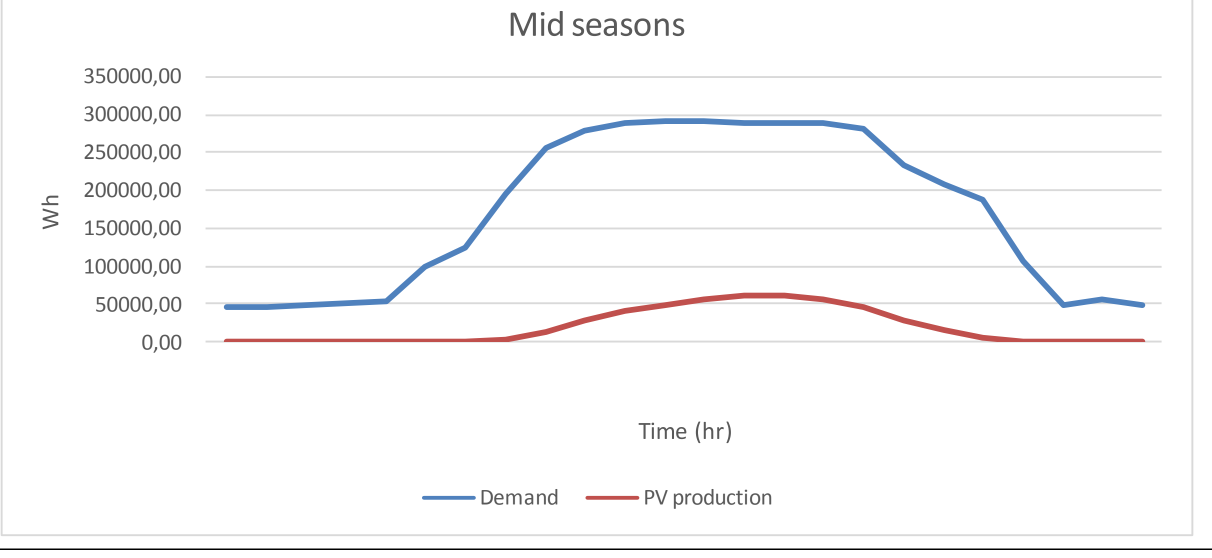


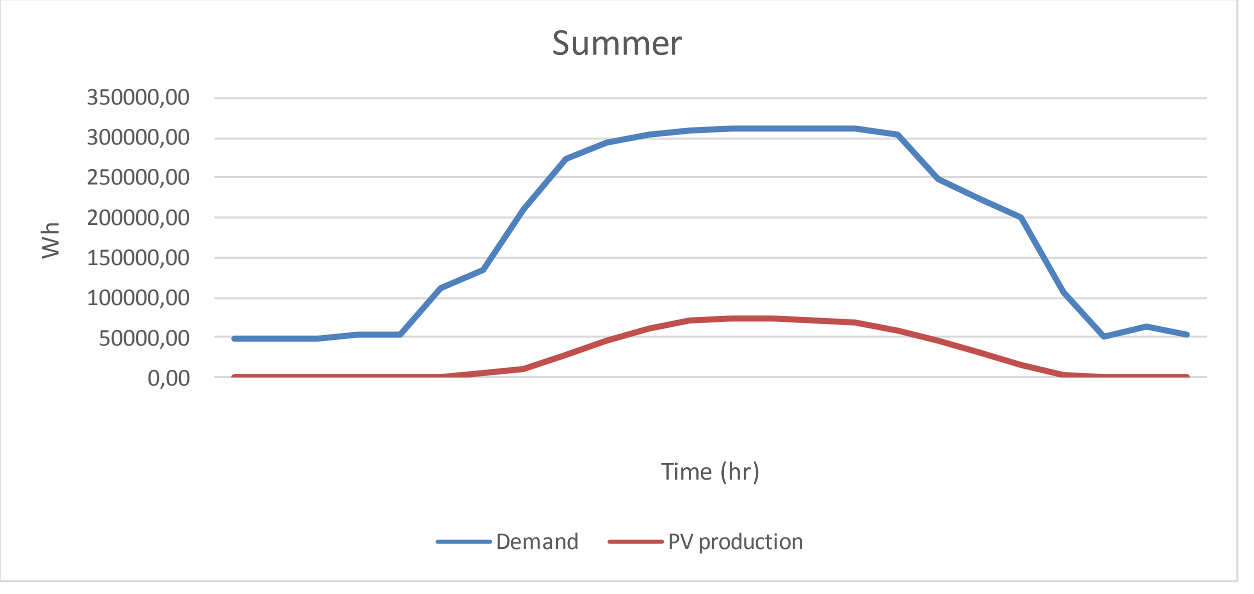
The improvements which have been included are the ones selected through PHPP simulations in D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems not to have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

Envelope + PV

Although we have seen that improvements in the envelope seem to not have a significant improvement in terms of grid interaction, the idea is to combine it with the PV solution described before with the idea to calculate the new Load Match index.







With these values we obtain that the load match during the winter days is approximately 2%, mid-seasons 7% and in the summer days 10% and the grid interaction is 35%, 33% and 34% for winter, mid-season, summer respectively.

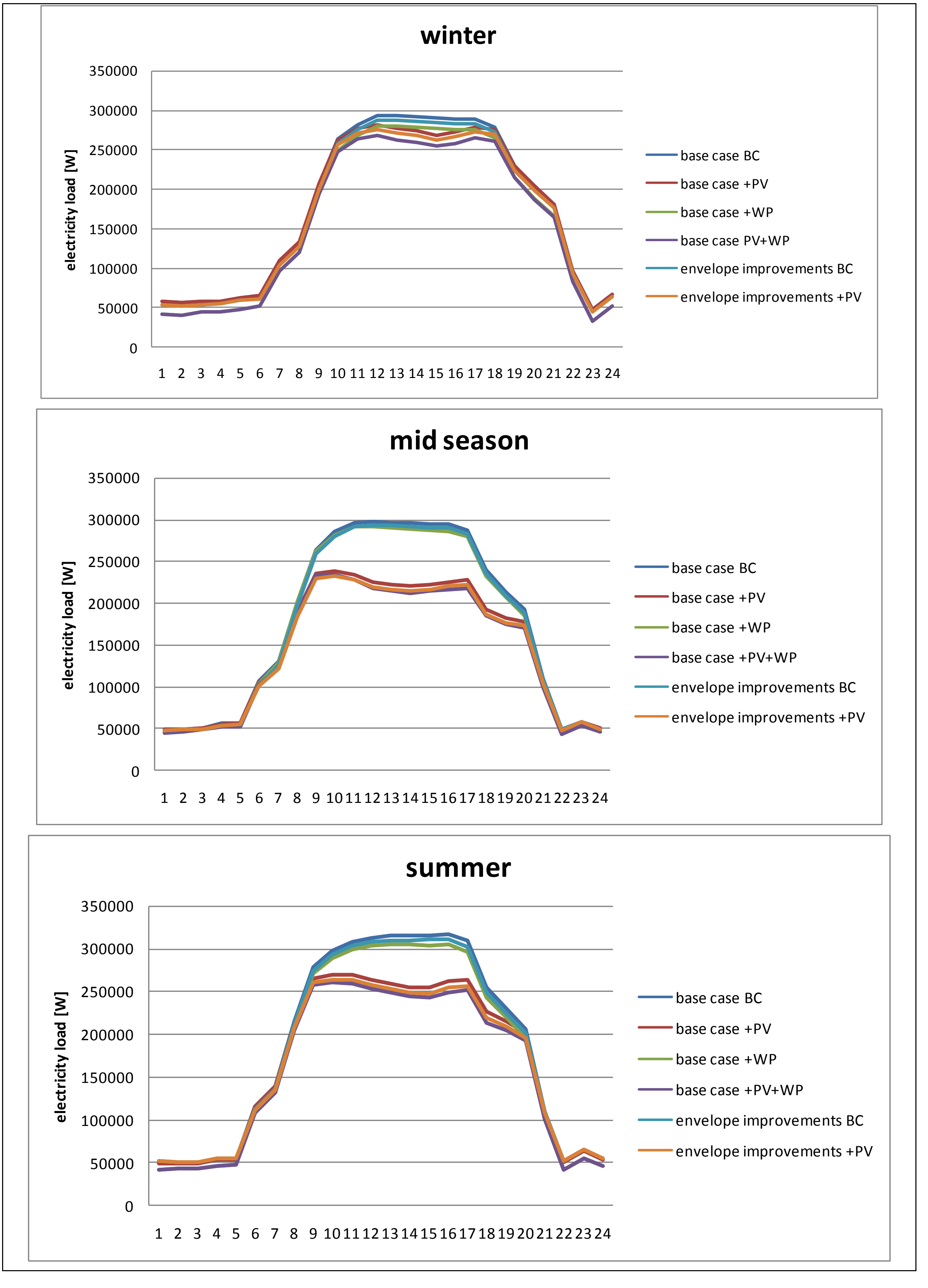
If we compare these values with the ones obtained only using the PV, we can see that the values do not present significant differences.

Summary

		Base case (BC)			Envelope improvements (EN)
		+PV	+WP	+PV+WP	+PV
LMavg	winter	2%	13%	14%	2%
	Mid-season	7%	8%	15%	7%
	summer	10%	4%	14%	10%
GI	winter	34%	36%	36%	35%
	Mid-season	33%	36%	33%	33%
	summer	35%	37%	35%	34%

Grid Interaction improvement

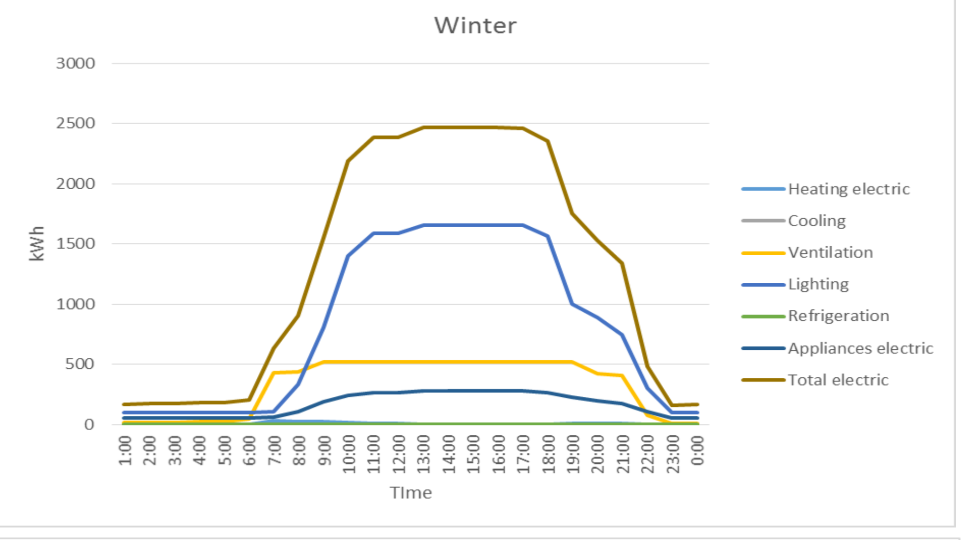
Season	BC + PV	BC + WP	BC + EN	BC+ PV + WP	BC + EN + PV
Winter	0%	-2%	0%	-1%	0%
Mid – season	3%	0%	0%	3%	3%
Summer	1%	-1%	0%	0%	1%

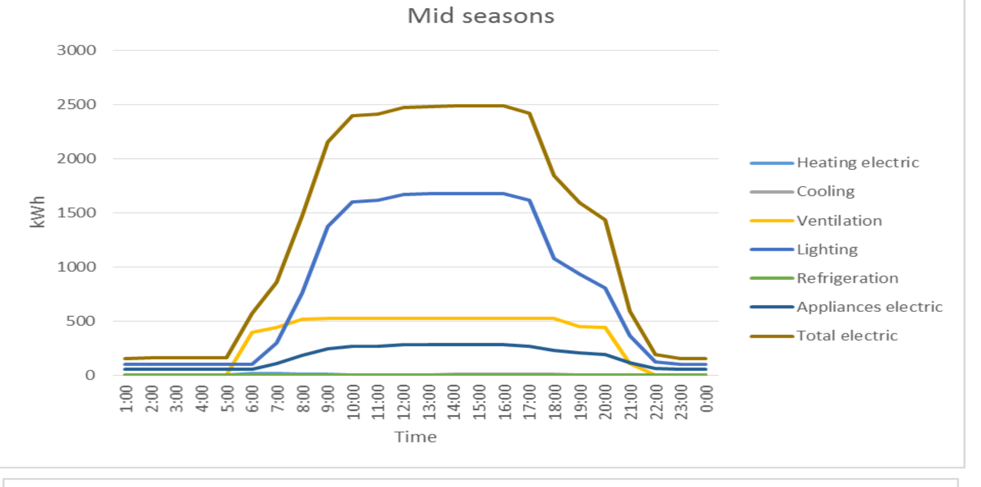

winter
electricity load [W]
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case PV+WP
envelope improvements BC
envelope improvements +PV
mid season
electricity load [W]
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +PV+WP
envelope improvements BC
envelope improvements +PV
summer
electricity load [W]
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +PV+WP
envelope improvements BC
envelope improvements +PV

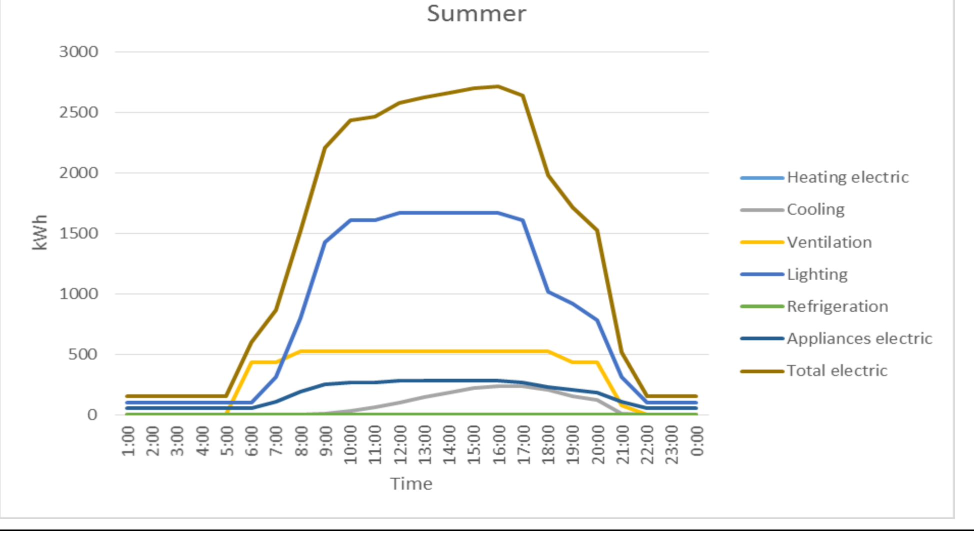
4.8 Reference SC in ST NIKLAAS based on WAASLAND

LOAD PROFILES (BASE CASE)

Total Surface: 60,700 m^2 (no supermarket)







The grid interaction is 40% in winter and summer and 41% in mid-seasons.

POTENTIALS

- The electricity demand of shopping malls in St Niklaas is mainly due to lighting and appliances and HVAC. This gives an idea in where the potential lies to reduce the electricity consumption of the shopping centre.
- The demand profile shows a clear correlated character with the timetable during the working hours. Thus, the highest values are produced from 9:00 to 16:00, although there is a minimum consumption mainly due to lighting and appliances outside working hours.
- There are no renewable systems for the electricity generation connected to the distribution grid of the market which affect regulations regarding the renewable installation typical to each distribution line.
- The urban environment and the presence of mainly low-rise buildings in the surroundings favour the installation of the photovoltaic and possibly wind turbines.

SOLUTIONS

On-site RES

Installation of a photovoltaic system which could be placed over the roof and oriented horizontal. Anyway, without caring the final placement, the photovoltaic generation profile is suitable for the demand profile of the building because the photovoltaic generation peaks coincide with the market demand peaks.

Below there are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity from the grid will be reduced.

Mini-wind system, in combination with the photovoltaic, minimizes the electrical consumption. It is important to note, this system presents great troubles with the installation both at aesthetic level and urban environment noise. Therefore, although from the energy point of view it is feasible; from the functional one it is almost discarded.

Photovoltaic installation

For St Niklaas, an installation of photovoltaic modules with a power density of 112 W/m^2 has been considered. The installed power was assumed to 3500kWp.

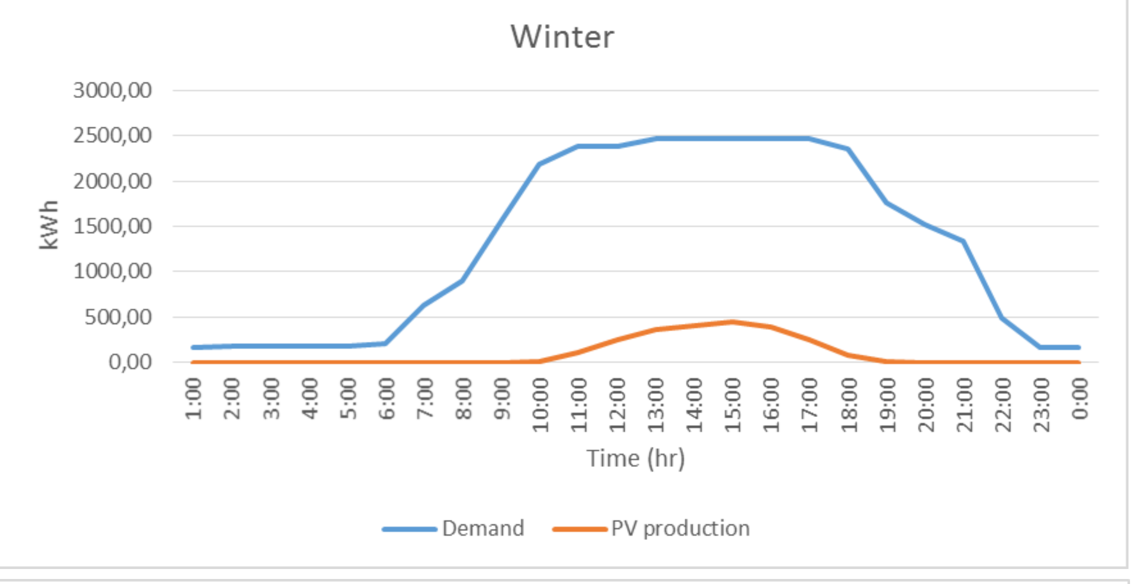
For the simulation in TRNSYS of the photovoltaic installation, a surface free of shadows of approximately 31300 m^2 has been considered, with a deviation of 0 degrees towards the South.

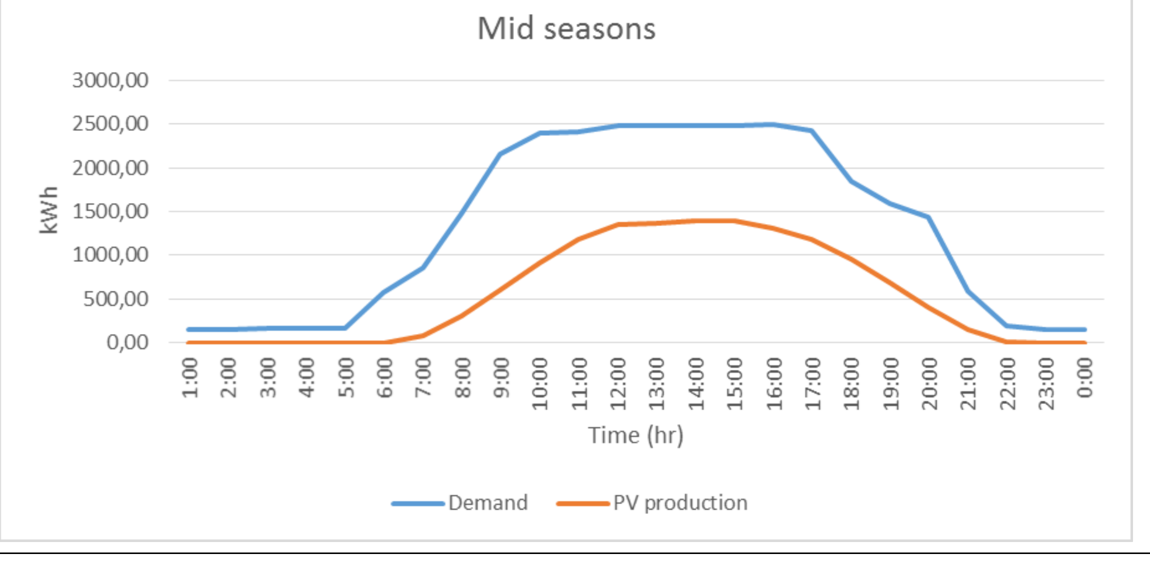
Table 0 shows the results for the hourly energy production for the different seasons:

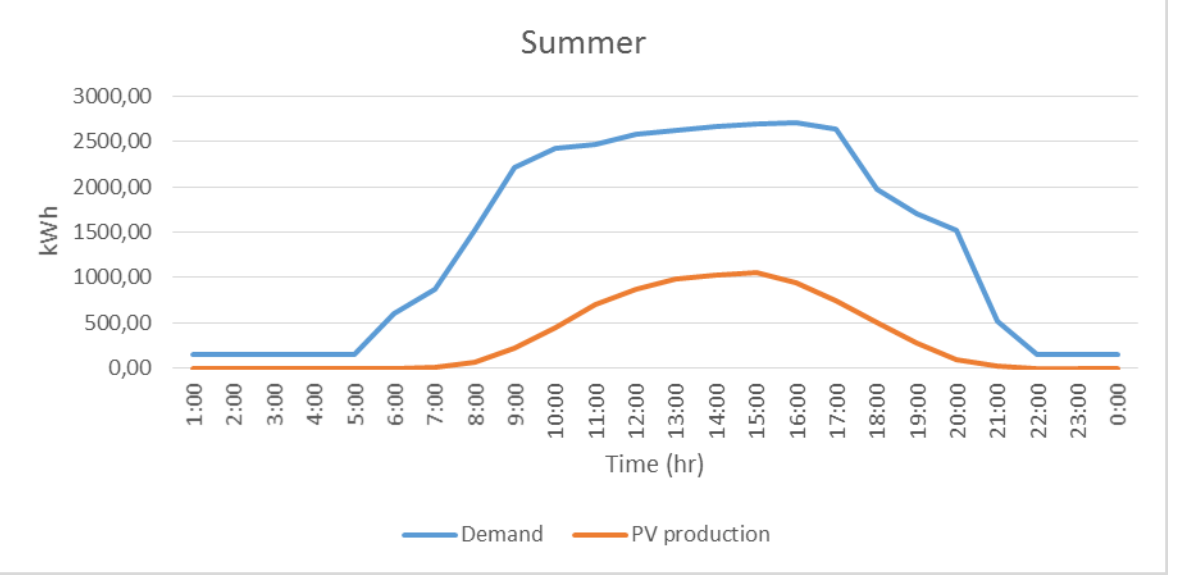
Table 20: Hourly energy production in kWh by season for the photovoltaic installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.04	110.94	245.00
Summer	0.00	0.00	0.00	0.00	0.00	0.00	12.18	72.58	228.17	452.99	700.66	877.52
Mid-season	0.00	0.00	0.00	0.00	0.00	0.06	76.93	300.77	603.54	919.37	1179.81	1351.23
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	361.25	402.93	452.10	385.02	245.54	86.76	10.43	0.00	0.00	0.00	0.00	0.00
Summer	979.22	1032.52	1061.03	941.59	742.15	505.96	276.62	99.75	19.57	0.17	0.00	0.00
Mid-season	1359.67	1393.93	1389.99	1316.14	1181.39	949.12	689.36	405.88	155.95	8.86	0.00	0.00

By overlapping the PV production (according to 3500kWp) with the load profile curves for the different seasons developed before, we obtain the following figures:







With these values we obtain that the load match during the winter days is approximately 7.2%, 26% during mid-seasons and 45% in the summer. The grid interaction that indicates the variability in the import from the grid is 36% for winter, 28% for mid-season and 26% in the summer.

Wind Power installation

A wind power installation has also been considered with a low power turbine of 150 kW, which allows its easy energetic integration in the system as well as its operation with low wind velocities.

Figure 8 shows the evolution of the power produced by the wind turbine through simulation in TRNSYS. It is possible to appreciate how it is not possible to reach the highest power and how there is a large variation in the power from one day to another.

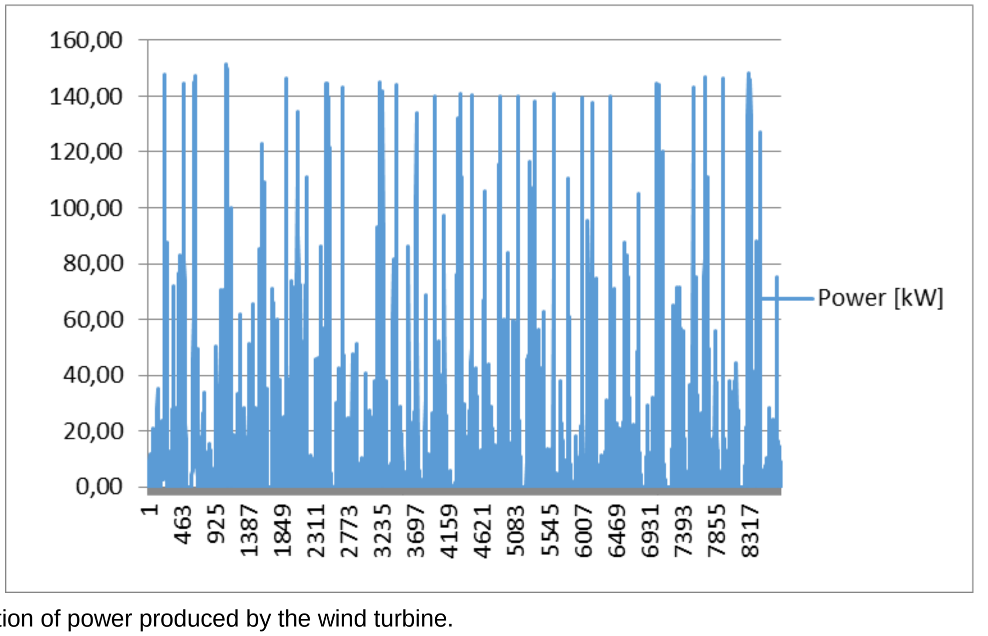


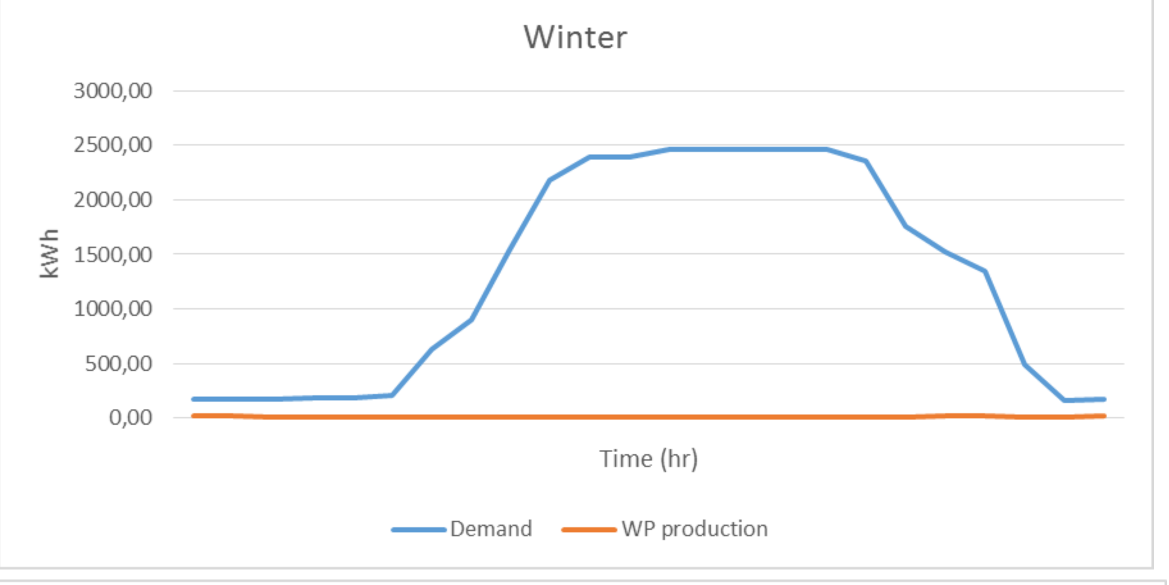
Figure 8: Evolution of power produced by the wind turbine.

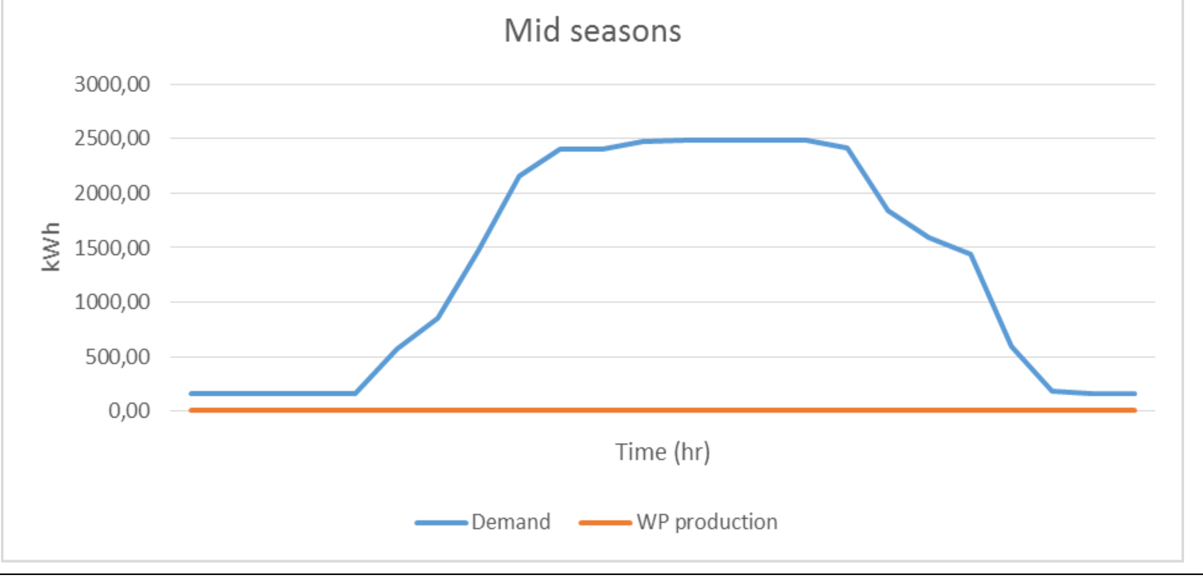
Table 11 shows the results for the hourly energy production for the different seasons:

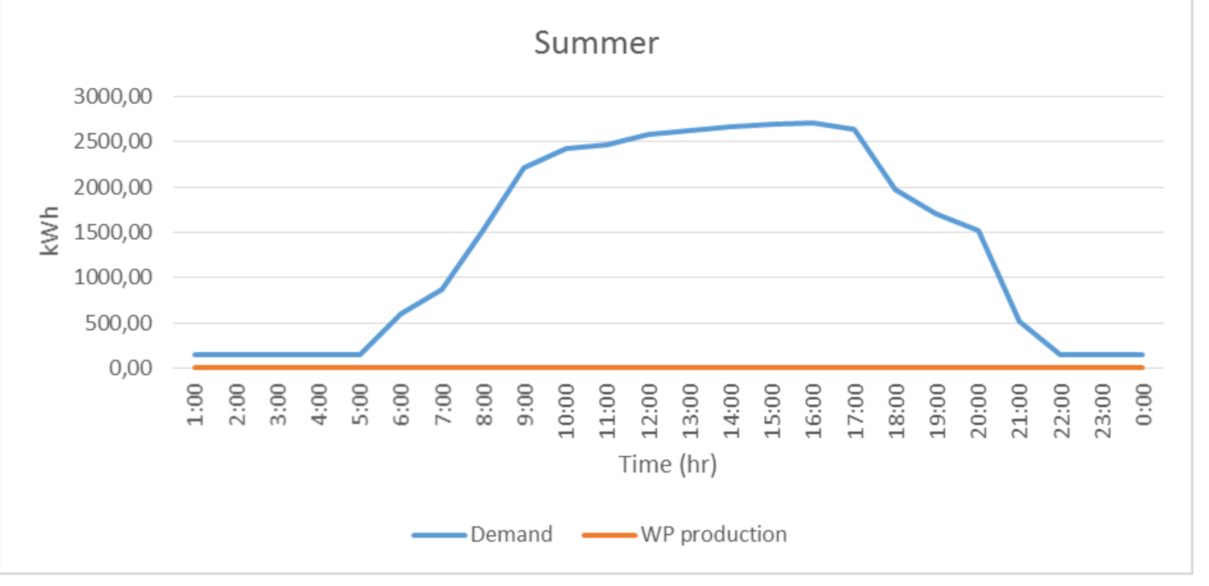
Table 11: Hourly energy production in kWh by season for the wind power installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	15.50	15.55	12.64	13.92	13.65	12.87	12.28	11.39	12.50	13.75	12.69	11.96
Summer	9.39	8.49	7.01	8.52	8.03	9.82	9.47	9.28	9.66	10.09	10.20	9.91
Mid-season	6.38	5.67	4.88	6.77	7.53	5.62	3.33	3.04	4.02	5.52	6.84	6.58
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	13.15	13.31	13.26	13.73	12.65	13.64	14.34	15.59	15.31	13.88	14.34	14.83
Summer	9.02	9.30	11.02	10.55	10.69	10.87	9.81	9.93	9.17	9.57	8.62	8.78
Mid-season	6.68	7.46	7.58	8.67	8.98	8.00	9.25	10.65	9.87	8.17	8.36	8.44

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons we obtain the following figures:



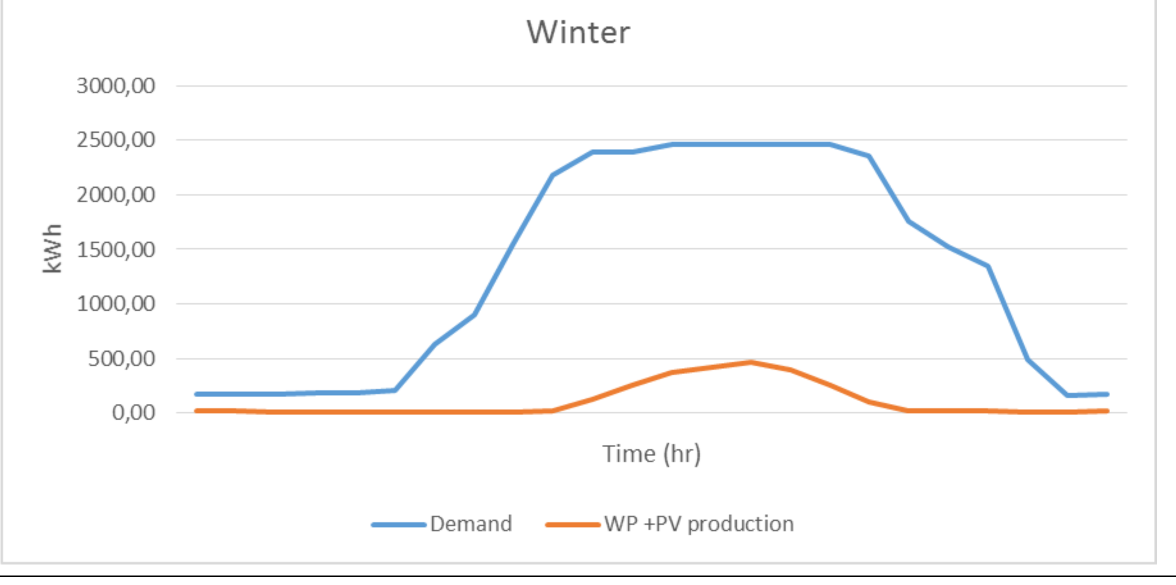


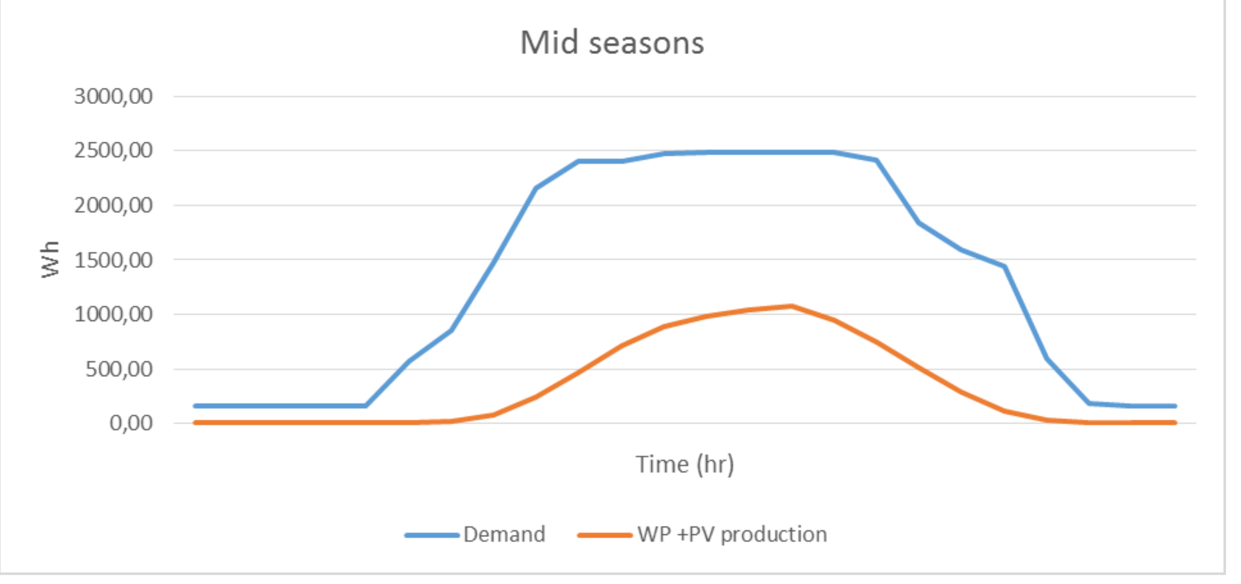


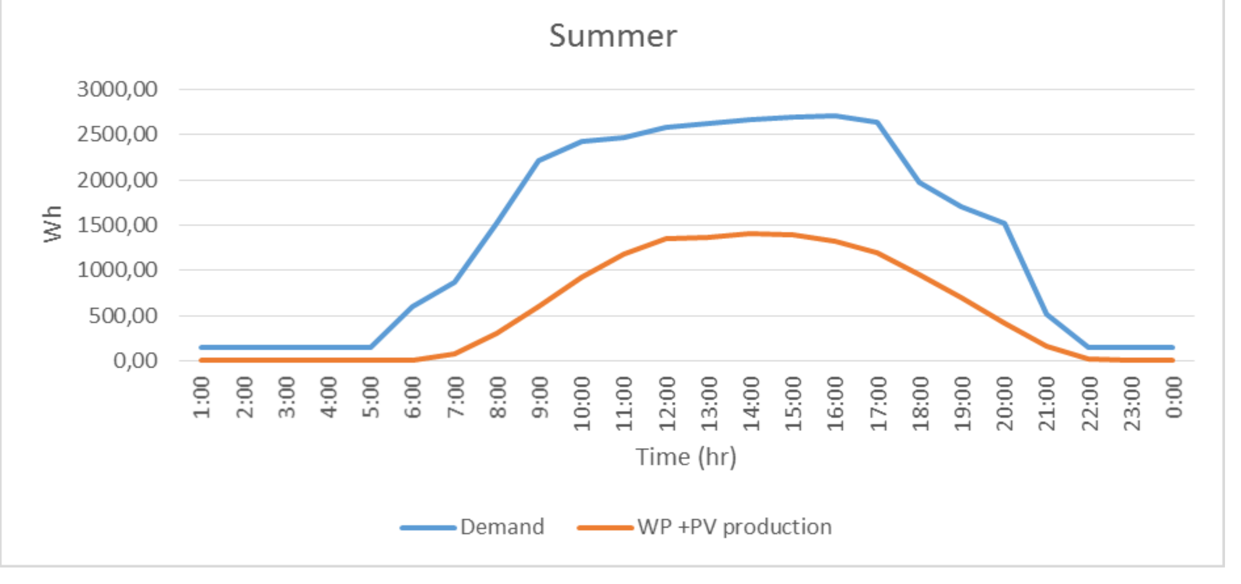
With these values we obtain that the load match for winter of 3%, a 2% in mid-season and in summer respectively. The Grid Interaction is 41% in winter and mid-season, and 40% in summer.

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time we obtain the following figures:







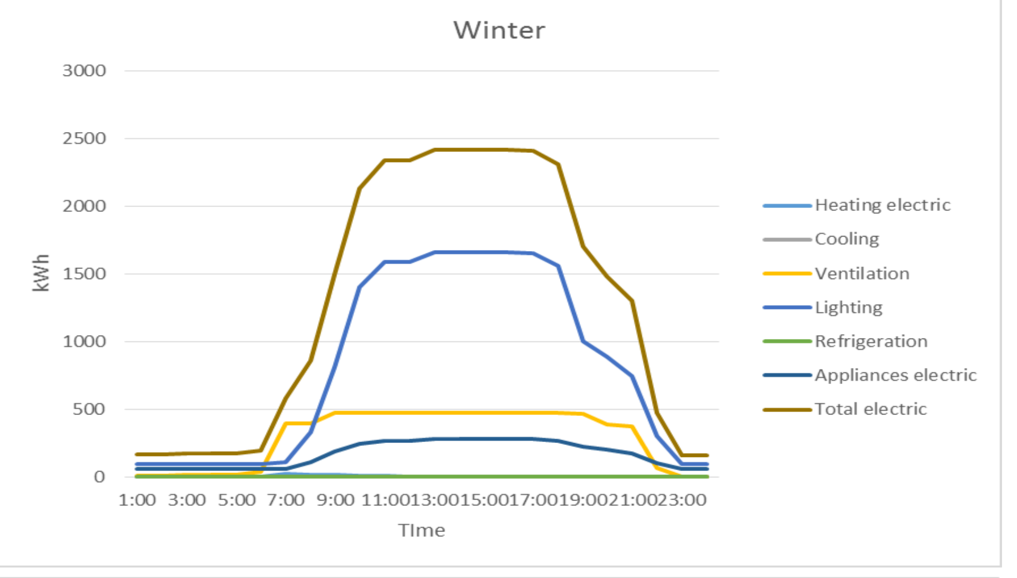
In this case, the load match is increased to 7% in winter, 17% in mid-seasons and 27% in summer, concerning the interaction with the grid the values are 39% in winter, 35% in mid seasons and 34% in summer.

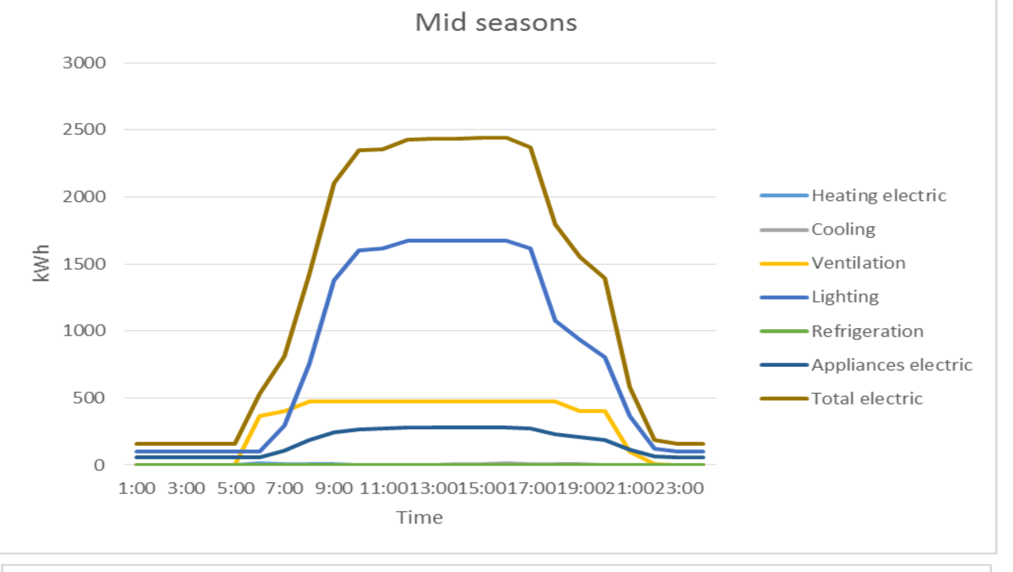
Energy saving

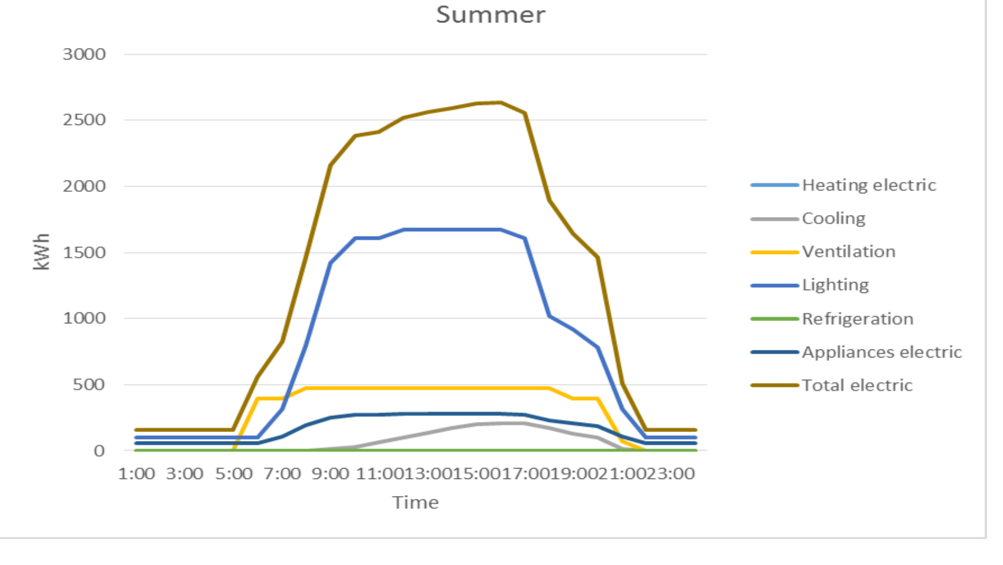
Envelope

Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, taking into account the HVAC systems are electrical ones, because the losses could be decreased.

If improvements in the envelope are included in this building, we obtain the following load profiles:


Winter
3000
2500
2000
1500
1000
500
0
kWh
1:00 3:00 5:00 7:00 9:00 11:0013:0015:0017:0019:0021:0023:00
TIme
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric


Mid seasons
3000
2500
2000
1500
1000
500
0
kWh
1:00 3:00 5:00 7:00 9:00 11:0013:0015:0017:0019:0021:0023:00
Time
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

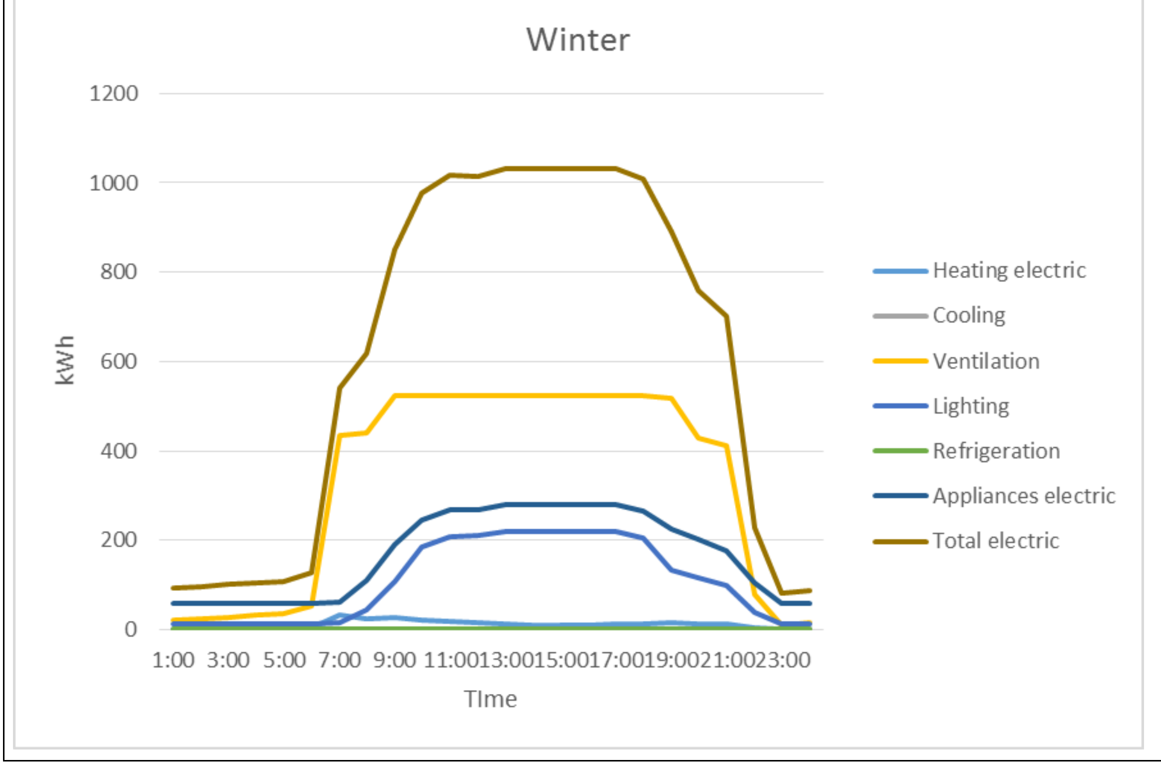

Summer
3000
2500
2000
1500
1000
500
0
kWh
1:00 3:00 5:00 7:00 9:00 11:0013:0015:0017:0019:0021:0023:00
Time
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

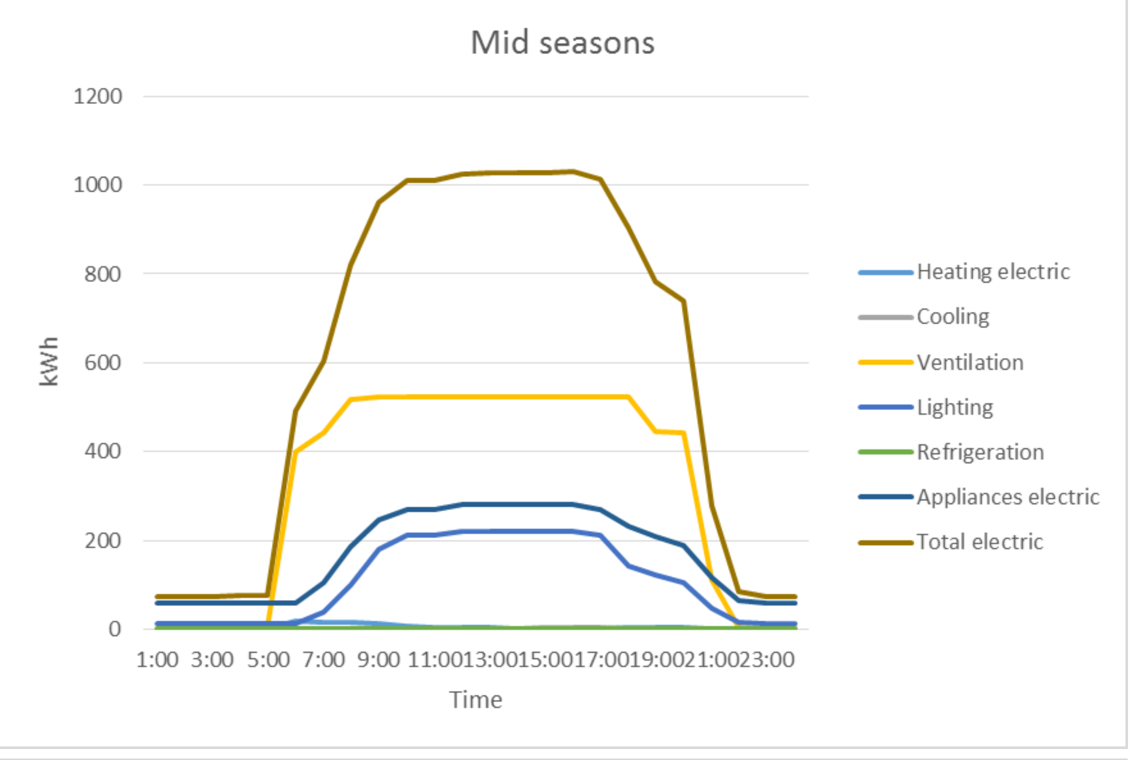
The improvements which have been included are the ones selected through PHPP simulations in D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems to not have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

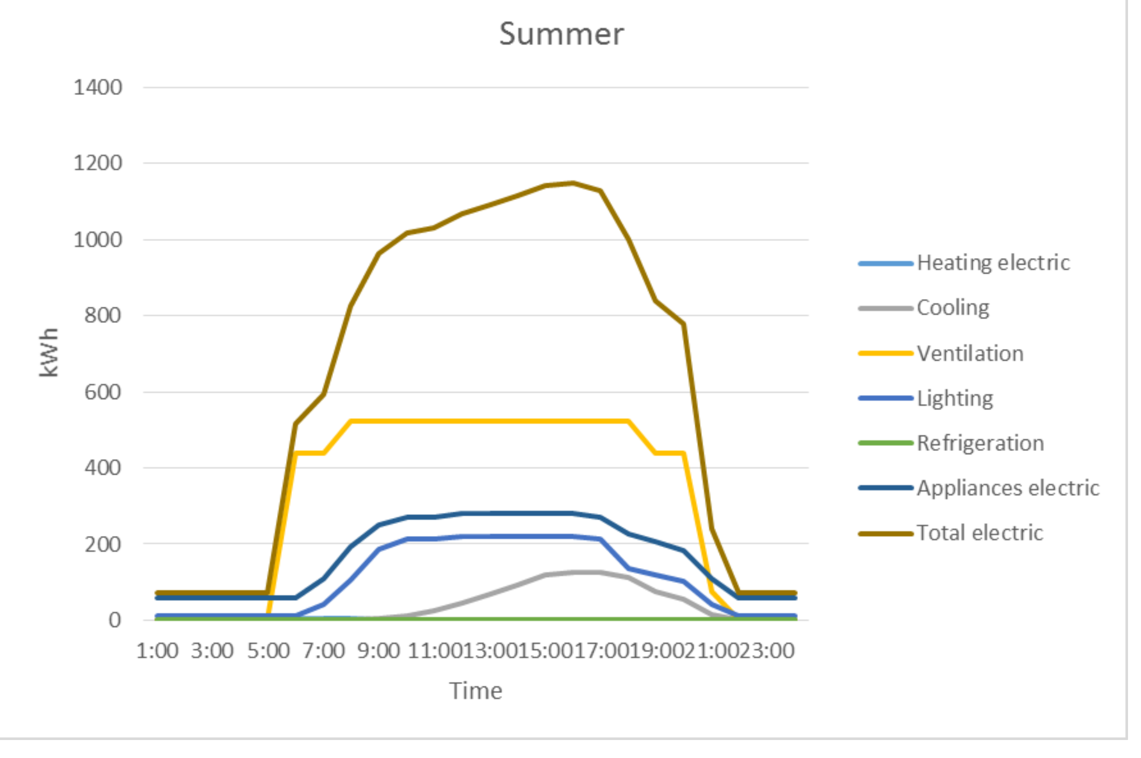
Lighting

Existing luminaries and lighting systems stand in for new equipment more efficient and with higher performance. The installation of electrical ballast and control equipment for the luminosity which allow dimmer regulation so as to adjust the lux level according to the indoor and outdoor conditions, as well as the comfort parameters in order to decrease the consumption when enough daylight.

The improvements in terms of lighting are shown in the following load profiles, this improvements are also based on PHPP simulations developed in D2.5 taken the most effective solution in terms of energy efficiency (From D2.5: V1, Reduce light density to 3 W/m^2 for common areas (and others) and 4.5 W/m^2 in shops).



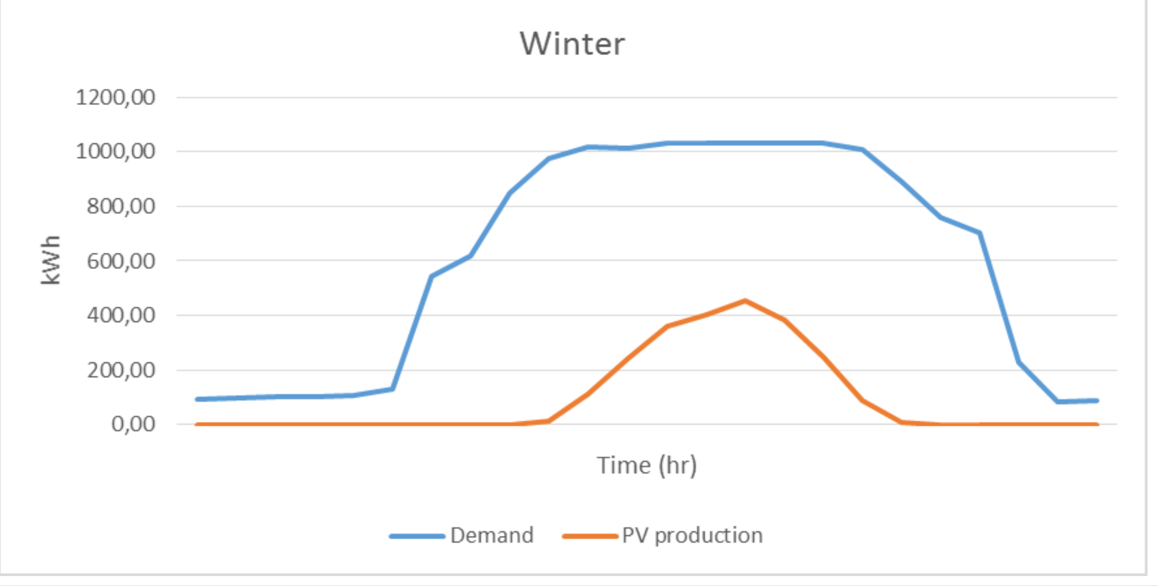


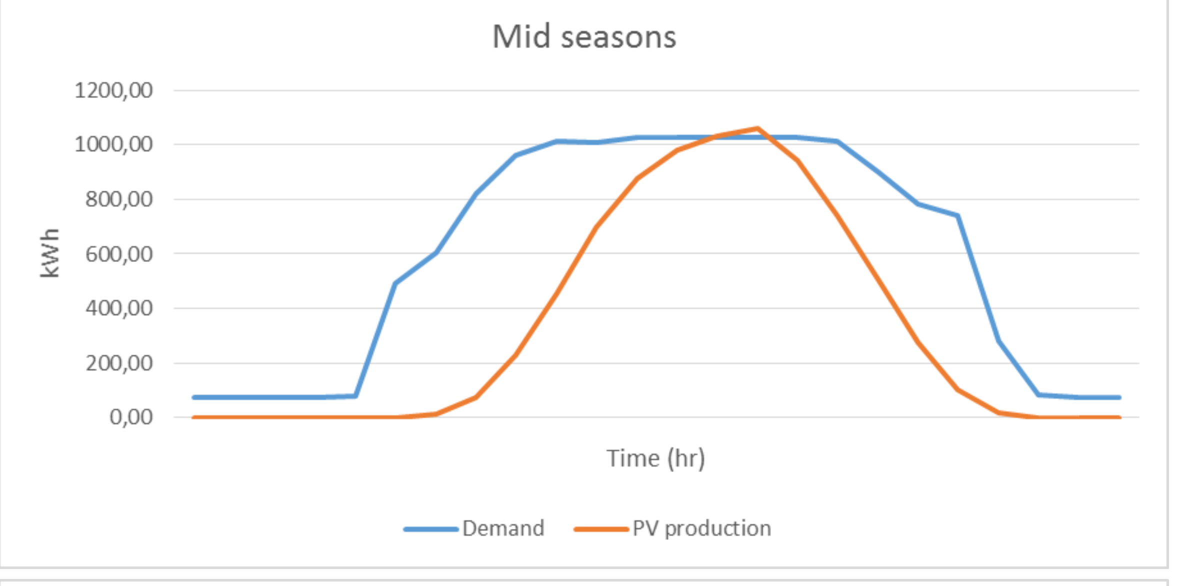


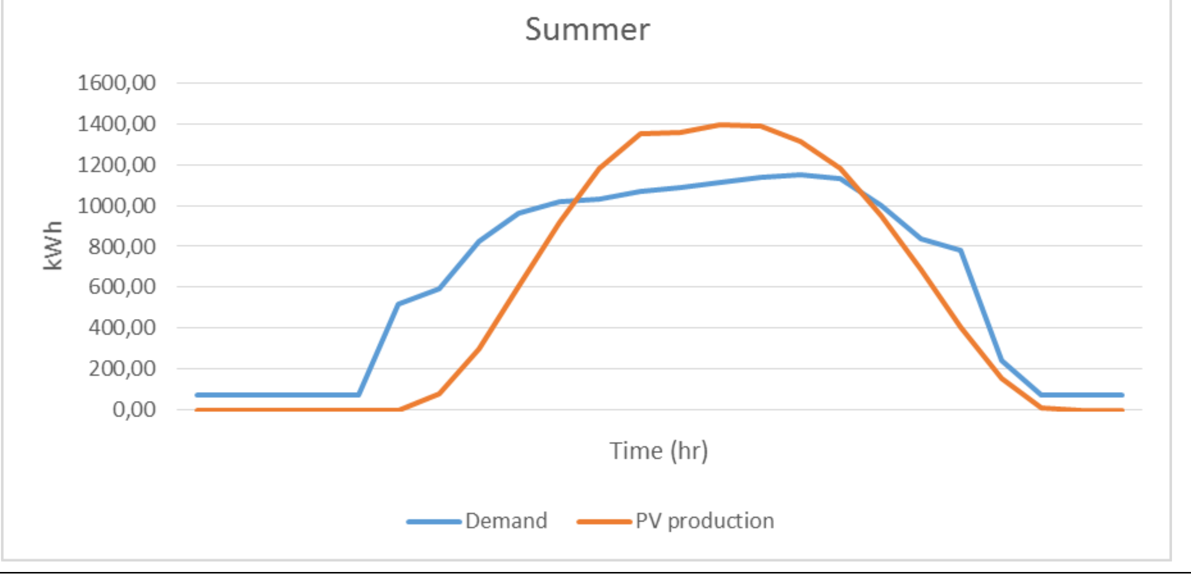
In this case, the grid interaction is reduced to 40% in winter, and 41% in mid-season and 39% in summer with the improvement in terms of lighting.

Lighting + PV

As the lighting solution seems to be a suitable solution, the idea is to combine it with the PV solution proposed before in order to calculate a new load match index.


Winter
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
PV production


Mid seasons
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
PV production


Summer
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
kWh
Time (hr)
Demand
PV production

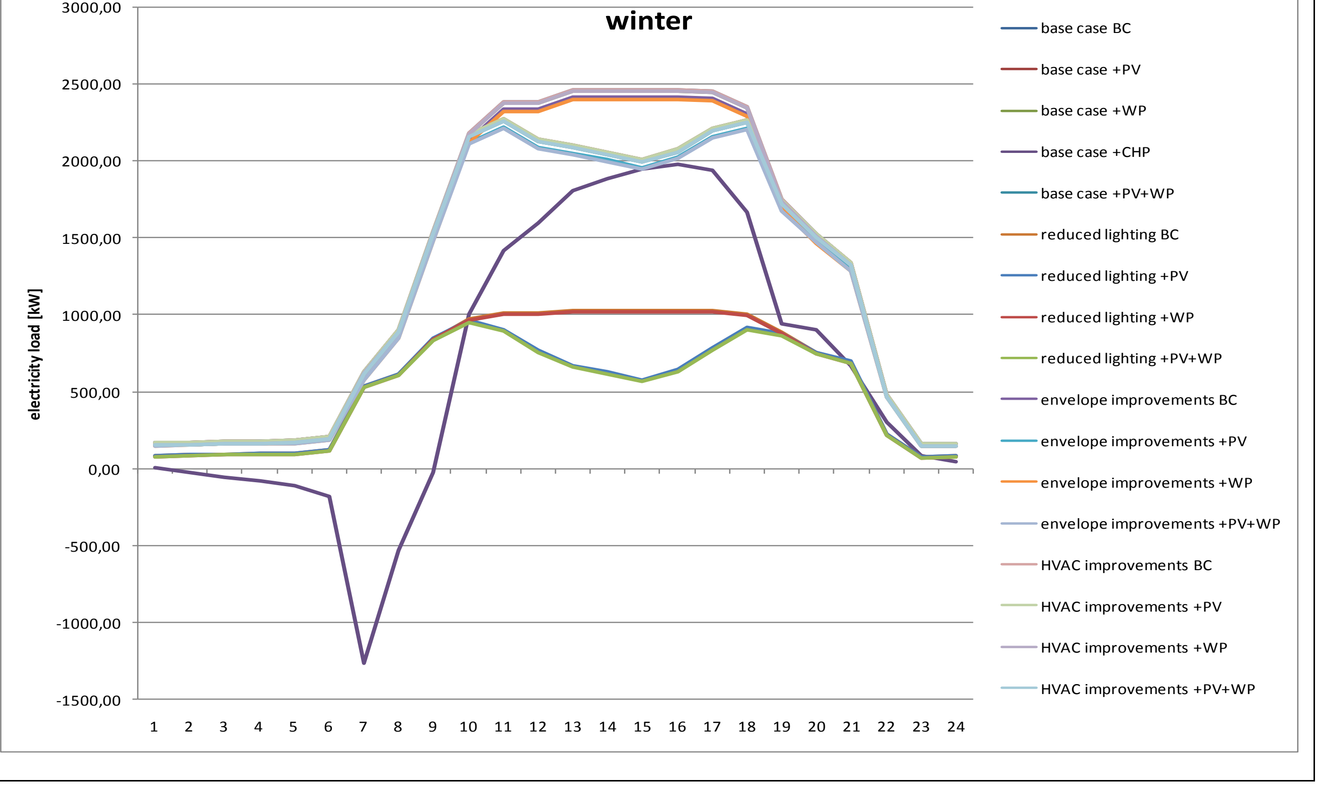
With these values we obtain that the load match during the winter days is approximately 15%, 38% during mid-seasons and 60% in the summer days. The grid interaction is 35% for winter, 34% for mid-seasons, and 47% for summer.

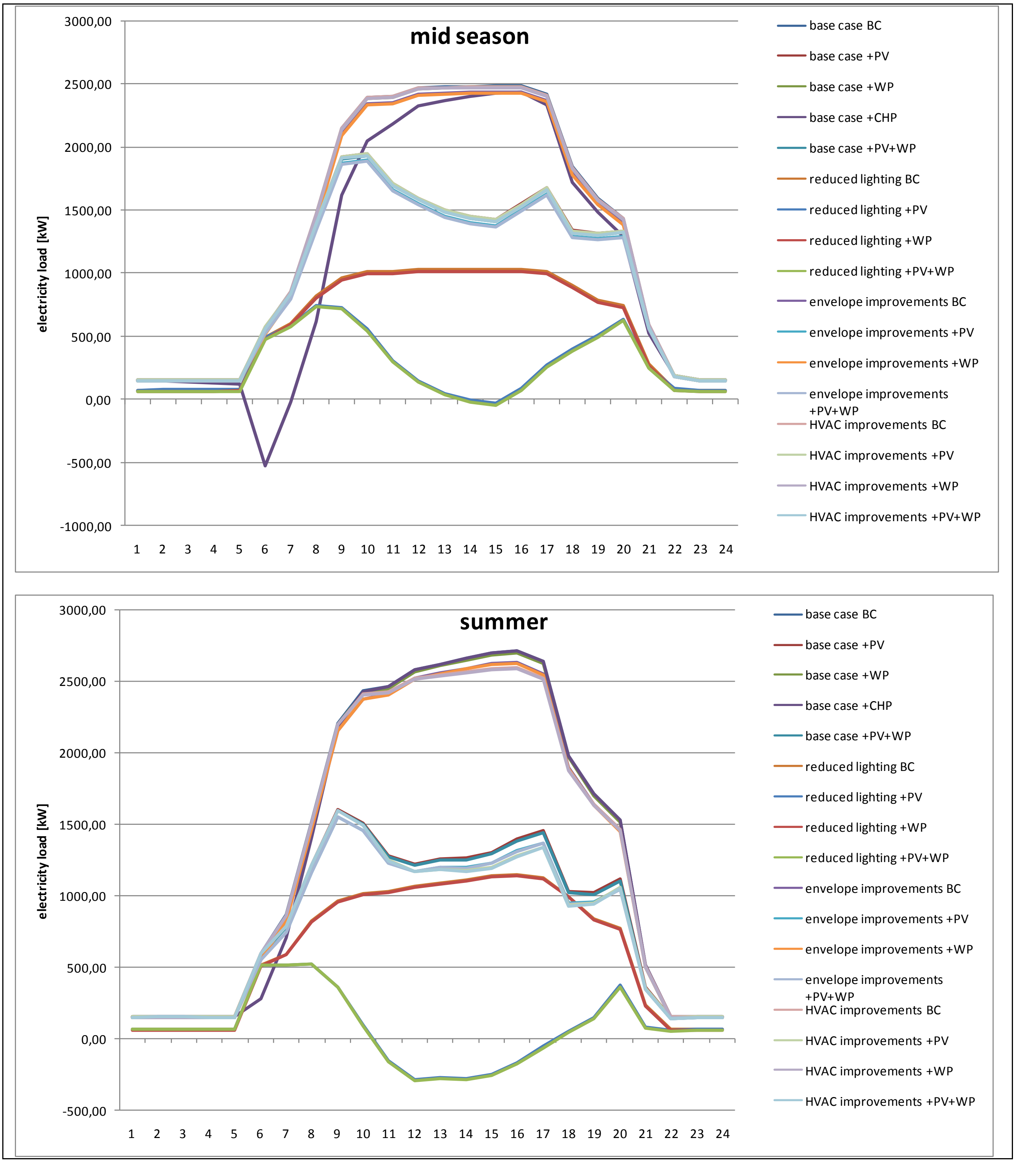
Summary

		Base case (BC)			Reduced lighting (LG)		Envelope improvements (EN)		HVAC improvements	
		+PV	+WP	+CHP	+PV	+PV+WP	+PV	+PV+WP	+PV	+PV+WP
LMavg	winter	3.9 %	3.3 %	81.1 %	9.4 %	15.4 %	4.0 %	7.4 %	3.9 %	7.2 %
	Mid-season	14.5 %	2.2 %	3.5 %	33.8 %	38.4 %	26.5 %	28.3 %	25.9 %	27.7 %
	summer	24.8 %	1.8 %	22.1 %	55.9 %	59.8 %	14.0 %	16.3 %	14.1 %	16.4 %
GI	winter	38.8 %	40.5 %	47.4 %	34.4 %	34.9 %	38.9 %	39.1 %	38.8 %	39.1 %
	Mid-season	34.7 %	40.7 %	42.4 %	33.7 %	34.1 %	34.5 %	34.6 %	34.6 %	34.8 %
	summer	34.3 %	39.9 %	40.3 %	46.6 %	47.1 %	33.6 %	33.7 %	32.7 %	32.8 %

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + LG	BC + EN	BC + HVAC	BC + PV + WP	BC + CHP	BC + LG + PV	BC + LG + PV + WP	BC + EN + PV	BC + EN + PV + WP	BC + HVAC + PV	BC + HVAC + PV + WP
Winter	1.5 %	-0.2 %	0.3 %	-0.1 %	0.0 %	1.2 %	-7.1 %	5.9 %	5.4 %	1.4 %	1.2 %	1.5 %	1.2 %
Mid – season	5.9 %	-0.1 %	-0.3 %	0.0 %	0.0 %	5.7 %	-1.9 %	6.9 %	6.5 %	6.1 %	5.9 %	5.9 %	5.8 %
Summer	5.5 %	-0.1 %	0.3 %	-0.1 %	-0.4 %	5.4 %	-0.5 %	-6.9 %	-7.3 %	6.2 %	6.1 %	7.1 %	7.0 %

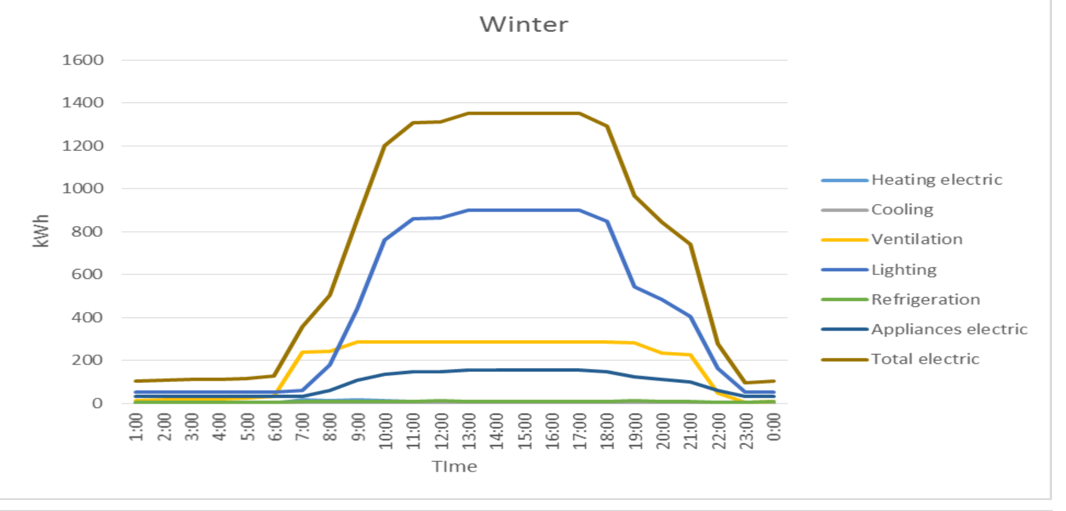


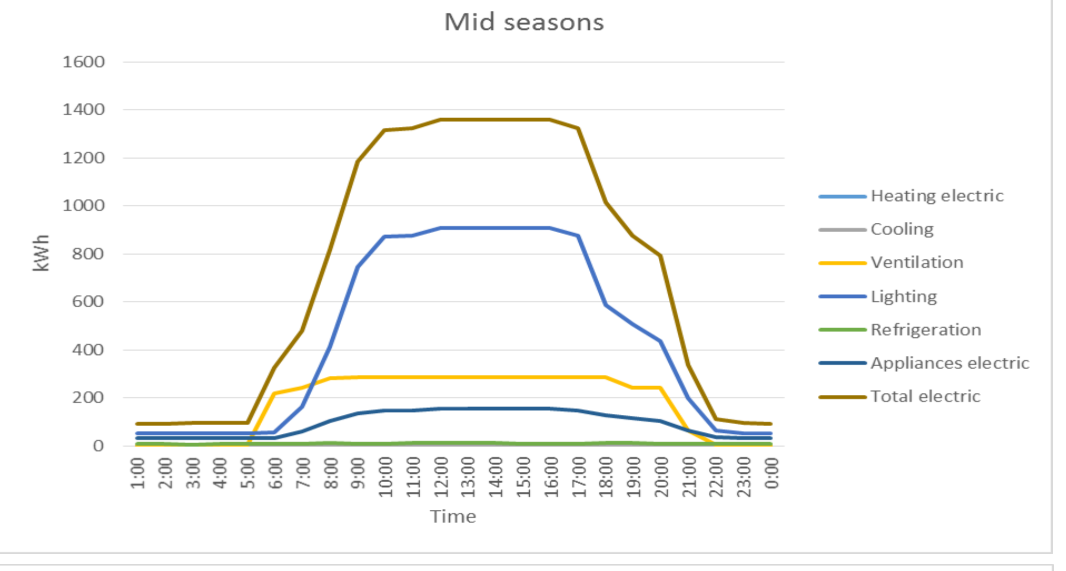

mid season
summer
electricity load [kW]
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
-500,00
-1000,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

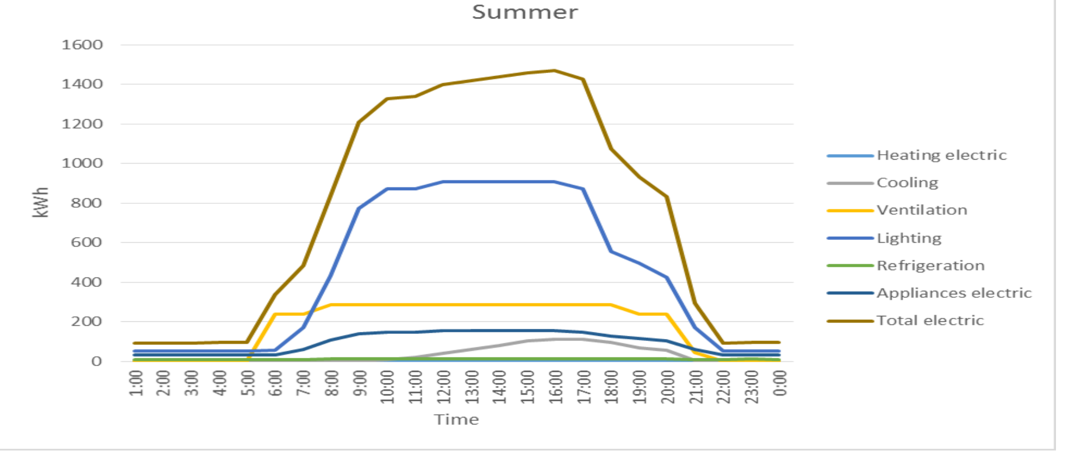
4.9 Reference SC in ANTWERP based on GRAND BAZAR

LOAD PROFILES (BASE CASE)

Total Surface: 33,000 m² (Supermarket area: 362 m²)







The grid interaction is 40% in winter, summer, and mid-season respectively.

POTENTIALS

- The electricity demand of shopping malls in London is mainly due to the lighting, HVAC systems and the energy consumption of the refrigerators used for the products' conservation.
- It is possible to install a PV system on the roof. Here, it is assumed that 9,000 m^2 can be covered with horizontal PV modules. This is done to be able to evaluate if a photovoltaic generation profile is suitable for the demand profile of the building i.e. the photovoltaic generation peaks coincide with the market demand peaks.
- It might be possible to install a wind turbine system, due to the surface available on the roof (~ 33,000 m^2).

SOLUTIONS

On-site RES

Installation of a photovoltaic system which could be placed over the roof and oriented to the South-East.
Mini-wind system, in combination with the photovoltaic, minimises the electrical consumption.

Below there are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity will be reduced.

Photovoltaic installation

For St Niklas an installation of photovoltaic modules with a power density of 112 W/m^2 has been considered. The installed power was assumed to 1000kWp.

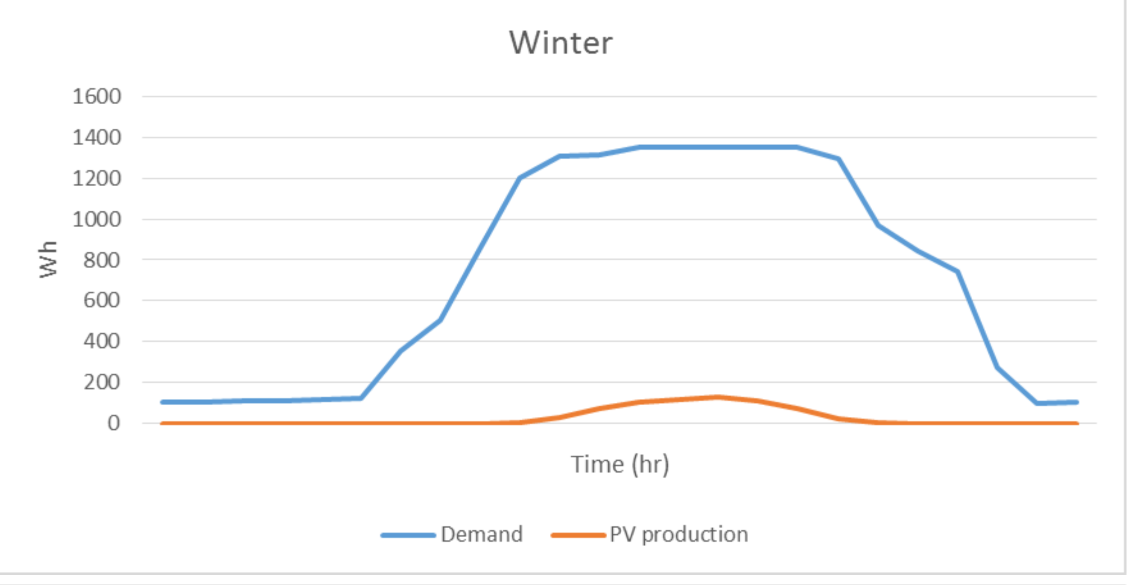
For the simulation in TRNSYS of the photovoltaic installation, has been considered a surface free of shadows of approximately 9000 m^2, with a deviation of 0 degrees respect to the South.

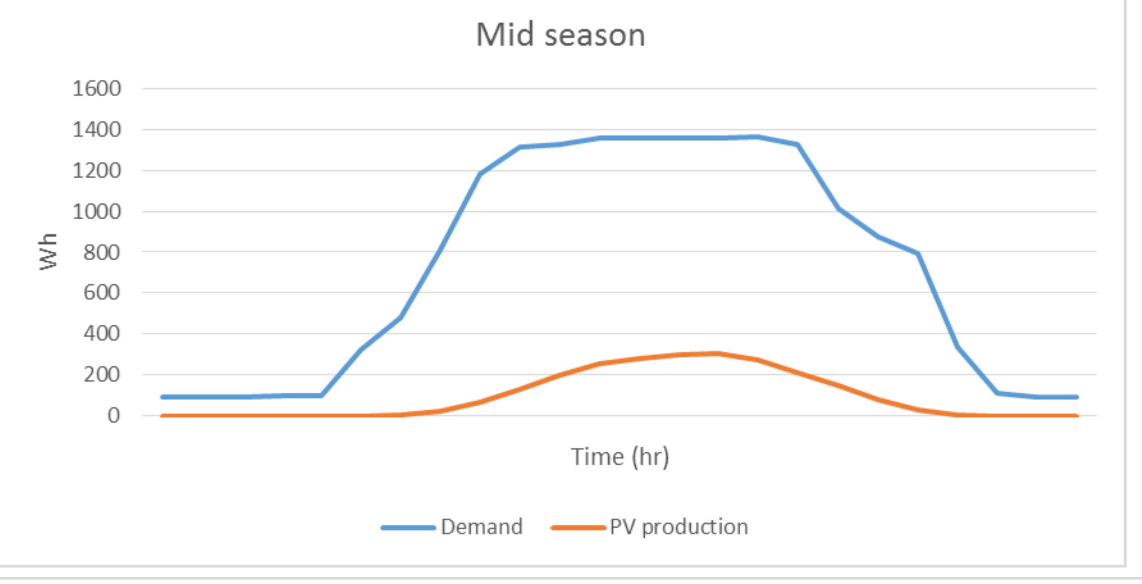
Table 12 shows the results for the hourly energy production for the different seasons:

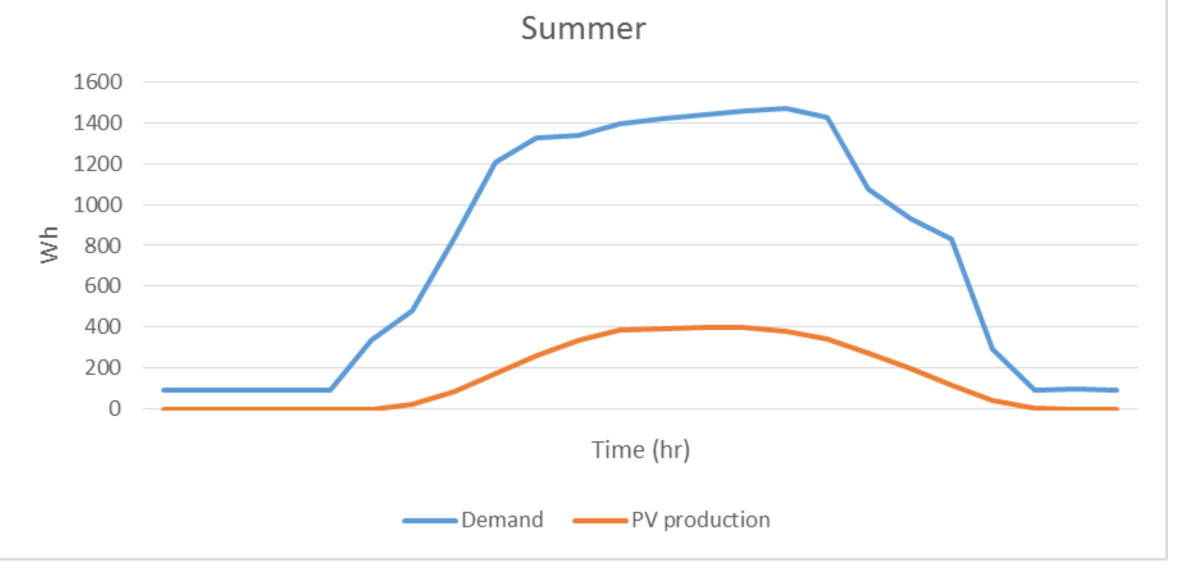
Table 32: Hourly energy production in kWh by season for the photovoltaic installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.17	31.90	70.45
Summer	0.00	0.00	0.00	0.00	0.00	0.00	3.50	20.87	65.61	130.25	201.47	252.32
mid season	0.00	0.00	0.00	0.00	0.00	0.02	22.12	86.48	173.54	264.36	339.24	388.53
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	103.87	115.86	130.00	110.71	70.60	24.95	3.00	0.00	0.00	0.00	0.00	0.00
Summer	281.57	296.89	305.09	270.75	213.40	145.48	79.54	28.68	5.63	0.05	0.00	0.00
mid season	390.96	400.81	399.68	378.44	339.70	272.91	198.22	116.71	44.84	2.55	0.00	0.00

By overlapping the PV production (according to 1000kWp) with the load profile curves for the different seasons developed before we obtain the following figures:







With these values we obtain that the load match during the winter days is approximately 2%, 8%

during mid-seasons and 13% in the summer. The grid interaction that indicates the variability in the import from the grid is 40% for winter, and 38% for mid-season and 39% in the summer.

Wind turbine installation

A wind power installation with a low power turbine of 150 kW has also been considered, which allows its easy energetic integration in the system as well as its operation with low wind velocities.

Figure 9 shows the evolution of the power produced by the wind turbine through simulation in TRNSYS. It is possible to appreciate how it is not possible to reach the highest power, with a large variation in the power from one day to another.

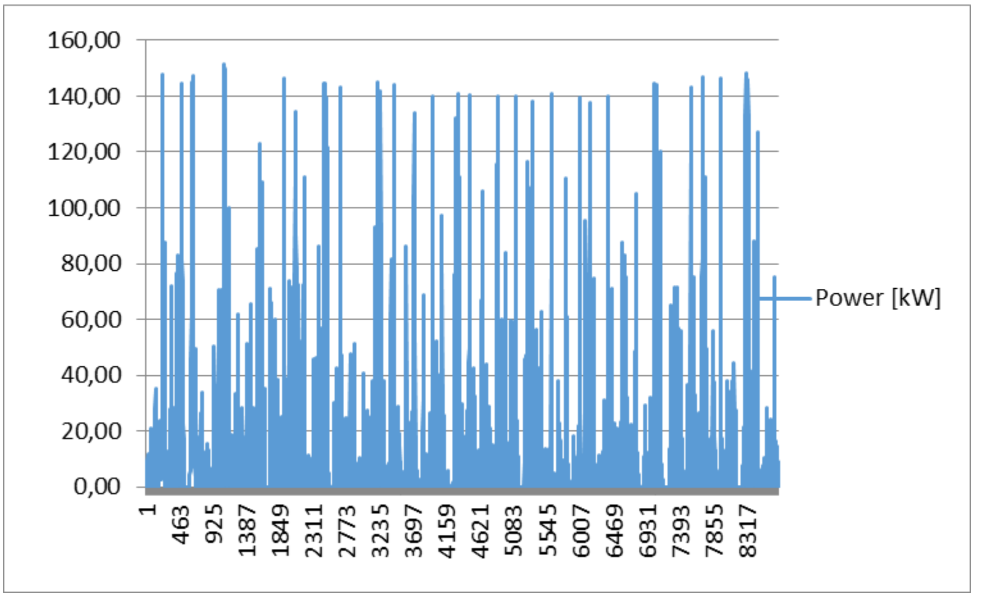


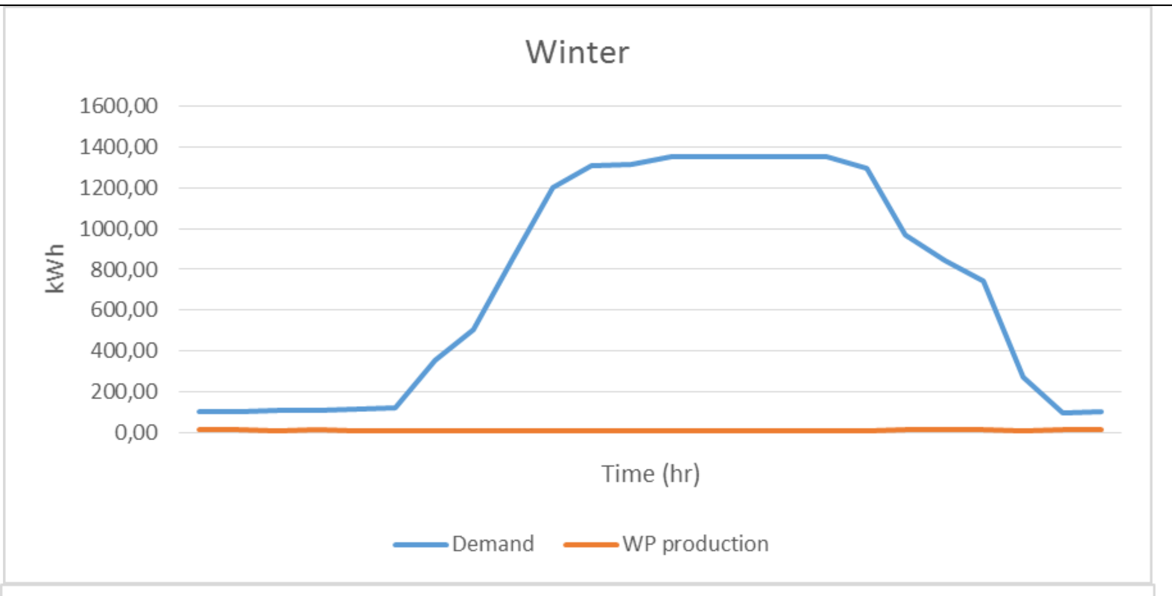
Figure 9: Evolution of power produced by the wind turbine.

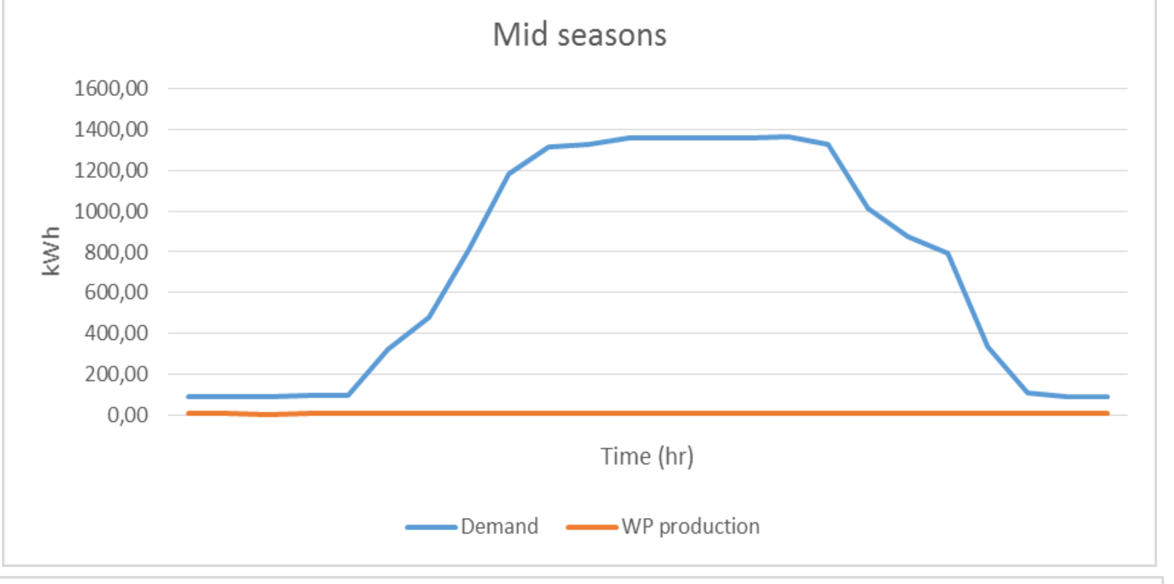
Table 13 shows the results for the hourly energy production for the different seasons:

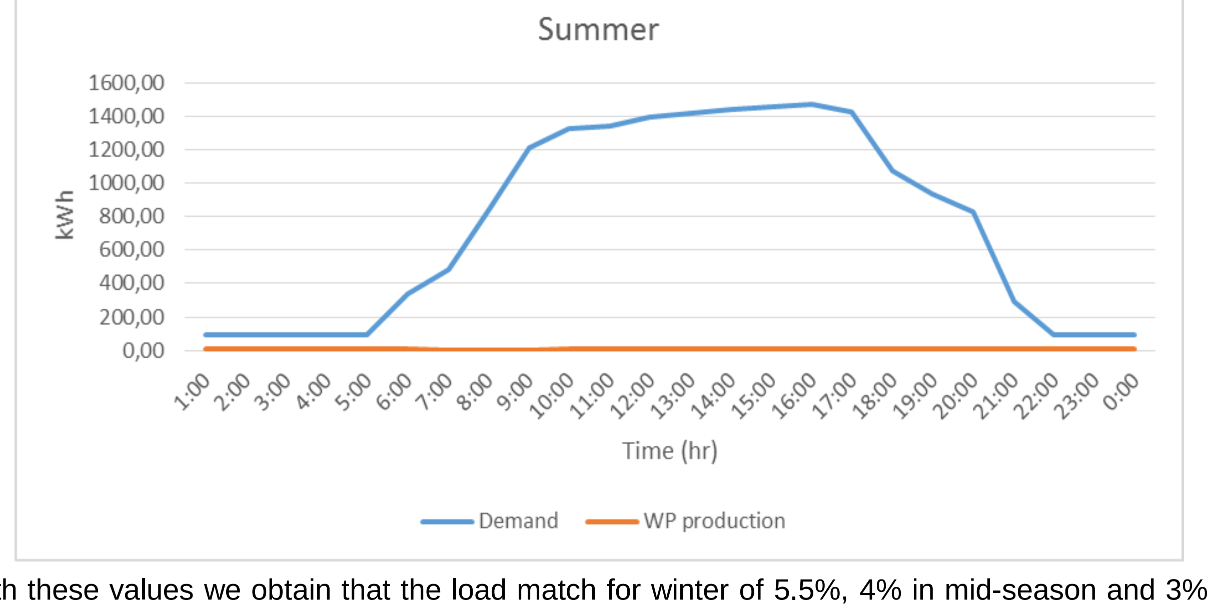
Table 13: Hourly energy production in kWh by season for the wind power installation

Time	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**	**12:00**
Winter	15.50	15.55	12.64	13.92	13.65	12.87	12.28	11.39	12.50	13.75	12.69	11.96
Summer	9.39	8.49	7.01	8.52	8.03	9.82	9.47	9.28	9.66	10.09	10.20	9.91
Mid-season	6.38	5.67	4.88	6.77	7.53	5.62	3.33	3.04	4.02	5.52	6.84	6.58
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	13.15	13.31	13.26	13.73	12.65	13.64	14.34	15.59	15.31	13.88	14.34	14.83
Summer	9.02	9.30	11.02	10.55	10.69	10.87	9.81	9.93	9.17	9.57	8.62	8.78
Mid-season	6.68	7.46	7.58	8.67	8.98	8.00	9.25	10.65	9.87	8.17	8.36	8.44

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons we obtain the following figures:



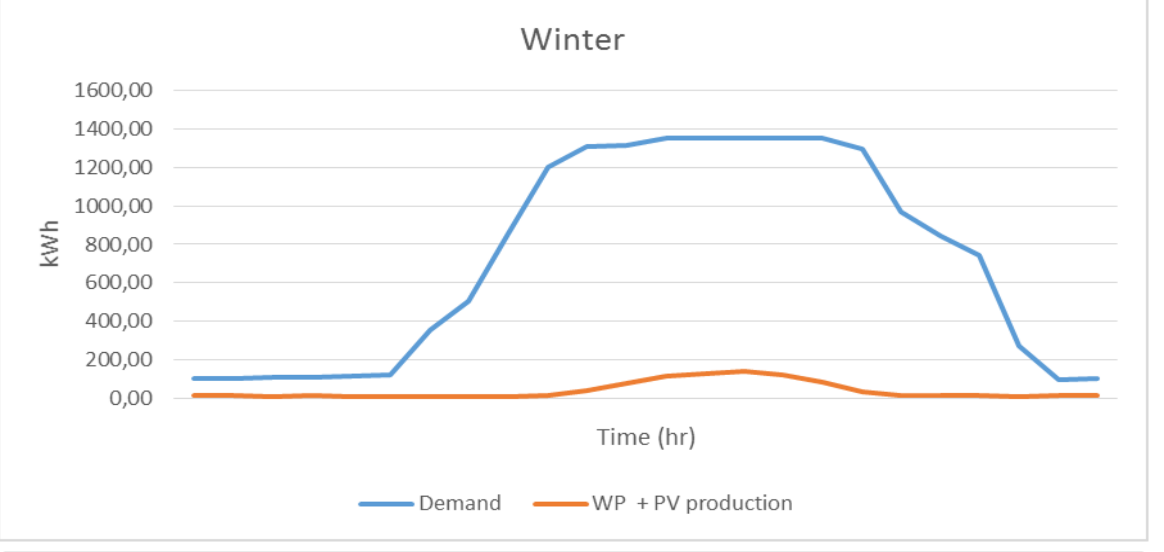


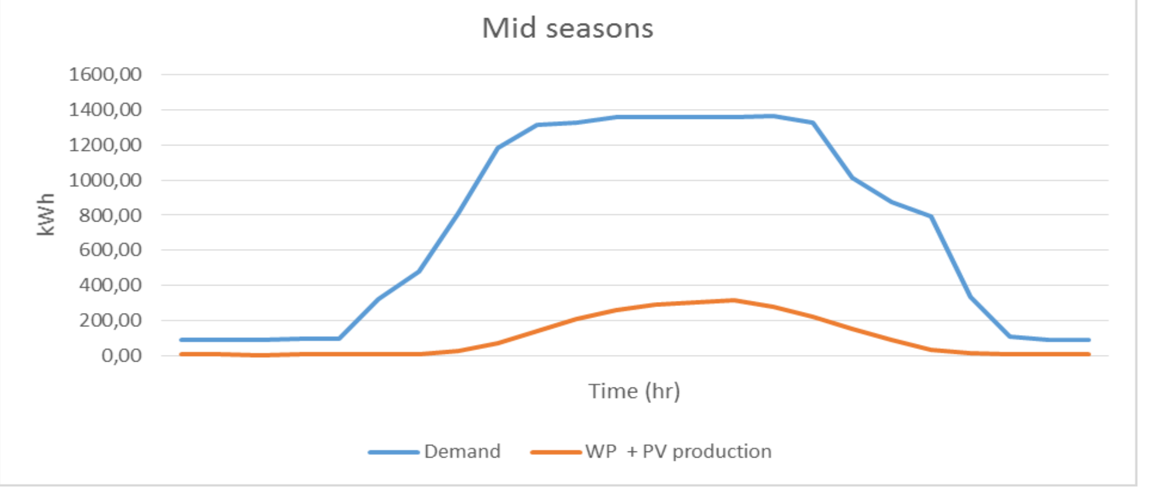


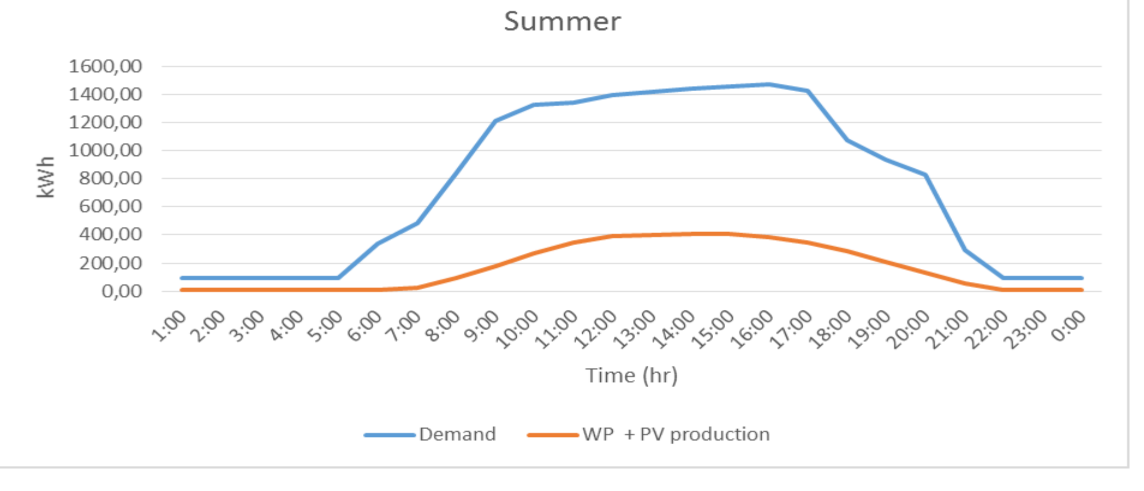
With these values we obtain that the load match for winter of 5.5%, 4% in mid-season and 3% in summer. The Grid Interaction is 40% in winter and summer and 41% in mid-season.

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time we obtain the following figures:







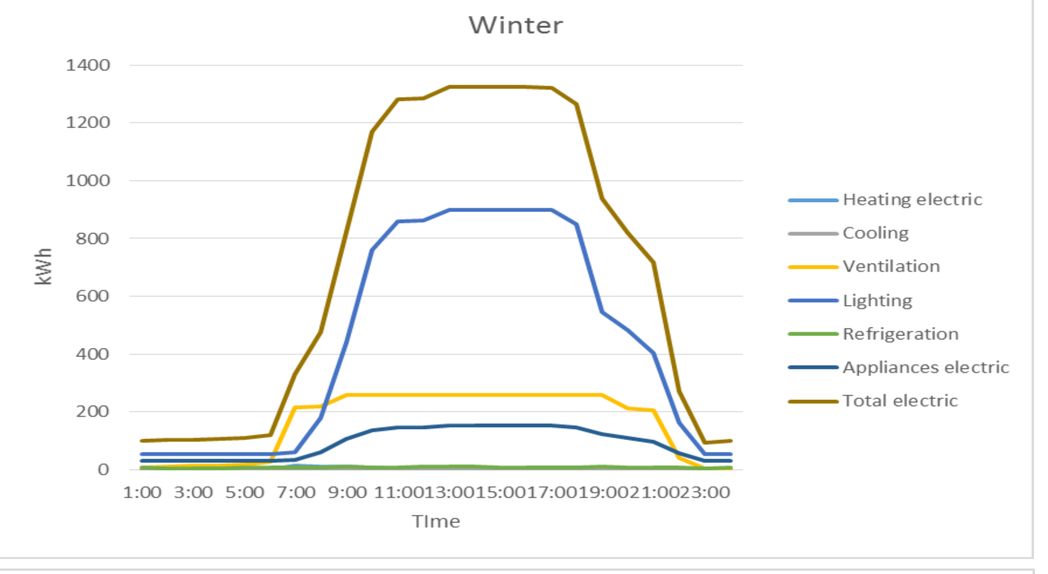
In this case the load match is increased to 7.5% in winter, 11% in mid-seasons and 16% in summer. Concerning the interaction with the grid the values are 40% in winter and 38% in mid seasons and 39% in summer.

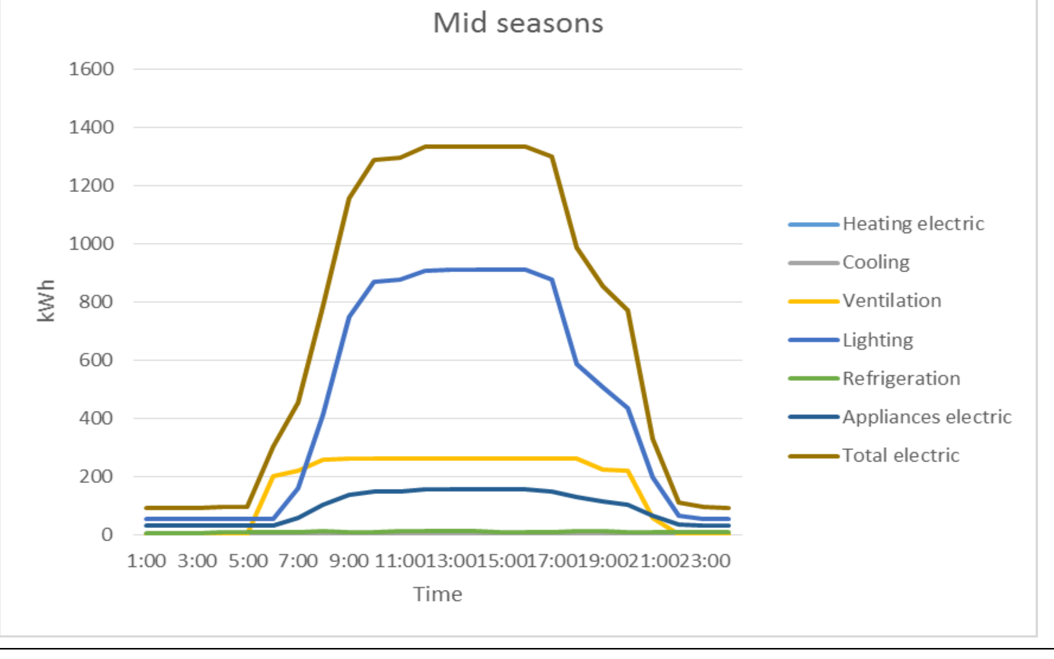
Energy saving

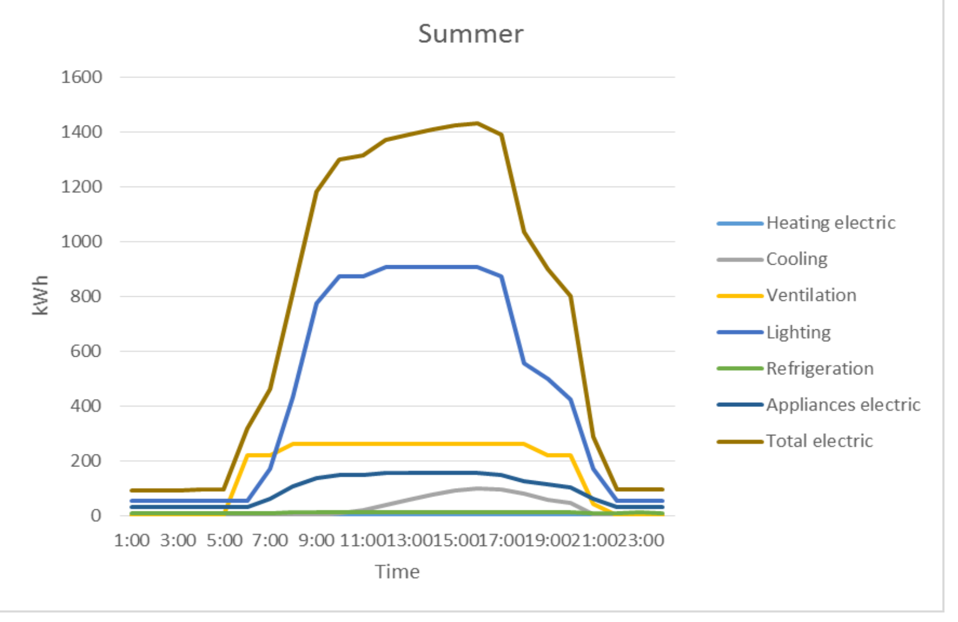
Envelope

Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, because the losses could be decreased.

If improvements in the envelope are included in this building, we obtain the following load profiles:



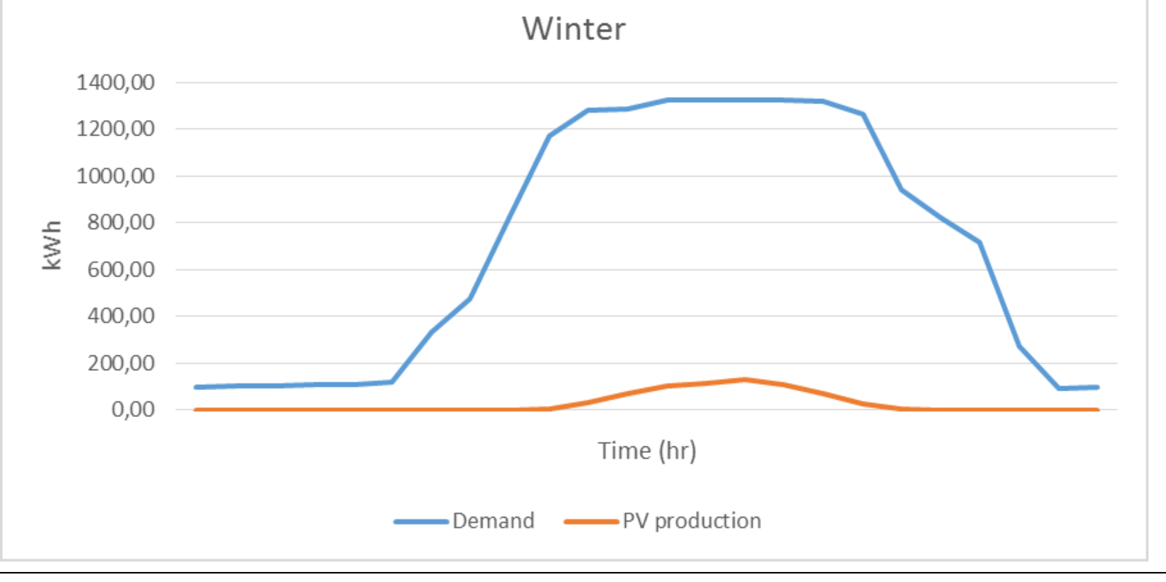


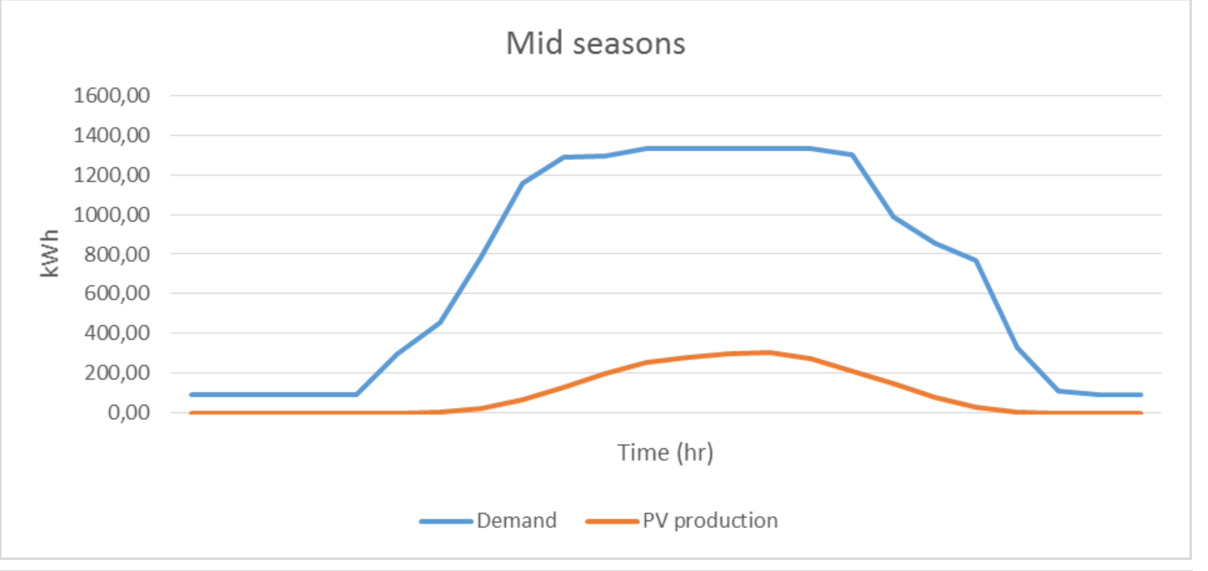


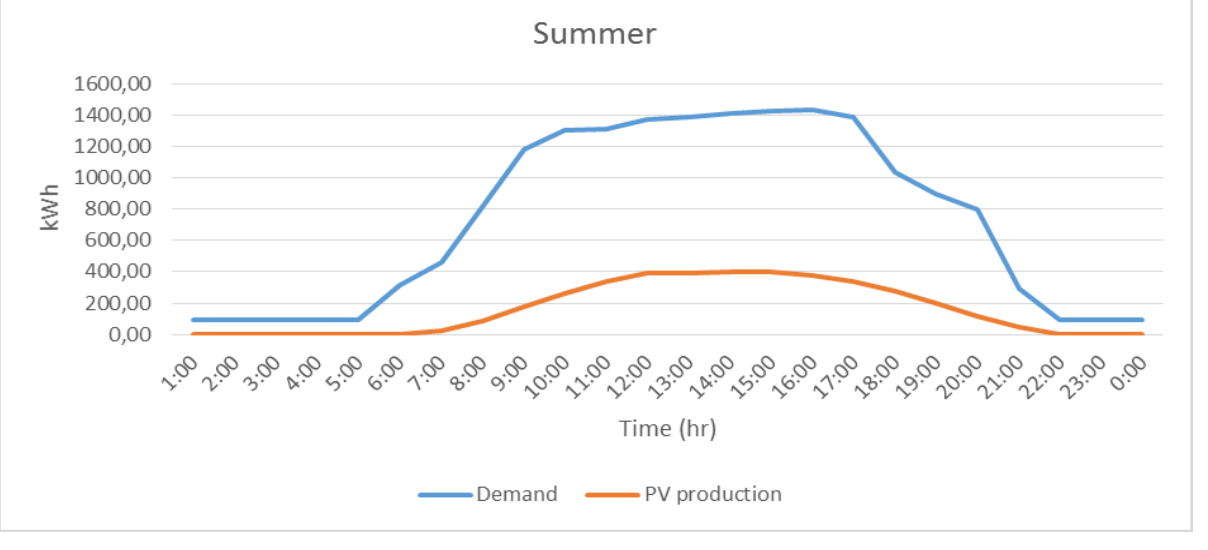
The improvements which have been included are the ones selected through PHPP simulations in D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems not to have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

Envelope + PV

Although we have seen that improvements in the envelope seem to not have a significant improvement in terms of grid interaction, the idea is to combine it with the PV solution described before with the idea to calculate the new Load Match index.





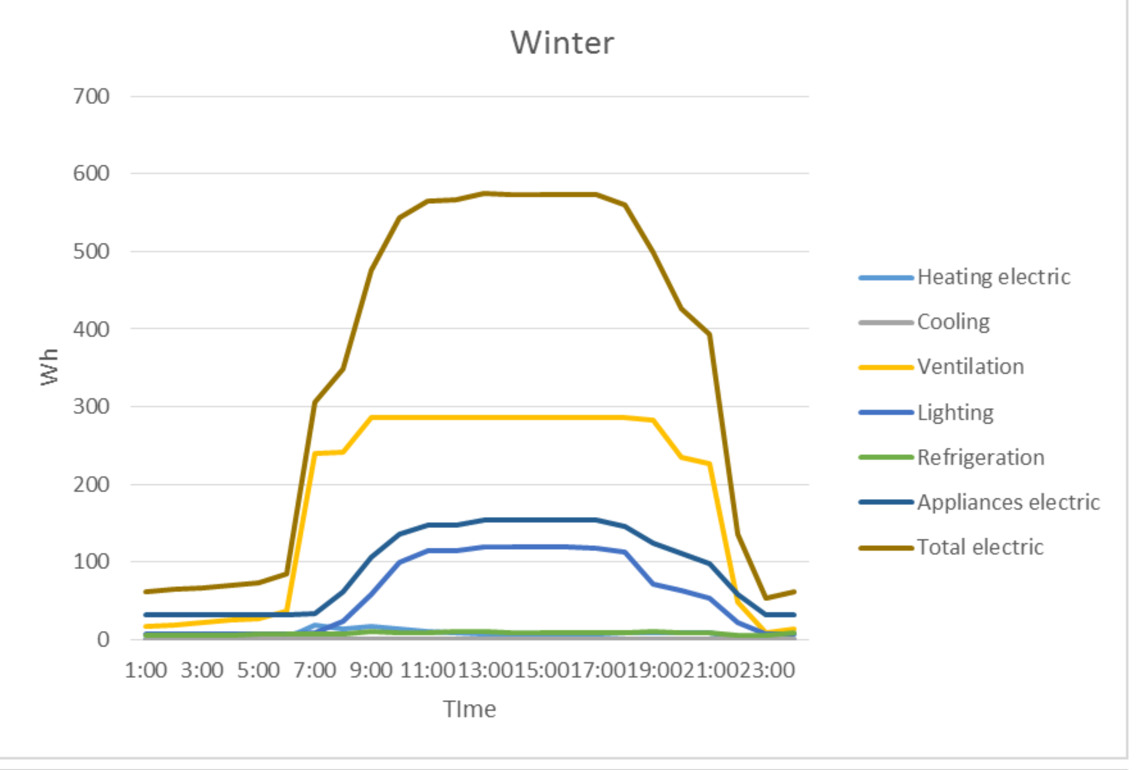


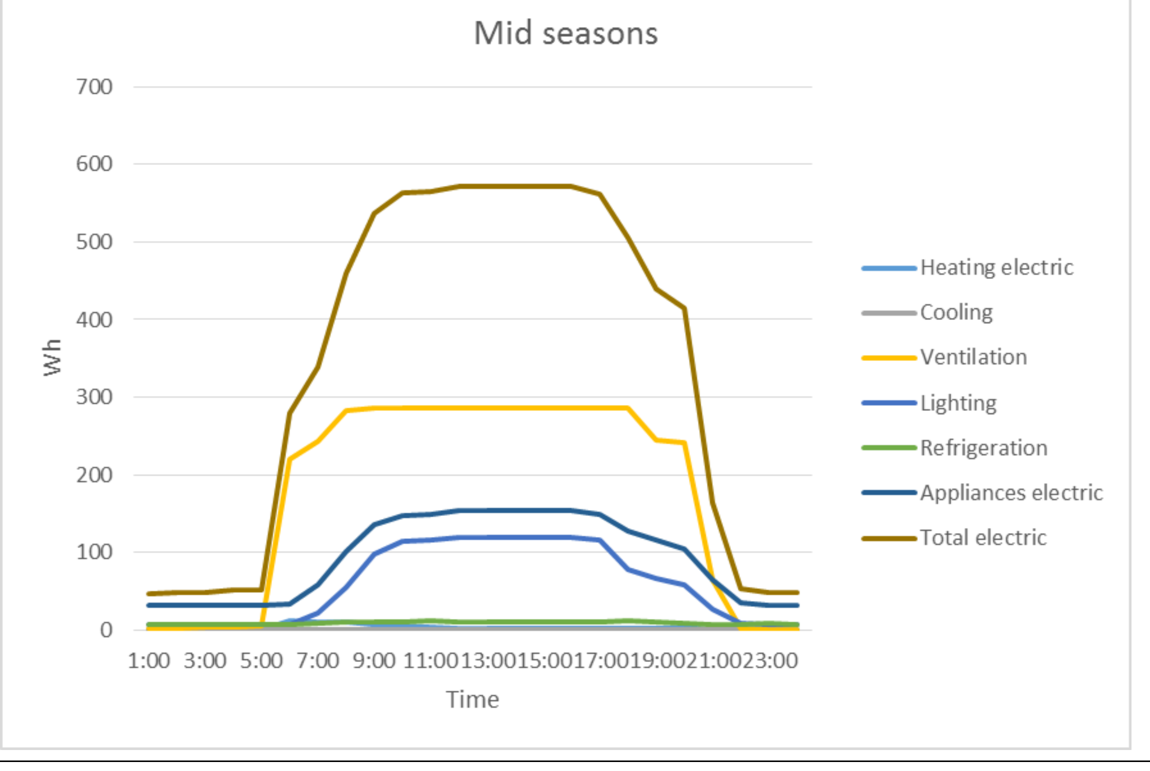
With these values, we obtain that the load match during the winter days is approximately 2%, mid-seasons 8% and in the summer days 13% and the grid interaction is 40% in winter and 38% in mid-season and 39% in summer.

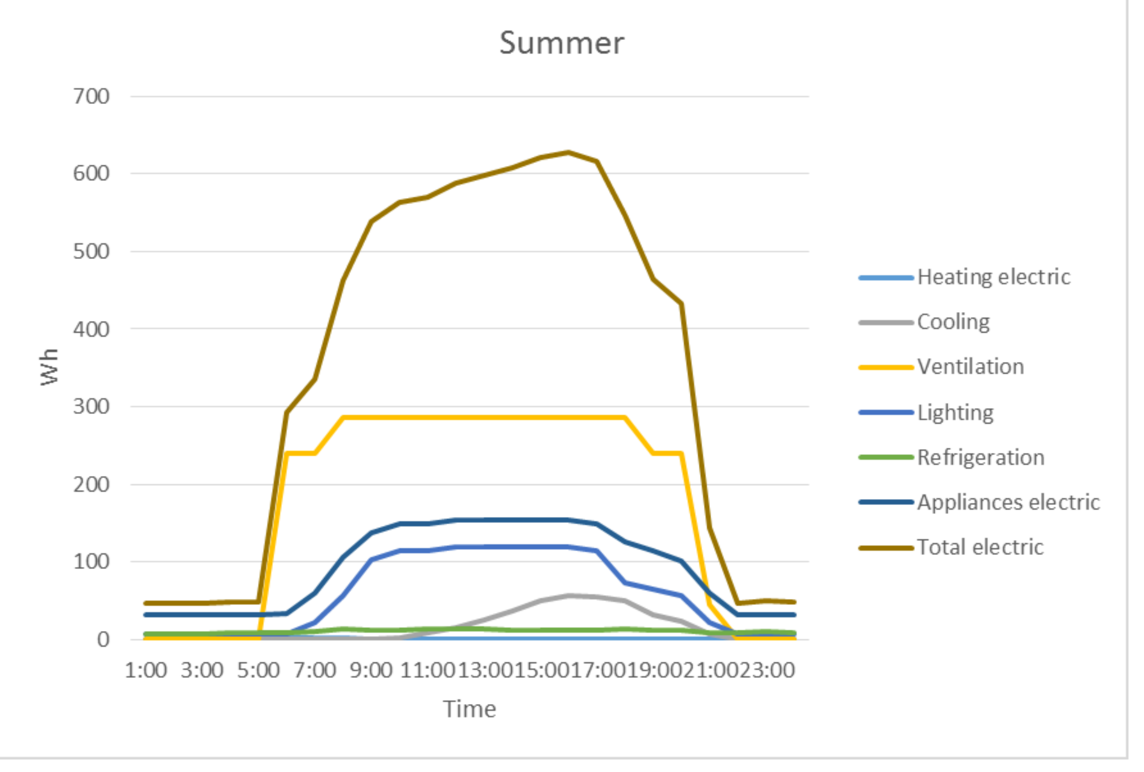
Lighting

Existing luminaries and lighting systems stand in for new equipment more efficient and with higher performance. The installation of electrical ballast and control equipment for the luminosity which allow dimmer regulation so as to adjust the lux level according to the indoor and outdoor conditions, as well as the comfort parameters in order to decrease the consumption when enough daylight.

The improvements in terms of lighting are shown in the following load profiles. These improvements are also based on PHPP simulations developed in D2.5 taking the most effective solution in terms of energy efficiency (From D2.5: V1, Reduce light density to 3 W/m^2 for common areas (and others) and 4.5 W/m^2 in shops).


Winter
700
600
500
400
300
200
100
0
Wh
1:00 3:00 5:00 7:00 9:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00
TIme
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

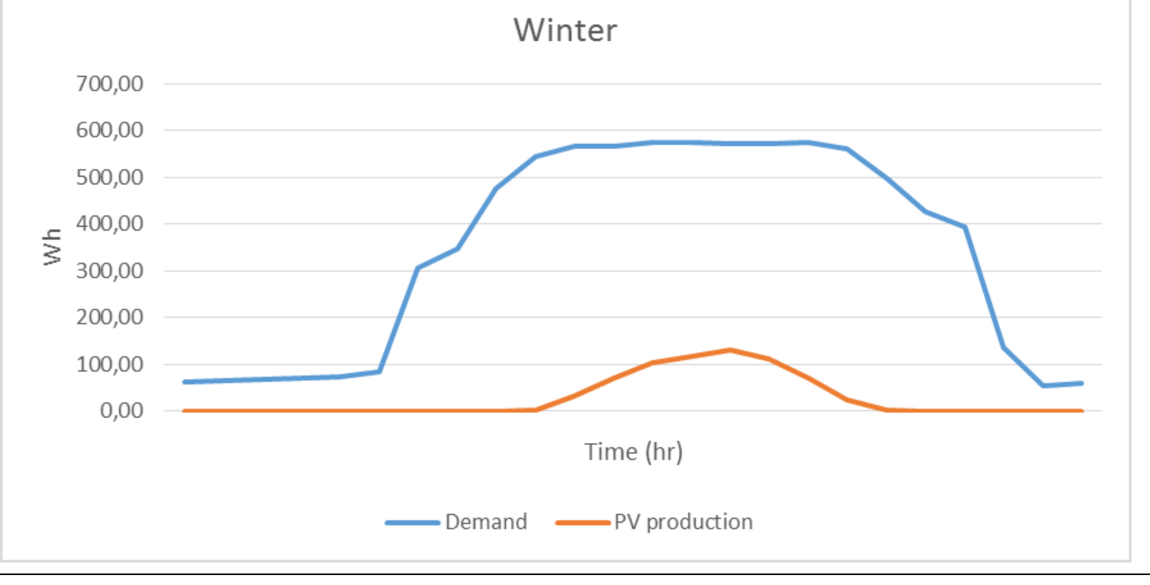

Mid seasons
700
600
500
400
300
200
100
0
Wh
1:00 3:00 5:00 7:00 9:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00
Time
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

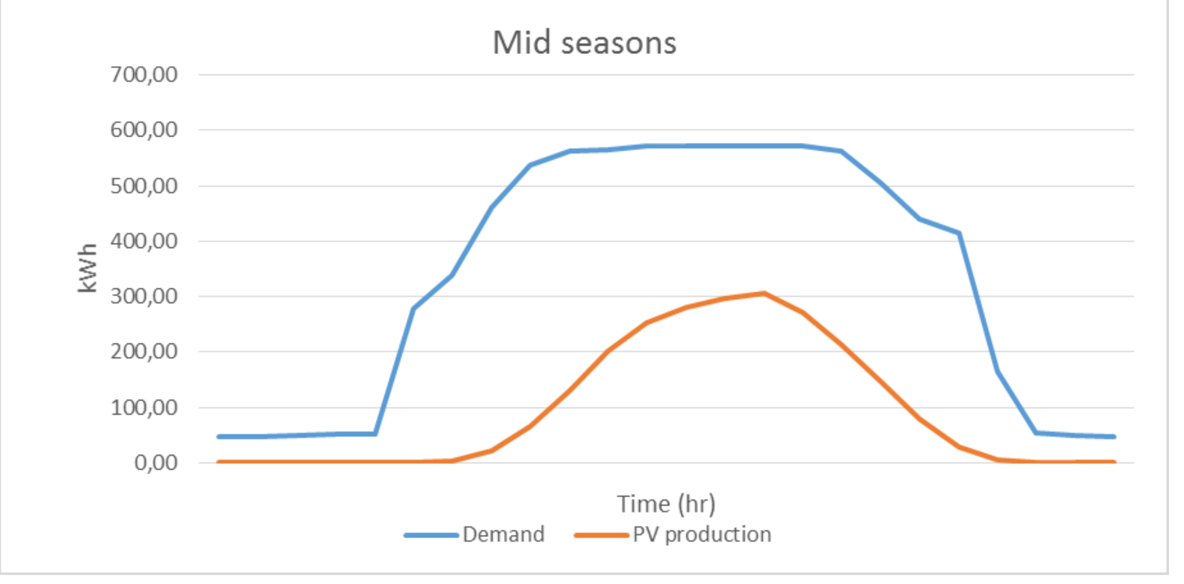


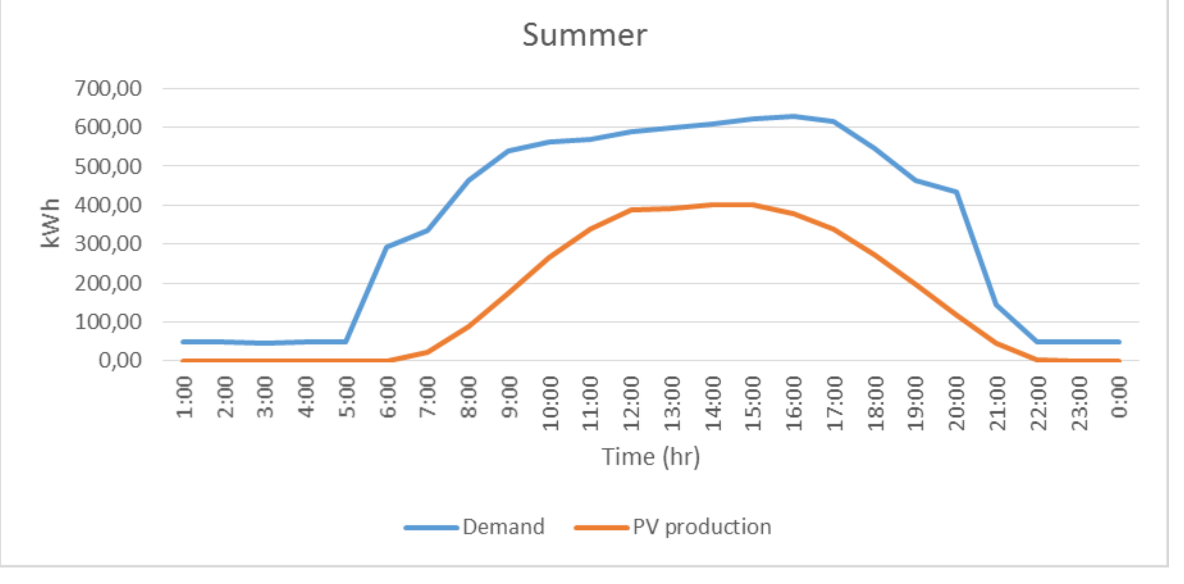
In this case, the grid interaction is reduced to 38% in winter and summer, and 39% in mid-seasons with an improvement in terms of lighting.

Lighting + PV

As the lighting solution, seems to be a suitable solution, the idea is to combine it with the PV solution proposed before in order to calculate a new load match index.







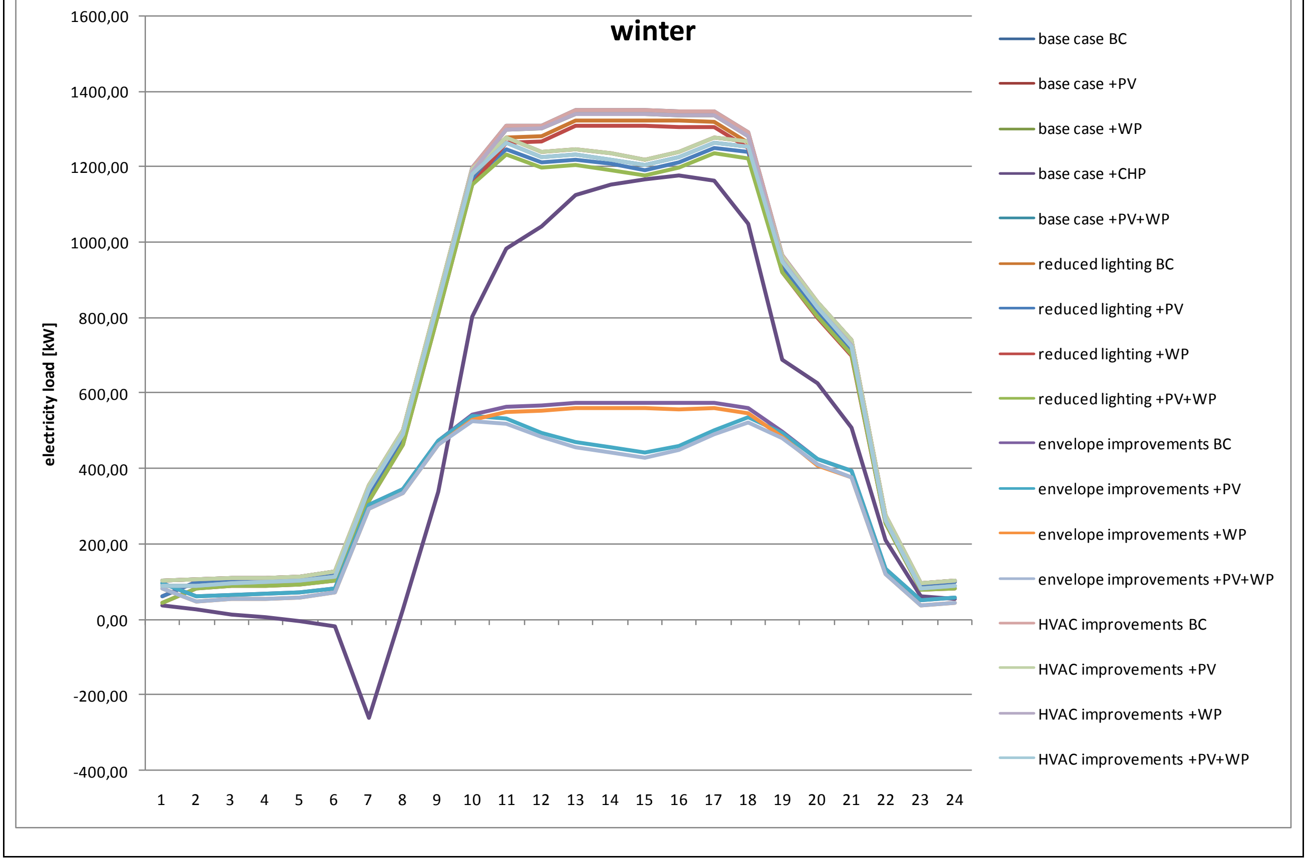
With these values we obtain that the load match during the winter days is approximately 5%, mid-seasons 17% and in the summer days 29% and the grid interaction is 37% for winter, 32% in mid-season, and 31% in summer.

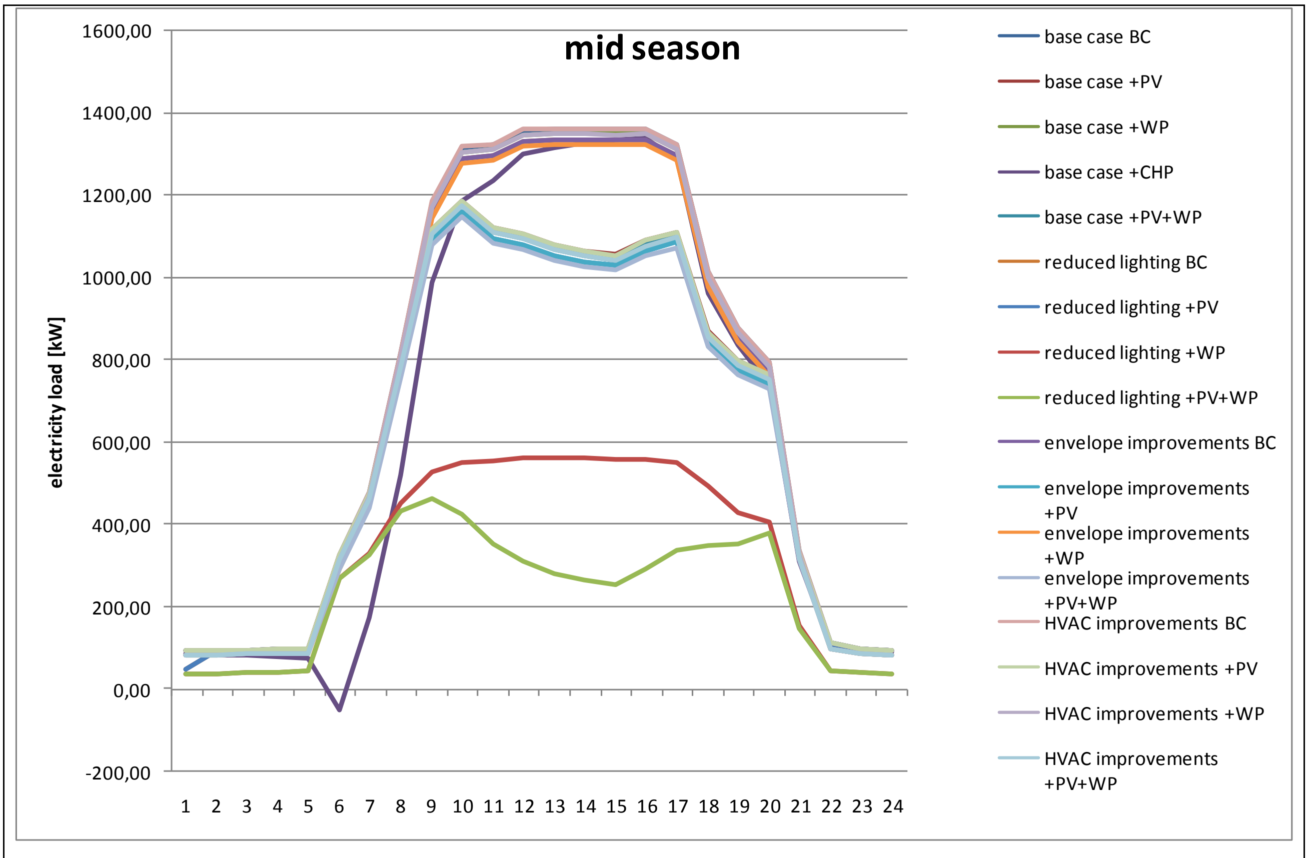
Summary

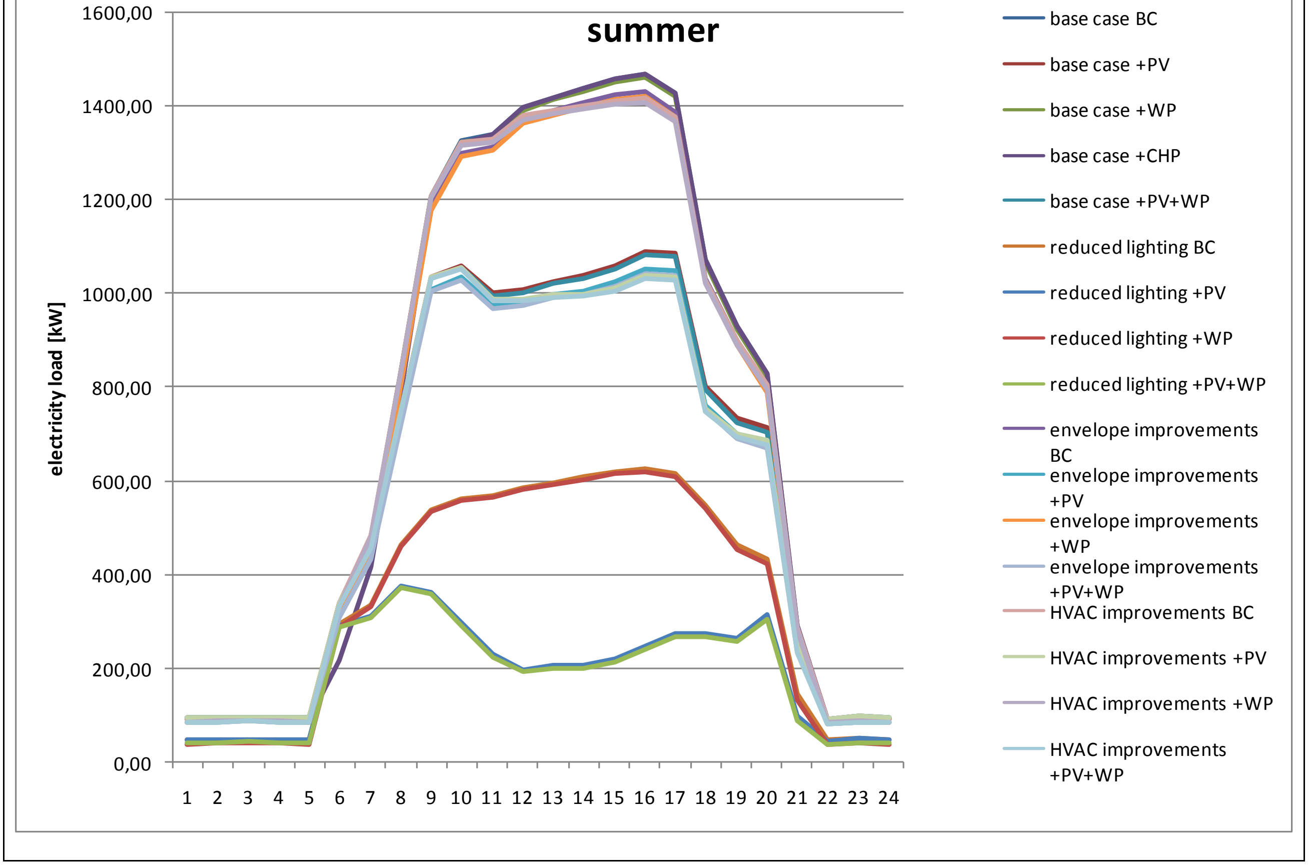
		Base case (BC)			Reduced lighting (LG)		Envelope improvements (EN)		HVAC improvements	
		+PV	+WP	+CHP	+PV	+PV+WP	+PV	+PV+WP	+PV	+PV+WP
LMavg	winter	2.1 %	5.5 %	50,6 %	4.8 %	14.2 %	2.1 %	7,8 %	2.1 %	7.5 %
	Mid-season	7.6 %	3.8 %	14,7 %	17.4 %	24.7 %	7.8 %	11,6 %	7.6 %	11.4 %
	summer	13.1 %	3.1 %	2,4 %	29.1 %	35.1 %	13.4 %	16,5 %	13.4 %	16.4 %
GI	winter	39.7 %	40.3 %	42,9 %	36.7 %	37.7 %	39.8 %	40%	39.7 %	40.1 %
	Mid-season	37.9 %	40.6 %	41,0 %	32.2 %	32.7 %	37.8 %	38%	37.9 %	38.1 %
	summer	39.0 %	39.8 %	39,9 %	31.2 %	31.5 %	39.0 %	39%	38.9 %	39.1 %

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + LG	BC + EN	BC + HVAC	BC + PV + WP	BC + CHP	BC + LG + PV	BC + LG + PV + WP	BC + EN + PV	BC + EN + PV + WP	BC + HVAC + PV	BC + HVAC + PV + WP
Winter	0.2 %	-0.4 %	0.9 %	-0.1 %	0.0 %	-0.2 %	-3.0 %	3.3 %	2.2 %	0.1 %	-0.3 %	0.2 %	-0.2 %
Mid-season	2.5 %	-0.3 %	0.1 %	0.0 %	0.0 %	2.2 %	-0.6 %	8.2 %	7.6 %	2.6 %	2,.3 %	2.5 %	2.2 %
Summer	0.6 %	-0.2 %	0.4 %	-0.1 %	-0.4 %	0.3 %	-0.3 %	8.4 %	8.0 %	0.5 %	0.2 %	0.6 %	0.4 %



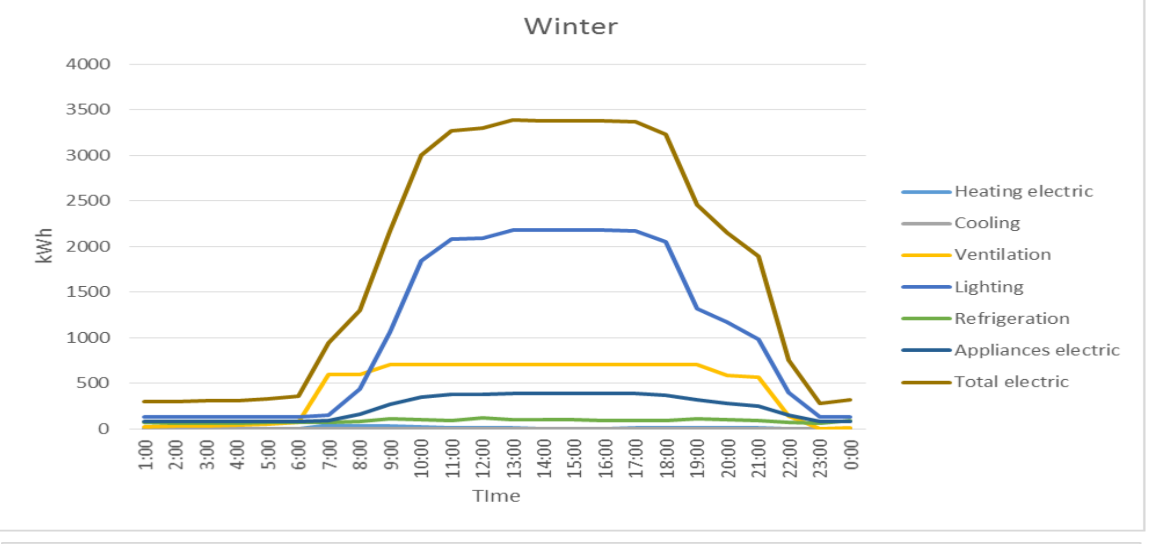

mid season
electricity load [kW]
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
-200,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

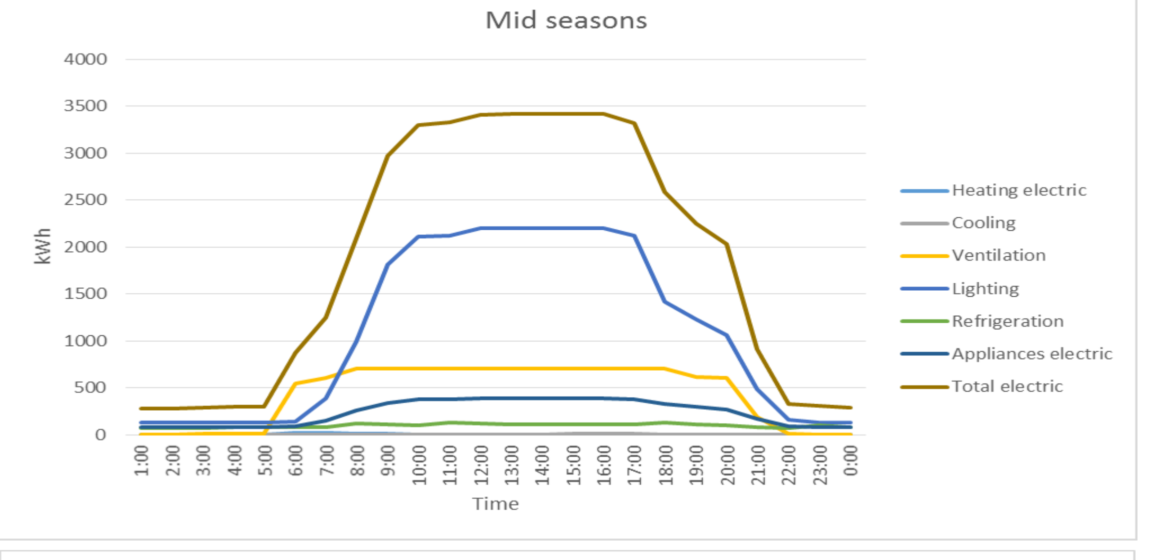

summer
electricity load [kW]
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

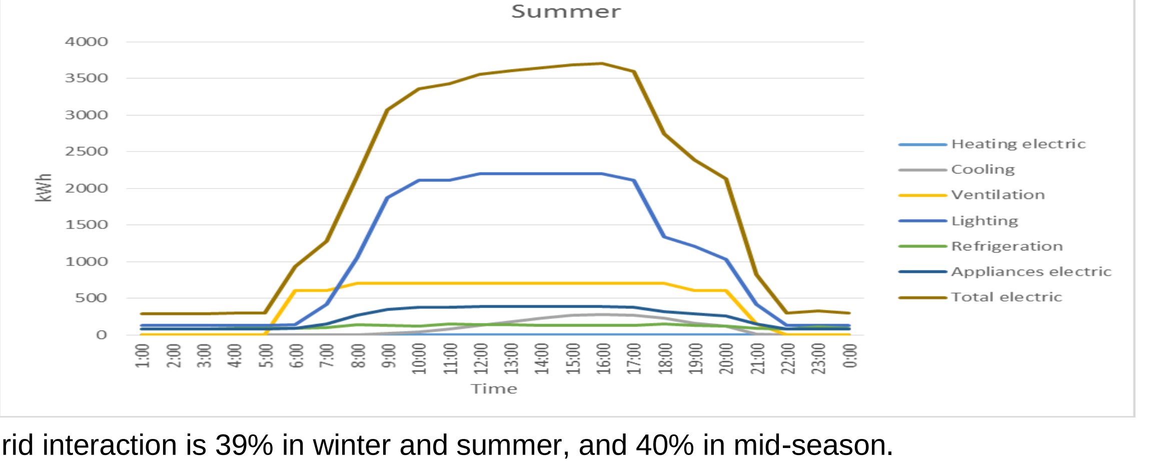
4.10 Reference SC in LONDON based on BRENT CROSS

LOAD PROFILES (BASE CASE)

Total Surface: 80,400 m^2 (Supermarket area: 3,850 m^2)







The grid interaction is 39% in winter and summer, and 40% in mid-season.

POTENTIALS

- The electricity demand of shopping malls in London is mainly because of the lighting, HVAC systems and the energy consumption of the refrigerators used for the conservation of the products.
- It is not clear if it is possible to install a PV system, due to the installations on the roof. Here, it is assumed that 4500m2 can be covered with horizontal PV modules. This is done to be able to evaluate if photovoltaic generation profile is suitable for the demand profile of the building i.e. the photovoltaic generation peaks coincide with the market demand peaks.
- It might be possible to install a wind turbine system, due to the surface available on the roof (~ 9,000 m^2).

SOLUTIONS

On-site RES

Installation of Photovoltaic system which could be placed over the roof and oriented to the South-East.

Mini-wind system, in combination with the photovoltaic, minimizes the electrical consumption.

Below there are some options for the exploitation of renewable energies, mainly wind and photovoltaic, so that the dependence of electricity will be reduced.

Photovoltaic installation

The roof of the shopping centre used for building services equipment. Nevertheless, it was assumed that half of the appr. 90,000 m^2 (45,000 m^2) could be covered with horizontal PV.

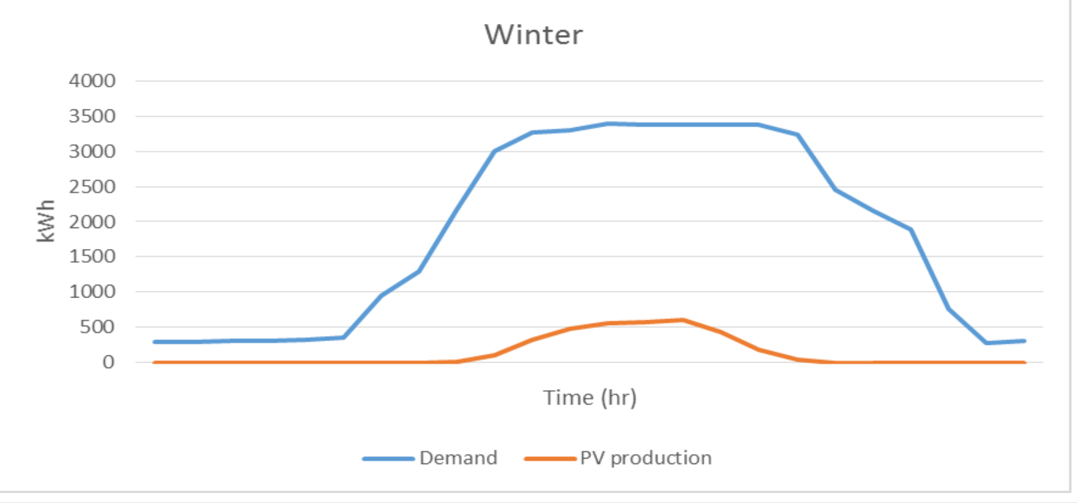
For the assessment of both wind and photovoltaic production, a dynamic simulation in TRNSYShas been performed, considering a photovoltaic installation of panels with 112 W/m^2, with a surface free of shadows of approximately 45,000 m^2, with an inclination of 0º oriented to the south.

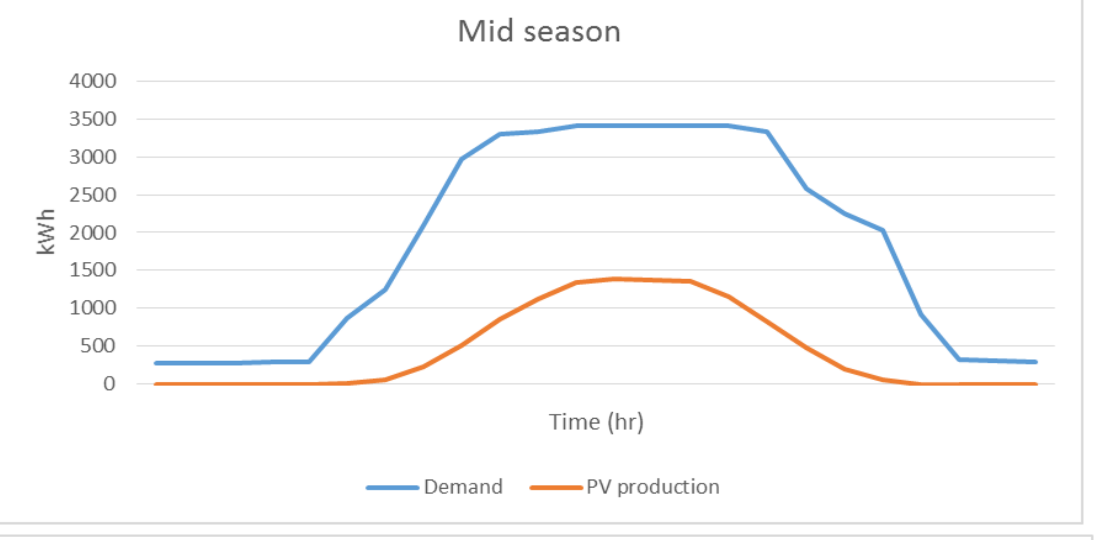
In Table 14, the results for the hourly energy production for the different seasons are shown:

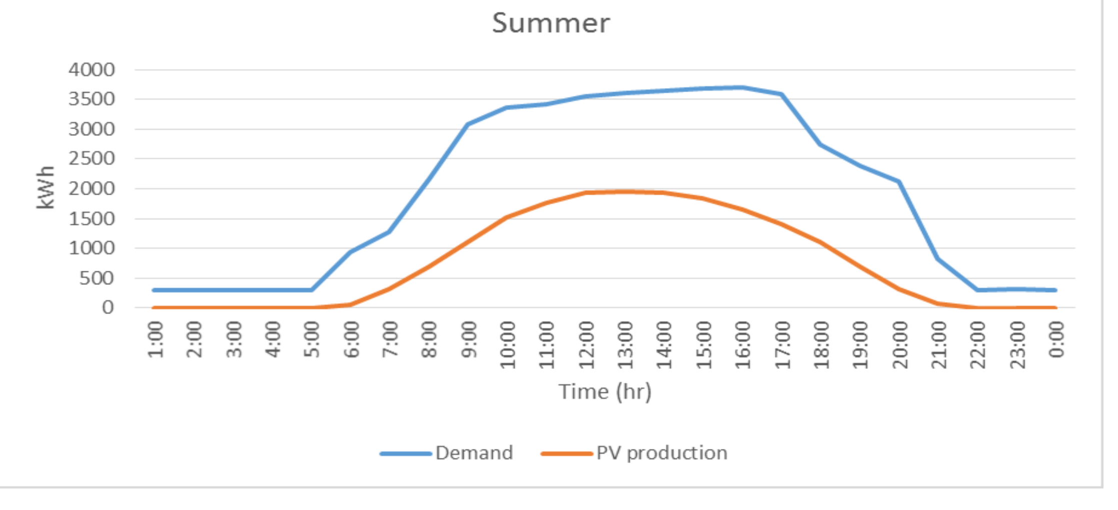
Table 14: Hourly energy production in kWh by season for the PV installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.57	107.96	320.07	481.06
Mid season	0.00	0.00	0.00	0.00	0.00	4.63	65.97	228.42	518.32	859.14	1129.85	1343.97
Summer	0.00	0.00	0.00	0.00	0.00	51.57	316.67	686.79	1109.06	1526.35	1757.26	1927.19
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	565.89	574.04	604.95	429.52	186.33	44.39	0.02	0.00	0.00	0.00	0.00	0.00
mid season	1393.86	1379.86	1354.15	1147.15	817.94	482.35	204.55	52.36	1.43	0.00	0.00	0.00
Summer	1952.51	1935.30	1832.73	1653.78	1415.10	1100.1	691.92	316.70	67.41	0.00	0.00	0.00

By overlapping the PV production (according to the 45,000 m^2) with the demand curves for the different seasons developed we obtain the following figures:







With these values we obtain that the load match during the winter days is approximately 4%, mid-seasons 14% and in the summer days 24%. The grid interaction that indicates the variability in the import from the grid is 37%for winter, 36% for mid-season, and 33% during summer.

Wind turbine installation

A wind turbine installation has been considered with a nominal power of 150 kW.

Through Energy Plus data, and the power curve of the wind turbine the annual electricity production can be estimated.

Figure 10 shows the evolution of the power produced by the wind turbine. It is possible to appreciate how much the power varies from one day to another.

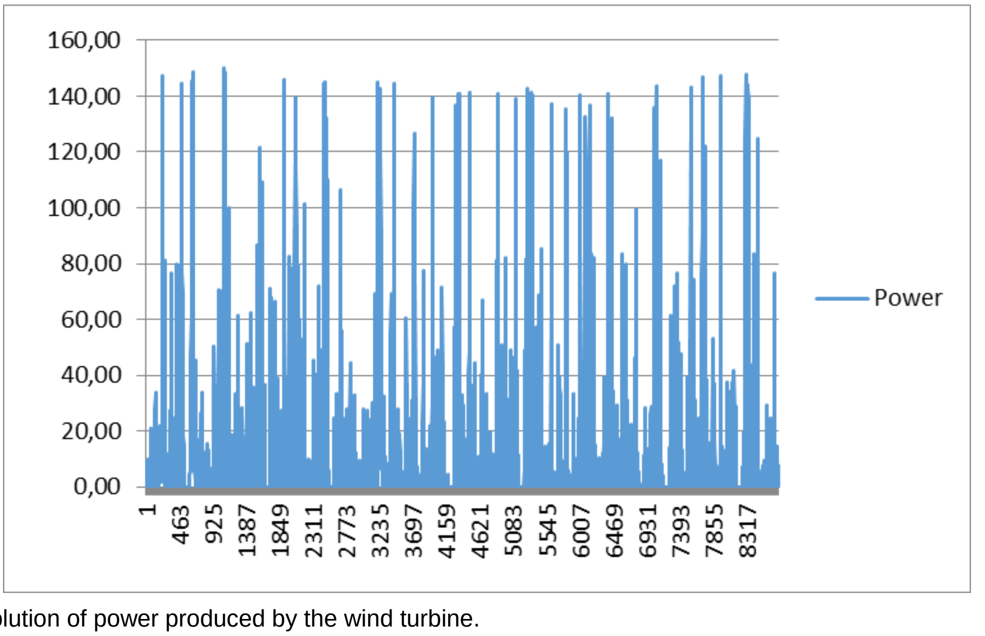


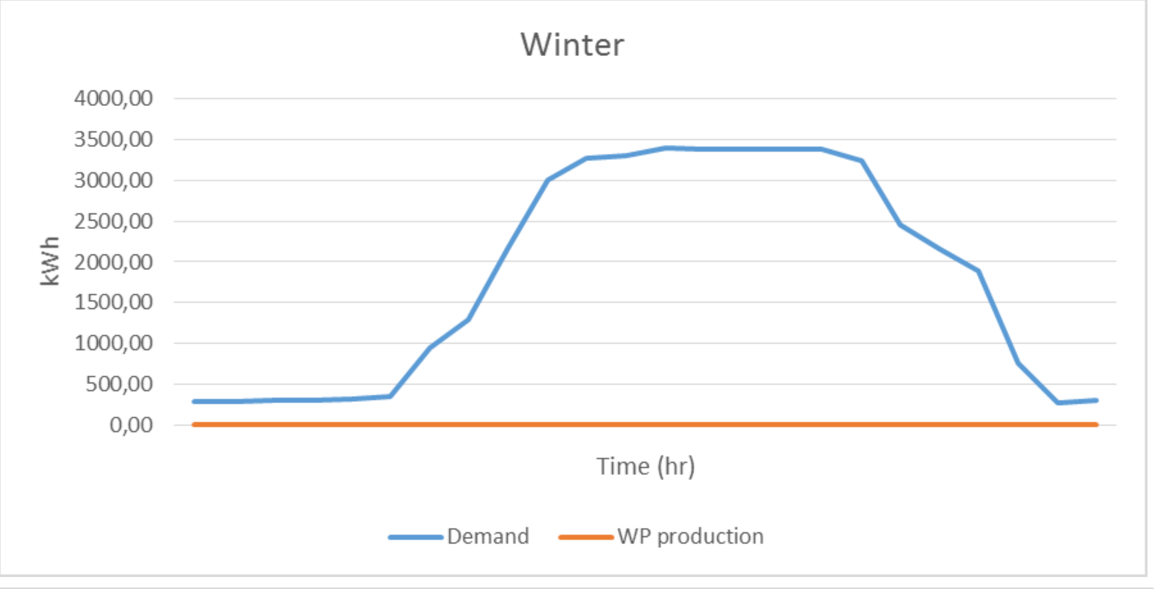
Figure 10: Evolution of power produced by the wind turbine.

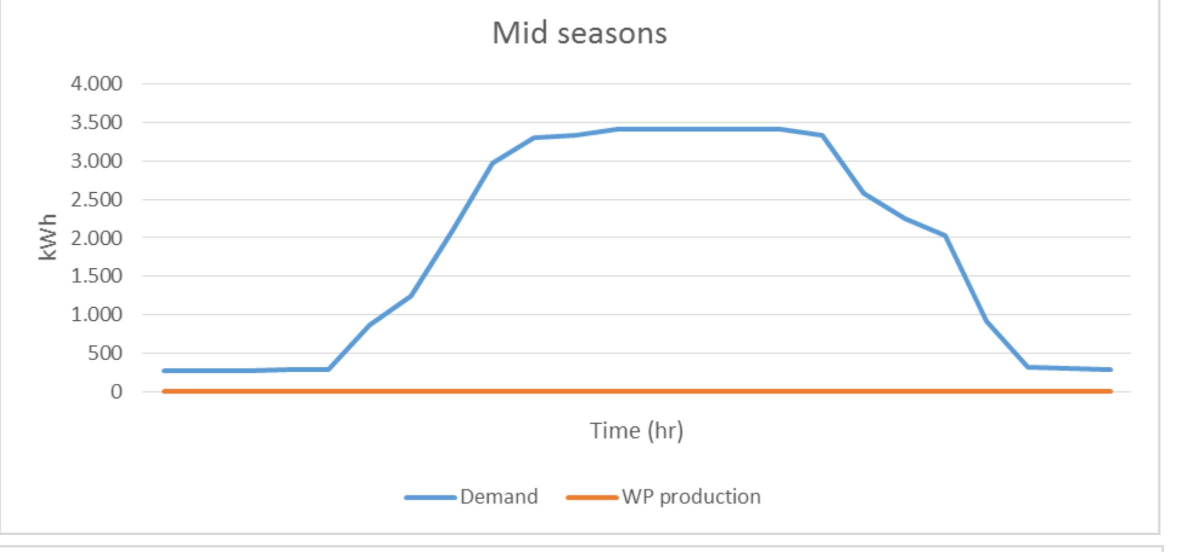
Table 15 shows the results for the hourly energy production for the different seasons:

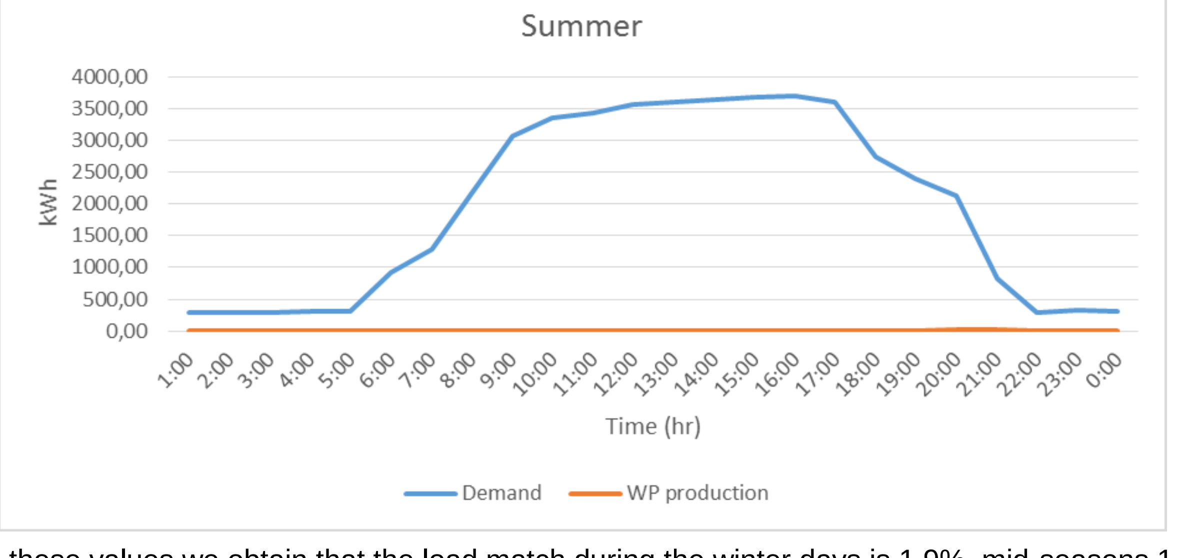
Table15: Hourly energy production in Wh by season for the WP installation

Time	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Winter	14.94	14.89	12.11	13.29	12.89	12.21	11.72	10.68	11.70	12.91	12.07	11.37
Summer	10.46	9.66	7.77	9.61	8.80	10.40	9.88	9.53	9.98	10.35	10.52	10.35
Mid-season	8.96	8.10	6.44	9.47	10.38	8.78	5.42	4.51	4.83	6.05	7.53	7.89
Time	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**	**0:00**
Winter	12.62	12.86	12.47	13.13	12.25	12.97	13.63	14.77	14.57	13.21	13.75	14.27
Summer	9.48	9.54	11.45	11.37	11.81	12.53	11.46	11.26	10.56	11.23	10.18	9.53
Mid-season	8.27	9.88	9.98	10.61	10.83	11.30	11.80	13.04	12.85	11.12	10.96	10.75

By overlapping the WP production (according to the 150 kW power turbine) with the demand curves for the different seasons we obtain the following figures:





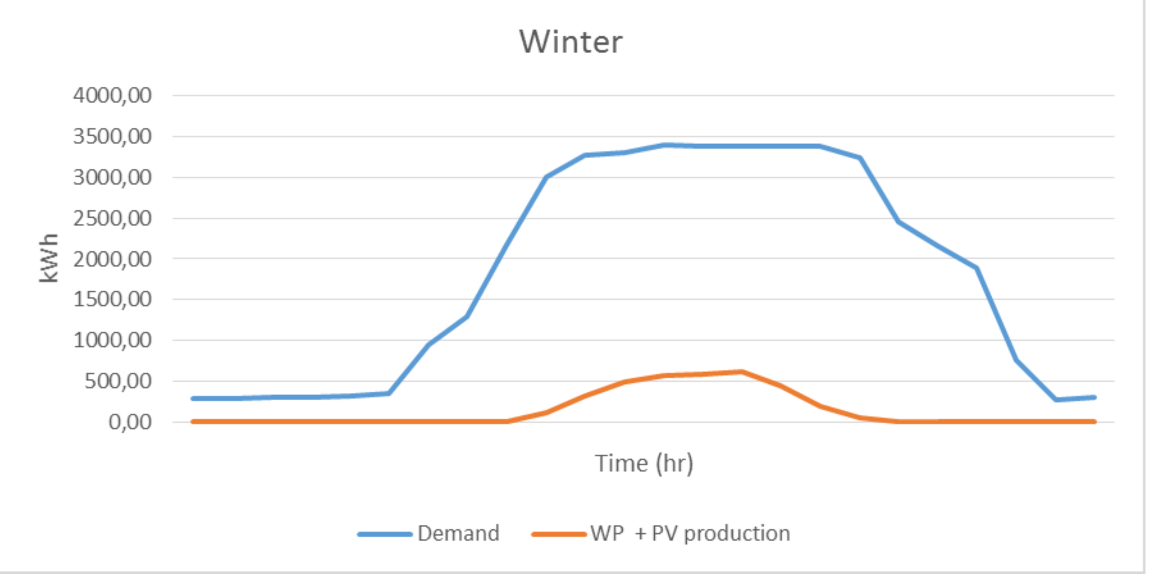


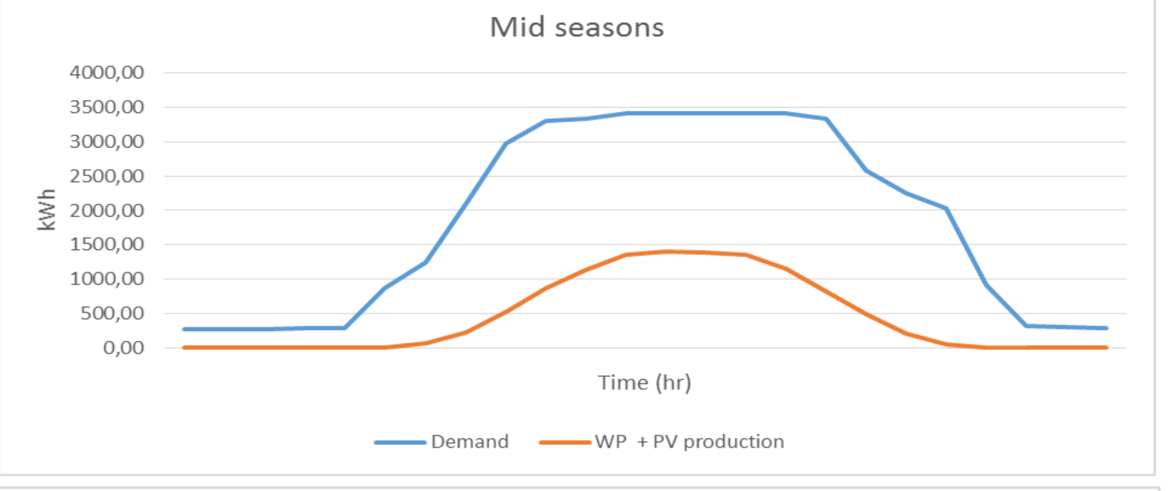
With these values we obtain that the load match during the winter days is 1.9%, mid-seasons 1.4% and in the summer days 1.3%. The grid interaction is 40% along winter and mid-seasons, and

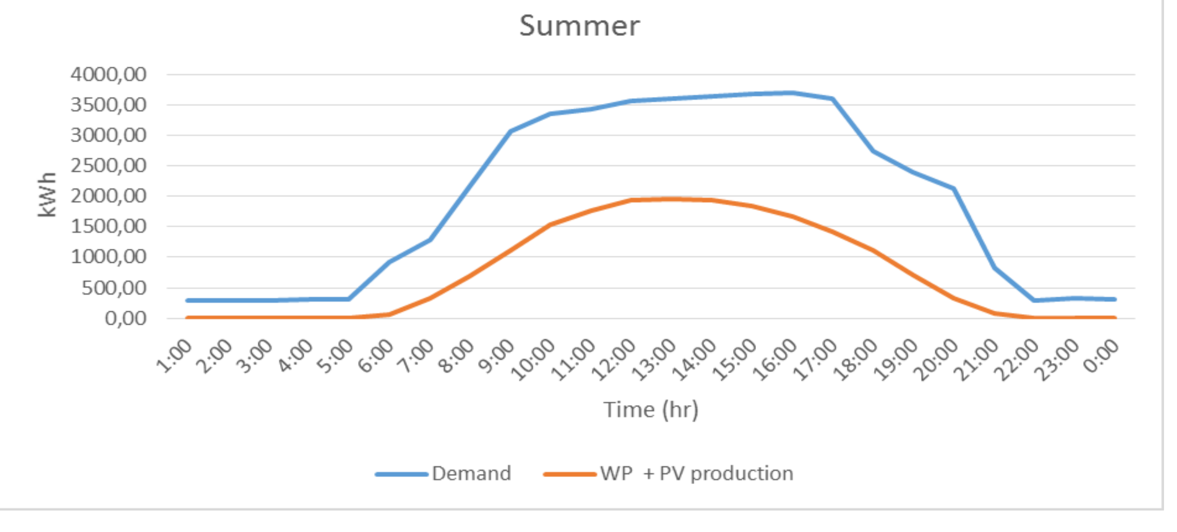
39% during summer.

Photovoltaic installation + Wind Power installation

If both RES solutions are considered at the same time we obtain the following figures:







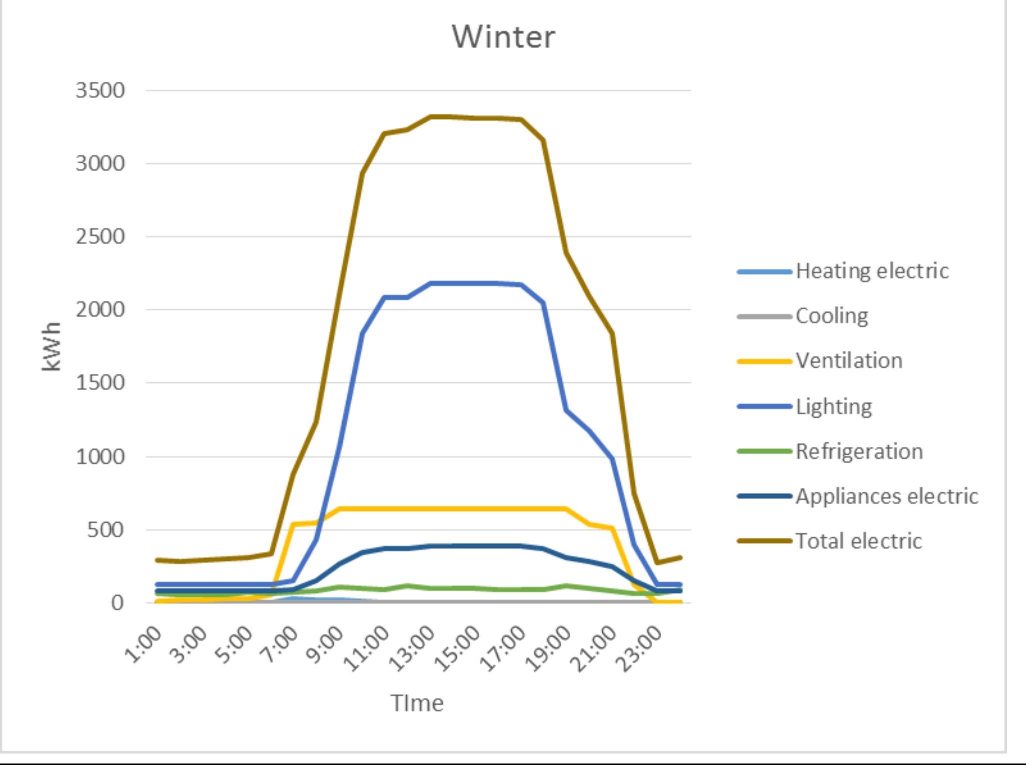
In this case the load match is increased to 6% in winter, 16% in mid seasons and 26% in summer. Concerning the interaction with the grid the values are 37% in winter, 36% in mid seasons and 33% in summer.

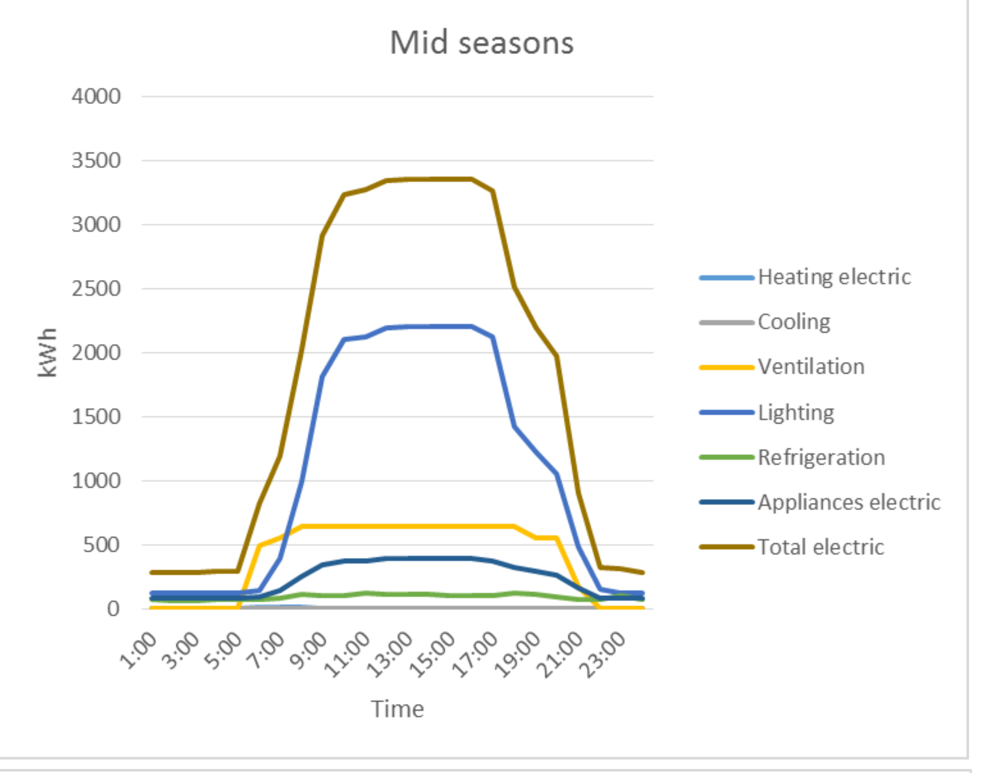
Energy saving

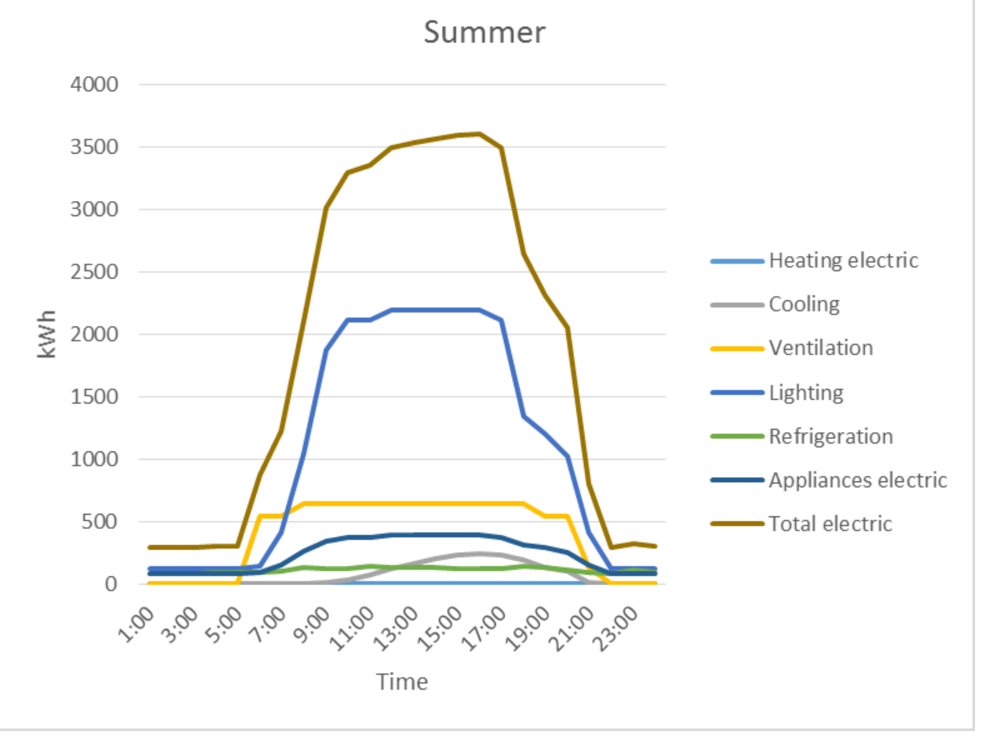
Envelope

Although it is not related directly to the electricity consumption, the improvements in the building closings would reduce the final consumption, because the losses could be decreased.

If improvements in the envelope are included in this building, we obtain the following load profiles:



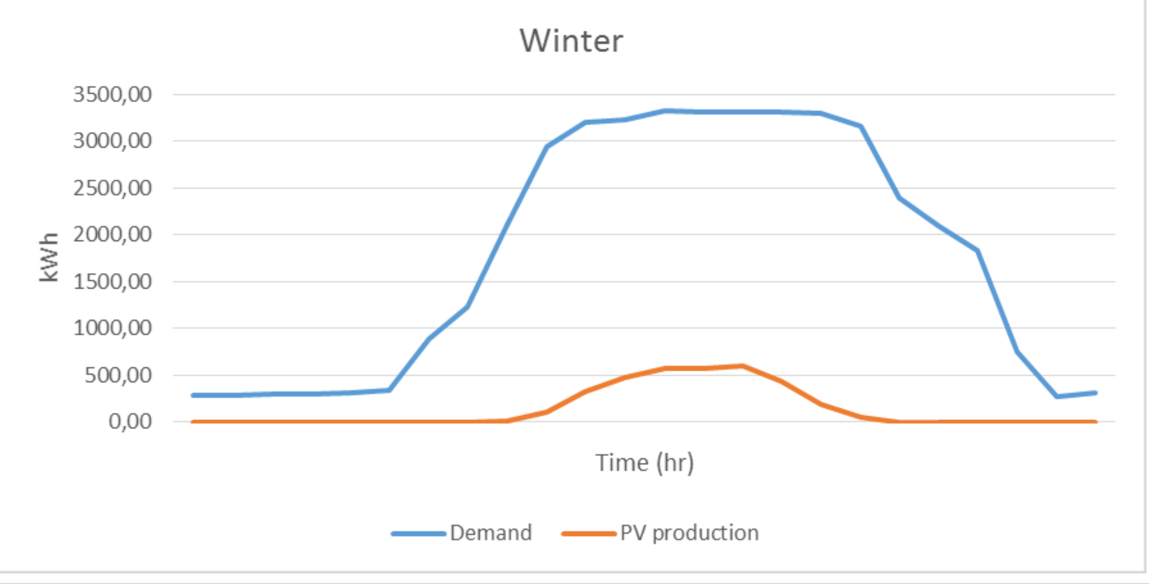


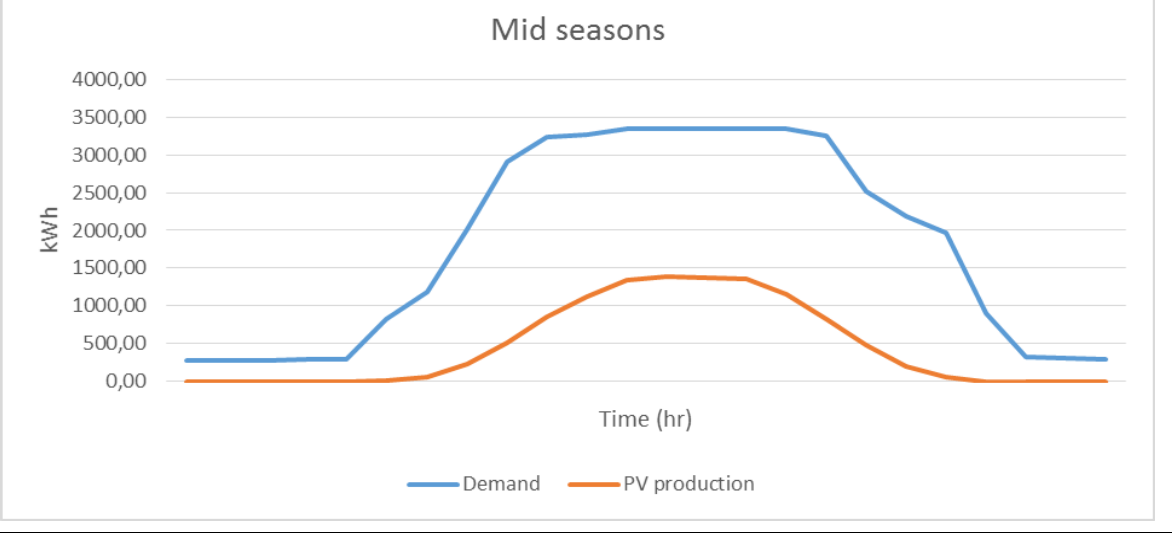


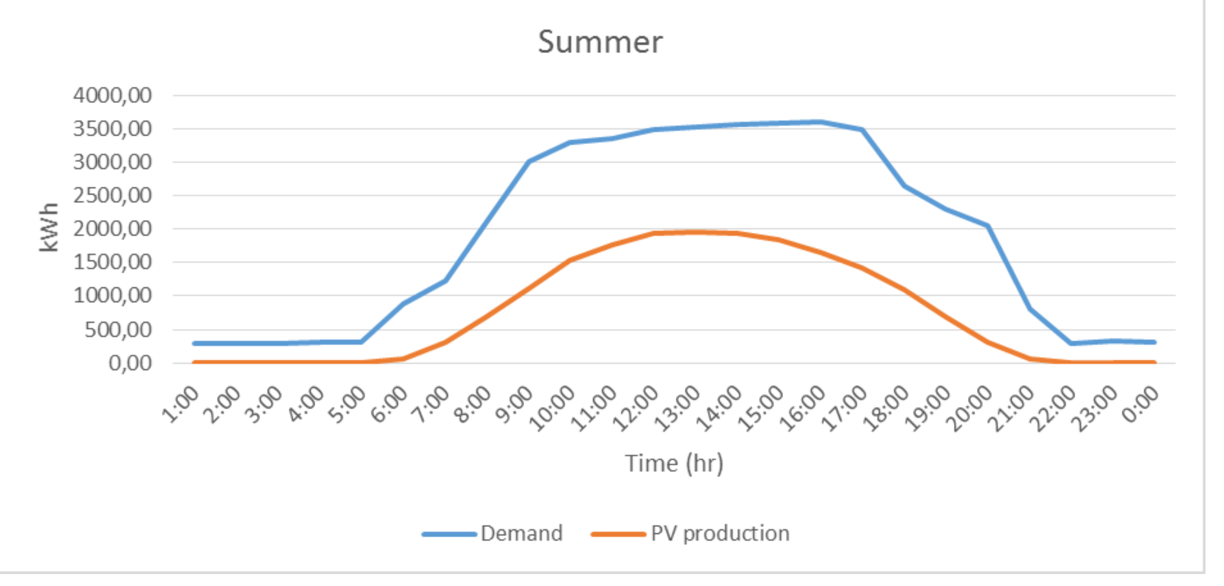
The improvements which have been included are the ones selected through PHPP simulations in D2.5 as the most effective in terms of energy reduction (From D2.5: V3, V4, V9, Reduce air changes to 0.6 hr-1, Night natural ventilation @3hr-1, Double insulation thickness, Window: U-value glazing=0,8; U-value frame=0,6). This energy efficiency solution seems to not have an important effect on the interaction between the building and the electrical grid as the grid interaction remains the same as in the base case.

Envelope + PV

Although we have seen that improvements in the envelope seems to not have a significant improvement in terms of grid interaction, the idea is to combine it with the PV solution described before with the idea to calculate the new Load Match index.





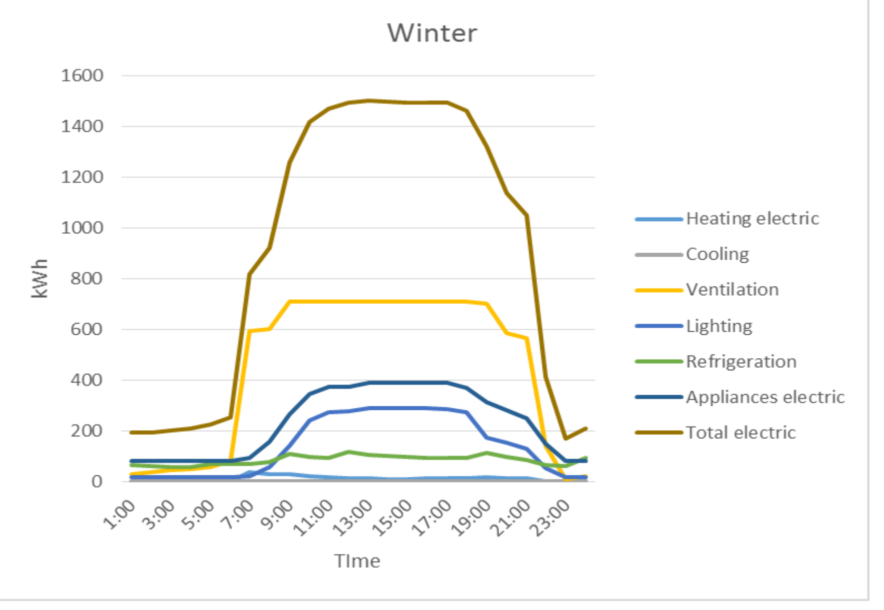


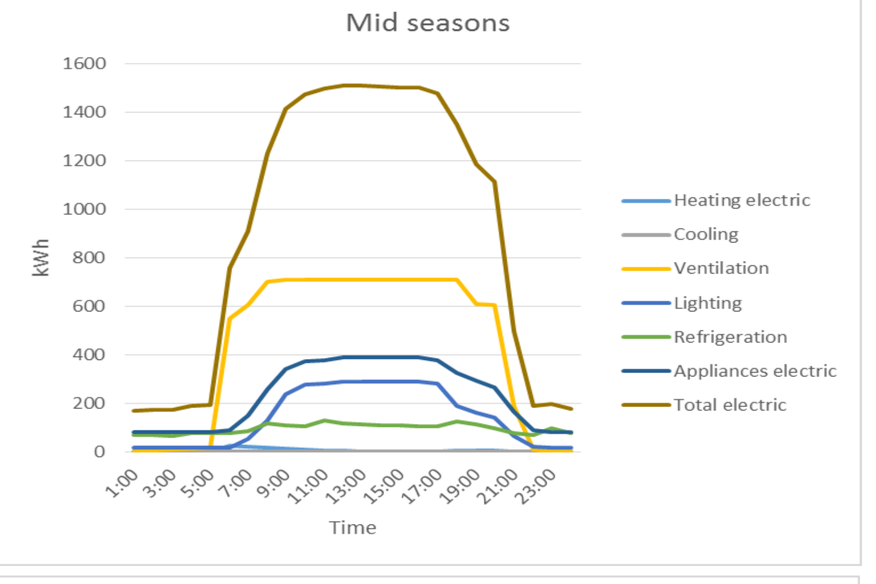
With these values we obtain that the load match during the winter days is approximately 4%, mid-seasons 15% and in the summer days 25% and the grid interaction is 37%, 35% and 32% for winter, mid-season, summer respectively.

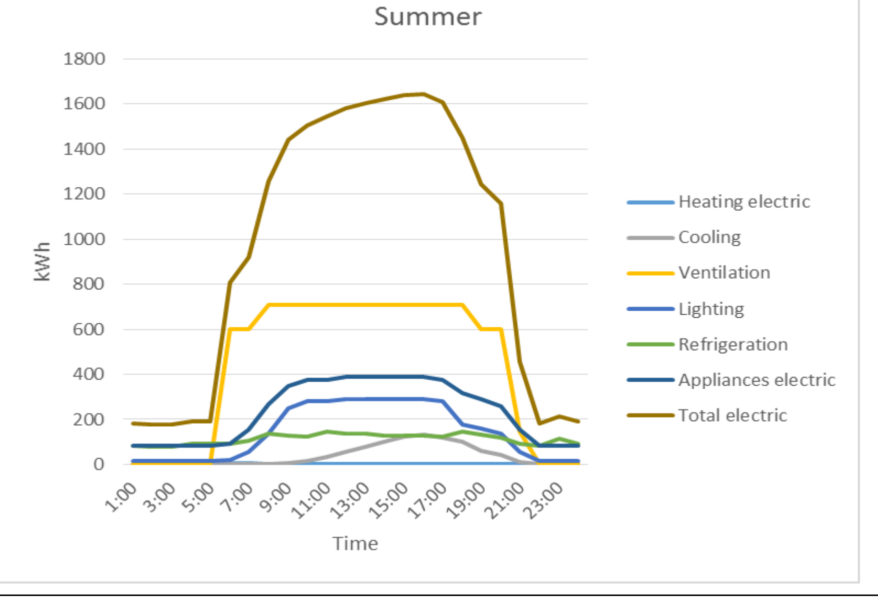
Lighting

Existing luminaries and lighting systems stand in for new equipment more efficient and with higher performance. The installation of electrical ballast and control equipment for the luminosity which allow dimmer regulation so as to adjust the lux level according to the indoor and outdoor conditions, as well as the comfort parameters in order to decrease the consumption when there is enough daylight.

The improvements in terms of lighting are shown in the following load profiles. These improvements are also based on PHPP simulations developed in D2.5 taking the most effective solution in terms of energy efficiency (From D2.5: V1, Reduce light density to 3 W/m^2 for common areas (and others) and 4.5 W/m^2 in shops).


Winter
1600
1400
1200
1000
800
600
400
200
0
kWh
1:00
3:00
5:00
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
TIme
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

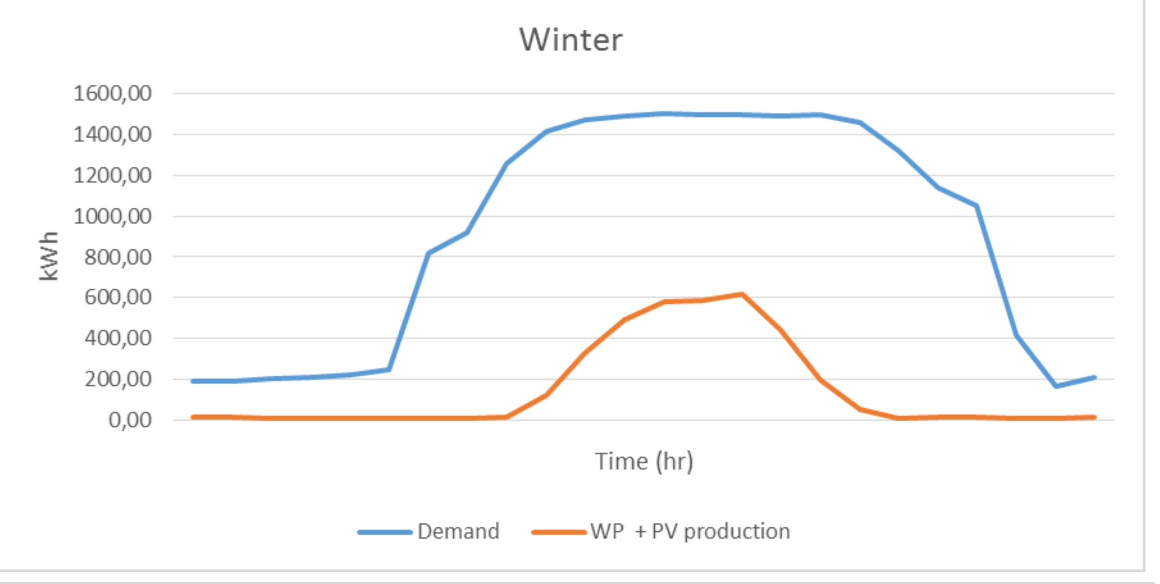

Mid seasons
1600
1400
1200
1000
800
600
400
200
0
kWh
1:00
3:00
5:00
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
Time
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

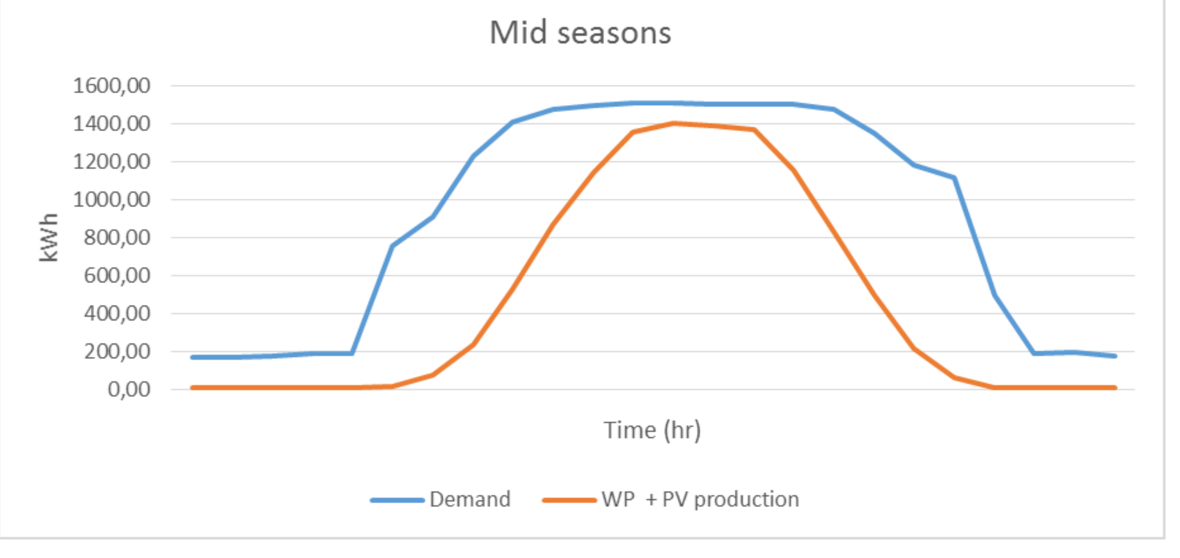

Summer
1800
1600
1400
1200
1000
800
600
400
200
0
kWh
1:00
3:00
5:00
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
Time
Heating electric
Cooling
Ventilation
Lighting
Refrigeration
Appliances electric
Total electric

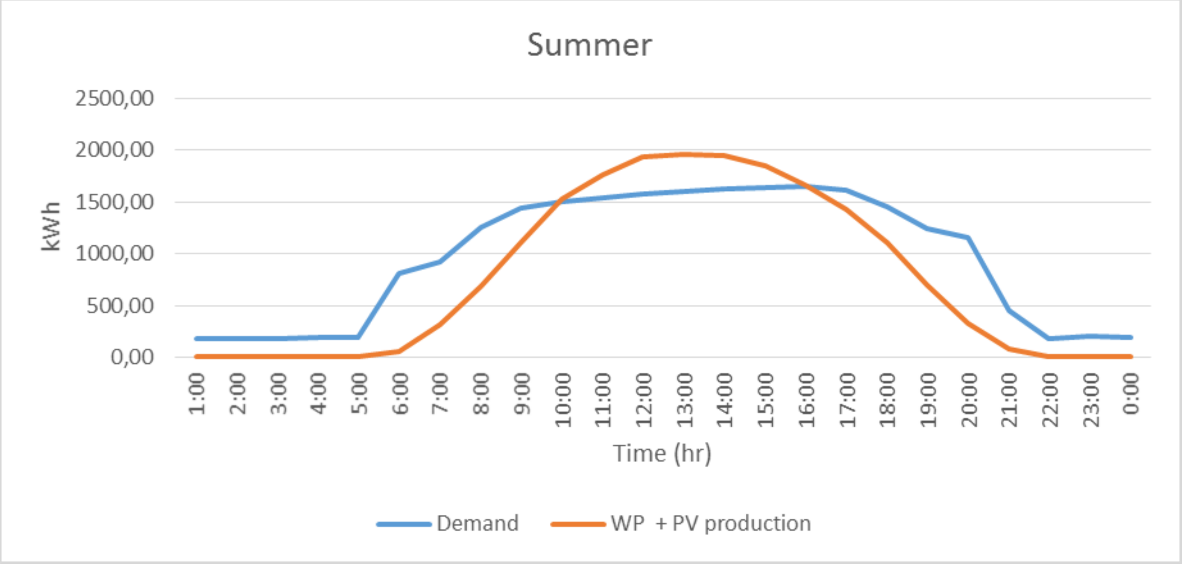
In this case, the grid interaction is reduced to 38% in winter and in summer, and 39% in mid-season with the improvement in terms of lighting.

Lighting + PV

As the lighting solution seems to be a suitable one, the idea is to combine it with the PV solution proposed before in order to calculate a new load match index.







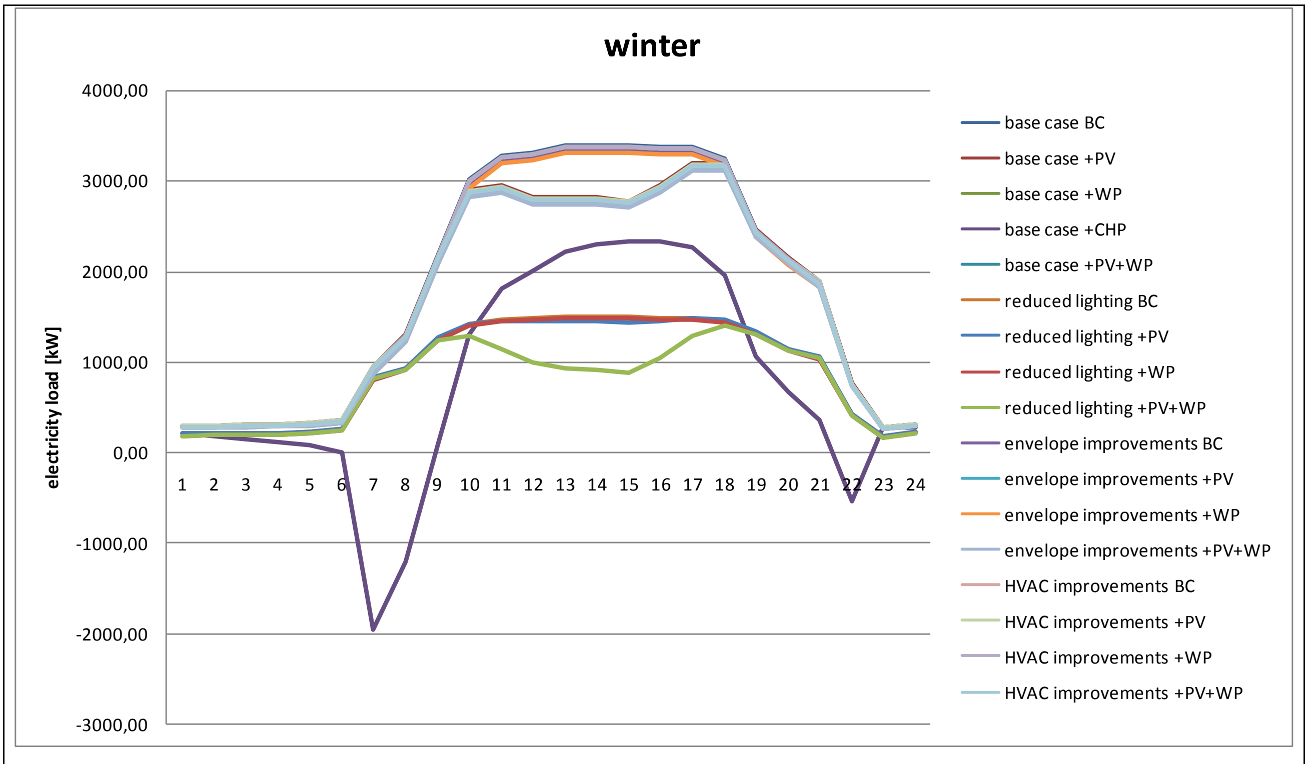
With these values we obtain that the load match during the winter days is approximately 1%, 3% during mid-seasons and 5% in the summer days. The grid interaction is 38% and 39% for winter and mid-season respectively, and 37% in summer.

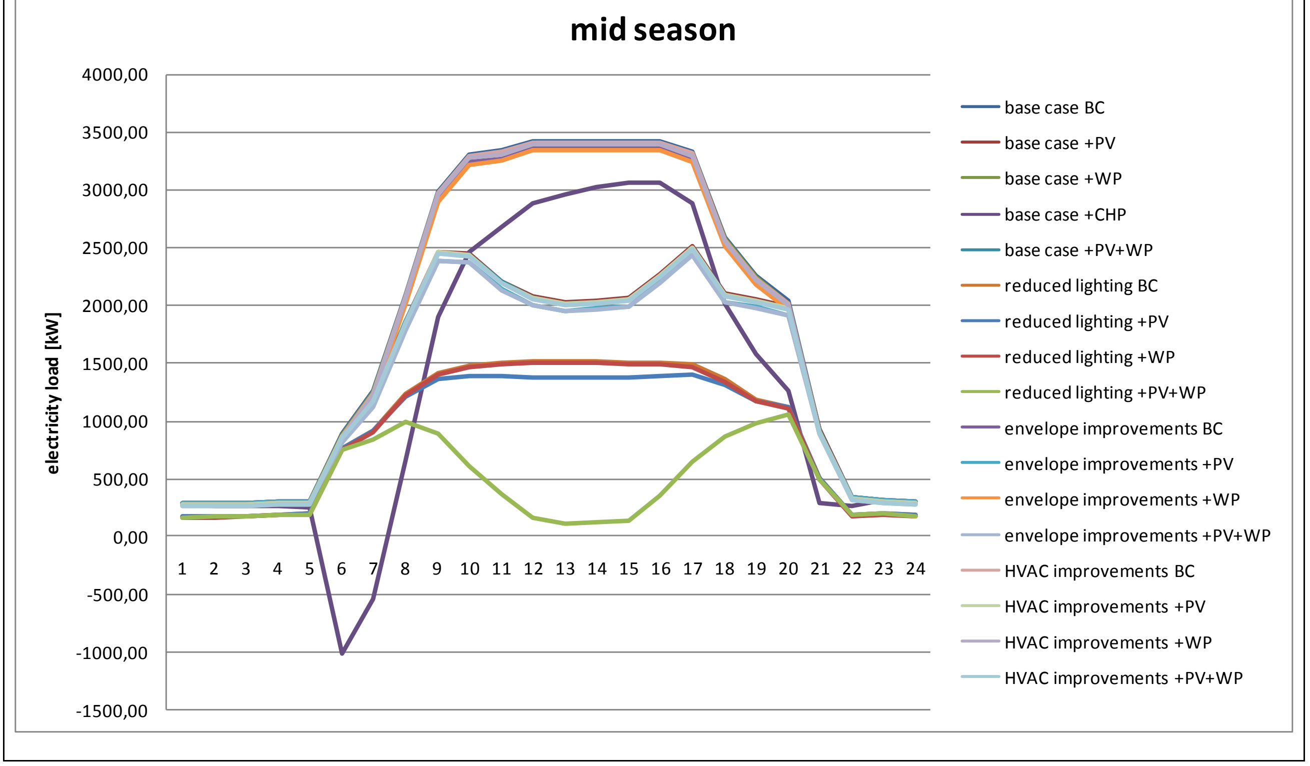
Summary

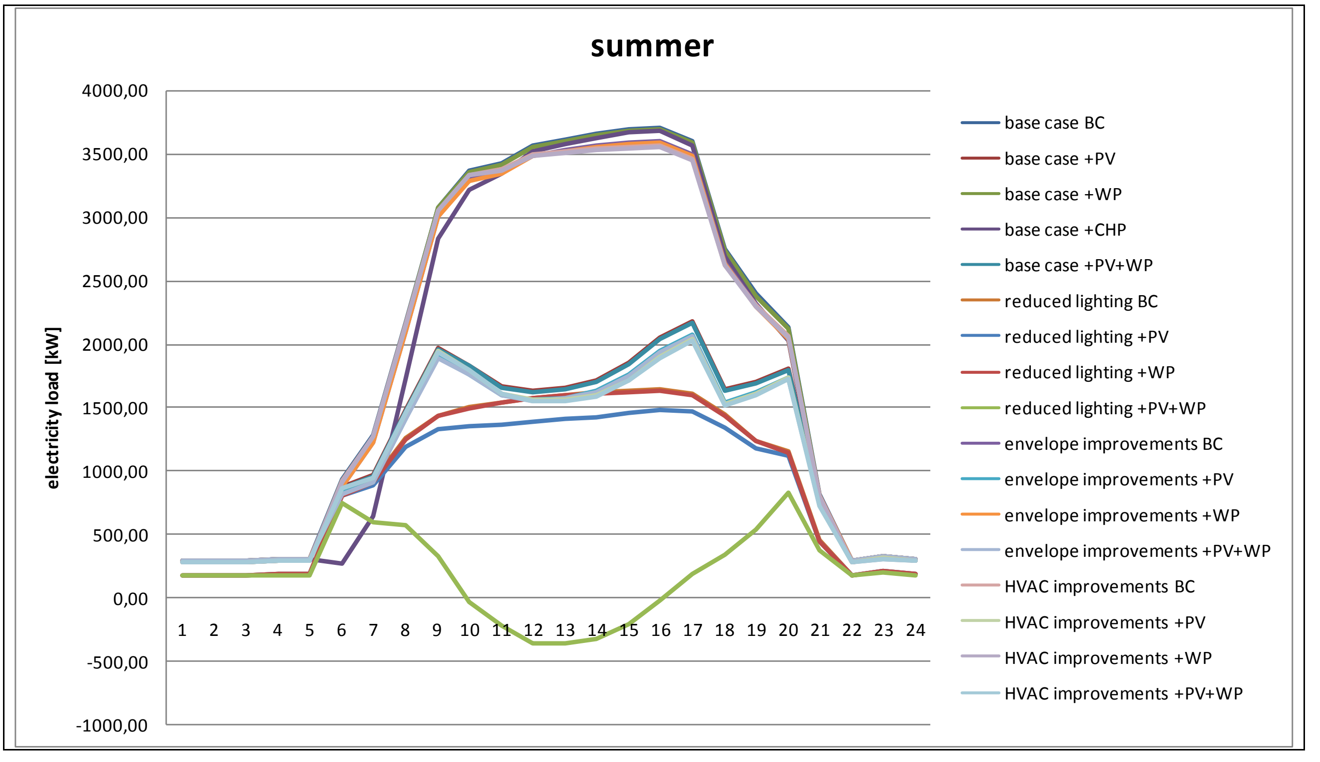
		Base case (BC)			Reduced lighting (LG)		Envelope improvements (EN)		HVAC improvements	
		+PV	+WP	+CHP	+PV	+PV+WP	+PV	+PV+WP	+PV	+PV+WP
LMavg	Winter	4.1 %	1.9 %	70.6 %	0.9 %	12.3 %	4.2 %	6.2 %	4.2 %	6.1 %
	Mid-season	14.3 %	1.4 %	33.7 %	3.1 %	33.6 %	14.6 %	16 %	14.3 %	15.8 %
	Summer	24.3 %	1.3 %	7.4 %	5.1 %	53.2 %	24.9 %	26.3 %	24.9 %	26.3 %
GI	Winter	37.0 %	39.5 %	51.2 %	37.8 %	32.5 %	37.0 %	37.1 %	37.1 %	37.2 %
	Mid-season	35.6 %	39.8 %	43.0 %	38.6 %	32.1 %	35.3 %	35.5 %	35.7 %	35.8 %
	Summer	32.7 %	39.1 %	39.6 %	37.3 %	39.9 %	32.5 %	32.7 %	33.1 %	33.3 %

Grid Interaction improvement

Season	BC + PV	BC + WP	BC + LG	BC + EN	BC + HVAC	BC + PV + WP	BC + CHP	BC + LG + PV	BC + LG + PV + WP	BC + EN + PV	BC + EN + PV + WP	BC + HVAC + PV	BC + HVAC + PV + WP
Winter	2.4 %	-0.2 %	1.4 %	-0.1 %	-0.1 %	2.2 %	-11.8 %	1.6 %	6.8 %	2.4 %	2.2 %	2.3 %	2.2 %
Mid-season	4.1 %	-0.1 %	1.0 %	0.0 %	-0.1 %	4.0 %	-3.3 %	1.1 %	7.5 %	4.3 %	4.2 %	4.0 %	3.8 %
Summer	6.3 %	-0.1 %	1.1 %	0.0 %	-0.4 %	6.1 %	-0.6 %	1.7 %	-0.9 %	6.5 %	6.3 %	5.9 %	5.7 %


winter
electricity load [kW]
4000,00
3000,00
2000,00
1000,00
0,00
-1000,00
-2000,00
-3000,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP


mid season
electricity load [kW]
4000,00
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
-500,00
-1000,00
-1500,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP


summer
electricity load [kW]
4000,00
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
-500,00
-1000,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
base case BC
base case +PV
base case +WP
base case +CHP
base case +PV+WP
reduced lighting BC
reduced lighting +PV
reduced lighting +WP
reduced lighting +PV+WP
envelope improvements BC
envelope improvements +PV
envelope improvements +WP
envelope improvements +PV+WP
HVAC improvements BC
HVAC improvements +PV
HVAC improvements +WP
HVAC improvements +PV+WP

5. Conclusions

There is a meaningful potential for shopping malls to provide services to the grid, especially referring to a better matching of electricity demand and electricity availability (coming from intermittent sources).

Through an analysis performed on CommON*Energy* reference buildings, it was possible to identify the most significant potentials:

- Old and inefficient systems, size of the systems not matching the demand and effect of airtightness: all these potentials cause high energy consumption and/or discomfort problems in shopping centres. This could be more related to old buildings.

- Free spaces both inside and outside the building able to be exploited with generation systems for example installing RES, cogeneration systems, etc. which then allow the buildings to produce their own electricity (self-consumption) or even to pour this electricity when there is a surplus of production to the grid with the possibility to get an economic benefit.

- Possibilities to use daylight (therefore reducing artificial lighting) especially when electricity is scarce or expensive: increase in electrical needs for lights but also for cooling due to the heat gains. In existing shopping centres, there is a huge potential when it comes to lighting. Many shopping centre concepts include large atria in the common areas in order to enhance daylighting. However, the shops very seldom have direct access to daylight. The façade is often partly or completely closed in order to avoid glare and unbalanced lighting problems in the shops. Extensive use of lighting effects with inefficient spotlights means that internal loads for lighting are very high, i.e. up to 30 W/m^2.

- Possibilities to exploit natural ventilation and thus reduce the electricity consumption from mechanical systems and at the same time from the electrical grid.

- Bad integration of thermal fluxes: possibility to recover waste heat and cold reducing the electricity demand from the grid for its production in case of electrical HVAC systems.

- No controllability of energy demand: uncontrolled peaks, for example due to a large affluence of people during unforeseen periods can cause network saturation problems.

- No presence of management systems that could optimise the self-consumption strategy, exploiting favourable tariffs. Here it is also important to notice the possibility to integrate batteries to store energy, for example from RES, when there is an overproduction, or when the tariff prices are lower. This gives the possibility to increase the independence from the grid in case of RES overproduction and reduce the energy costs. The combination of a management system with energy storage also gives the possibility to provide electricity to the grid in periods of high saturation.

- Problems with reactive power compensation and presence of harmonics unfiltered, usually in 5 and 7 due to the presence of nonlinear loads (for example: Mercado del Val). All these have got a direct impact, introducing disturbances from the shopping centre to the electrical grid.

It is important to note that this list is only a general list extracted from the information available from 10 shopping centres, and for each specific case, it would be necessary to develop an exhaustive analysis.

Table 16 summarised the solutions proposed for each building, reflecting the degree of improvement in the interaction between the shopping centres and the electrical grid with different colours. Then, depending on the degree of improvement, it will be possible to extract a general idea of the most feasible solutions to be applied in shopping centres in general.

In this table, using different colours, the idea is to identify which solutions are more efficient (using the KPIs calculated in chapter 4) in each specific case, taking into account all available information. The colour is going to indicate if the solution is more or less effective for each shopping centre. In the legend below the table, it is possible to see which colour matches with the degree of effectiveness (large, medium or low) of the specific solution (PV, Wind “WP”, Cogeneration “CHP”, Lighting improvements “LG”, Envelope improvements “EN”, HVAC improvements, Refrigeration improvements “RF”).

Table 16: Load match and GI improvement in the interaction between the shopping centres and the electrical grid with the different solutions proposed for each shopping centre

Load Match	BC + PV	BC + WP	BC + CHP	BC + LG	BC + EN	BC + HVAC	BC + RF
Mercado del Val	12,60%	2,00%		10,07%	1,06%		
City Syd, Storebrand	6,20%	13,40%	71,33%	6,63%	0,17%	-0,10%	
Genova Ex Officine Guglielmetti	11,20%		12,00%	10,60%	0,77%	0,50%	0,87%
Katané	15,40%		9,13%	12,43%	1,46%	0,03%	0,43%
Donauzentrum, unibail Rodamco	12,20%		27,23%	11,30%	0,30%	0,27%	0,33%
Studlendas, Baltisches Haus	6,33%	6,67%			0,00%		
Pamary, Baltisches Haus	6,33%	8,33%			0,00%		
Waasland Shopping Centre, Devimo	14,40%	2,43%	35,57%	18,63%	0,33%	0,23%	
Grand Bazar	7,60%	4,13%	22,57%	9,50%	0,17%	0,10%	
Brent Cross	14,23%	1,53%	37,23%	17,27%	0,34%	0,24%	

*Note: Load Match for the energy efficiency solutions (Lighting "LG", Envelope "EN", HVAC and Refrigeration "RF") has been calculated taking into account the PV integration and then discounting it of the final value.

GI improvement	BC + PV	BC + WP	BC + CHP	BC + LG	BC + EN	BC + HVAC	BC + RF
Mercado del Val	6,00%	0,00%		6,00%	0,00%		
City Syd, Storebrand	0,37%	-0,93%	-7,93%	-0,10%	-0,67%	-0,03%	
Genova Ex Officine Guglielmetti	5,20%		-1,23%	5,17%	0,20%	0,03%	1,17%
Katané	6,87%		-1,47%	4,63%	0,10%	-0,03%	-3,40%
Donauzentrum, unibail Rodamco	5,23%		-4,20%	2,23%	-0,03%	-0,07%	-0,50%
Studlendas, Baltisches Haus	1,00%	-0,67%			0,00%		
Pamary, Baltisches Haus	1,33%	-1,00%			0,00%		
Waasland Shopping Centre, Devimo	4,30%	-0,13%	-3,17%	0,10%	-0,07%	-0,13%	
Grand Bazar	1,10%	-0,30%	-1,30%	0,47%	-0,07%	-0,13%	
Brent Cross	4,27%	-0,13%	-5,23%	1,17%	-0,03%	-0,20%	

Legend:

- Large improvement (green)
- Medium improvement (yellow)
- Low improvement (red)
- Not defined (grey)

As a general idea from this table and following the analysis developed for each of the shopping centres in the previous sections, it is possible to conclude that for most of the shopping centres depending on the location (mainly at the outskirts and without many elements like buildings surrounding them), the availability of surface suitable to install generation systems, and suitable weather conditions (good irradiance and/or good wind conditions), it would be a good idea to study the possibility to integrate (or increase in case it is already installed) on-site RES such as PV or wind power. It is also important to note that these RES systems need a resistant structure to be integrated. With the information collected it is possible to conclude that for the Load Match, Mercado del Val, Genova Ex Officine and Katané, present their higher potential in terms of PV integration, while Studlendas and Pamarys present their higher potential in WP integration. Regarding the GI improvement all of them present a high potential of improvement in terms of PV integration while, on the other hand, the WP present a negative value so this implies that it affects the interaction with the grid. Some of the inconvenients detected for the integration of this kind of systems, could be from the aesthetical point of view such as in the Valladolid demo case (Mercado del Val) in which although the weather conditions are suitable and there is space on the roof, it would not be possible to install these kind of systems due to their historical character or due to problems related with the noise produced by the wind turbines. An interesting option to overcome part of these issues is the possible integration of PV as part of the building itself (BIPV). Then it would be possible to reduce the aesthetical impact of the integration of PV panels on the roof. This option was proposed in Mercado del Val through PV tiles instead of PV panels, and for Genova Ex Officine, using the parking lot sheds as PV elements.

From the point of view of the energy production; depending on the space inside the building and the energy needs (both electrical and thermal), it is also possible to install a cogeneration system which would allow covering the base loads for electricity demand getting at the same time an improvement in terms of thermal energy. This solution would reduce the electrical demand from the grid through self-consumption and also gives the possibility to provide heating in winter, or even cooling if this cogeneration unit is combined with an ab/adsorption unit in summer, reducing therefore the electricity consumption in case of electrical HVAC systems. This solution has been proposed with more or less degree of integration for some of the buildings with a very high influence in terms of load match, being the higher improvement in almost all of them. However, on other hand, their influence in terms of Grid Interaction is negative.

There are also solutions focusing on energy savings. Within the energy actions that can be undertaken in a shopping centre are those associated to lighting (adjustment of lighting levels for each zone, replacement of lamps by others more efficient (LED, use of natural lighting), improving the buildings' insulation, replacement of old and inefficient equipment with others of higher performance, waste heat recovery strategies, etc. All these actions allow reducing energy consumption, and therefore the demand from the electrical grid, finally improving the grid interaction. These energy saving solutions have been proposed for all the shopping centres depending on the potentials detected in each case. Energy efficiency measures focusing on lighting have the highest potential of improvement in both terms Load Match (LM) and Grid Interaction (GI). The other three suggested solutions (improvements in the envelope, in the HVAC systems and in the refrigeration) seem to not have a relevant effect in terms of LM, or even a negative effect in terms of GI improvement.

Integrating an energy storage in combination with any of the solutions identified above (RES systems and cogeneration) gives the opportunity to improve the energy behaviour of the shopping centre, therefore increasing its autonomy from the electrical grid. This would allow to separate production and consumption, being able to obtain even an economical profit. Installing an energy storage is very relevant in the case of RES systems, because these systems are very intermittent in terms of electricity production, depending completely on the weather conditions. It is also important to note the possibility to use energy storage systems to allow the buildings to store electricity from the grid when the prices are lower (valley periods) and use it in peak periods when the electricity would be more expensive and the grid more saturated.

Another measure to improve the interaction between shopping centres and grids is the implementation of an energy management system: a system that collects, in detail, organisational and technical measures in the centre, in order to track the evolution of the energy consumption of the facilities and equipment of the centre and detect deviations in energy consumption, adopting the necessary corrective measures. This would allow the building to distribute and consume the energy in an optimal way at every moment, avoiding inappropriate energy consumption and therefore reducing the demand from the electrical grid. This system would also allow limiting the demand peaks by disconnecting during short periods of time some loads or by shifting them from one period to another. Some of the analysed shopping centres do not present building management systems and this is why they have a high potential to integrate them.

Finally, it is also important to mention the possibility for these shopping centres to install compensation equipment which allows reducing the reactive power and the possibility to install harmonic filters with the idea to avoid the harmonics introducing perturbations on the grid.

Not less importantly is to mention the non-technical barriers: economic (investment cost and return on investment), execution timing; owner and/or manager awareness of technology, installation and operative issues; legal and technical aspects.

The highest potentials to improve load match and grid interaction are of course in the old and inefficient systems which consume a lot of electricity. The absence of control and management systems able to dynamically adapt the consumption/production fluxes, as well as available spaces free of obstacles and with suitable conditions either inside or outside the building, produce high improvement potential. RES and cogeneration systems could be integrated, using local natural resources through daylight and natural ventilation strategies.

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Annex 1: Additional building-grid interaction indicators

- Net Exported energy

  The general equation is the following, which depending on the data resolution and period can become the yearly, monthly, daily, etc.

$$ne(t) = e(t) - d(t)$$

- Peak power Generation/Export

  The peak power generation/export (G_{des}) represents the normalized peak value of the on-site generation or exported energy with respect to the nominal grid connection capacity (E_{des})

$$\overline{G_{des}} = \frac{G_{des}}{E_{des}} = \frac{max[g(t)]}{E_{des}}$$

$$\overline{G_{des}} = \frac{G_{des}}{E_{des}} = \frac{max[e(t)]}{E_{des}}$$

- Peak power Load/Delivered

  The peak power load/delivered (L_{des}) represents the normalized peak value of the load with respect to the nominal grid connection capacity.

- Generation Multiple

  The generation multiple (GM) relates the size of the generation system with the design capacity load and it is expressed by the ratio between generation/load peak power and the exported/delivered peak powers.

  $GM=G_{des}/L_{des}$

- Design Range

  Defined as the amplitude between the generation/load or the exported/delivered energy values.

  $A_{des}=G_{des}- L_{des}$

- Capacity factor

  The capacity factor indicates the total energy exchange with the grid divided the nominal connection capacity; basically, a measure of the utilization of the grid connection:

$$CF_{b,E} = \frac{\int_{\tau_1}^{\tau_2} |ne(t)|dt}{E_{des} \cdot T}$$

- Dimensioning rate

  The maximum absolute value of the net exported energy:

$$DR = \frac{max[|ne(t)|]}{E_{des}}$$

- <u>Peaks above Certain Limit</u>
  It indicates the part of the analyzed period for which the net export energy exceeds a certain barrier.

$$E_{>E_{lim}} = \frac{\int_{\tau_1}^{\tau_2} dt_{|ne(t)|>E_{lim}}}{T}$$

- <u>Grid Citizenship Tool</u>
  It focuses on the qualitative assessment of the way a building interacts with the greater power system (e.g., low-voltage power grid). It consists of several factors: component ratio (CR), storage ratio (SR) and intermittency ratio (IR).

- <u>Load Cover Factor and Supply Cover Factor</u>
  The load cover factor (γ_{LOAD}) represents the percentage of the electrical load covered by electrical generation. The complementary index, the supply cover factor (γ_{SUPPLY}), represents the fraction of the on-site generation used by the building.

$$\gamma_{load} = \frac{\int_{\tau_1}^{\tau_2} min[g(t) - S(t) - \zeta(t), l(t)]dt}{\int_{\tau_1}^{\tau_2} l(t)dt}$$

$$\gamma_{supply} = \frac{\int_{\tau_1}^{\tau_2} min[g(t) - S(t) - \zeta(t), l(t)]dt}{\int_{\tau_1}^{\tau_2} g(t)dt}$$

Where S(t) is the storage and ζ(t) the losses.

They are useful to illustrate both the daily and seasonal effect, the production of pattern of different RES technologies and the applied operation/control strategies including storage.

Annex 2: Quality of energy supply in Mercado del Val

In this subsection, is shown the analysis carried out in the Provisional Market of Valladolid with the grid analyzer described in Annex A2.1 in order to characterize the quality of the interconnection between the building and the electrical grid.

Equipment and registration point

The analysis has been developed in the Provisional Market due to the fact that Mercado del Val is not going to be operative until after the rehabilitation works, however is assumed that the results of this analysis are not going to vary significantly due to the location (near to Mercado del Val), size and type of activity.

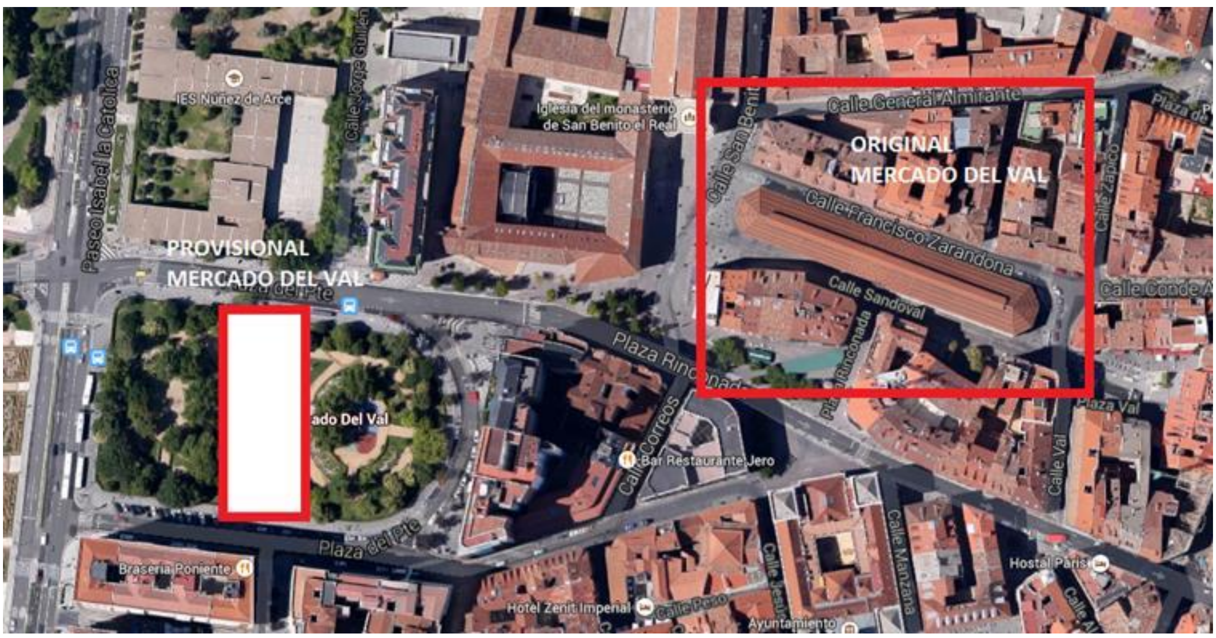


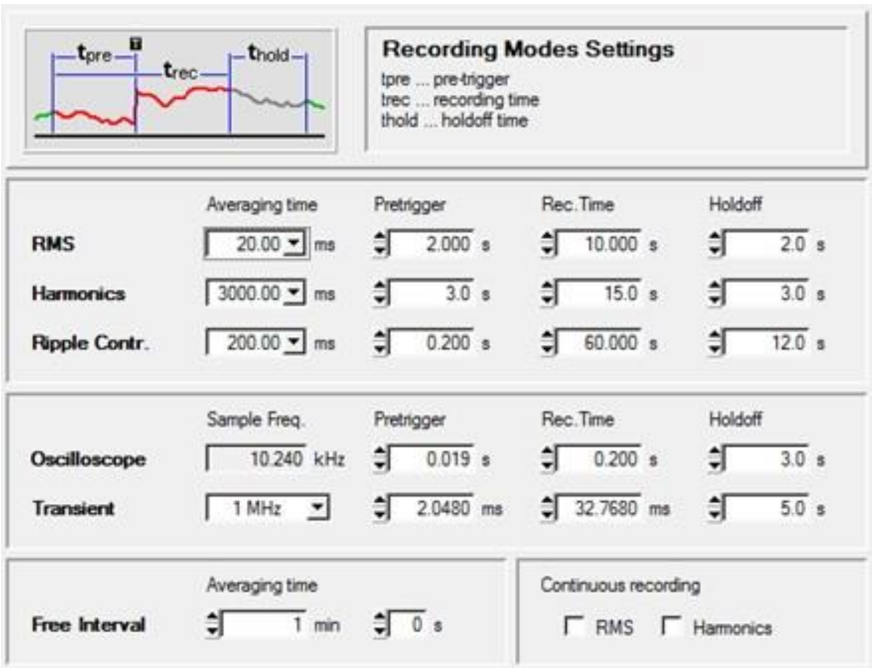
Figure 11: Location of Provisional Val Market and Original Val Market (Source: Google Maps)

The validation of the interaction between the supply point and the electrical grid needs to cover two important aspects. First, to have equipment capable of recording the characteristics of the electrical grid, which are marked by the EN 50160 standard indicated above, and secondly, to select the most appropriate measurement point.

To carry out the different test of quality supply, a three phase power grid analyzer has been used[1]. A one minute information register period has been considered, varying this frequency

[1] Equipment model FLUKE 1760, which is under Class A IEC 61000-4-30 standard, and designed for advanced power quality analysis as well as compliance checks.

for the event log according to the established criteria, to be able to characterize them properly.



With regard to the registration point, it has been considered more appropriate, the general service of electricity supply of the work stations and general services of the provisional Val market, recording values of voltage and current, immediately after main switch.

Figure 42: Images of the measurement point and installation of the recording equipment.

Methodology

To contrast and validate the installation performance, it is necessary to start from reference indexes based on existing legislation. Behavioral anomalies of the facilities or possible interferences on the correct operation of the electric system can be identified based on these norms. The quality specifications of electricity supply is specified in the EN 50160.

Frequency

For coupled networks with synchronous connections to a network of high voltage, the following variations are allowed in tension:

- 49,5 Hz --- 50,5 Hz for 99,5 % of a year
- 47 Hz --- 52 Hz for 100 %

Amplitude

The norm establishes that the effective voltage variations must be between -10% and +5%.

Waveform

This parameter sets the similarity between the analyzed wave and a perfect sinusoidal signal. The distortion is associated with the presence of voltage harmonics. Two types of measures are used for evaluation:

- *Rate of total harmonic distortion (THD)*

THD is a measure of signal distortion level, but being an aggregated indicator, it should be complemented by individual harmonics limits. The norm establishes that the range of variation must be maintained between 0% -8%.

- *Particular Harmonics*

In normal operating conditions, during each period of one week, 95% of the effective values of each harmonic tension, averaged over 10 minutes, should not exceed the values in the following table:

Table 17: Values maximum for harmonics

Period	*Variation [%]*	*Period*	*Variation [%]*
		21	0% --- 0.20%
2	0% --- 2.00%	*22*	0% --- 0.20%
3	0% --- 5.00%	*23*	0% --- 0.74%
4	0% --- 1.00%	*24*	0% --- 0.20%
5	0% --- 6.00%	*25*	0% --- 0.70%
6	0% --- 0.50%	*26*	0% --- 0.20%
7	0% --- 5.00%	*27*	0% --- 0.20%

Period	*Variation [%]*	*Period*	*Variation [%]*
8	0% --- 0.50%	*28*	0% --- 0.20%
9	0% --- 1.50%	*29*	0% --- 0.63%
10	0% --- 0.50%	*30*	0% --- 0.20%
11	0% --- 3.50%	*31*	0% --- 0.60%
12	0% --- 0.20%	*32*	0% --- 0.20%
13	0% --- 3.00%	*33*	0% --- 0.58%
14	0% --- 0.20%	*34*	0% --- 0.20%
15	0% --- 0.30%	*35*	0% --- 0.56%
16	0% --- 0.20%	*36*	0% --- 0.20%
17	0% --- 2.00%	*37*	0% --- 0.53%
18	0% --- 0.20%	*38*	0% --- 0.20%
19	0% --- 1.50%	*39*	0% --- 0.52%
20	0% --- 0.20%	*40*	0% --- 0.52%

Values higher than the harmonics of prime numbers are allowed. This is because an important factor in this distortion is the high-power electronic converters, which are present in the power converter in greater or lesser extent.

Phase symmetry

The way to measure the phase symmetry of the system is from the level of imbalance, which is limited to 2%.

Following is a summary table with the limits established by the norm:

Table 18: Limits established by Norma 50160

Nominal values	
Nominal voltage Un:	230.00V
Nominal frequency:	50.00Hz
Event Limits	
Dip threshold:	90.00%
Swell threshold:	110.00%
Interruption threshold:	1.00%
Hysteresis:	2.00%
S/L Interruption time threshold:	180.00s
EN50160 Statistics	
Voltage 95% pos. limit:	110.00%
Voltage 95% neg. limit:	90.00%
Voltage 100% pos. limit:	110.00%
Voltage 100% neg. limit:	85.00%
Frequency 95% pos. limit:	101.00%
Frequency 95% neg. limit:	99.00%

Frequency 100% pos. limit:	104.00%
Frequency 100% neg. limit:	94.00%
Long-term Flicker Plt:	1.00
Max. number of Events:	100
Unbalance:	2.00%
THD:	8.00%
Rapid Voltage Changes	
Minimum rate of change:	5.00%

Analysis of the recorded data

Two types of analysis have been done.

Normative EN 50160

The supply at the point of connection to the provisional Val market has been analyzed, throughout the entire measurement period, according to the parameters established by setting limits and times of registration imposed by EN 50160.

Based on the quality standard it has been obtained as a result, that the installation does not distort the quality of the network where Spanish demosite is located, during the period of record (Figure 13). It is meant by quality power supply, no interruption surges, deformations caused by harmonics in the network and voltage variations above permitted levels of the electrical signal supplied and can jeopardize the computers that are network connected.

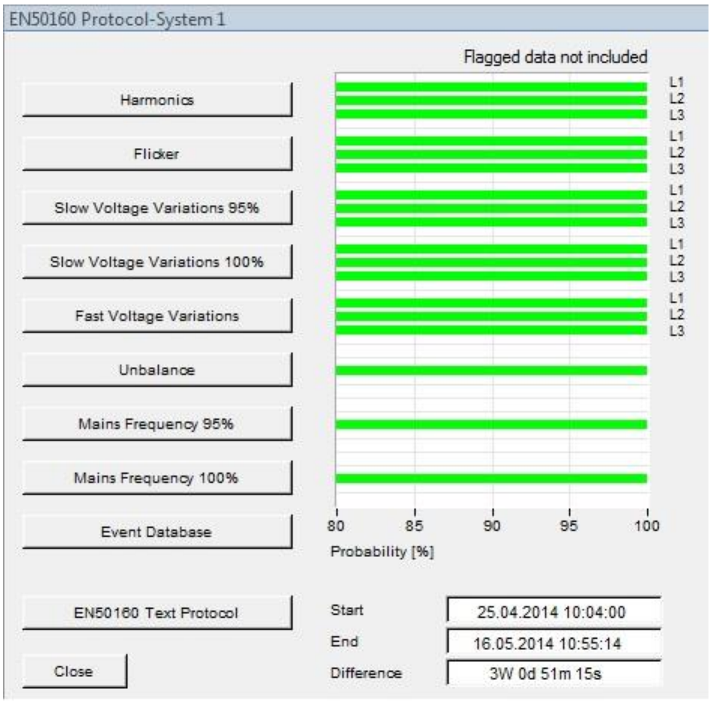


Figure 53: Standards compliance EN 50160

Evolution of the main electrical parameters.

Complementary to the implementation of EN 50160, has been considered the analysis of the evolution of the main electrical parameters characterizing the connection over the same period of registration and that helps to characterize in more detail the relationship between energy consumption of Val market and distribution network to which it connects.

The evolution of such values are displayed in graphs where each colour represents a type of phase.

Main conclusions for each parameter:

- Voltage: any voltage drops or overvoltage problems is caused in equipment to which supply is provided.
- Active and reactive power: Daily energy demand curve has been identified. There are also imbalances, especially during periods when the market is operating. It seems necessary to propose compensation measures of these values through suitable capacitor systems, either globally compensation in the point of supply or to the equipment causing this consumption.
- Flicker peaks detected can be associated with the connection/disconnection of some equipment. Generally they do not affect other equipment connected to the grid.

With this information is possible to confirm that it is possible to introduce saving and efficiency measures (e.g. peak shaving of demand curve from 8 am until 3 pm) and incorporate RES in Spanish democase since the grid is not saturated.

Voltage

Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. A voltage collapse occurs when the system try to serve much more load than the voltage can support.

The evolution of the RMS (*root mean square*) values in each phase, show minor variations, as is usual in an urban supply. This means that any voltage drops or overvoltage problems is caused in equipment to which supply is provided.

Value	Max. [V]	Time	Min. [V]	Time
Urms L1	241,500	Wen30/04/2014 0:00 close	230,770	Wen 07/05/2014 10:20
Urms L2	242,400	Sun 27/04/2014 19:40 close	232,120	Thu 08/05/2014 13:30
Urms L3	242,030	Sat 26/04/2014 10:40 open	233,280	Fri 09/05/2014 21:40 close

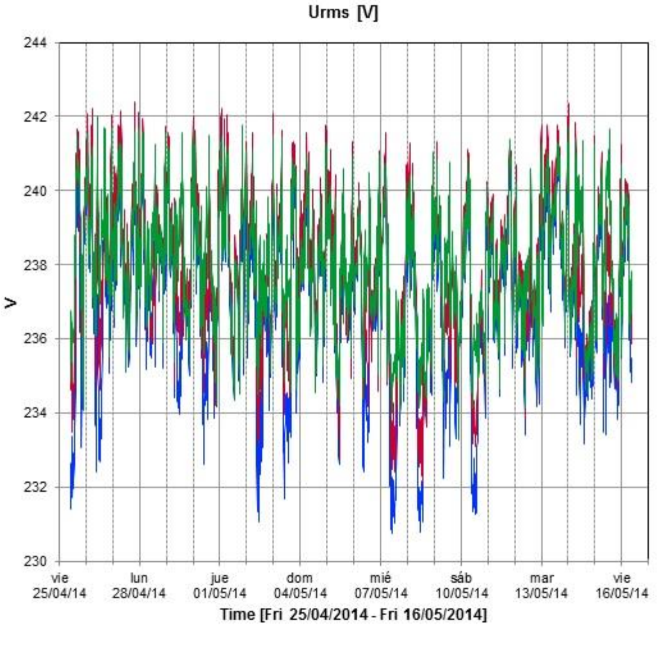


Figure 14: Evolution of RMS voltage values during the registration period

Active Power

Active power (real power of facility) analysis shows similar behaviour for all the working days, while a different behaviour was observed for holidays and other periods when the market is closed. The maximum power values observed was 58.3 kW (around 2pm on weekday), minimum power registered of 3.5 kW (on Sunday morning), maintaining a base of requested consumption of 8 kW.

Detailed analysis of the consumption for each of the phases indicate an imbalance because of the wide range of values obtained, especially during periods when the market is operating, which may be due to the operation of single-phase loads associated with certain stalls. The consequences of grid imbalance include impaired control and regulation equipment, uneven loading of the transformer (losses, noise), uneven motor operation (losses, wear) and reactive power costs.

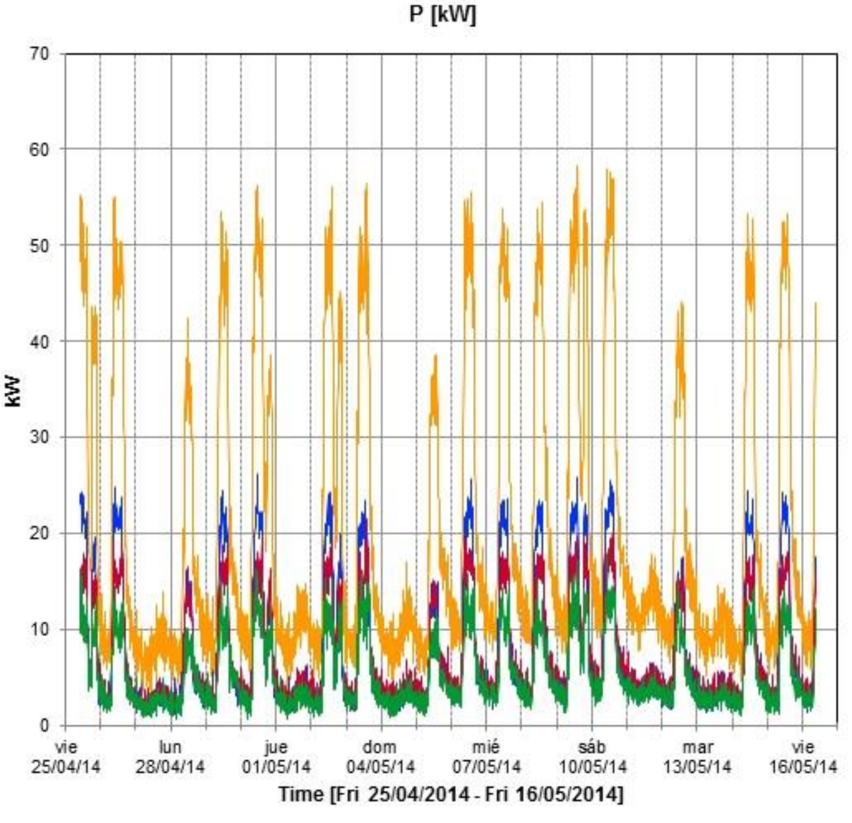


Figure 15: Evolution of active power consumed during the measurement period.

Here below are shown the demand curve associated with a typical working day and a day when the market is closed.

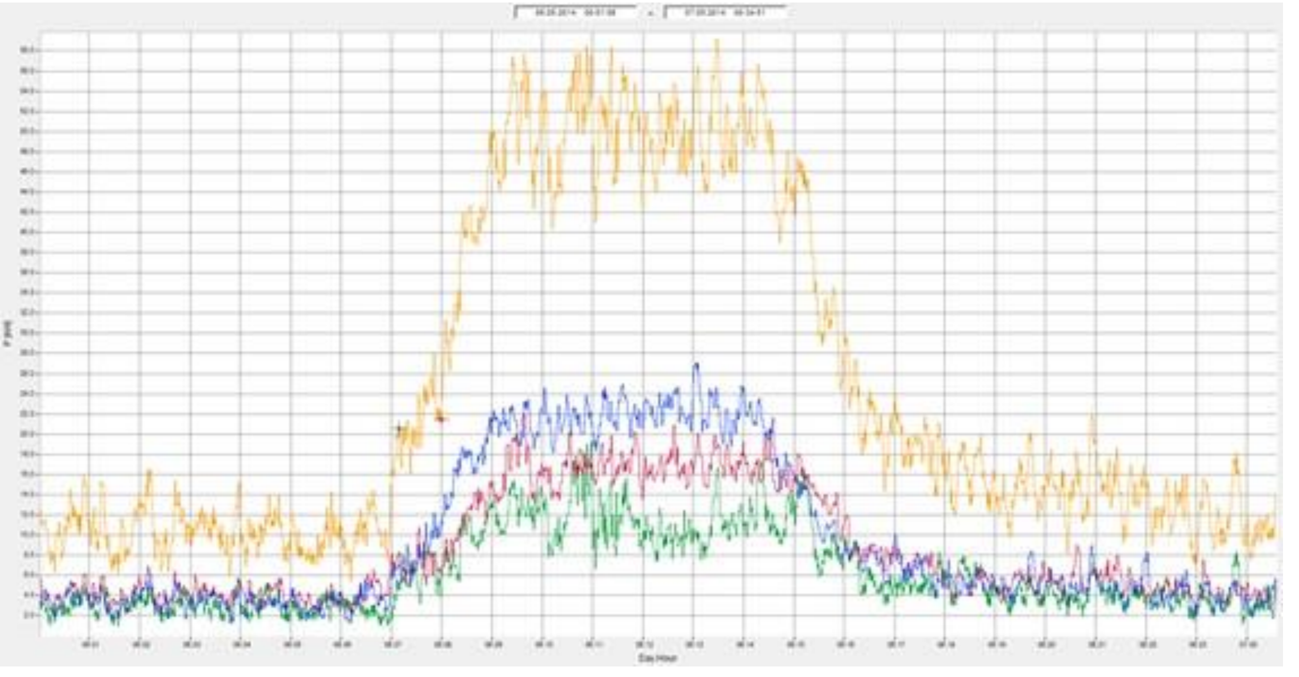


Figure 66: Demand curve for a working day

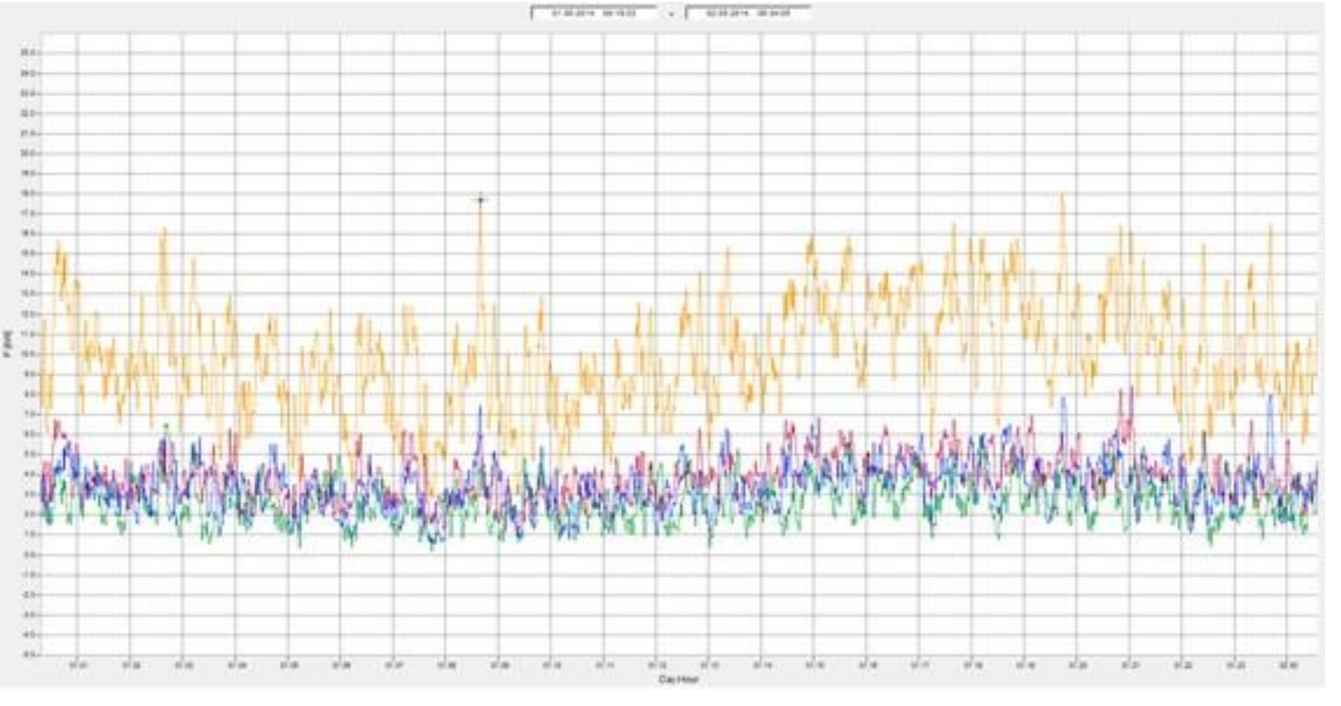


Figure 177: Demand curve for a day when the market is closed

The demand starts at 6 am and increase until it reaches the standard value at around 9 am; it is then pretty stable until 3 pm when it starts to decrease until it goes back to the base value at around 7 pm. The profiles basically follow the operation of the stalls so the consumption is mainly attributable to lighting and refrigeration at the beginning, then when the market is in open for the central hours of the day.

Reactive Power

A similar analysis was conducted for the consumption of reactive power. High values of reactive power consumption, correlated with active power consumption are generally observed. Consequently, the current flowing is greater than that required for useful work demanded and this causes a power loss of the facilities

In general terms, decreasing reactive power causing voltage to fall while increasing it causing voltage to rise.

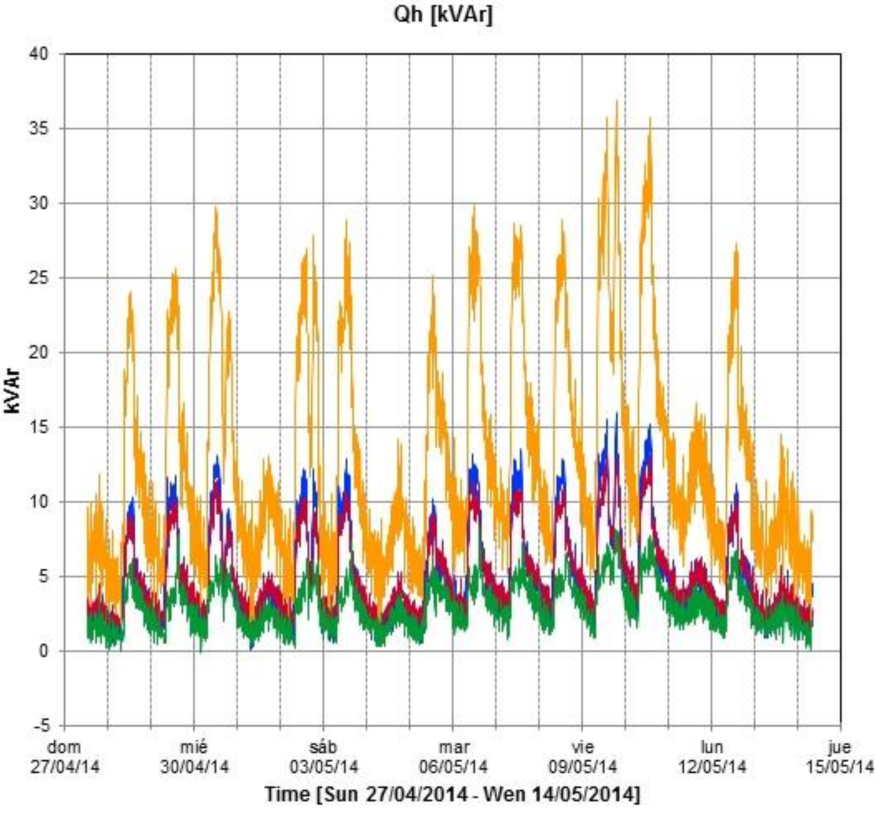


Figure 18: Evolution of reactive power consumed during the measurement period.

In more detail are shown in Figure19 and Figure 80 the different behaviour of reactive energy consumption on a typical working day when the market is open and another in which the market is closed and the unique consumptions are due to refrigeration systems for food preservation.

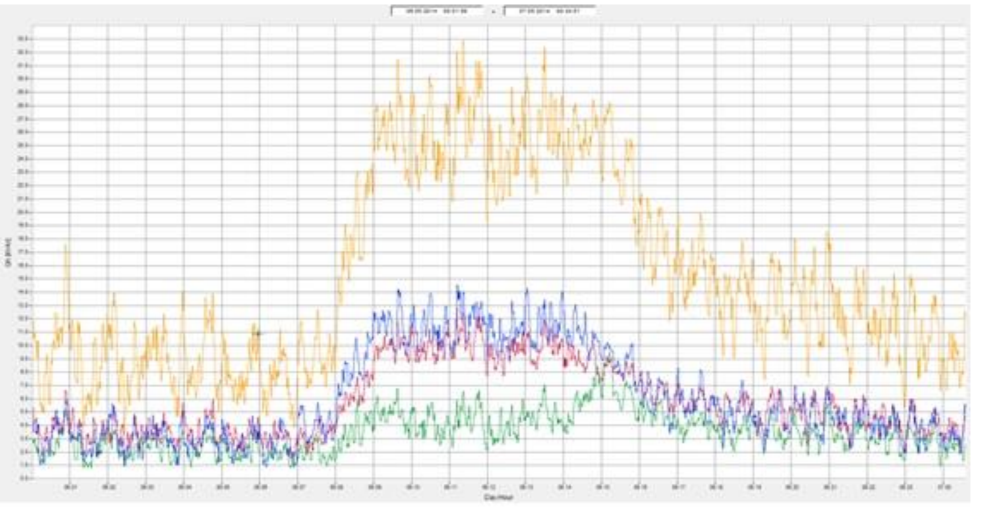


Figure 19: Reactive energy consumption curve in a day of normal operation.

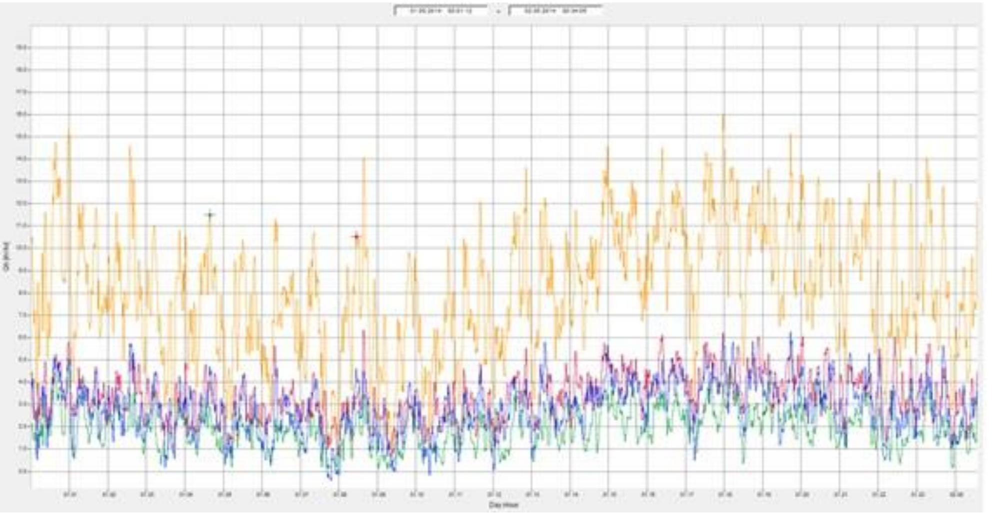


Figure 80: Reactive energy consumption curve in a day when the market is closed.

Cos of Phi

Cosine of phi is defined as the angle of existing displacement between the current wave and their voltage wave. In phase values are defined as the angle formed between the active power (P) and apparent power (S) of a load. Low CosPhi means greater current demand for a given power compared to a larger one. This implies oversize the cable section. On the other hand low CosPhi, increases the apparent power, which requires an increase in the transported power and thereby the power generated. This is not desired by utilities, therefore they penalize low CosPhi, forcing its improvement or imposing a higher cost of energy supplied.

AT Mercado del Val, we observed lower values according to the high consumption of reactive power previously detected, and not properly compensated.

Figure 91 reflects maximum and minimum values and the color legend.

Value	Max. [1]	Time	Min. [1]	Time
CosPhi L1	0,996	Thu 01/05/2014 7:50	0,637	Tue 06/05/2014 1:00
CosPhi L2	0,994	Wen14/05/2014 7:20	0,666	Sat 03/05/2014 19:10
CosPhi L3	1,000	Wen 14/05/2014 7:20	-0,999	Mon 28/04/2014 7:10
CosPhi Sum	0,989	Wen14/05/2014 7:20	0,680	Tue 06/05/2014 1:00

Figure 91:

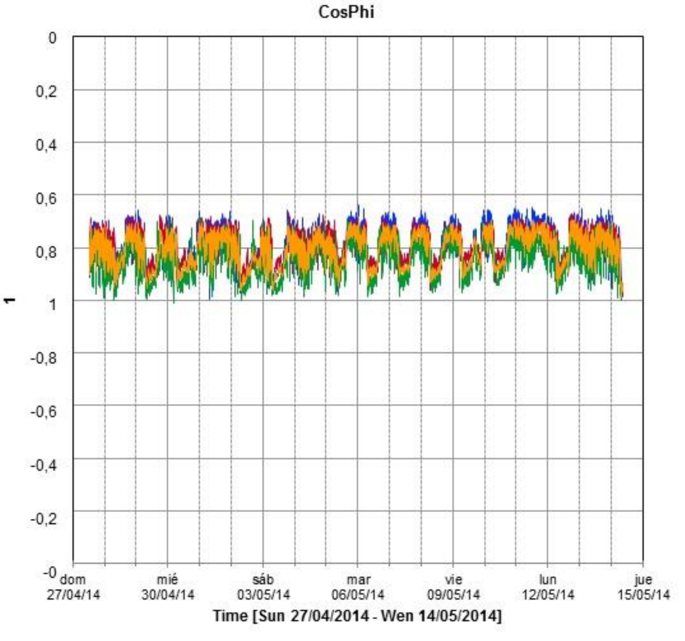


Figure 102: CosPhi evolution during the registration period

Given the reactive power values detected, it seems necessary to propose compensation measures of these values through suitable capacitor systems, either globally compensation in the point of supply or to the equipment causing this consumption.

Harmonic distortion rate (THD)

Harmonics are high frequency components that distort the sinusoidal signal. Their impact on the electrical systems is very important, as it modifies the value of the reactive power, both capacitive and inductive of the different linear components. Also, this causes the appearance of neutral currents, increases the load factor of the transformer, increase hysteresis losses in the magnetic cores, change the speed in the motors, etc.

Figure 113 shows the harmonic development of the voltage wave at the point of connection that provides electricity supply to the provisional Val market.

Color legend

Quantity	Unit	L1 / L12	L2 / L23	L3 / L31
Urmsrel to h01 of h	[%]	*****	*****	*****

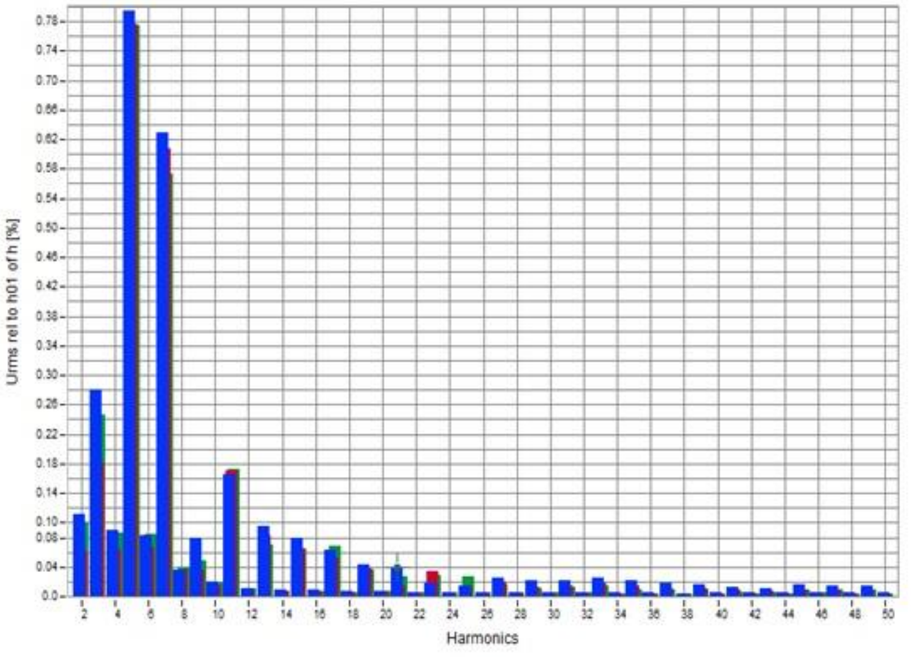


Figure 113: Harmonic development of the voltage wave during the registration period.

It is important in the analysis of the quality of the network to analyze the values that have harmonic components, both the value of each particular sequence and as global aggregate values. To do this the Total Harmonic Distortion rate (THD) is defined which shows an average value of the harmonics of a sinusoidal electrical signal.

In the following figures the evolution of this parameter is shown during the analysis period, both the voltage wave (THDU) Figure4 and wave intensity (THDI), Figure 25.

Color legend Figures 24 and Figure 25.

Quantity	Unit	L1 / L12	L2 / L23	L3 / L31
THDU and THDI rel to h01	[%]	*****	*****	*****

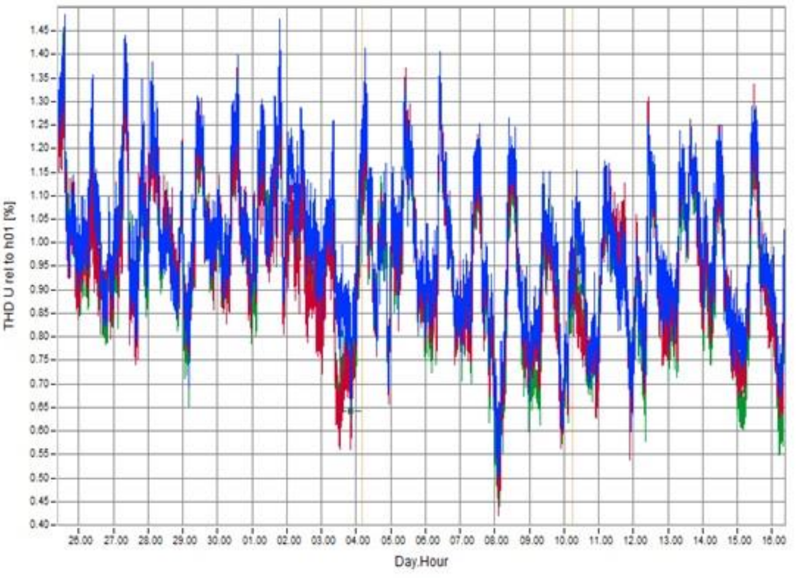


Figure 24: Evolution of THDU during the registration period.

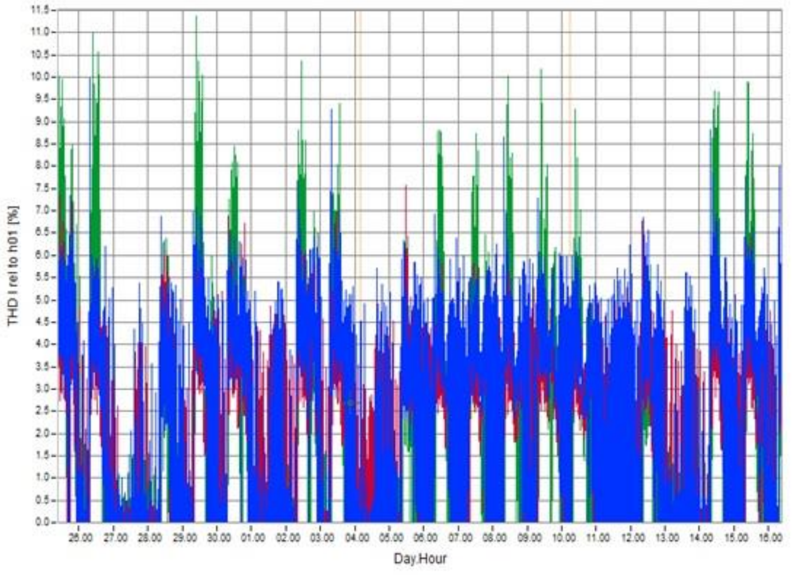


Figure 125: Evolution of THDI during the registration period.

THDU values below 2.5% and UTHDI below 15% do not cause problems in the electricity supply. As can be seen in both figures these conditions have been verified during the registration period.

Flicker

Flicker is another phenomenon that affects the quality of the network, and has its origin in frequency variations of the electric signal. It is constituted as one of the major problems of regulation produced by voltage variations in the network, depending on the amplitude, frequency, and duration of fluctuations.

For the measurement two parameters are set: Pst and Plt which assess the presence in the short and long term respectively. The installation meets the quality standard, so there is not a significant presence of flicker. This can be seen in Figure 26 which shows the evolution of Pst during the registration period.

Colors legend Figure 26136.

Quantity	Unit	L1 / L12	L2 / L23	L3 / L31
Pst	[1]	*****	*****	*****

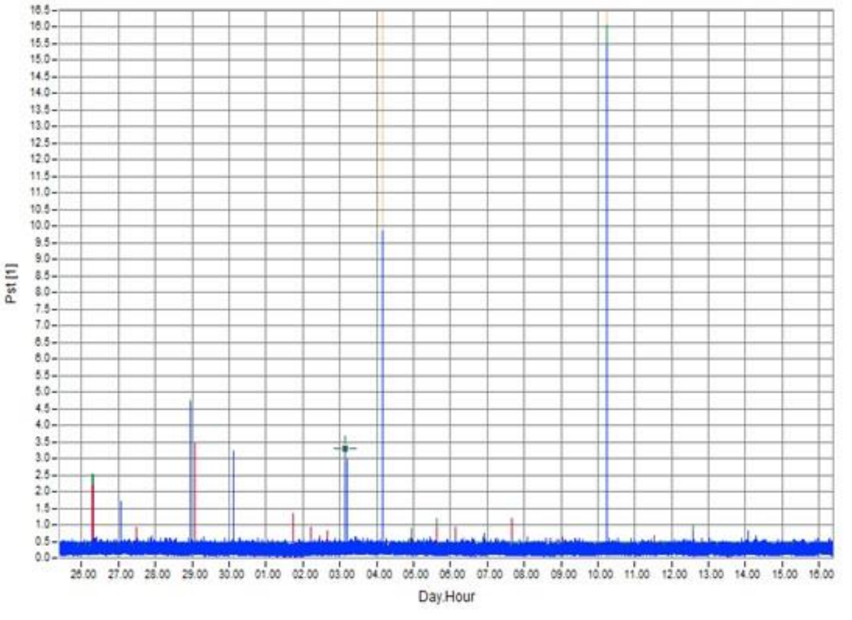


Figure 2613: Flicker evolution (Pst) during the registration period.

The noticed peaks can be associated with the connection/disconnection of some equipment, but generally does not affect other equipment connected to the grid.

Curve CBEMA

A classification and positioning on a CBEMA curve is an effective way to determine the criticalness of recorded events. This is a curve that classified the events in the electric grid versus the sensitivity of electronic equipment. It is an indication of the impact that certain operation conditions may have on the users.

The analysis of events that have occurred shows as they are of mild severity and not causing problems on different machines.
Electrical events can affect the system in two ways: by defect intensity and duration. Important events with short duration can be equivalent to insignificant defects, but that elongate over time. On this basis, in CBEMA the events of the network are represented in

the XY space, in which the X axis corresponds to the duration of the event on a logarithmic scale and the Y axis the amplitude in percentage in relation to the tension. This methodology defines regions of the XY plane (duration-magnitude) that electronic equipment must withstand to continue with the proper operation.

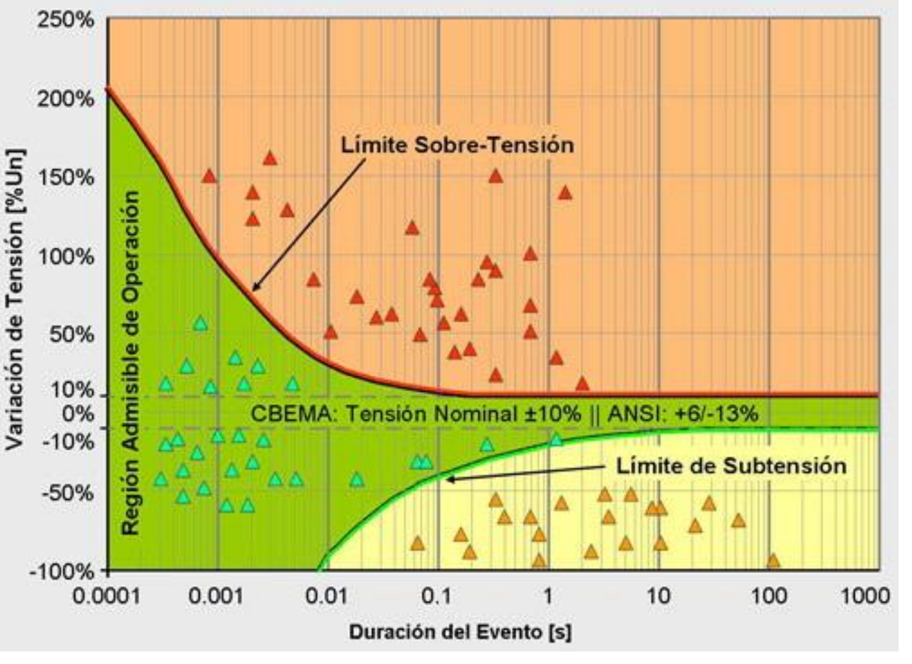


Figure 2714: CBEMA curve representation (Source: http://www.ecamec.com)

In CBEMA representation there are three zones:

- The upper curve is defined by a minimum duration of 1 millisecond cycle and voltage deviation from nominal voltage of about 200%. Usually the curve is used from the one tenth of a cycle (0.1 cycles) due to the practical limitations of the power quality instruments and the differences of opinion on the definition of magnitudes in the frame of sub cycle times. Those points above the positive trace represent causes of malfunction, such as faults in isolation, overvoltage shots, and over excitation, and can damage electronic devices.

- The area between the curves, the region with the voltage value +/-10%, is defined as supply stable state margin. Any voltage variation within +/-10% will not be evaluated as an event or disturbance.

- The area below the negative curve represents points involving causes of voltage loss due to the lack of energy. Events located in this area affect the proper functioning of the instruments connected to the network but do not cause damage.

Figure 28 shows the CBEMA curve, obtained from the events registered in the point of electric supply of the provisional Val market. Indicate that events in them are represented by colour points where the colour indicates the type and phase:

Colours legend Figure 28.

Quantity	Unit	L1 / L12	L2 / L23	L3 / L31
VoltageDips U	[%]	*****	*****	*****
VoltageDips 3-ph U	[%]	*****	*****	*****
RMS LowerLimit U	[%]	*****	*****	*****
Oscilloscope-Max U	[%]	*****	*****	*****

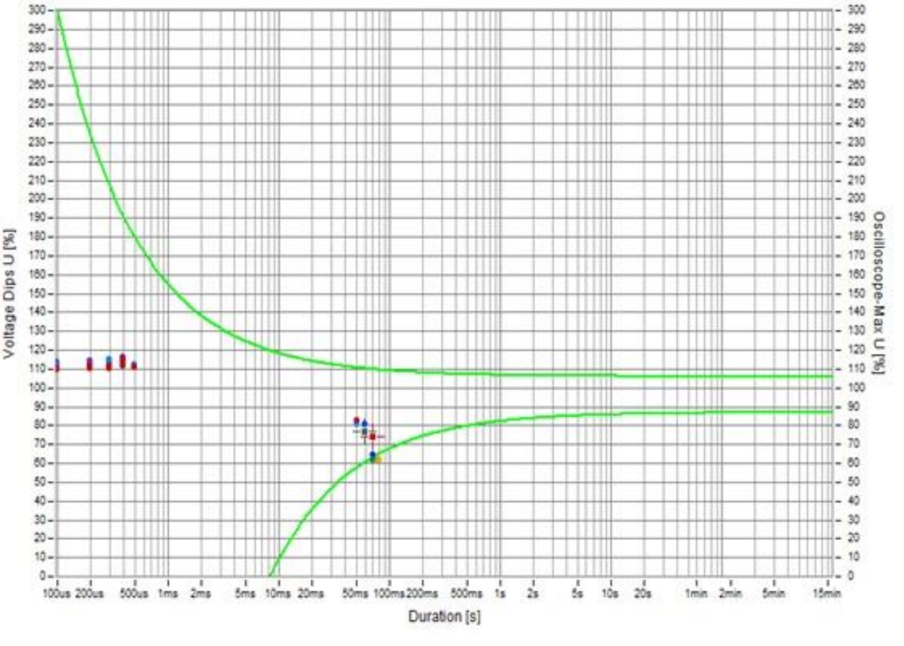


Figure 28: CBEMA curve of the events registered during the registration period.

A2.1 Grid Analyzer

For Valladolid demo case, together with the information collected through the questionnaire, has been used a grid analyzer which main information is summarized in this section.

Grid analyzer: Fluke 1760 Three-Phase Power Quality Recorder.

Class-A compliance for the most demanding power quality tests: Designed for troubleshooting in utility and industrial power distribution systems in medium- and low-voltage networks, the three-phase Fluke 1760 Power Quality Recorder provides the flexibility to customize thresholds, algorithms, and measurement selections. It has 8 channels (4 currents /4 voltages or 8 voltages) and captures the most comprehensive details on user-selected parameters and allows for later analysis and reporting.

Figure 29: Grid analyzer

Applications

- Detailed disturbance analysis – Perform high-speed transient analysis and uncover root cause of equipment malfunction for later mitigation and predictive maintenance. The fast transient option, with its 6000 V measurement range, allows capture of lightning strikes.
- Class-A quality-of-service compliance – Validate incoming power quality at the service entrance. Thanks to Class A compliance, the Fluke 1760 allow sun disputable verification.
- Event correlation at multiple locations – Thanks to GPS time synchronization, users can quickly detect where a fault occurred first, either inside or outside the facility.
- Galvanic separation and DC coupling: Allows complete measurements for example on UPS systems including the battery voltage and power output.
- Power quality and power load studies – Assess baseline power quality to validate compatibility with critical systems before installation and verify electrical system capacity before adding loads.

PQ Analyze software

The Fluke 1760 includes comprehensive software for detailed power quality analysis on PCs with Windows® based operating systems. In the online function, the software enables remote instrument setup, job processing, real-time verification of actual measurement values, and data download in the online function. Data can be viewed in trend diagrams for root cause analysis or in statistical summaries in a variety of formats. You can also generate professional reports with the Report Writer function. Next figure 30 shows the output figures, whereas next 5 tables (Table 19) provide characteristics of software.

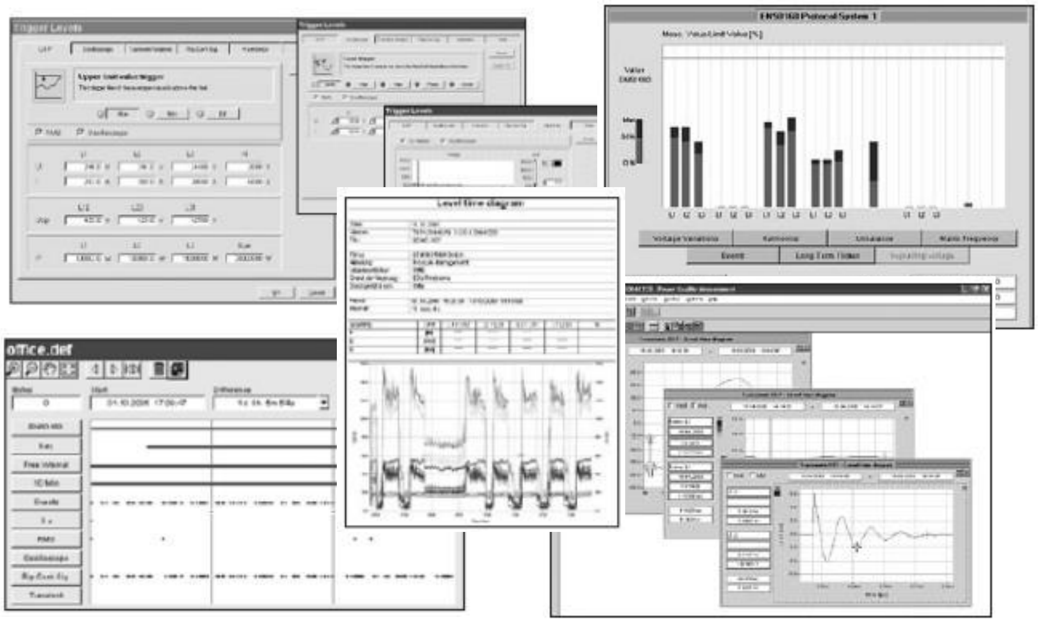


Figure 30: PQ Analyze software

Table 19: Main characteristics of software of grid analyzer

Overview of measurement functions	
Statistical Evaluation	Power quality statistics according to EN 50160 and DISDIP tables like ITIC, CEBEMA, ANSI
Event List	Dips, swells and interruptions are detected and stored in the event list. Also any trigger which fires generates an event added to this list. The Event list shows the exact time when the event occurred as well as the duration and magnitude. Sorting by several attributes of these events is possible to select one for further root cause analysis. RMS values, transients and fast transients can be stored if a trigger fires.
Continuous Recording	Fluke 1760 records RMS values together with corresponding minimum and maximum values for: • Voltage • Current • Power P, Q, S • Power Factor • kWh • Flicker • Unbalance • Frequency • Harmonics/Interharmonics continuously with the following time aggregations: Day 10min Free Interval, e.g.: 15 min, 2h
Triggered Recordings	RMS: Aggregation time is adjustable between 10 ms (1/2 cycle), 20ms (1 cycle), 200ms (10/12 cycles) or 3 sec (150/180 cycles). Calculating RMS values, Harmonics and Interharmonics is performed synchronous to the power frequency. Basic aggregation for harmonics and interharmonics is 200ms Oscilloscope: Sample rate is 10,24 kHz for all 8 channels Fast Transients: Sample rate is selectable from 100 kHz to 10 MHz for channel 1-4 FFT of Fast Transients
Mains Signalling	Phases and N-conductor, Voltage and current
Online Mode	Variable refresh rate. This feature allows verification of instrument set up and delivers a quick overview of oscilloscope, transients and events.

General specifications	
Intrinsic uncertainty	refers to reference conditions and is guaranteed for two years
Quality system	developed, manufactured as per ISO 9001: 2000
Environment conditions Operating temp. range Working temp. range Storage temp. range Reference temperature Climatic class Max. operating altitude	 0 °C ... +50 °C; 32 °F ... +122°F -20 °C ... +50 °C; -4°F ... +122°F -20 °C ... +60 °C; -4°F ... 140°F 23 °C ± 2 K; 74°F ± 2 K B2 (IEC 654-1), -20 °C ... +50 °C; -4°F ... +122° 2000 m: max. 600 V CAT IV*), power supply: 300 V CAT III 5000 m: max 600 V CAT III*), power supply: 300 V CAT II *) depending on sensor
Reference conditions	Environment temp.: 23 °C ± 2 K ; 74°F ± 2 K Power supply: 230 V ± 10 %, Power frequency: 50 Hz / 60 Hz Signal: declared input voltage U_{din} Averaging: 10 minute intervals
Housing	insulated, robust plastics housing
EMC Emission Immunity	 Class-A as per IEC/EN 61326-1 IEC/EN 61326-1
Power supply Range Safety Power consumption Battery pack	 AC: 83 V ... 264 V, 45...65 Hz DC: 100 V ... 375 V IEC/EN 61010-1 2nd edition 300 V CAT III max. 54VA NIMH, 7.2 V, 2.7 Ah In case of a power supply failure an internal battery maintains the supply for up to 40 minutes. Afterwards, or in case of discharged accumulators the Fluke 1760 is turned off and continues the measurements with the latest settings as soon as the supply voltage returns. The battery can be replaced by the user.
Display Power LED Channel LEDs	Fluke 1760 features LED indicators for the status of the 8 channels, phase sequence, power supply (mains or accumulator), memory usage, time synchronization, and data transfer. • Permanent light: normal power supply from mains. • OFF: supply via internal accumulator in case of a power failure. 3-color LEDs per channel for: • overload condition • under load condition signal level in nominal rang
Data memory	2 GB Flash memory depending on model
Memory model	Linea
Interfaces	Ethernet (100MB/s), compatible to Windows® 98/ME/NT/2000/XP RS 232, external modem via RS 232
Baud rate for RS 232	9600 Baud ... 115 kBaud
Dimensions (H x W x D)	325 mm x 300 m x 65 mm; 2.8 x 11.8 x 2.6 in.
Weight (without accessories)	appr. 4.9 kg; 10.8 lbs.
Warranty	2 year
Calibration interval	1 year recommended for Class-A, otherwise 2 years

Signal conditioning	
Range for 50 Hz systems	50 Hz ± 15 % (42.5 Hz … 57.5 Hz)
Range for 60 Hz systems	60 Hz ± 15 % (51 Hz … 69 Hz)
Resolution	16 ppm
Sampling frequency for 50 Hz power frequency	10.24 kHz, The sampling rate is synchronized to mains frequency.
Uncertainty for frequency measurements	< 20 ppm
Uncertainty of internal clock	< 1s / day
Measurement intervals Min-, Max-values Transients	Aggregation of the interval values as per IEC 61000-4-30 Class-A Half cycle, e.g.: 10 ms RMS values at 50Hz Sample rate 100 kHz …10 MHz per channel
Harmonics	as per IEC 61000-4-7:2002: 200 ms
Flicker	as per EN 61000-4-15:2003: 10 min (Pst), 2 h (Plt)

Measurement inputs	
Number of inputs	8 galvanically isolated inputs for voltage and current measurements.
Sensor safety	up to 600 V CAT IV depending on sensor
Basic safety	300 V CAT III
Nominal voltage (rms)	100 mV
Range (peak value)	280 mV
Overload capacity (rms)	1000 V, continuously
Voltage rise rate	max. 15 kV / µs
Input resistance	1 MΩ
Input capacitance	5 pF
Input filter	Each channel is equipped with a passive low-pass filter, an anti-aliasing filter and a 16-bit A/D converter. All channels are sampled synchronously with a common quartz-controlled clock pulse. The filters protect against voltage transients and limit the signal rise rate, reduce high frequency components and especially the noise voltage above half the sampling rate of the A/D converter by 80 dB, thus achieving very small measuring errors in an exceptionally large amplitude range. This is also valid under extreme operating conditions like transient voltages at the output of converters.

Uncertainties	
Uncertainty at reference conditions With Sensor 1000 V With Sensor 600 V	Uncertainty including the voltage sensors is in compliance with IEC 61000-4-30 Class-A. All voltage sensors are suitable for DC ...5 kHz 0,1% at Udin = 480 V and 600 V P-N 0,1% at Udin = 230 V P-N
Intrinsic uncertainty for harmonics	Class I as per EN 61000-4-7:2002
Reference conditions	23 °C ± 2 K < 60 % rH; 74 °F ± 2 K < 60 % rH Warmed up instrument > 3h Power supply: 100 V ... 250 V ac
Temperature drift:	100 ppm / K
Aging:	< 0.05 % / year
Common mode rejection	> 100 dB at 50 Hz
Temperature drift	Change of amplification through temperature: < 0.005 %/K.
Aging	Change of amplification due to ageing: < 0.04 %/year
Noise	Noise voltage, input short-circuited: < 40 µV.
DC	± (0.2% rdg + 0.1% sensor)

When quality of a grid is measured, results are provided in a report with a structure defined in this mentioned normative where also the monitoring periods required for each installation are compiled.

- **Harmonics:**
  - Statistics
  - Measurement values
- **Flicker**
  - Statistics
  - Measurement values
- **Slow voltage variations**
  - Statistics
  - Measurement values
- **Fast voltage variations**
  - Statistics
- **Unbalance**
  - Statistics
  - Measurement values
- **Frequency**
  - Statistics
  - Measurement values

- **Events**
  - Overvoltage
  - Voltage dips
  - Short interruptions
  - Long interruptions

Annex 3: Identification of capacities of a building as supply grid services

A shopping centre under retrofitting can become an interesting opportunity for achieving that such building can act as a supply grid services. A simple methodology can be applied as follows in future retrofitting works in order to identify the capacities to integrate solutions for improving the self-consumption and decrease the energy demand of the building.

The identification of capacities can follow these steps:

- Identification of data which characterize the building energy profile. Main data to be compiled are provided in table 20.
- Develop a questionnaire for gathering information from buildings. See questionnaire below.

Table 20: Data required for charactering the building energy profile

<table>
<tr><th></th><th colspan="2">Data required</th><th>Information provided</th></tr>
<tr><td rowspan="4">Characterization of shopping mall</td><td colspan="2">Type of shopping mall</td><td>Energy necessities of building</td></tr>
<tr><td colspan="2">Surface</td><td>Size of building</td></tr>
<tr><td colspan="2">Schedule of opening and working electrical appliance</td><td>Capacity of building to apply energy management demand</td></tr>
<tr><td colspan="2">Description of HVAC, lighting, refrigeration systems</td><td>Define the replacement of these systems by more efficient systems, incorporate energy saving concepts</td></tr>
<tr><td rowspan="5">Consumption profile of shopping centre</td><td colspan="2">Curve of demand and maximum peak demand</td><td>Identify the measures to apply around energy management demand</td></tr>
<tr><td rowspan="4">Energy consumption
(kWh/m^2 year)</td><td>Total energy consumption
(kWh/m^2 year)</td><td rowspan="4">Classification of demand
Dimensioning of RES facilities</td></tr>
<tr><td>Lighting consumption
(in summer and winter)
(kWh/m^2 year)</td></tr>
<tr><td>HVAC consumption (in summer and winter)
(kWh/m^2 year)</td></tr>
<tr><td>Refrigeration consumption (in summer and winter)
(kWh/m^2 year)</td></tr>
</table>

	Equivalent hours: Energy consumption/power [h].		Number of hours with an energy consumption taking into accounts certain power.
	Maximum demand/maximum power installed [kW/kW].	Maximum demand[kW]	If energy demand is higher that power installed, equipment are oversizing
		Maximum power installed[kW]	
	Maximum demand/maximum power hired with the supplier company [kW/kW].	Maximum power hired with the supplier company[kW]	If energy demand is higher that power hired, it is paying more in invoices
	Capacity of energy storage /energy consumption [kWh/kWh].	Capacity of energy storage[kWh]	If building is capable of storing energy surplus
Energy supply	Power installed by surface (kW/ m^2)	Total power installed (kW/m^2)	Dimensioning of RES facilities
		Power installed for lighting system (kW/m^2)	
		Power installed for HVAC system (kW/m^2)	
		Power installed for refrigeration system (kW/m^2)	
	Maximum power hired with the company (kW)		
	Tariff hired		Analysis of suitability of tariff hired
	Type of supply (Low voltage-individual / Medium voltage with own centre or belonging to the supplier)		Allow to know legislative and technical requirements.
	Capacity of the connection line RES		Capacity of grid to admit energy from RES.
Possibility of connection modification	Existence of devices of control and regulation, harmonic filter and capacitor of batteries. – Harmonic filters are used for eliminating harmonics which are created by non-linear devices connected to the power system. High levels of power system **harmonics** can create voltage distortion and power quality problems. – Capacitors of batteries are devices which make possible to reduce the demand of reactive energy from the grid which makes to increase the bills and damage facilities.		The existence of these devices allows to incorporate RES in building without affecting the grid quality
	Available flat surface free of shadow for being covering by renewable facilities in a building/building surface already utilized.	Available fat surface free of shadow for being covering by renewable facilities(m^2)	Capacity of building to integrate PV panels and location
		Building flat surface free of shadow already	

		utilized(m^2)	
	Peak sun hours		
	Average velocity of wind at 30 meters		Capacity of building to integrate wind turbine
	Available capacity of the grid [KVA]		Capacity of grid to admit the surplus of energy produced in the building
	Power installed in the shopping centre/real capacity of the grid	Power installed in the shopping centre	
		Real capacity of the grid	
	% power provided by renewable sources/total capacity of grid for renewable sources	Power provided by renewable sources	The normative in some countries (as Spain) restrains the amount of RES in the grid to a value or percentage
		Total capacity of grid for renewable sources	
Quality of grid	**Harmonics:** – Statistics – Measurement values		Distortion of wave forms that occur when the wave forms of voltage and current differ in a purely sinusoidal due to the effect produced by the presence of harmonics.
	Flicker – Statistics – Measurement values		Voltage fluctuations and flicker (Flicker): Asymmetric variations of the envelope stress. This phenomenon usually occurs by loads that experience continuous or rapid variations in stress.
	Slow voltage variations – Statistics – Measurement values		
	Fast voltage variations – Statistics		
	Unbalance – Statistics – Measurement values		Voltage unbalance, which is linked usually to the emergence of negative sequence components and /or zero sequence fundamental frequency voltages in the network.
	Frequency – Statistics – Measurement values		Frequency variations: Deviations of the fundamental frequency of the system with respect to its nominal value. They occur by a sudden imbalance between production and consumption, being more important in isolated or weak systems, affecting condensers and inductances.
	Events – Overvoltage – Voltage dips – Short interruptions – Long interruption		Variations in the wave amplitude which are produced by significant changes in the demand. Depending on the duration, they are named as interruptions, voltage dips or transient voltage surge.

A3.1 Questionnaire

Following is attached the letter that has been used for trying to get the information from reference buildings:

Dear [*charge and name of person*]:

One of the aims of *Project* CommonEN*Energy* is to identify saving and efficiency measures in all those shopping centres which collaborate with us. With this objective, we have elaborated the current questionnaire which will help us in the compilation of information around the energy demand of buildings.

This questionnaire is mainly focused in the characterization of the energy demand, identification of periods of peak-load and acquisition of data regarding the level of saturation of the grid in which building is connected.

As a result, we will be able to define specific solutions for each shopping centre which cover the following categories:

- Exploitation of renewable energies for self-consumption as well as possibilities of storage energy for electro-vehicles.
- Defining measures addressed to diminish the energy consumption through the classification of the building demand and solutions linked with energy saving without affecting the current working of the building.

Thank you for your time.

Please, ask these questions regarding general information about its building:

- Which type of shopping mall corresponds with this building?
  - Shopping centre
  - Market
  - Hypermarket
  - Retail park
  - Factory outlet
  - Specially centre

- Surface (m^2):

- In which urban context is located the building?
  - Urban
  - Suburban
  - Isolated zone

- Schedule of opening:

- Schedule of working electrical appliance:

Please, provide the following information:

- Daily energy demand curve (*).This information is one of the most relevant to be acquired.
- Description of type of tariff hired with energy provider.
- Capacity of building to be covered with solar panels:
  - In this building, which is the available flat surface free of shadow for being covering by solar panels (m^2)?
  - In this building, which is the flat surface free of shadow already utilized (m^2)?

Please, select the option which corresponds with the characteristics of electrical grid supply in this building.

- Type of supply:
  - Low voltage-individual.
  - Medium voltage:
    - With own centre
    - Centre belonging to the supplier
- Existence of devices of control and regulation:
  - Able to manage and control the energy consumptions.
  - Capacitors of batteries.
  - Harmonic filters.

Please, put in contact with its electrical provider and fulfill the column "Value" with the information regarding the grid.

Variable	Value
Available capacity of the grid [KVA].	
Power provided by renewable sources	
Total capacity of grid for renewable sources	

Please, fulfill the column "Value" with the information regarding energy consumption in its building. Questionnaire is focused in electrical consumption.

Variable	Values
Total energy consumption (kWh/m^2 year)	
Lighting consumption (in summer and winter) (kWh/m^2 year)	
HVAC consumption (in summer and winter) (kWh/m^2 year)	
Refrigeration consumption (in summer and winter) (kWh/m^2 year)	
Total power installed (kW/m^2)	
Power installed for lighting system (kW/m^2)	
Power installed for HVAC system (kW/m^2)	
Power installed for refrigeration system (kW/m^2)	
Surface of building (m^2)	
Maximum demand [kW]	
Maximum power installed [kW]	
Maximum power hired with the supplier company [kW]	
Capacity of energy storage[kWh]	

Annex 4: Definition of concepts for decreasing mismatch building-grid

This Annex collects information about different concepts that will allow then and knowing the potentials in each of the shopping centres to propose solutions in order to carry out the possible improvement actions detected in each of the reference buildings.
The solutions proposed and developed in this Annex are:

- On site RES
  - Photovoltaic energy.
  - Wind energy.
- Cogeneration.
- Energy storage.
- Peak shaving of demand curve.
- Energy saving solutions.

Each solution proposed, cover mainly a detail explanation, issues to be taken into account for the selection of the technology and restrictions.

A4.1 On site RES

A4.1.1 Photovoltaic Energy

The photovoltaic process converts sunlight into electricity using photovoltaic cells. These photovoltaic cells are thin, flat wafers manufactured using semiconducting materials, which act as insulation at low temperatures and as conductors when exposed to heat or light energy. This structure is electrically bonded together due to the low voltage (typically approximately 0.5 V) as well as for obtaining a better weather resistance. The structure formed is known as photovoltaic modules which are in turn connected together in an array. Output voltage depends on the number of cells in a panel and the crystal structure of the semiconductor used.

Solar panels can be manufactured of several materials, which influence in the efficiency obtained as well as in the cost.

Apart of the current cells for producing electricity, with the aim of reducing the investment, a new product named BIPV (Building integration of photovoltaic cells) has emerged in the market. This product replaces conventional building materials in parts of the buildings, becoming functional parts of the building envelopes such as roofs or facades. BIPV products can act as shading devices and also form semi-transparent elements for fenestration.

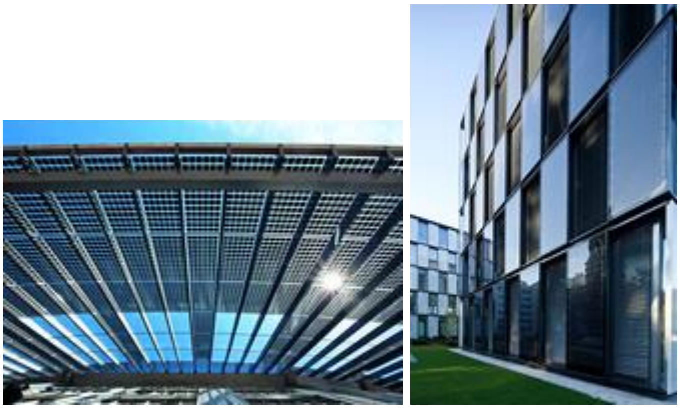


Figure 151: BIPV products (Source: http://www.schueco.de)

Photovoltaic systems, can be categorized as stand-alone photovoltaic systems, and grid connected photovoltaic systems.

- **Stand-alone system:** has the advantage that no grid-connection is required, however, batteries will be needed in order to store power for the times when the sun is not shining. This system is utilized for areas without distribution lines, existing in market several options.
  - Stand-alone systems powered by single PV array. The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load.

    Figure 162: Direct-coupled standalone system.

    Since there is no electrical energy storage (batteries), the load only operates during sunlight hours, being this design suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems.

  - Stand-alone PV systems with batteries storage powering DC and AC loads.

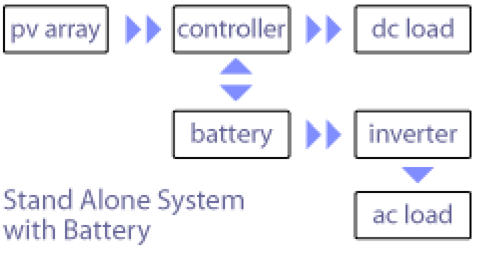
    

    Figure 33: Standalone system with battery.

- Photovoltaic Hybrid System with battery storage powering DC and AC loads and using a using a backup power source (wind, engine-generator or utility power).

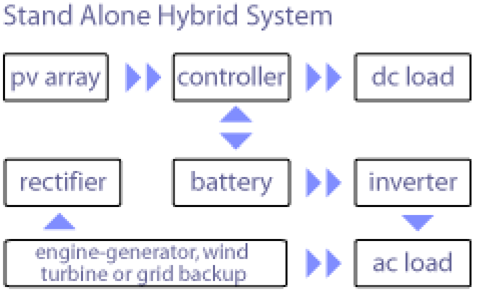


Figure 174: Standalone hybrid system.

The battery is connected to the PV system through a charge controller which protects the battery against overload or shock, and may also provide information on system status or allow measurement and prepaid electricity used. If alternative current is required, then an inverter to convert the direct current is necessary. Typical applications for systems not connected to the network are mobile repeaters, electrification systems in remote areas or rural electrification in developing countries. This system has been utilized over 20 years for its reliability, low cost, ease of maintenance and suitability of any size.

- **Grid connected photovoltaic system:** they are designed to be interconnected with the electric utility grid, being the system more utilized worldwide. After conversion from direct current (DC) to alternating current (AC), the power generated by the cells is used for matching the electricity demand of the building. Only the excess energy produced is fed into the grid.

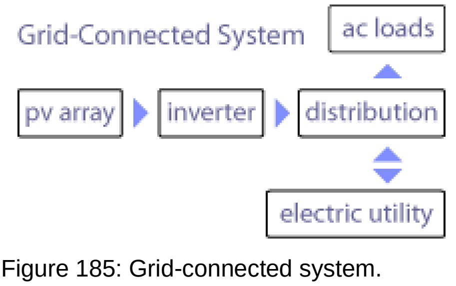


Figure 185: Grid-connected system.

Issues to be taken into account in the selection of technology

PV energy is the most easily scalable type of renewable energy generation; it can be produced in amounts from a few kilowatts as the residential scale up to multiple megawatts at the utility scale. Other benefits associated are its modular nature in desired currents and voltages levels, low maintenance cost, long effective life, high reliability, and rapid responses in output to input radiation changes.
Issues to be taken into account in the selection of solar energy: cell efficiency, power per unit, and available surface.

Cell efficiency

Power conversion efficiency is given by the efficiency of their solar cells and the physical layout of the PV element and it is defined as the ration between the power which is capable of generating the PV element and the amount of solar energy received.

Power conversion efficiency is calculated as follows: $\eta = P_{max}/EA$

Where,

P_{max} is the maximum power point in W or Watt-peak (Wp).

E is the input light irradiance in W/m^2

A is the surface area of the solar cell in m^2.

The performance of a photovoltaic solar panel depends on some external variables such as temperature of operation, solar radiation, the orientation of the panel facing the sun, dust, aging, etc. (V.V. Tyagi et al, 2013).

An elevated temperature in the module decreases the performance of the solar cells, which makes decrement the output power. This happens especially in monocrystalline although polycrystalline modules are also affected. However, temperature has a less influence in thin film solar cell.

On the other hand, as the solar irradiance rises, the PV module efficiency also increases due to the high number of photons hitting the module, which makes increase the current. For constant temperature conditions, curves vary with the incidence of solar radiation, which in this case mainly affects the intensity. However, voltage remained approximately constant. In this sense, it is very important the placement (orientation, inclination with respect to horizontal) of the panels, since the values of radiation change throughout the day depending on the inclination of the sun above the horizon. Placing the panels in an airy place since the panel power decreases with increasing temperature.

In order to produce the most electricity, the Solar PV array should be orientated between south-east and south-west. It is not absolutely necessary for the array to face due south. There will be only a small percentage power loss, as a result of moving a few degrees east or west of south. In many cases, the proposed Solar PV array orientation and tilt are determined by the design and location of the building.

Dust is also affecting the PV efficiency because it may block the coming irradiance onto PV modules. The power output drop drastically as dust density increases.

Power per unit

The maximum power output of a photovoltaic panel is one of the most important features. Normally complementation of a photovoltaic system requires the use of panels with output of at least 30 watts. The power modules are formed varies between 50Wp and 250Wp, depending on the effectiveness and cell types of components. There are major trading powers at the expense of increasing the effective area of the panel.

Available surface

In order to know the capacity of a building to be covered by solar panels, it is necessary to evaluate the available surface for solar panels in roof and façade taken into account the architectonic barriers (existence of air conditioning equipment, chimneys, terraces, the existence of shadows or restrictions for the historical value of the building) and the limitations of the own technology (level of irradiation according to the orientation and tilt).

As general, PV arrays need a shade-free site oriented between south-east and south-west. Shade on any part of the array will greatly reduce the performance of the whole unit. The ideal pitch is 30–40 degrees, but this can be reduced to as little as 15 degrees, enabling arrays to be installed on flat roofs or behind parapet walls.

Solar cells can be installed in a large variety of places such as: sloped roofs/ flat roofs, facades and shading systems, being south facing sloped roofs the best location due to the favorable angle with the sun. In fact, any part of the roof or external walls that is well-exposed to sunlight such as skylights, claddings, windows, external shading devices and railings can be used for PV integration, although roof surfaces are the preferred area for installing PV elements due to their advantageous irradiation values. However, façades also offer enormous potential especially in Nordic region where the angle of the sun is low all throughout the year.

In slopped roofs, its characteristics (slope, azimuth, available surface) determine the performance of the PV installation, whereas in flat roofs, the modules can be optimally positioned with supporting structures and adjusting the inclination angle

In the case of façade locations, technical requirements are higher because of the wiring and junction boxes which have to be hidden, being the fixing of the array in building much difficult. PV sunscreen devices are installed in shading systems: they achieve the shadow of the building in summer besides the generation of electricity.

How to dimensioning a solar facility

In order to dimensioning a photovoltaic system, it must take into account following general points:

- Climatology: Average radiation and peak sun.
- Available surface in building free of shadow.
- Energy demand of building and peak power.
- Possibility for connecting to the grid.

Restrictions

- Energy production depends on the level of irradiance and temperature achieved in the panel which varies with meteorological conditions. However, if these two meteorological variables could be forecasted with sufficient precision, it is possible to estimate the electricity production of a PV system.
- Fully integration of a generator into the grid requires that the electricity produced by the generator is known beforehand. With this knowledge, the generator can be included in grid planning and it would be possible to dynamically adjust its output in response of real time demands from the grid. Solar system requires energy storage to provide energy in the absence of insolation (fuel cell, lead acid battery and hydrogen).
- High initial investment can be compensated with subsidies and feed in tariffs received by the production of energy with RES. Nevertheless, the elimination of subsidies and feed-in-tariffs in many European countries have supposed to stop the exponential behaviour of its growth occurred in the last years.

A4.1.2 Wind Energy

Wind power is the conversion of wind energy into a useful form of energy through wind turbines. The motion of the blades turns a rotor, converting the kinetic energy of the wind into electrical energy. The amount of power generated depends on the 'swept area'. Therefore, the larger the area the greater the potential output. Ideally, the system should be connected to the National Grid, allowing excess electricity to be sold. In locations where connection is not feasible, batteries can be used to store excess energy until it is required.

The main system components of a small wind electric system are the rotor, generator, tower and core electrical components.

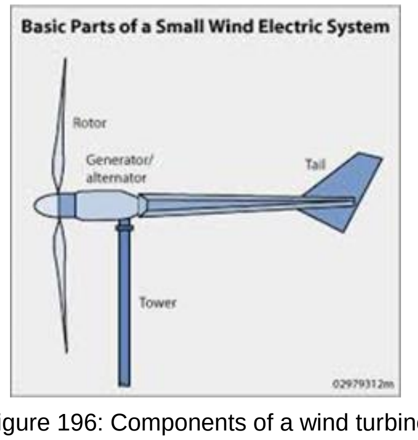


Figure 196: Components of a wind turbine
(Source:http://en.openei.org/wiki/Small_Wind_Guidebook/What_are_the_Basic_Parts_of_a_Small_Wind_Electric_System)

A wind turbine is mounted on a mast to lift it into the path of the wind. The mast is then either fixed directly to a building (for short masts and small turbines) or free-standing away from the building it serves (for taller masts and bigger turbines). Turbines can be designed to change their direction according to the direction of the wind, so they can generate electricity whatever the wind direction. A wind turbine only generates electricity when it is turning, and has no capacity to store electricity; therefore a back-up system is needed.

There are basically two types of turbines to choose from, vertical axis wind turbines and horizontal axis wind turbines. They both have their advantages and disadvantages.

- **Horizontal axis wind turbines**: The rotating axis of the wind turbine is horizontal, or parallel with the ground. Comparing with vertical axis, this option is able to produce more electricity from a given amount of wind. So if the production of energy with this technology is the priority, horizontal axis is likely the choice. Nevertheless, axis is generally heavier and it does not produce well in turbulent winds.
  This type of turbine is the most used for producing energy from wind although in residential applications, vertical axis turbines have their place, too.

Figure 207: Horizontal axis wind turbine
(Source: SWIFT Wind Turbine or http://www.cascaderenewableenergy.com)

- **Vertical axis wind turbines** stand the rotational axis of the turbine vertical or perpendicular to the ground. Vertical axis turbines are primarily used in small wind projects and residential applications since they are able to produce well in tumultuous wind conditions. Vertical axis turbines are powered by wind coming from all 360 degrees, and even some turbines are powered when the wind blows from top to bottom. Because of this versatility, vertical axis wind turbines are thought to be ideal for installations where wind conditions are not consistent, or due to public ordinances the turbine cannot be placed high enough to benefit from steady wind.

Figure 38: Vertical axis wind turbine (source: http://cleantechnica.com)

A small wind system can be standalone (off-grid) for cover the consumption of isolated buildings or connected to an electric distribution system (grid-connected). These pretty reliable systems include a battery where the excess energy is stored until there is no wind or sun. Another possibility is to use these machines to produce energy and inject it in the grid. Also, they are usually accompanied by solar photovoltaic panels as part of small hybrid systems by means of combining the power of the sun and wind in order to help ensure the power supply.

Issues to be taken into account in the selection of technology

- Power curve of the wind turbine.
- Height of the place where installing wind turbine.
- Average wind speed in the location.
- The frequency distribution of the wind: estimate of the number of hours that the wind will blow at each speed during an average year.

Output power

The output power of a wind turbine is calculated as follows: $P = \frac{1}{2} \rho CAV^3$

Where,

- P refers the power (W)
- ρ is the air density which corresponds with approx. 1.2 kg/m^3
- C is an efficiency factor known as the Power Coefficient which depends on the machine design.
- V is the wind speed (m/s).
- A corresponds with the rotor swept area exposed to the wind (m^2).

It is necessary to remark that importance of the wind speed since a slight increase in these parameters influence so much in the output power obtained.

It is common to use the nominal rated power for a wind turbine. However, this can lead to errors, especially if this parameter is used to compare turbines since it represents the high capacity that can provide this device. It is much more correct to define a turbine by its power curve which provides the power provided by each wind speed. Power curve is obtained from each manufacturer.

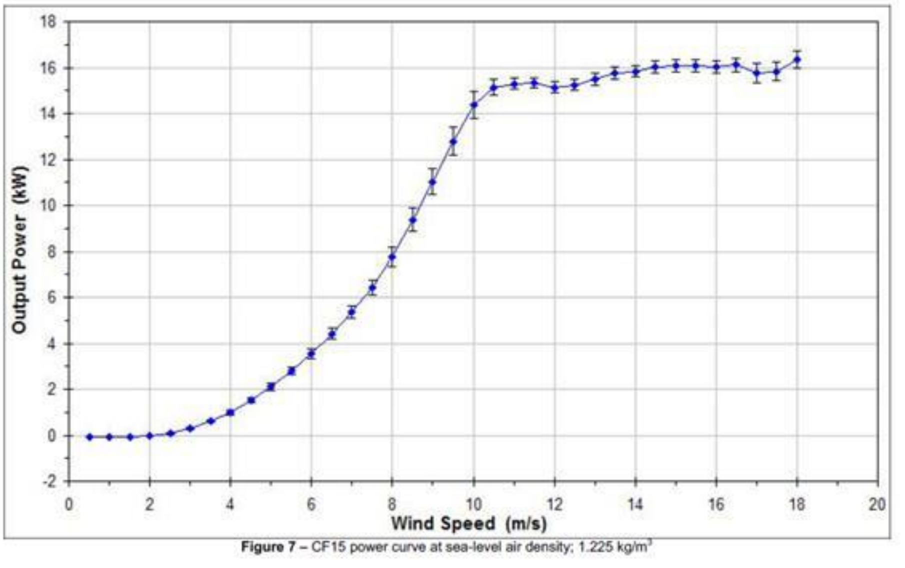


Figure 39: Power curve of a wind turbine (source: Intertek)

Energy generated

The generation of energy can be estimated by means of following formula:

Average rated capacity of each turbine x number of turbines x capacity factor of turbine class x 8,760 (hours in a year).

Following table 21 shows the possibilities to use the wind power according to the average speed wind yearly (Power Guide, 1994).

Table 21: Possibilities to use the wind power

Annual average wind of 10 meter high	Possibility of Using Wind Energy
Less than 3 m/s	It is usually not feasible, unless there are special circumstances to better assess the resource
3-4 m/s	It can be a good choice for wind water pumping equipment Not suitable for wind power generation equipment(wind generation)
4-5 m/s	Wind powered pumps are economically competitive with diesel equipment Wind generation with autonomous equipment is viable.
More than 5 m/s	Viable for autonomous systems(pumping and energy generation)
Over 6 m/s	Viable for autonomous systems(pumping and energy generation) and for systems connected to the grid

Location

As the efficiencies and performances of new wind turbines are continuously rising, the choice of a suitable location with a wind quality becomes essential. In fact, the selection of a location must take into account the main crucial characteristics affecting the wind quality: the overall wind speed, the consistency of the wind speed and the consistency of the wind speed direction.

Turbines must be sited in areas on ably exposed location and work best at a height where wind speeds are high and there are no obstructions from buildings, trees or other features that would cause turbulence. Consequently, they are often difficult to integrate successfully into an urban environment; hence they are more suitable for rural locations.

In order to generate the optimum annual electricity yield, a wind turbine should face in the direction of the prevailing wind. This is normally south-west, but can vary from place to place. Generator needs to place only few meters above roof building and according to experts, they should be considered only where the local annual average wind speed is 6 meters per second since the amount of energy generated would not justify the capital cost.

Restrictions

The main problems for integration of wind turbines in buildings or urban areas are their visual impact and on-going debate over the efficiency of smaller and urban systems. As a general rule, it is recommended turbines installations away from built-up areas.

It is important to know that wind turbines produce some noise, which may be audible within a certain distance and also in certain light conditions; turning blades create flicker and shadows, if the shadows extend to a property or garden they could be an irritant. Regarding to the vibration, most manufacturers recommend installing pads with the brackets to dampen the vibration of the working turbine also the noise is not generally an issue with small modern wind turbines.

Wind turbines can be grid-connected or off-grid. However, they can also be direct systems, meaning the electricity they generate is channeled directly to the point of use; in this case the point of use has to be able to work from DC electricity, making this an unsuitable option for many domestic situations.

A4.1.3 Cogeneration

Cogeneration (Combined heat and power – CHP) is the simultaneous production of electricity and heat. Through the utilization of the heat, the efficiency of a cogeneration can reach 90% or more. Cogeneration is a highly efficient form of energy conversion and it can achieve primary energy savings of approximately 40% by compared to separate purchase of electricity from the national electricity grid and a gas boiler for heating.

<u>Main characteristics of the most CHP systems</u>

The main benefits for CHP systems are:

- Increased efficiency of energy conversion and use: CHP, requires less fuel to produce a give energy output, and avoids transmission and distribution losses that occur when electricity travels over power lines.
- Lower emissions to the environment: less fuel is burned to produce each unit of energy output; CHP reduces air pollution and greenhouse gas emissions.
- Large cost savings.
- Opportunity to more decentralized forms of electricity generation.
- Improved local and general security supply.
- Production of thermal energy and electricity when and where is needed.

Thermal efficiency

$$\eta = \frac{W_{out}}{Q_{in}} = \frac{\text{Electrical Power Output} + \text{Heat Output}}{\text{Total Heat Input}}$$

Where:

- η = Efficiency
- W_{out} = Total work output by all systems
- Q_{in} = Total heat input into the system

The typical energy distribution is:

- Electricity: 40%
- Heat: 50%
- Losses: 10%

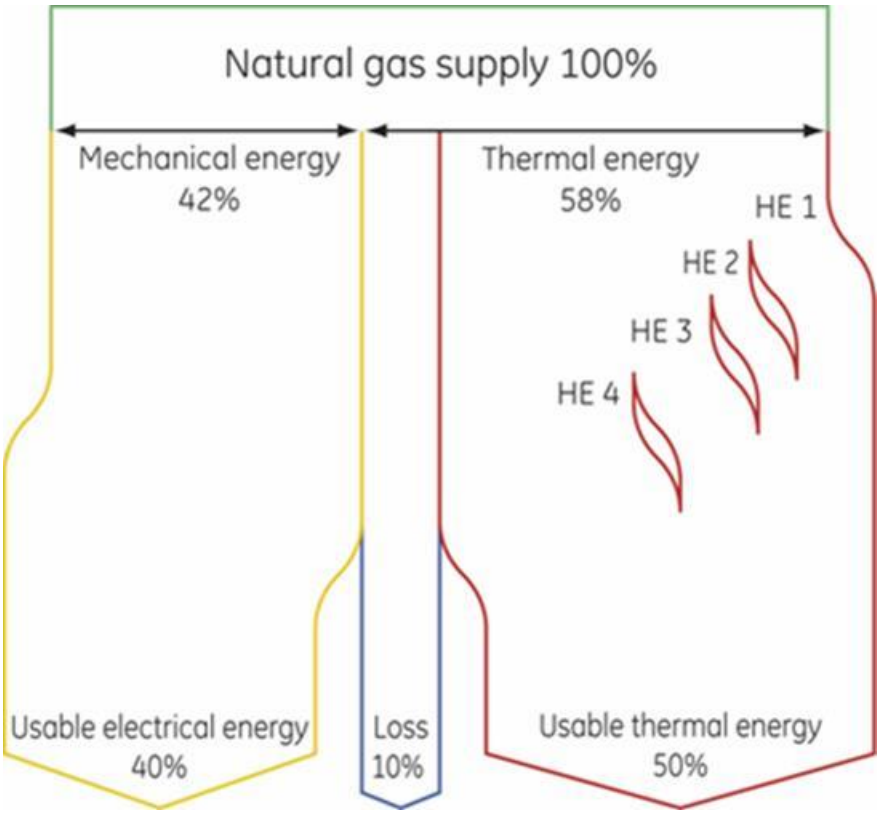


Figure 40: Typical energy distribution for a CHP system (Source: www.clarke-energy.com)

Issues to be taken into account in the selection of technology

The viability of CHP installations depends on a good base load of operation, both in terms of an on-site electrical demand and heat demand. In practice, an exact match between the heat and electricity needs rarely exists. A CHP system can either meet the need for heat or be run as a power plant with some use of its waste heat.

- Base electrical load matching: in this configuration, the CHP unit is sized to meet the minimum electricity demand of the site base on the historical demand curve. The rest of the needed power is purchased from the utility grid. The thermal energy requirement of the site could be met by the cogeneration system or by additional boilers. If the thermal energy generated with the base electrical load exceeds the plant's demand and if the situation permits, excess thermal energy can be exported to neighboring customers.
- Base thermal load matching: the cogeneration system is sized to supply the minimum thermal energy requirements of the site. Stand-by boilers or burners are operated during periods when the demand for heat is higher. The prime mover installed operates at full load at all times. If the electricity demand of the site exceeds that which can be provided by the prime mover, the remaining amount can be purchased from the grid. Likewise, if local laws permit, the excess electricity can be sold to the power utility.
- Electrical load matching: the facility is totally independent of the power grid. All the power requirements of the site are to be taken into account while sizing the system. If the thermal energy demand of the site is higher than the generated by the cogeneration

system, auxiliary boilers are used. On the other hand, when thermal energy demand is low, some thermal energy is wasted (if there is a possibility can be exported to neighboring facilities).

- Thermal load matching: is designed to meet the thermal energy requirement of the site at any time. During the period when the electricity demand exceeds the generation capacity, the deficit can be compensated by power purchased from the grid. If local legislation permits, electricity produced in excess at any time may be sold to the utility.

Cogeneration feasibility requires an understanding of hourly, daily, weekly, monthly and yearly electrical consumptions, including peak demands and thermal loads (heating and/or cooling).

Factors for selection

- Fuel(s) available, or in the case of a waste heat recovery system, the temperature of waste heat recovery.
- Temperature of heat required.
- Heat to power ratio (the ratio of recoverable heat to electrical output).
- Amount of electrical output required.
- Form of thermal load and conditions.
- Available space.
- Air emissions, noise.
- Engine turn down (ability to vary thermal and electrical output).
- Maintenance and reliability.

The heat and power demand patterns of the user affect the selection (type and size) of the cogeneration system. For instance, the load patterns of two energy consuming facilities shown in Figure 211, would lead to two different sizes, possibly types also, of cogeneration systems.

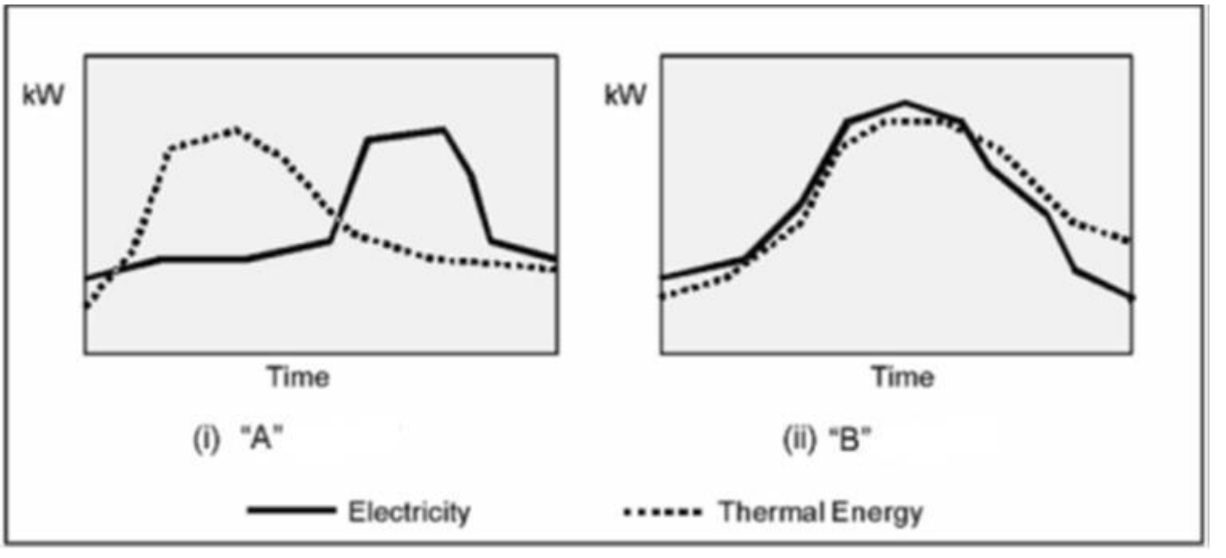


Figure 211: Heat and power patterns of two different buildings (Source: www.productivity.in).

The viability can be increased where opportunities for trigeneration (electricity, heating and cooling) are needed.

CHP is most efficient when heat can be used on-site or very close to it. Overall efficiency is reduced when the heat must be transported longer distances. Electricity can be transmitted in a simple wire, and over much longer distances for the same energy loss.

A4.2 Energy storage

Energy storage options for managing supply-demand mismatches

Energy storage could assist in smoothing out the mismatches between the time-varying demand for energy and the energy supply, being used in certain situations (e.g. for providing emergency backup or off-grid autonomy).

There appear to be two main drivers for increasing the application of energy storage, where the goal is to:

- Reduce energy costs. Electricity bills can usually be reduced by shifting energy use from a time of peak demand (high price) to an off-peak (lower price) time, (so reducing the need for building new power plant and electricity infrastructure to satisfy an otherwise increasing peak demand). Much depends on the tariffs that apply in the peak and off-peak periods and the objectives of the electricity industry in the region of interest.

- Reduce the carbon intensity of energy use. By integrating more variable renewable power sources into the built environment, the carbon footprint of the electricity supply can be reduced (e.g. by absorbing in a storage system excess solar PV or wind generation for later use). Much depends on the funding schemes and tariffs in place to afford the renewables. These vary with region and in time, but in general the increased implementation of renewable power sources is central to the EU's objectives for 2020 and beyond so that adequate progress can be made towards achieving a low-carbon economy by 2050.

Energy storage cannot of itself save energy as it involves at least one energy conversion with associated energy losses. Therefore its justification is principally an economic one; there is no conventional energy saving rationale. In many EU nations the future role of energy storage hinges upon the acceptability of curtailing (wasting) excess renewable energy production resulting from the increasing levels of solar PV and wind power, which will otherwise be necessary to maintain grid stability. Energy storage solutions therefore need to face this supply-side issue as well as the demand-side variation caused by consumer behaviour.

Energy storage may be applied in a centralized or distributed manner with regional, district or building level energy stores. There are several technologies which may be classified as power-in/power-out energy storage (e.g. batteries, flywheels, pumped storage and flow batteries). For these the main economic drivers are the unit cost of the input electricity (€/kWh), the turn-round efficiency and the unit sale price (€/kWh) of the output electricity. In addition, there is an emerging category of energy storage which may be described as power-in/energy-out (e.g. conversion to heat, conversion to hydrogen by electrolysis, conversion to hydrogen-derived fuels such as synthetic natural gas by combining hydrogen with waste carbon dioxide). In the simplest form these may involve only one energy conversion (e.g. the conversion of power to hydrogen for injection of hydrogen into the gas grid).

The main economic drivers are the unit cost of the input electricity, the conversion efficiency, and the unit sale price of the output heat or gas. Although the sale price of heat/gas tends to be low in most situations (much lower than electricity), the sale price of hydrogen can be high but competitive with diesel/petrol for a mobility application due to the high degree of taxation applied to transport fuels. So the economic feasibility of applying an energy storage solution (whether it be power-in/power-out, or power-in/energy-out) will relate to the renewable resources and low-carbon objectives of a particular region and in this project to the shopping mall under consideration, especially important is the possibility to use this energy storing system to assist the grid and therefore use (store) the energy when abundant and not require it when it is scarce.

On the demand side, energy is used for heat, power and mobility applications and an energy storage system can be designed to manage the supply/demand mismatch of each type of energy demand. Its role is to "valley fill" and "peak shave", which may be undertaken on a daily cycle, weekend/weekday cycle or longer term cycles as a function of the storage technology capability. Before a system can be sized, the energy storage solution needs to be considered in terms of three phases to decide the duty cycle:

- Charge Phase: rate of charge, how often is it to be charged per day/week/year, what is the charge duration, what is the charge efficiency.
- Hold Phase: how long until discharged, what energy loss is incurred, what is the hold efficiency.
- Discharge Phase: how often per day/week/year, for what duration, what is the discharge efficiency.

Hydrogen is of particular interest because (i) an electrolyser can achieve the charge phase at different rates, on a variable intermittent cycle and is highly responsive; (ii) the hydrogen store will maintain exactly the same state-of-charge until hydrogen is removed or added, so it offers an indefinite hold period; and (iii) the hydrogen can be used by a fuel cell, boiler, vehicle, engine or converted to another fuel (e.g. methane or ammonia). This set of attributes provides hydrogen with the greatest flexibility when considering energy storage solutions. Energy storage concepts have been considered here for heat, power and mobility applications involving electrolytic hydrogen.

Energy demand variations across 24h periods are usually significant for each type of demand. However, the demand variation by season for heat is usually the most dominant factor, simply because it's driven by requirements/expectations for comfortable indoor temperatures throughout the year and influenced heavily by weather. Compared with heat, the demand profile for electricity and transport fuel is much less influenced by seasonality (unless the heating load is mainly met from electricity).

Outline consideration has been given to the three shopping mall sites of Valladolid (Spain), Trondheim (Norway) and Genoa (Italy), but most consideration has been given to Trondheim. Data supplied by EURAC for the CitySyd shopping mall in Trondheim (Figure 222 - Figure 232) indicates a peak daytime heat (for heating and DHW) demand of about 400 kW in winter, dropping to less than 50 kW in summer, whereas winter electricity demand is more stable at around 200 kW during winter, rising slightly in summer to 325 kW with increased air-conditioning demand. So energy storage objectives may include at one extreme smoothing out the seasonal variation in heat demand, while at the other providing some emergency back-up energy for very occasional use when the grid power supply fails. The value proposition to the investor needs to be defined for each energy storage concept in order to define the required system and to judge its feasibility.

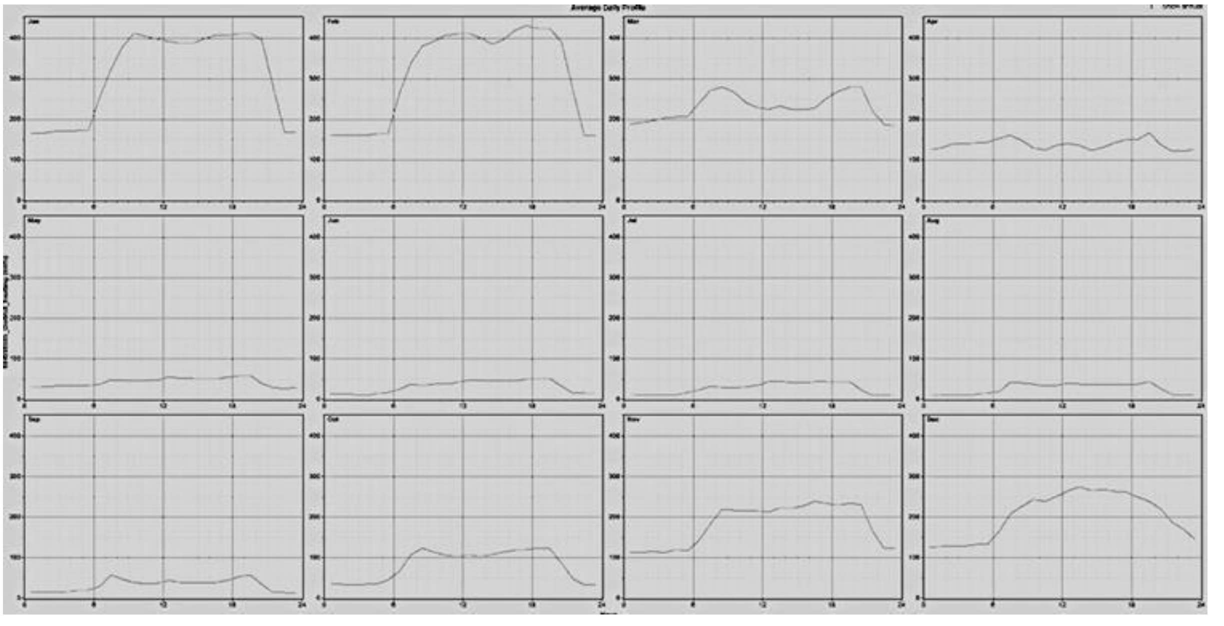


Figure 222: CitySyd District Heating Profile (Source: EURAC)

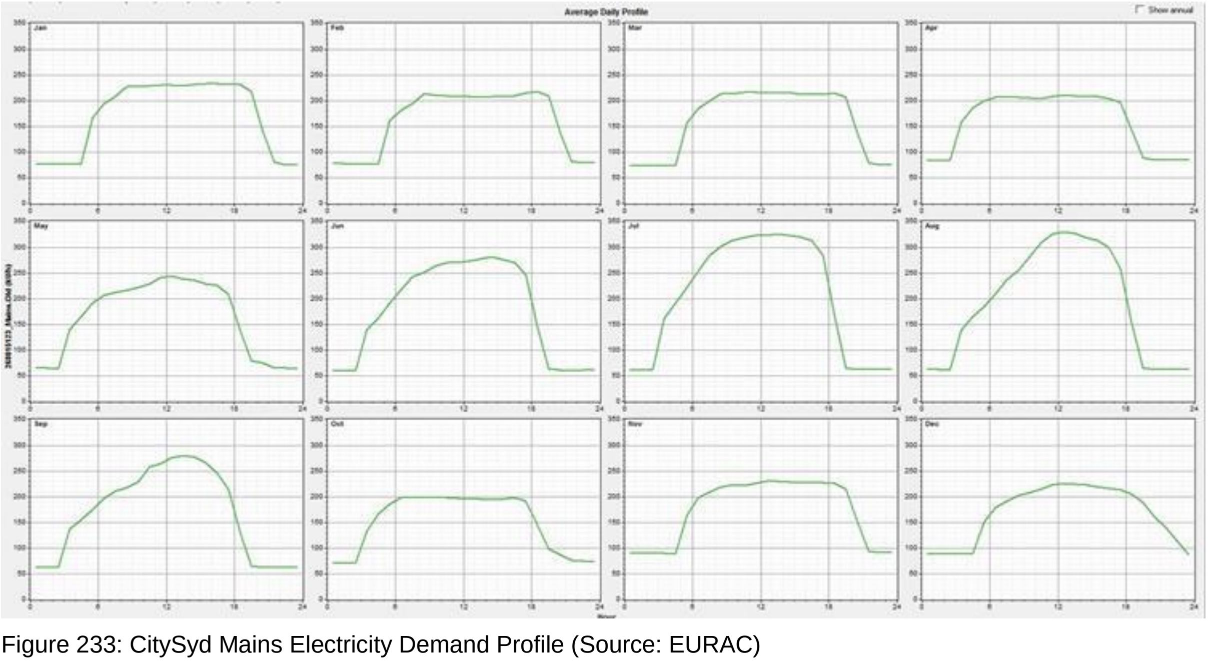


Figure 233: CitySyd Mains Electricity Demand Profile (Source: EURAC)

On the supply side, electricity is derived from coal, gas, hydro, nuclear fuel, biomass, solar PV and wind power. Integrating the latter two of these into the power system creates the need for storage; Figure 24 shows that seasonal variation in PV generation in a northerly latitude like Trondheim can be considerable (source: htpp://homerenergy.com). This can be partially offset by wind generation which peaks in the winter, but a need for seasonal storage in addition to daily fluctuations will remain. Furthermore significant quantities of installed wind and PV capacity results in periods of excess renewable energy, which is of low or negative value. This is a generic problem emerging across the EU, but mostly in regions with islanded grids or weak interconnections to other nations. So the economics of the energy storage system can be improved if it can operate to absorb this cheap input electricity whenever it is available. In addition, the economics can be improved further if the energy storage system can offer a “balancing service” to the grid operator where it can be switched on/off/up/down on a short time base to assist supply/demand matching and voltage/frequency control within the grid (source: https://www.gov.uk/goverment).Therefore it is important to consider the supply-side, as well as the demand side, when assessing the feasibility of applying an energy storage system for buildings in a given region.

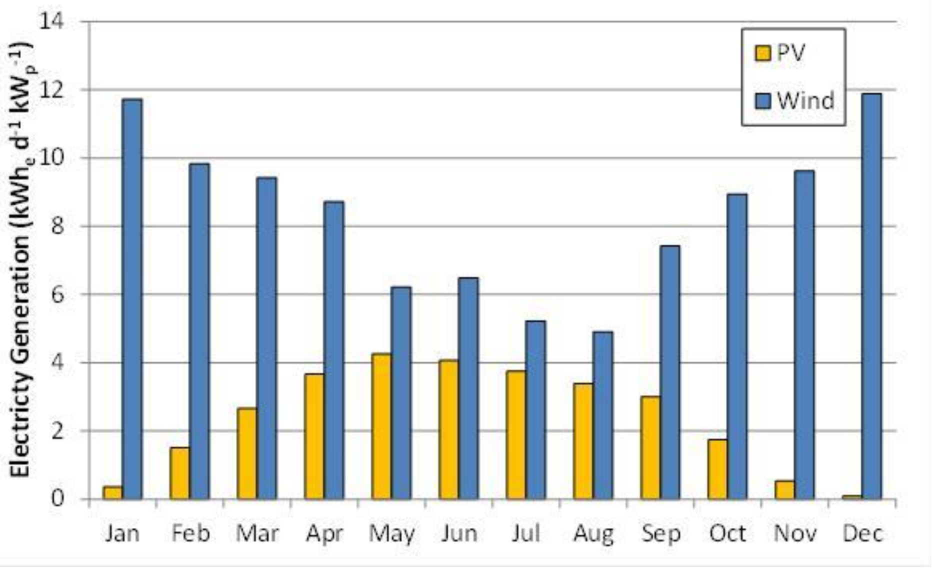


Figure 244: Estimated electricity generation from PV and wind in Trondheim.

Shopping malls require heat and power, and they provide an opportunity for refueling/recharging vehicles (customer cars, delivery vans, materials handling vehicles). Shopping malls also tend to have substantial roof areas, which lend themselves to applying solar PV, and in some cases substantial parking areas which lend themselves to locating energy storage equipment (and/or PV canopies). Arguably a shopping mall could be viewed as a hub for renewables and energy storage both to assist energy management of the building and to provide value to the community/customers. The latter is considered principally for the mobility application, where people can recharge their battery electric vehicles (BEVs) or refuel their fuel cell electric vehicles (FCEVs) at the shopping mall while they shop. Here it is important to note that BEV recharging would increase the mall’s power consumption during opening hours, while FCEV refueling could increase the mall’s power consumption only during the night by restricting the electrolyser operation to an off-peak tariff.

Table 22: Energy storage options involving hydrogen for managing supply-demand mismatches resulting from the exploitation of renewable energy

End use	Application
Power	1.1 Backup Power 1.2 Primary Power 1.3 Hybrid H_2-battery storage
Transport	2.1 Hydrogen refueling station for customer FCEVs or HICEs 2.2 Hydrogen bus refueling 2.3 Materials handling vehicle refueling
Heat	3.1 Catalytic boiler to convert hydrogen to heat 3.2 CHP engine running on hydrogen 3.3 Power-to-gas for H_2 injection into local gas network
Backup Hybrid	Any of the above with a stationary Fuel Cell for backup power.

Consideration of these storage concepts has focused on Trondheim as this site has been selected for storage technologies, but these principles will also mostly apply to Valladolid (Spain) and Genoa (Italy). Discussion focusses on PV storage due to the potential for installation of up to 500 kWe of PV on the shopping mall roof in Trondheim, but also includes discussion of wind energy imported from the grid. This provides the renewables context for the considered energy storage concepts.

POWER

Backup Power

A major application for fuel cells is the provision of backup power, with a significant commercial market in the telecoms sector (source: http://dantherm-power.com). Despite care to ensure security of supply, grid networks occasionally experience interruptions of supply (outages), particularly in winter months when demand is high. Therefore there may be a justification for employing energy storage to provide backup power for emergency purposes.

A 50 kW fuel cell is probably sufficient to provide emergency lighting and operations compared to the peak demand of 350 kW. Call up for this service would be minimal say around 10 hours p.a. This requires 500 kWhe of electricity from a fuel cell, which in return requires 30 kg of hydrogen assuming a fuel cell system efficiency (hydrogen to AC power) of 50% (source: http://future-e.de). 1650 kWh p.a. of electricity would be required to generate this hydrogen by electrolysis.This might be met by an electrolyser of a few kW operating for a few hours overnight, or absorbing the base load output from a 500 kW rooftop PV system. The overall efficiency of this emergency service is poor, around 30%, but this may be acceptable given the value proposition.

The hydrogen store would need to be mounted outside the mall and its physical size would be a function of the electrolyser operating pressure, assuming a compressor is not employed. The role of the electrolyser is then to trickle charge the tank ready for an emergency requirement. The component sizes will increase if the emergency power level increases above the assumed 50 kW or 10h p.a., but the electrolyser size will remain relatively small. Such a hydrogen system, involving a significant store of hydrogen, for providing emergency backup could also be extended to deliver hydrogen to other applications at other times by installing a greater capacity electrolyser.

Primary Power

An extension to the backup power option is the provision of primary power. A roof containing 500 kW of 45° fixed-tilt, south-facing PV panels could generate around 450 MWh of electricity p.a. If all of this is sent to electrolysis this could generate 8,250 kg (277 MWhch) of H2 p.a. at an efficiency of 55 kWhe/kg. If reconverted to electricity through a fuel cell, this could generate 139 MWhe of electricity assuming a fuel cell system efficiency of 50%. Mains power and lighting consumption for the CitySyd shopping mall have been estimated by EURAC to be about 1,550 MWhe p.a., so about 9.0% of this could be generated from the fuel cell. This could be topped up with electricity stored by the electrolyser overnight taking advantage of any cheap off peak electricity tariff and delivered by the fuel cell during daytime hours to avoid the expense of higher daytime prices, or augmented by using the electrolyser to absorb the output from a local wind turbine.

The overall turn round efficiency is again poor at about 30% and this option is unlikely to win favour in Norway because electricity prices are relatively low due to the large amount of hydropower (i.e. storage in the power system). Additionally, the electricity mix in Norway has already a high share of renewables. However, this option could be attractive in other countries where the ratio of peak/off-peak prices is much greater. Of course, some of the electrical demand can be met directly by the PV panel without using storage. However peak demand is expected to be around 325 kW, so there will be times when the power produced by the 500 kW panel exceeds this. This excess PV could be exported to the grid, but alternatively it could be stored onsite in the form of hydrogen to increase the mall's autonomy and reduce the need to rely on the grid. The seasonal variation in solar power generation and energy demand is so high in Trondheim that a detailed analysis of the variation in supply and demand is needed to ensure hydrogen storage requirements are not excessive. In addition to seasonal storage, electrolysis could store solar power generated during the day for providing electrical demand overnight. Hourly data detailing the variation in the shopping mall's electrical demand is needed to quantify the size of electrolyser needed to capture the electricity available, the size of the fuel cell needed to deliver electricity to the shopping mall, the amount of electricity captured by the electrolyser, the amount delivered by the fuel cell and the size of tank needed to size these components.

In addition to operation from a PV panel where this is available, another option for hydrogen storage is the operation of the electrolyser overnight and at weekends simply to store cheap off-peak electricity for use in the shopping mall during peak times. This can reduce electricity bills, and also assist the electricity grid in storing excess renewable electricity during off-peak periods (e.g. excess wind power during periods of high wind, or periods of high rainfall when hydroplants need to reduce reservoir levels) and in peak-shaving (reducing demand from the mall at peak times) when the grid may struggle to meet demand. This can increase the mall's energy autonomy (through increased onsite storage) by increasing its ability to generate its own power when needed, and reduce the mall's burden on the grid. Once stored as hydrogen, the hydrogen can then be used for providing power to the shopping mall when demand for power is required.

Hybrid Hydrogen-battery storage

Solar power can be stored as hydrogen, but excess PV or wind can also be stored in the form of batteries. In fact, there is scope for considering hybrid hydrogen-battery systems where hydrogen storage is preferred for weekly/seasonal storage (important in locations like Trondheim with a strong seasonal swing in PV production) and batteries performs the bulk of hourly / daily cycling. Batteries achieve a high turn-round efficiency (>70%) and are well suited to meeting intraday variations and load spikes. However, hydrogen storage does not suffer from self-discharge, making it a much better option for long-term storage than batteries. Batteries are also prone to sit at low states of charge for long periods when performing seasonal storage with severe implications for battery life, whilst a hydrogen tank may, in fact, prolong its life by being partially full for long periods. Unlike batteries, hydrogen also allows the storage capacity to be decoupled from the power plant, allowing a smaller electrolyser to process a larger amount of electricity than a battery could. Typically, an electrolyser is switched on to capture solar power when a battery reaches a high state of charge, storing energy in the form of hydrogen for long-term storage. This hydrogen is reconverted to electricity to meet demand when a battery reaches a low state of charge, until solar power increases again in supply. Overnight, when a battery is full, the electrolyser could be switched on to accept electricity from the battery to increase headroom for the battery to store excess PV the next day.

The elegance of this approach is that a hydrogen storage system assists the shopping mall to achieve greater energy autonomy while reducing the strain on the electricity grid for meeting variable demand. The design of a hybrid hydrogen/battery energy storage system is complex, especially if a high degree of energy autonomy is desired.

TRANSPORT

Hydrogen vehicle refueling

Hydrogen vehicles have long been considered as one of the main options for decarbonizing transport, and are now entering the mainstream with major OEMs (Honda, Hyundai, Toyota etc.) beginning construction of significant numbers of Fuel Cell vehicles in 2014-15 (source: https://www.gov.uk/goverment). They have several distinct attributes compared with BEVs, namely: (i) can be refueled in minutes not hours; (ii) have ranges of >500km, similar to petrol cars; and (iii) the hydrogen can be generated by electrolysis out of time phase with the

hydrogen demand, so enabling valley-filling on the electricity grid rather than increasing the daytime power demand.
There is therefore considerable potential for using a hydrogen system at the CitySyd shopping mall in Trondheim for reducing carbon emissions associated with the shopping mall's use. A number of options for hydrogen refueling exist.

Figure 255: Example of a HRS (Source: Hyundai)

Fuel Cell Electric Vehicles (FCEV) are a form of electric vehicle where a fuel cell is used instead of a battery to provide the power. The advantages of this include refill time (comparable to regular diesel/gasoline times), range (590 km for a Hyundai IX35 on a full tank) and worldwide standardization on refueling method. Conversely BEVs require technology breakthroughs to achieve long range and rapid refueling. Hydrogen Internal Combustion Engine (HICE) vehicles are also feasible and cheaper than FCEV although the range is limited to ~ 240 km. There have been various HICE projects for buses in the EU and North America, although it is generally considered that FC buses will win through.

The shopping mall could offer a commercial refueling station for customers driving FCEV and offer fuel on a reward scheme for frequent shoppers. It could also have its own fleet of hydrogen-powered vans for couriering light goods around the site and for journeys across the city to reduce carbon emissions.

Utilizing the full output of a 500 kWe PV panel on the shopping mall roof, about 8,250 kg p.a. of zero-carbon hydrogen could be generated for vehicle refueling. A FCEV driving 16,000 km p.a. requires about 150 kg p.a. of hydrogen, meaning that CitySyd could generate enough hydrogen to provide enough fuel to travel 880,000 km (~55 cars).

Utilizing the same solar yield to give 8,250 kg of hydrogen for refueling a HICE vehicle travelling 16,000 km p.a. requires about 550 kg p.a. of hydrogen, meaning that CitySyd could generate enough hydrogen to provide enough fuel to travel 240,000 km.

Hydrogen production could be boosted further if, in addition to a 500 kW rooftop PV installation at CitySyd, green windpower or hydropower is imported from the grid. A typical containerized unit like the example on Figure 254 above powered by green energy would be capable of producing 28,000kg p.a. if operated continuously, equating to 3 million km of carbon-free fuel if used by a FCEV (enough to fuel 187 FCEVs) or 800,000 km if used by HICE vehicles.

Hydrogen Bus Refueling

People travel to the mall by car and bus. One option for encouraging zero emission transport is to use energy storage to provide a bus refueling facility at the mall, so encouraging the deployment of H2 buses and encouraging some people who travel by bus rather than car. A typical bus carries and requires approximately 30kg/day of hydrogen if travelling on routes in and around a city, so the HRS design can be undertaken to provide enough fuel for one or more bus depending on the frequency of bus arrivals/departures at the mall. In the above example 8250kg of hydrogen would be sufficient to fuel one bus 5 days per week across the year.

Material Handling Vehicles (MHV)

Another major option is the use of hydrogen-powered material handling vehicles (MHVs, typically forklifts or pallet trucks). This can be for warehouse or restocking activities onsite. Hydrogen-powered MHVs are one of the earliest markets for hydrogen-powered vehicles and are increasingly being used around the world (ITM Power, 2012). They have no emissions or fumes and so are preferred for operation in enclosed spaces to diesel-powered MHVs, and operate for longer at full power and take much less time to refuel than battery-powered vehicles. With up to 8,250 kg p.a. of hydrogen available, this could power 22 MHVs consuming 1 kg/d over the course of a year.

If hydrogen vehicle refueling is the preferred option for CitySyd, the amount of hydrogen produced and the amount of vehicles refueling can be increased by topping up the hydrogen generated from onsite solar power with hydrogen generated with electricity from the grid. This reduces the shopping mall's grid independence, but could offer greater utilization of the refueling plant and also assist the grid with capturing excess grid electricity at off-peak times (e.g. overnight and at weekends). Using grid electricity could increase carbon emissions due to the carbon intensity of the grid, but this is low in Norway anyway and could reduce further over time.

HYDROGEN FOR HEAT PROVISION

Another important energy demand for shopping malls is in the form of heat. Hydrogen storage can also play an important role in the provision of heat.

Catalytic boiler

Hydrogen can be oxidized electrochemically at low temperature in a catalytic boiler to heat water. In 2012 Giacomini in Italy launched a catalytic hydrogen boiler for providing underfloor heating in eco homes and similar low-energy environments (source: http://www.giacomini.co.uk). 8,250 kg p.a. of hydrogen from onsite solar power could generate 277 MWh p.a. of heat as catalytic boilers are effectively 100% efficient. The overall efficiency of this approach is around 60%.

The heating demand of the CitySyd shopping mall has been estimated by EURAC to be around 1,140 MWh p.a., so 19.9% of this could be generated from zero-carbon hydrogen. An excess of hydrogen could be generated during the summer as a peak of 500 kWe from the solar panel could result in 300 kWth during the day once converted to hydrogen and then heat, versus an average heat demand of about 25 kWth. Some hydrogen would need to be stored for use overnight or for use later in the year, or for other uses of hydrogen than for providing heat. Hourly data on CitySyd's heat demand is needed before the hydrogen storage needs can be quantified.

CHP engine

As a combustion engine, CHP systems are also well-understood and widely available. Hydrogen generated from solar power could be used in a CHP engine to generate heat and power onsite. This has the added advantage of generating electricity as well as heat, leading to a higher overall efficiency. This could run exclusively on hydrogen, or as a mixture with natural gas.

The addition of hydrogen to natural gas provides a means of reducing the carbon emissions from gas combustion and does not require the use of a HICE. For example 8250kg of hydrogen per annum generated from onsite solar power would, if consumed as a 20:80% mix with natural gas by volume, be sufficient to operate a 200 kWe CHP engine of 200 kWe operating for 6,000 hrs. p.a. (assuming the engine has an electrical efficiency of 30%, 80% overall efficiency). This could be sufficient to generate 1,190 MWh of electricity and 1,980 MWh of heat per year, or around 77% and 174% of the mall's electricity and heating demand respectively (i.e. potentially enough heat generation to export excess heat to the local community).

Power-to-gas

One option that is gaining increasing attention is the ability to store excess solar energy in the form of hydrogen, which is then stored in the local gas network rather than in onsite hydrogen cylinders or tanks (ITM Power, 2013), which need space and tend to be expensive. In some situations this can considerably reduce the hydrogen storage requirements, and is particularly appropriate for the quantities and storage timescales for locations like the CitySyd shopping mall. There is normally an upper limit on the quantity of hydrogen that can be mixed with natural gas and stored in this way, and in most of Europe this is typically 5-10% by volume. This leaves considerable scope for generating significant quantities of hydrogen, injecting this into the local gas network, and reducing significant quantities of carbon emissions from local natural gas users. For larger quantities of hydrogen, upgrades to local gas networks and end use appliances can allow higher fractions of hydrogen to be injected. Alternatively, technology is currently under development that allows hydrogen to react with CO_2 to create synthetic methane, which can be injected at higher quantities into the local gas distribution network than pure hydrogen could be. This methanation approach could be an attractive option for the longer term.

BACKUP HYBRID

As discussed above, a 50 kW fuel cell could be ideal for providing emergency backup power to a shopping mall in case of grid interruptions. With little usage over the course of a year, such a system could be used relatively simply in conjunction with other hydrogen appliances to increase the utilization of the hydrogen storage system and to meet a wider range of energy demand; this application would reduce the use of fossil fuels typically used as main fuel for UPS. A fuel cell providing primary power under normal circumstances could also be called upon to provide electricity during a grid interruption. A fuel cell could also be housed adjacent to a hydrogen refueling system normally used for refueling fuel cell vehicles or material handling vehicles, but where the hydrogen can be rerouted to a stationary fuel cell for providing emergency power. Or a hydrogen system normally providing space heating through a catalytic boiler or CHP engine could divert hydrogen to a fuel cell to provide power during a blackout situation.

A4.3 Peak shaving of demand curve and classification of the demand

As addressed in the introduction chapters the deeper implementation of RES and the relatively high energy demand of the European building stock, make it necessary to achieve more flexibility in managing the electricity systems. Recent years has seen an increasing focus on energy efficient operation from facility management in shopping centres, especially with the introduction and improvement of systems for building automation, energy management and demand control (NVE, 2014). Demand side management and smart technologies is expected to play an important part when moving towards more effective energy use in shopping centres and the inclusion of local energy production with a more intermittent nature.

Peak shaving of electricity demand is linked to energy security, which can be attributed to three key areas, in which electricity supply must fulfill without:

- Creating great price fluctuations,
- Cost becoming too high, and/or
- Failure in the energy supply, or grid capacity limits affecting operation time.

The reliability of energy security in the overall supply is complex. In this section, it will be addressed to what extent energy efficiency measures and local RES capacity affect peak demand in shopping centres. This may in turns improve energy security, but the factors influencing energy security will not be discussed further. There are two principle concepts which will be addressed:

- Reducing energy usage in shopping centres through load management.
- Load matching by adding RES capacity on site and/or energy storage solutions.

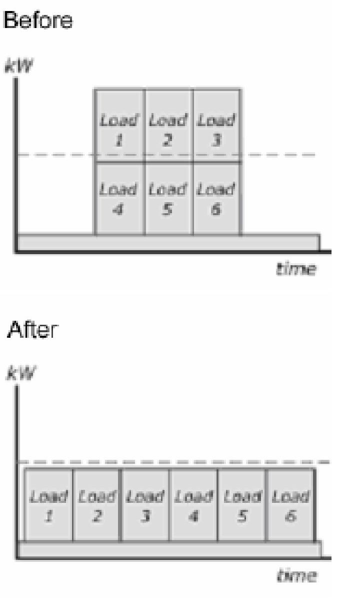
Traditionally, peak shaving of buildings energy demand has been in use by facilities managers to reduce stress on local installations and lower energy bills from penalty based tariffs. Specific demand charges in tariff rates are typically per peak kW of the billing period, but other peak demand tariff definitions also exist: i.e. customer charge, power factor charge, loss factor charge, fuel adjustment costs, demand control response; penalties or credits. The counterpart is a flat rate which is unaffected by peak demand, like in the case of the Norwegian reference building. Apart from that example, markets with greater energy price fluctuations, and various time dependent tariffs are common among the reference buildings, like variable day and night tariffs (see i.e. the country comparison in Appendix). These schemes can provide economic incentive to perform measures specifically targeted at peak shaving, shifting of loads and/or combined with energy demand reductions, or load matching by introducing local RES capacity.

Reducing usage through load management.

One effective way to improve flexibility with the local grid supply is to apply different smart grid technologies for load balancing, load shifting and peak shifting. Demand side management, and more recently intelligent load management, can be a manual, or semi- to fully automated process (Dam et. al. 2008).

Response steps in demand side management systems (Yeang, 2008).

1. Monitoring is the first step to control demand.
2. With the data a load management system can predict an estimate of energy demand for the next period.
3. A "near peak demand" warning signal can be produced by the systems, which alerts the facility manager. Load reduction requests can also come from utility companies.
4. There are three types of demand response (Dam et. al. 2008):
   - In a manual system the facility manager get time to act on the signal and may choose to manually reduce loads.
   - In semi-automatic systems the building staff can be given a suggestion of non-critical loads to shut down, based on a local management policy prioritization.
   - In a fully automated system the external signal triggers a pre-programed response. However, it should still give the operator awareness and ability to override the event.
5. While activated, systems can be designed to continually monitor the situation and shift between loads i.e. to meet thermostat requests.
6. Similarly, the process of return back to normal can be a manual process up to a fully automated process.



In a recent study, Adinolfi et. al. (2014) presents a case study of an Italian shopping centre, proposing a methodology for intelligent load management and evaluating how it could be implemented to control the power consumption of some of the characteristic loads in a shopping centre. A mathematical model is developed in order to compare different results using a predicative rate control algorithm. 378 electrical loads with a peak load of 1639 MW are considered in the model. Each one characterized with its own one-day absorption profile, reference switch and priority level (i.e. illumination, kitchen dishwasher, fridge and HVAC located in different type of shops and restaurants). The simulations show good results in terms of peak shaving and respect the target consumption set to less than 1100 kWh/hour, or 275 kWh/15 minutes.

Especially the high extent of thermal loads in shopping centres (like fridges and other refrigeration units, central cooling loops, heating and ventilation) can be assigned a lower priority; postponing the restoration of target temperature, or shifting load cycles between units (thermostatic behaviour). However, other essential loads may not so easily be turned on or off, considering their effect on productivity over time, or critically important processes related to safety, i.e. lighting of cargo loading zones. Loads can also be prioritized by the time they can be turned off before being brought online, i.e. up to 15 minutes for a refrigeration unit.

Load matching by adding RES capacity on site

There are several ways to display the load matching and grid interaction. Regarding load matching the following three give a good picture of the correlation between on-site demand and supply of energy:

- Load cover factor – the percentage of the electrical demand covered by on-site electricity generation (see chapter 2)
- Supply cover factor – percentage of electricity generated on-site that is used by the building (see annex 1)
- Load match index (see chapter 2)

It is possible to illustrate both the daily and seasonal effect, the production pattern of different renewable energy technologies, and applied operation/control strategies. The advantage of factors over energy demand and energy production profiles is the possibility to take into account the influence of different types of storage, e.g. batteries, building thermal mass. Moreover, when computing the load cover factor, we can investigate the influence of different strategies and measures of load modulation, e.g. demand side manager.

The hourly supply cover factor is a good indicator of when and how much of the on-site supply is self-consumed, and thus indicates the periods when building acts as supplier of energy. It should be noted that without knowing the characteristics of the local energy systems, it should not be concluded if high or low cover factors are preferable.

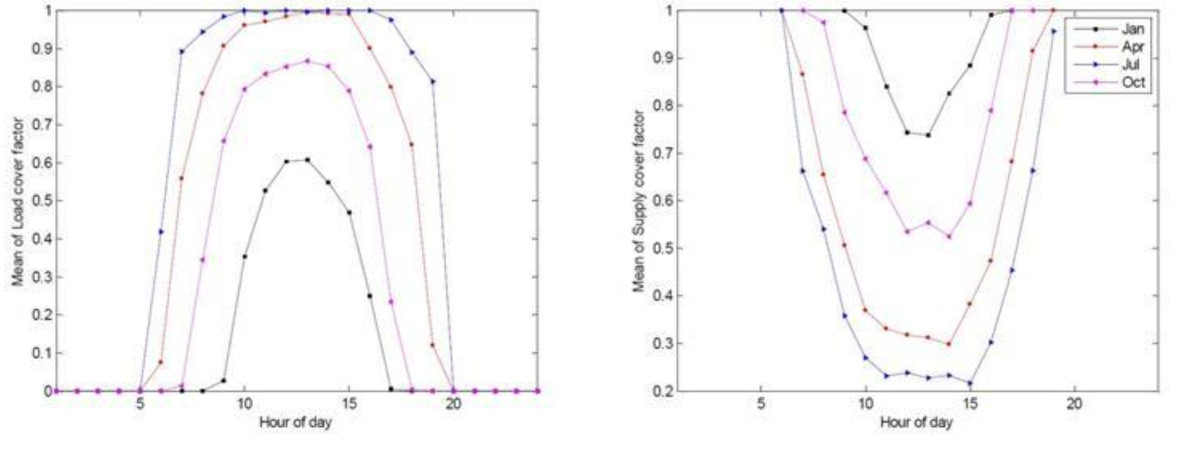


Figure 46: Example of load cover factors (right) and supply cover factors (left) represented as mean values for four months (Source: Salom, 2014).

For grid interaction there are two factors considered to be the most indicative:

- Generation multiple – relates the size of the generation system with the design capacity load, expressed as the ratio between generation/load peak powers or exported/delivered peak powers.
- Dimensioning rate – expressed as the ratio between maximum absolute value of the net exported energy divided by designed connection capacity

Grid interaction refers to the energy exchange between the building and the power grid. Graphical representation of net exported energy in load duration curves has been proven to be a useful way to concentrate a lot of information in the same graph: delivered and exported peak values, amount of time when the building is exporting or demanding energy to or from the grid, period when the building is self-sufficient if a storage system is present, etc. Several buildings could be compared if this information is presented in a normalized form related to the connection capacity, together with information on what extent the building is using the grid. Generation Multiple (GM) is an index which relates peak values for exported/delivered energy and also can be used with generation/load values. Dimension Rate (DR) relates the building with the electrical grid although the designed connection capacity of the grid, Edes, needs to be known which has been proven is not the case in some of the simulated test cases.

Figure47 shows an example of a duration curve for export, generation and load on the left. On the right side of Figure, the same example is shown as a duration curve of net electricity export normalized with the designed grid connection capacity. The design generation, $\overline{G_{des}}$, and design load, $\overline{L_{des}}$, are represented in dotted lines.

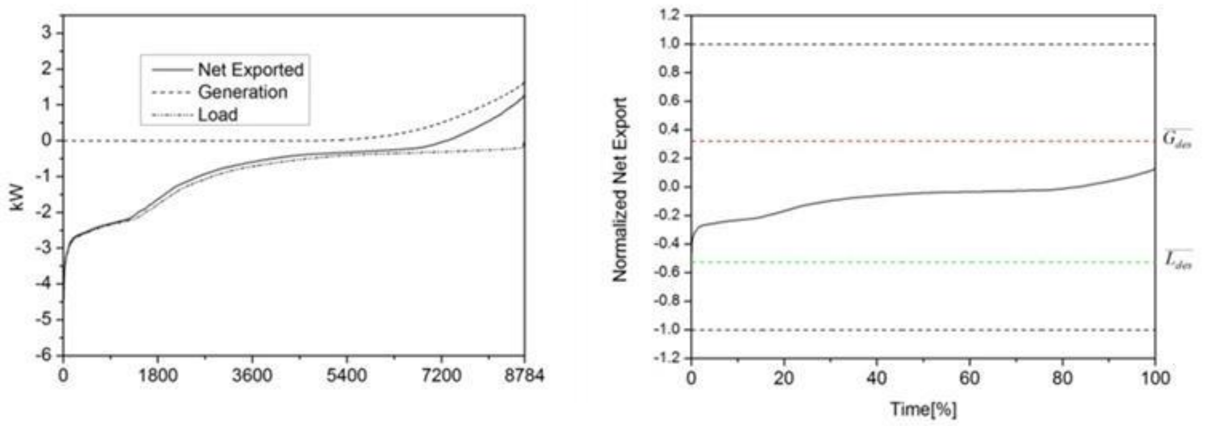


Figure 47: Example of duration curve for generation, load and net exported electricity (left) and Normalized net exported electricity duration curve (right). (Source: Salom, 2014).

Coloured contour graphs ("carpet diagrams") give a meaningful display of when and how much a building is importing or exporting energy over the year. Figure 48 shows a typical individual house with PV in a heating dominated climate on the left and a building with CHP on the right. The red end of the scales shows export. It is easy to see that the house with PV exports during daytime in the warmest months, whereas the CHP-building exports both day and night during the winter months when the heating demand is biggest (Salom, 2014).

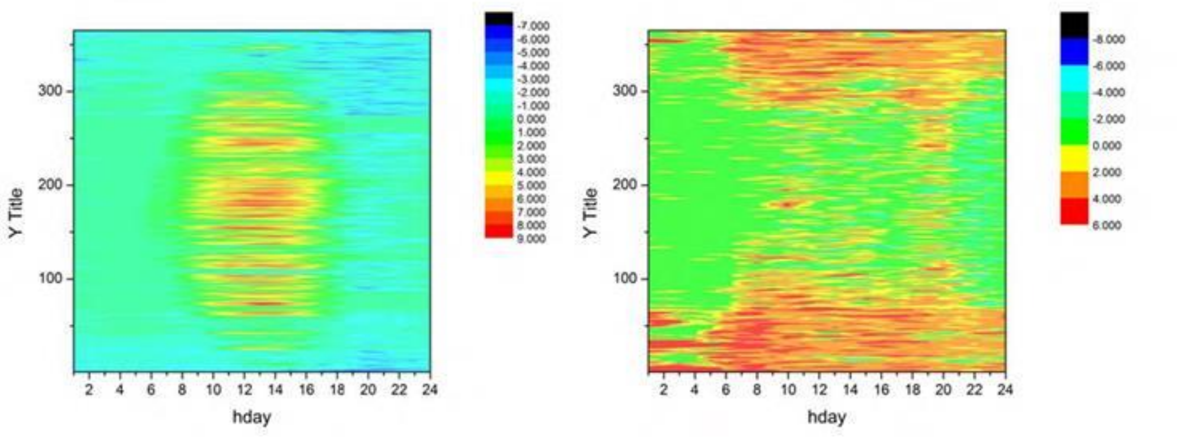


Figure 48: Example of coloured contour plots of net exported energy from a typical house with PV in a heating dominated climate (left) and similarly for a building with CHP generation on the right (Source: Salom, 2014).

A4.4 Energy saving solutions

Taking into account some of the common potentials identified in shopping malls (see D2.2), we describe following the solutions that could be adopted in a retrofitting of an old mall to save energy and therefore modify and hopefully improve the interaction between the building and the grid. It worth to point out in the beginning of this document that most of measures create interconnection between the effects they can generate. For example, the use of daylighting improves the electrical consumption of lighting but at the same time can generate an increase of the cooling consumption if the daylighting opening is not correctly integrated with shading devices. Therefore, the combined effects need to be considered. The possible energy saving measures are divided into four topics: envelope, lighting HVAC system, refrigeration.

Following table 23 summarizes the approaches of energy saving concepts aimed to be incorporated to shopping centres.

Table 23: Energy saving solutions

	Lighting	HVAC	Refrigeration
PASSIVE	Penetration of natural light (e.g. adding/retrofitting openings and glazing) Redirection of light Shading	Good insolation Airtightness Solar shading Reflective coating Natural ventilation/ free cooling	Air-tight closure systems for cold rooms and refrigeration cabinets Ducts and pipes insulation Ambient free-cooling for products and goods Reduction of non-process heat loads Correctly stock display cabinets
ACTIVE	Efficient equipment (fixtures and lamps) Lighting control (presence sensors, programmable swich-off)	Replacement of inefficient equipment and components Energy flux management and strategies (e.g. heat recovery, ventilation strategies (Equipment control and management	Optimization of the refrigeration unit (pressure and temperature) Efficient refrigeration unit components (EC motors, evaporator, expansion valve, condenser) Heat/cold recovery systems

ENVELOPE

With the envelope we define the structure that separates the internal space from the surrounding environment to help create a comfortable indoor climate all year around. There are several possible solutions associated with the envelope, commonly referred as passive solutions to differentiate them from the active moving elements. The passive solutions influence the energetic needs of different systems (heating, cooling, ventilation, and lighting) as well as the occupant's comfort. In addition to high thermal insulation for windows, roof and walls, thermal mass as well as airtight envelope, we want to highlight the importance a few additional measures:

- Solar shading
- Green integration
- Reflective coating
- Natural ventilation

Daylighting and daylighting systems will be treated separately in following subsections.

Solar shading

Solar shading is the term used to identify a number of systems to control the amount of heat and light from the sun admitted to a building. These properly designed elements allow reducing the cooling needs during the summer months while still taking advantage of the solar gains during the winter months (taking advantage of the different incidence angle during the year). Compared to other building typology, for shopping mall cooling loads tend to be more important and therefore the needs to properly control solar gains, while at the same time using daylighting to reduce artificial lighting use and increase visual comfort. Therefore, it is often important to consider the correct compromise between solar gain control and daylighting with the associated visual comfort benefits. Shading devices can be both internal (e.g. shade, blinds) and external (e.g. overhangs and vertical fins). By using exterior shading devices it is sometimes possible to obtain performance equivalent to unshaded higher performance glazing. If we consider that in commercial buildings and shopping mall, the external facades are usually glazed and obstructions-free (because of the great visibility of interior ambient they want to give to the consumers), notable energy can be saved by exploiting external shading. Additionally, these overhangs can be used for energy generation. Figure48 shows a smart solution by using overhang as site for PV panels.

Figure 49: PV panels integrated in external solar shading (Source: http://www.solarpv.co.uk/solar-pv-louvres.html)

Green integration

Planting of trees and shrubs can also be used as strategy to control solar gains if applied externally (e.g., on pergolas and beam overhangs), while if applied internally can modify the microclimate (Figure 50). Selective planting can shade not only windows and other apertures but also whole facades and roofs, reducing conductive as well as radiative heat gains.

Figure 50: Example of solar shading by using vegetation (Source: http://en.wikipedia.org/wiki/Green_wall)

Reflective coating

Another solution is the use of reflective coating to reduce the heat transfer into the building and therefore the cooling needs. Especially used for roof application (cool roof) these surface coatings lower the surface temperatures of the roof, resulting in greater comfort inside the building and less demand on air conditioning equipment, resulting in lower energy costs. These solar reflective coatings are typically a white roof coating consisting of a polymeric binder blended with pigments and other additives or silver containing asphalt, pigment flakes and pure aluminum resulting in a silver reflective coating.

Natural ventilation

Ventilation is one of the main energy needs of a shopping mall. In addition to partially serve as regulator for thermal comforts it also provides the hygienic and health conditions needed in the building. There is a significant potential to use natural ventilation also in non-residential building and therefore using favorable outdoor conditions and air movement to guarantee adequate conditions. It uses natural forces such as thermal buoyancy and wind pressure difference for air movements with no or minimal use of electricity. In addition several studies demonstrated increased IEQ and occupant satisfaction (Hummelgaard et al., 2007) with natural ventilation used in schools and offices. It is especially appropriate to eliminate excess heat generated from internal gains (e.g., lighting, appliances and occupants), often one of the recurring issues of shopping malls. Different natural ventilation strategies exist including cross ventilation, stack effect, night/ventilate cooling depending on the configuration and needs. These solutions perform best if coupled with high thermal mass. Correct design of the building geometry, layout and openings must be plan to fully exploit this potential. Nevertheless, integration between natural and mechanical ventilation (hybrid system) is often needed in building with high density of users, because of the indoor air quality standards should be guaranteed.

LIGHTING

Lighting accounts for a significant fraction of electricity consumption in retail buildings. Mainly there are three possible ways to obtain energy saving associated with lighting issue in addition to generally avoid waste (light on when daylighting is sufficient). Even if we are going to present separately possibilities and restrictions of these solutions it worth to highlight that the best results in term of energy saving could be reached by mixing and merging in the right way all of them. The main solutions are:

- Exploitation of the daylighting potential to reduce the use of artificial lighting
- Penetration of natural light
- Redirection of light
- Control of elements (e.g., shadowing elements)
- Replacement of old and inefficient lighting equipment (luminaires and lighthouse) with new one more efficient
- Use of lighting controls according to different needs.

Daylighting

This concept focuses primarily on architectural design, orientation, space distribution to exploit the use of daylighting to provide occupant with comfortable natural light conditions. The goal is to maximize the use of daylight as the primary source of ambient light in regularly occupied spaces, thereby minimizing the use of electric lights and decreasing cooling loads (often critical in shopping mall). The main concept consists in placing windows (side-lighting), skylight (top-lighting) or other opening and reflective surfaces so that during the day natural light provides effective internal lighting to an elevated visual comfort levels. Therefore, in addition to providing enough daylight we must ensure that it is done without any undesirable side effects. Whenever daylighting is not sufficient in providing adequate visual comfort levels it can be integrated with artificial lighting. When there is adequate ambient lighting provided from daylight alone, this system has the capability to reduce electric lighting power resulting in saved energy. In addition to this direct saving there could be indirect saving due to the control of solar gains as well as the reduction of interior gains due to the lower use of artificial lights. In addition, there will be several benefits related to user comfort and perception.

Daylighting requires an integrated design approach to be successful, because it can involve decisions about the building form, siting, climate, building components (such as windows and skylights), lighting controls, and lighting design criteria. For this reason the optimization of daylighting in an existing building requires more efforts than for a typical new build. The layout of the building impacts strongly on the potential for daylighting use and should be optimized. The first step of daylighting design for retrofits is to consider the geometric proportions of existing spaces in relation to existing windows and skylights. Next, search for opportunities to improve daylight penetration and distribution throughout regularly occupied areas despite those limitations.

The main opportunities to improve the daylighting conditions are in the modification of the building envelope. These can be grouped in the following ways:

- Adding or retrofitting apertures;
- Adding or retrofitting glazing in existing windows;
- Adding redirecting elements to direct light to dark areas.

These solutions result to be more effective if combined with an interior reconfiguration of the space. This can create redirection of the light with consequent light distribution and illuminance levels optimization. Beyond adding windows or skylights to a space, daylighting involves carefully balancing heat gain and loss, glare control, and variations in daylight availability. For example, successful daylighting designs will carefully consider the use of shading devices to reduce glare and excess contrast in the workspace. Additionally, window size and spacing, glass selection, the reflectance of interior finishes, and the location of any interior partitions must all be evaluated. Even excluding actual windows improvements, changes to interior reconfiguration and design can make big difference in perceived light quality. Care must be taken to protect from known issues: overheating and glare.

Adding or retrofitting apertures

Most of the daylighting design solutions are focused on openings in the walls such as daylight windows (side-lighting) or skylights for top-lighting. The main issues for side-lighting are the dependence on orientation and uneven distribution, while for top-lighting the risk of overheating. Windows and skylights are light transmitting glazed portion of the roof of a building letting the natural light coming inside. Although these elements can be either passive or active, the majority of them are passive because their function is just allowing natural light to penetrate from roof. Some of these systems also attempt to reduce the daylight ingress in the summer months, balancing daylighting with cooling loads or track the suns (more common for skylights). Care must be taken to avoid excessively large opening and glare.

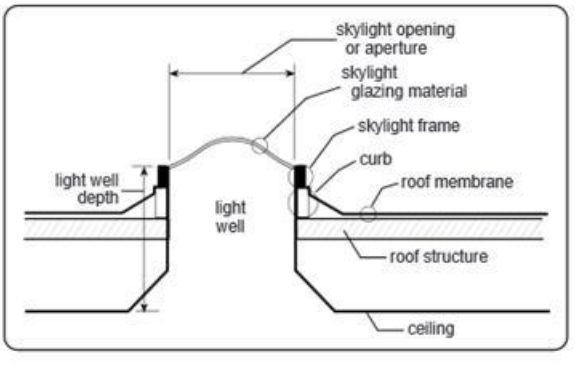


Figure 51: Components of a typical skylight (left) and an example Chadstone Shopping Centre Melbourne, Australia (right). (Source: http://buchan.com.au/projects/chadstone-shopping-centre)

A common approach is to use the skylights to provide the basic ambient light for the building along with a back-up electric ambient system on photo controls, while using specific electric lights to provide higher levels of task lighting in critical locations. This design approach is referred to as “task-ambient” lighting and it is mandatory especially in big retail shop/shopping mall where the main target is to focus attention on goods also through the light. From a designer’s point of view, the challenge is to integrate the form and light-admitting properties of the skylight with the design concept for the building. This is usually done by selecting skylights that complement the ceiling grid and room proportions. Often limitations arise due to competition for roof and wall space and due to the fact that external walls are opaque because of building type, layout and worries from the owners.

Adding or retrofitting glazing in existing windows

Even if high-performance glazing do not have insulation ratings close to those of wall constructions, the window area needs to be a careful balance between admission of daylight and thermal issues such as wintertime heat loss and summertime heat gain. In retail building where internal gains drive the cooling needs there is the necessity to carefully design high-performance glazing system admitting considerable light and blocking the entrance of the heat (SHGC parameter). This is typically achieved through spectrally-selective films. These glazing are typically configured as a double or triple pane insulated glazing unit. This construction gives the insulated glazing unit a relatively high insulation rating, or U-value, as compared to single pane glass. A low-emissivity coating is also often part of these high-performance glazing units, which further improves the U-value of the unit. The glazing also assists with the glare and transparency.

Adding redirecting elements

One of the most important issue of daylighting and side-lighting and top-lighting is the uneven distribution (high level near the opening and low level far away). Daylighting system capable of controlling via shading and redirection of light assist with this issue. Examples are redirecting lamellas, ceiling or tubular daylight devices (TDD) and in general light harvesting technologies. The TDD is a type of top-lighting device that employ a highly reflective film on the interior of a tube to channel light. Tubular daylight devices tend to be much smaller than a typical skylight and consequently they provide less visual contact with the external environment but still deliver sufficient daylight for dimming the electric lighting resulting in energy saving.

During the day the light transmitted varies; that is why light tubes can be combined with artificial light in a hybrid set-up in order to obtain the desired level of lighting. When the artificial light is provided by LED technology, the energy use can be reduced up to 94% making an unbeatable sustainable lighting option and the most energy-efficient commercial lighting solution.

Replacement of inefficient lighting equipment

As mentioned above in combination with an effective daylighting system there should be an efficient artificial (and controllable) artificial lighting system to integrate and provide adequate lighting level when daylighting is not available. An electric lighting system should be capable of meeting all of the building lighting needs during occupied times when daylighting is inadequate. It is important that artificial lights should be use carefully and not misguide the costumers but to for instance display and focus the attention. It is critical to place light only where and when it is needed, enabling overall lower energy use. In addition, the new elements should have elevated efficacy (lumen/W), therefore reducing power density (W/m^2). For instance a typical incandescent lamp has an efficacy of 10-13 lm/W, while a CFL is 50-70 lm/W and LED 80-120 lm/W.

The possible energy saving action can be grouped in:

- Replacement of existing inefficient lamps
- Replacement of existing inefficient old fixtures

A cross use of both energy saving way can lead to better performance and result in term of energy saved.

Replacement of existing inefficient lamps

A huge potential of energy saving lie in the replacement of old and inefficient lamps. The main actions that be applied are the replacement of fluorescent lamps, the most used in retail and shopping centres with higher efficient lamps such as T5 fluorescent lamps, ceramic metal halide lamps and LED. The most common type of fluorescent lamp is tubular and linear in shape. 3rd generation T5 lamps have much greater efficacy with respect to older ones: 100 lm/W versus 80 - 70 lm/W.

All fluorescent lamps need ballasts to maintain the current passing through the lamp at a certain value. There are mainly two types of ballasts: electromagnetic ballasts and electronic ballasts. Although electronic ballasts are more expensive, they have higher energy efficiency and can save money in the long term. Besides, electronic ballasts generate less heat during operation and therefore help reduce energy used for air conditioning.

Ceramic metal halide (CMH) lamps represent extremely effective replacement of higher pressure sodium and Quartz metal halide lamp. Compared with incandescent and fluorescent lighting, HID lamps have a higher luminous efficacy. These kinds of lamps have negative resistance, which causes them to draw an increasing amount of current; hence, they also require a current-limiting device as the ballast. Unfortunately, they have long warm-up time. On the other side CMH lamps deliver superb colour rendering, a features really important in shopping mall and retail.

LED is the most promising technology solution: it uses at least 75% less energy and last 25 times longer than an incandescent lighting. Their unique characteristics including compact size, long life and ease of maintenance, resistance to breakage and vibration, good performance in cold temperatures, lack of infrared or ultraviolet emissions, and instant-on performance are beneficial in many lighting applications. They generate less thermal heat so they can also help to reduce the cooling demand, increasing the energy saving potential. One of the defining features of LEDs is that they emit light in a specific direction, making this technology particularly suitable for commercial applications. Since directional lighting reduces the need for reflectors and diffusers that can trap light, well-designed LED fixtures can deliver light efficiently to the intended location. Because of the lack of fixtures, the installation of LED should be carefully designed in order to avoid glare problems. Costs of LED lighting products vary widely. Good-quality LED products currently carry a significant cost premium compared to standard lighting technologies. However, costs are declining rapidly.

Replacement of existing inefficient old fixtures

This solution simply relies on replacing old inefficient luminaries with new and more efficient one that allows redirecting the luminous flux where is needed. Depending on the specific lighting use, different fixtures with different range of light distribution can be found in the market. Remarkable energy efficiencies results can be also reached by redesign the total exterior lighting power e.g. lighting for parking area, façades, building grounds, entry lights. For example, a way to follow is to reduce 25% of the design level when no occupants are present between midnight and 6:00 a.m. When considering the replacement of lighting in parking area, it is necessary to choose luminaries that provides low contrast ration for safety issue of the drivers. Substitution of high pressure sodium light with led with results in better light distribution. Safe environment where pedestrian/vehicles conflicts exist is highly reduced. Energy saving is about 58%. In general, for both exterior and interior lighting, it is important to select fixtures and lamps that suite with the climate considered. For example, as a simple rule of thumb, exterior fluorescent perform best in warmer climates while LED perform better in colder climates. The use of efficient lighting elements and controls applies also to external lighting.

Lighting controls

To optimally integrate daylighting and artificial lighting solutions lighting control systems are often needed. For that sensors and controls are installed leaving the possibility to attenuate/switch electric light automatically in response to the presence of daylight. The aim of proper lighting control is both to minimize electric lighting during unoccupied hours and to use daylighting when good level is available. To meet these objectives, consider occupancy controls, daylight controls, multi-level switching, and improved zoning. The control is also fundamental to avoid excessive entry of daylight and glaring. Wired and wireless (less invasive) ICT technologies are available. Another way to reach an intelligent use of both artificial and natural lighting is to set certain working schedule. For example, it could be convenient to reduce the lighting power the last working hour before the closing or the following one hour after the opening. The control should be used to regulate the shading and redirection lighting system as well the operation of artificial lights through presence or luminance level logics. Important that the different areas have logics tailored to their needs. In addition, artificial lighting should be designed to guide and direct the costumer attention to the product (accent lighting) and therefore kept to the minimum, without unnecessary uses.

HVAC SYSTEM

The HVAC (heating, ventilating, and air conditioning) system is responsible for providing the thermal and hygienic needs of a shopping mall. An efficiently designed and operated building and HVAC system reduces the amount of energy needed to control hygrothermal conditions and air flow in a space. In addition to the passive solutions regarding thermal insulation, natural ventilation and solar gain controls there are specific solutions regarding the HVAC system that promise to lead to energy savings. To reduce the consumption associated with HVAC in addition of focusing on passive strategies to reduce the needs, it must exist a strong focus on: 1) energy efficient equipment 2) energy flux strategy 3) equipment control and management.

Energy efficient equipment and components

The current equipment could be replaced with ones with greater efficiencies. This is especially true when the existing systems are old, inefficient or malfunctioning. Some of the most efficient technologies include:

- High efficient (e.g., condensing) boilers;
- High efficiency air-conditioning systems;
- Heat pumps
- Combined heat and power (co- and tri-generation);
- Biomass boiler or District heating depending on availability and special conditions;
- Economizers;
- Heat recovery systems;
- Chillers.

It is important to have modular system so to be able to optimize the operation but at the same each shop having a separate system should be avoided. In addition the ducting and pipes needs to have well designed: reduced number of fittings, elevated insulation and reduced leakage. The distribution system (radiant floor or ceiling, fan coils or primary air) should be also designed in according to the performance of the generation system. Attention should also be paid to having efficient auxiliaries (e.g., fans, motors) and to install equipment of the correct size and balance systems.

Energy flux strategy and recovery

In addition to passive solutions capable to reduce the needs by e.g., improving the layout and the space distribution, the recovery of heat waste from different points, the exploitation of free cooling should be recovered. For example:

- Exhaust air recovery:
    - Recovery of heat from e.g., refrigeration system, data centre, exhaust gases;
    - Thermal cascade between the fluids at different temperatures;

- Pre-heating and cooling with renewable sources (e.g., solar or ground).

- Specific strategies associated with ventilation (in addition to natural ventilation described previously):
  - Exploitation of economizer: Air-side economizer can help to save energy by providing free cooling when ambient condition are suitable to meet all or part of the cooling load. They use cooler outside air as a means of cooling the indoor space instead of consuming energy by running compressors;
  - Demand controlled ventilation (DCV): allow to control the amount of outside air provided to each zone based on the occupancy/CO_2 concentration instead or on a day schedule in the Building automation system;
  - Heat recovery ventilation (HRV) and energy recovery ventilation (ERV): allow to recover energy that would otherwise be wasted. It is mainly used for ventilation air but all the heat/cold fluids should be examined to identify possible synergies (thermal cascade). By using an air-to-air heat exchanger, it is possible to connect the supply and the exhaust ducts, using the exhaust air to preheat/precool the supply air, resulting in saved energy. ERV also recovers the enthalpy. The solution can be considered in dry climate to precool the incoming ventilation using indirect evaporative cooling. For this strategy, the incoming ventilation air (the primary airstream) is not humidified; instead, a separate stream of air (the secondary or heat rejection stream) is humidified, dropping its temperature, and is used as a heat sink to reduce the temperature of the incoming ventilation air. The source of the heat rejection stream of air can be either outside air or exhaust air from the building. If the air source is exhaust air, this system becomes an alternative for exhaust air heat recovery;
  - Transpired air collectors: renewable energy technology that, when coupled with a mechanical system, provides free heating of the air. This air collector systems essentially consist of a dark-colored, perforated façade installed on a building's south-facing wall. The air passes over the surface when the panel absorbed the solar radiation providing pre-heating;
  - Variable air volume control (VAV): it consists in using variable speed drivers to regulate air pressure and temperature. The simplest variable air volume control (VAV) system controls air from a single supply duct and varies the airflow to each zone or room based upon the temperature in the room. A VAV system consists of four basic parts: a thermostat, a precision actuator controlled damper, an airflow sensor, and a controller. When the thermostat measure a space temperature at the temperature set-point, the controller closes the damper until the airflow reaches a predefined lower limit. As the room temperature moves away from set-point, the controller opens the damper until the airflow reaches a predefined upper limit. It is a very suitable system when there is the necessity to maintain different comfort level in different zone.

Equipment control and management

Building system control and management strategies in shopping mall and retail buildings are crucial to ensure correct operation. The operation should therefore be regulated by a central brain (building management system – BMS) acquiring information from the field and deciding the best strategies to deliver the required conditions for each zone and tenants.

Control strategies and automation system can help to reduce energy. Examples are:

- Water supply temperature according to the outdoor weather and forecasting to ensure the appropriate heat to given to the space and the temperature difference between supply and return is correct;
- Programmable thermostats to zone the building different according to the needs and the time of day and week. Special-purpose areas, such as offices, work rooms, or special sales areas with significantly different lighting, equipment loads, or occupant density than the general sales area should be controlled as separate zones. To do this each zone needs to be equipped with a temperature sensor and then the system-level controller can use this information in addition with the utilization schedule and the needs of each room to control the operation of all components of the system. During these times, the system is shut off and the temperature is allowed to drift away from the occupied set-point. Zoning also can be accomplished with multiple HVAC units or a central system that provides independent control for multiple zones.
- Temperature setback for unoccupied periods. This is connected to the programmable thermostat. For example, treating daytime and night-time operation differently or reducing the power supplied in specific time period during the day (opening and closing time). A common strategy is the night setback in which some components are switched off or operated at reduced level.
- System-level controller for optimal start. They determine the time required to bring each zone from the current temperature to the occupied set-point temperature. Then, the controllers regulate the operation to reduce the amount of time the system operates and reduced unnecessary conditioning of space during unoccupied time.
- Pre-occupancy ventilation period can help purge the building of contaminants and avoid constant ventilation during unoccupied times;
- Night free cooling based on indoor and outdoor temperature: when, during night, the outside temperature is cooler than (usually at least 3-5 degrees lower) the inside, it worth to use the fresher outside air to cool the building.
- Ventilation and energy recovery strategies mentioned above (DCV, HRV).

REFRIGERATION

In food related retail, refrigeration is one of the main energy needs. Supermarkets are the highest energy intensity buildings of the whole commercial sector; most of their energy consumption is covered by refrigeration. So far, it seems reasonable to spend some effort trying to make the sector more efficient.

Energy saving solution can be grouped into several different ways:

- Strategies to reduce heat gain
- Strategies to reducing heat load
- General setting and operation rules

Reduction of refrigeration heat gains

When dealing with refrigeration, a first step in the energy efficiency improvement process should consist in a review of the system heat gains (i.e., cold losses). Heat gains include warmer air entering the cabinet/cold room and heat produced by electrical equipment within the cooled space. Therefore there are two opportunities to reduce heat gains:

- Reduce cold air changes: the use of plastic strip curtains for cold room or doors, blinds and double glazing on cabinets and refrigerators helps keeping the warm air from entering. Some other measures can relate to the improvement of the air tightness of cold rooms (sealing leaks maintaining air tightness and thermal integrity), insulations of cabinets and pipework. These measures can lead to savings up to 30% with a payback period of around one year;
- Use EC (electronically commutated) replacement motors for evaporator fans. Conventional shaded-pole AC motors can be replaced with DC EC motors. This can result in energy savings of up to 65% for the fan motor. Since the EC motor consumes less energy, there will be less heat to remove for the refrigeration system. Savings achieved can be maximized by fitting a whole new fan assembly instead of just replacing the motor. In most applications the payback period for fitting EC motor fans is one to two years, but it can be much shorter.

Reduction of refrigeration heat load

It is important to identify and reduce unnecessary heat load of the cooling system. Heat loads can be split into process (water cooling, product/process cooling, blast chilling and freezing) and non-process heat loads (evaporator fans, lights, defrost, air infiltration through doors and gaps and heat transfer through insulation). In systems with a secondary refrigerant such as chilled water, glycol or brine, non-process heat loads include circulation pumps and distribution heat gains. We can identify different ways to reduce heat loads. Some examples are listed below:

- Exploitation of free cooling: some processes occur with simultaneous heat and cool. Using an heat exchanger to transfer heat from one stream to another it is possible to reach double savings;

- Ambient free-cooling: pre-cooling a product using ‘free ambient cooling’ before using a refrigeration system is a common opportunity to reduce energy use. For example, a cooked product at 100°C should not go straight into a chiller or blast freezer. It is better to cool the product as much as possible using an ‘ambient stream’ first;
- Reduction/ removal of unnecessary process heat load: process streams are sometimes cooled unnecessarily, or a single cooling stream, such as chilled water, might be used for two different purposes, one of which requires a much lower temperature than the other (thermal cascade process) therefore using the same streams more than once taking advantage of the different cooling needs;
- Reduction of non-process heat loads: parasitic heat loads which are not the result of a ‘core process’ must be reduced. These include the internal gains of e.g., heat generated by pumps, fans and lights, as well as heat infiltration through envelope. Simple steps can help to reduce the internal gains lead to double savings.
- Remote condensers that eject the heat directly outside the building space and not inside
- Efficient compressors and evaporators

General setting and operation rules

In addition to measures to reduce heat gains and loads, it is also possible to achieve better efficiency in the refrigeration unit by allowing a correct operation of all the components. Optimization of working pressures and temperatures is strongly recommended in order to keep cost low. Some examples:

- Evaporator set points should be as high as possible.
- The Expansion valve should be carefully controlled to increase efficiency. For example with Thermal Expansion Valves (TEV) or Electronic Expansion Valves (EEV) for efficiency;
- Compressor is the most energy consuming component. It should be set at the lowest condensing temperature possible and keep suction pressure only as low as is required;

Other maintenance and simple operational measures leading to energy savings include:

- Leakage of refrigerant should be avoided. Therefore, regular maintenance, cleaning and leak repair to minimize the energy spend for refrigeration.
- Optimize air flow for refrigeration equipment: by performing visual surveys of refrigeration units and components to ensure correct operation and clear of obstructions;
- Optimize the use of air curtain making sure they are in the right place and in good working order;
- For large refrigeration units, turn the fans off when the door is open for an extended period;

- Correctly stock display cabinets: optimize product display on lines to avoid blocking air flow that can add 3% to a store's refrigeration costs. Overloading display cabinet's decreases product quality and increases energy use by as much as 10%-20%;
- Cabinets, especially open-fronted and integral ones, should be located away from heat sources;
- Correctly control use of anti-condensation: the use of the spray reduces the need for electrical anti-condensation methods.

CONCLUSION

RES systems depends a lot in the weather conditions in which they are going to be applied, but also in the specific characteristics of the building and the place where they are going to be integrated. Cogeneration could be very useful in shopping centres with a considerable electrical base demand and also with thermal needs. Storage systems could allow to store energy in order to save money (when the tariff is at its lowest price), or even to storage electrical energy from RES systems when there is a surplus of electricity. Peak shaving and energy saving solutions; seem to have the possibility to be applied in almost all the buildings, maybe excluding some of the newest.

Annex 5: Policies and normative for the development of energy sector of countries in which reference shopping centres are located

A5.1 Spain

Energy sector

Currently, Spanish energy dependence rounds 76% and although it increased in recent decades, this trend has reserved with the impetus of the renewable energy sector and the economic crisis which and has made to diminish the energy demand. The highest share in the energy mix comes from crude oil and petroleum products.

In the case of electricity sector, it maintains an exporter status from 2003. According to data from APPA, the association for RES promotion, the installed power in RES in 2013 was 50,689 MW, which supposed an electrical production of 113,575 GWh, corresponding with 41% of the energy demanded. In the electricity mix, the shares are more equally divided between natural gas, renewables and nuclear energy. The share of renewable electricity is mainly hydro and wind.

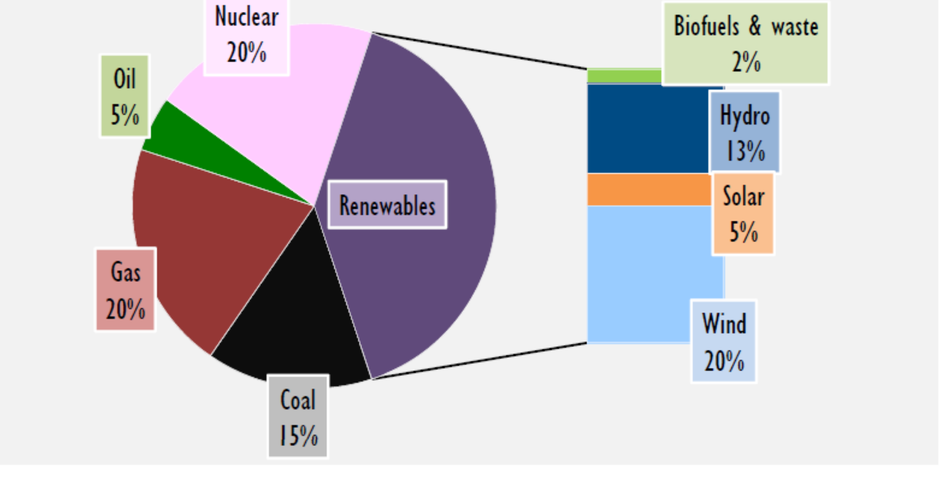


Figure 262: Gross electricity generation in Spain (Source: IEA 2014)

Photovoltaic power accumulated in 2012 reached 4,525 MW, climbed Spain until the second place in the world (after Germany). In the case of wind source, the country is the second in wind energy installed capacity, behind only Germany and on par with the US. However, these data are referred to large facilities since small scale facilities are not very development yet. With few exceptions, the small power wind turbines are not being used for distributed generation-near the point of energy-, and disposal of surplus electricity to the grid due to be subjected to a similar regimen to wind farms of great power, while the investment ratios are much higher.

Policies and normative which regulates the renewable energy sector

The previous situation is the consequence of the good weather conditions as well as the development of a suitable normative which has intended to support the RES sector. Supportive measures have been introduced in the framework of the Energy Plan 2011-2020 to encourage the RES sector. The plan estimates that renewable energy should contribute 22.7% to the final gross consumption of energy by the year 2020 and in the case of the production of electrical energy, this should reach 42.3%. Such provisions indicate that Spain should exceed the objectives fixed for the said period by Directive 2009/28 on the promotion of the use of energy from renewable sources. Furthermore, Spanish market for renewable energy has received high levels of investment, specially directed towards solar energy. However, in the last years new measures have been adopted by the Spanish Government which may make more difficult to meet RES targets. Currently, Royal Decree 413/2014 establishes a new legal and economic regime for electricity production facilities regulating using renewable energy source, cogeneration and waste. These facilities will receive remuneration for the sales of energy valued at market price and, if applicable, an additional remuneration for investment (RI, Remuneration on the Investment) and operation cost (RO, Remuneration on the Operation) which are not covered by the market price.
On the other hand, Building Technical Code defines a minimum solar PV installed power to be integrated in buildings. Royal Decree 314/2006 sets up mandatory requirements of installing solar PV on different types of buildings depending on several parameters: climatic zone, surface as well as use and type of the building.

Grid issues: Priority to renewable energy

In Spain, renewable energy plants are statutorily entitled to priority access to, connection to and use of the grid. Renewable electricity is granted priority dispatch in the electricity markets at no cost, provided the stability and security of the grid infrastructure can be maintained. Renewable energy plants operate under the so-called “Special Regime”.
Plant operators may be contractually entitled to the expansion of the grid. If the expansion is required for a plant to be connected to the grid, the operator of the plant shall bear the costs of the expansion works (“deep” connection charges). Apart from that, the grid operator is obligated to expand its grid in compliance with the general legislation on energy (www.res-legal.eu).

A5.2 Norway

Energy sector

The Norwegian electricity production is based on hydropower (a share of 96 % of the total Norwegian net generation in 2013). Historically this has made it possible to have low electricity prices and a large energy intensive industry as well as use electricity for heating of buildings. In addition to being rich with hydrological resources, the Norwegian continental shelf is abundant with oil and gas reserves, which have made Norway a large exporter of crude oil and the second largest supplier of natural gas to Europe.

The Norwegian net exchange of power changed from 7.6 TWh net import in 2010 to 4.4 TWh net export in 2013 (ENTSO-E, 2013)(SSB, 2012). These numbers illustrate the importance that the weather conditions have on the net generation capacity. A large reservoir capacity provides flexibility, but still it is vulnerable to dry years, which is emphasized in combination with cold weather and the high heating demands of the building stock. Figure shows that for the past years, monthly electricity end-use in January was more than double of July. The average electricity price is shown to fluctuate accordingly, which make investments in energy efficiency measures aimed at reducing electricity consumption in the cold season particularly viable (NVE, 2012).

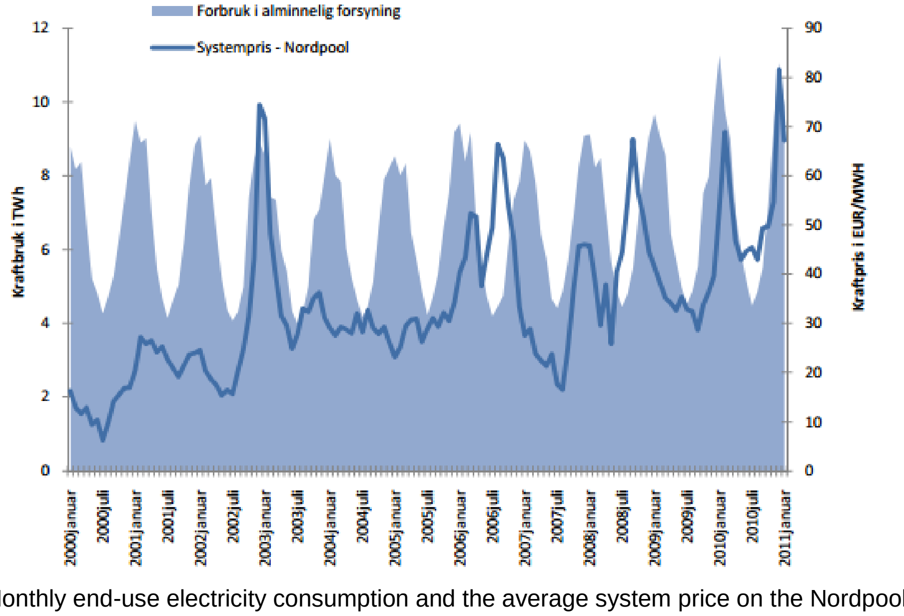


Figure 53: Monthly end-use electricity consumption and the average system price on the Nordpool market in EUR/MWh (Source: NVE, 2011).

Norway has adopted a strategy for development of offshore wind power and is planning to expand hydropower production by utilizing previously untapped hydropower potentials (smaller unprotected watercourses) and by refurbishing some older installations for increased effect. The total installed generation capacity at the end of 2012 was 32,715 MW.

Net increase in hydropower generation capacity during 2013 has been about 379 MW (1.25 TWh), amounting to ca. one-thirds from older installations, new hydro power (<10MWh) and wind power (NVE 2014).

Policies and normative which regulates the renewable energy sector

The overall target of the Norwegian energy and climate policy is to reduce greenhouse gas emissions by 30% (compared with 1990) by 2020 and to be carbon-neutral in 2050, taking into account the country's contribution to emission reductions abroad (Rosenberg, 2013). Through negotiations with the EU, Norway has pledged that 67.5% of its energy consumption will come from renewable energy by 2020 (compared to 61% in 2010). Even though Norway is not an EU member state, the country participates in the EU Emission Trading System (OED, 2012). It is believed that Norway may play an important role in reducing emissions abroad by exporting renewable energy (including hydro, onshore and offshore wind, as well as biomass), but also by offering reductions from carbon capture solutions as they mature (SERN, 2013). Norway has chosen to cooperate on meeting their renewable energy target of 67.5% by 2020 in a common green certificates scheme with Sweden, introducing the certificate scheme in 2012. This mechanism ensures that the renewable energy installations will be deployed where it is most cost efficient to do so (SERN, 2013).

Household energy use has also been identified as an area for further efficiency gains. The Norwegian government has predominantly been focusing on reducing consumption in the buildings sector as a whole, with the state enterprise for energy efficiency. Energy Fund is a government fund established to ensure a long-term, predictable and stable source of finance for energy efficiency and the promotion of renewable energy (SERN, 2013). In 2014 new programs were introduced for commercial building owners/ developers to support investments to realize energy efficiency potential in existing buildings, introduction of innovative building technologies, and restructuring to renewable heating plants (Enova, 2013).

Grid issues: Priority to renewable energy

The Norwegian transmission system operator Statnett's investments have increased in recent years to carry out grid developments and improve the transmission grid both domestically and abroad. There are plans to build several new cross-border interconnections in order to strength the integration between the Nordic electricity market and the rest of Europe (by doubling the capacity to Europe within the next decade). This includes possible connections by Statnett to Germany, UK and the Netherlands as well as between its own regions (Statnett, 2013). In relation to this a debated idea has been to offer Norwegian hydropower on a larger scale, as the storage capacity could be used to offset the intermittent nature of renewable energy. This is an argument for the need to increase the electricity production in Norway (Karlstrøm, 2012). However, it will require tremendous investments in pump-storage power plants and large capacity interconnections (Midttun, 2012).

A5.3 Italy

Energy sector

Italian energy demand has fallen by a 3% down to 317 TWh in 2013. 41 TWh were produced by renewables with an increase of 21% compared to 2012. The highest share in the electricity mix comes from gas and renewables, where hydro is the main source followed by solar.

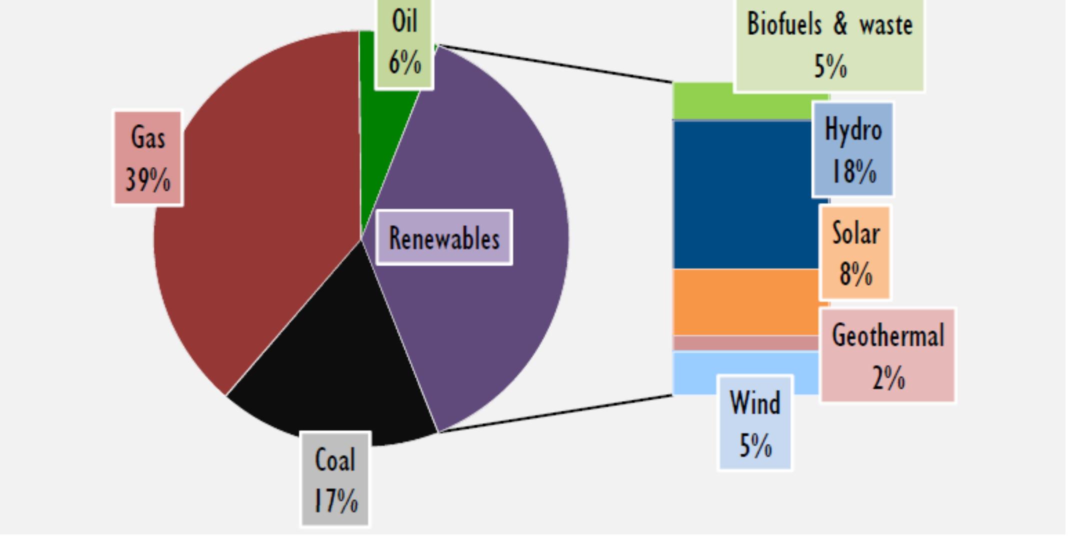


Figure 54: Gross electricity generation in Italy (Source: IEA 2014)

Policies and normative which regulates the renewable energy sector

In Italy, electricity generated from renewable energy sources is promoted through a number of feed-in and premium tariffs and a tendering system. Depending on the source and the size, RES-E plant operators may be obliged to opt for a certain system or may choose between the available ones. Electricity may be sold on the free market or through “ritiro dedicato” (purchase by Gestore dei Servizi Elettrici at a guaranteed price). Under certain conditions, electricity producers can make use of "scambio sul posto" (net-metering).

Grid issues: Priority to renewable energy

Italy has experienced some electricity liberalisation, although not to extend of Nordic countries. Nowadays there are an increasing number of electricity providers although consumer regulations partially limit effective retail market. The availability of smart metering (already 90% deployment since a few years, mainly to fight fraud) allows taking full advantages of the possibilities offered by Demand Side Management (DSM) and Demand

Response in its different forms, including flexible Time of Use (TOU) tariffs. Hourly TOU tariff was offered first to higher-voltage customers and has been gradually extended to lower-voltage costumers based on peak/off-peak times. All households and small businesses have a maximum power peak consumption allowance (typically 3 kW in a residential building) in their contract. All the meters installed from 2012 have the capacity of record bi-directional energy flow. An incomplete list of tariff plan available today is:

- Fixed contract (e.g., annual, monthly) based on prices for peak and off-peak hours; the price difference between peak and off-peak is about 10 €/MWh
- National Universal Price “Prezzo Unico Nazionale (PUN)” on hourly basis; the users knows approximately the hourly electricity cost for the day before.
  The prices for each hour of the past years are available at http://www.mercatoelettrico.org/It/download/DatiStorici.aspx
- National Universal Price “Prezzo Unico Nazionale (PUN)” on monthly basis based on day periods (F1, F2, F3 periods).
  http://www.mercatoelettrico.org/It/Statistiche/ME/PrezzoMedioFasce.aspx

The average PUN value (National Universal Price / “Prezzo Unico Nazionale) for 2013 was of 63 Euros/MWh (16.6% less than in 2012). It was registered a larger share of the ‘market of day before’ compared to other tariff schemes. In Italy the increase of electricity generated by wind and solar PV has had an impact on the price of electricity in the Italian energy stock exchange. In 2013 electricity was exchanged at null price for 300 hours and this figures has risen to 430 in the period January-May 2014 (data GME: Gestore Mercati Energetici). The decrease in price is noticeable during the daily peak hours thanks to the solar PV contribution. On the contrary, prices have risen during the evening peak where electricity produced by fossil fuel power plants is sold at a higher price (

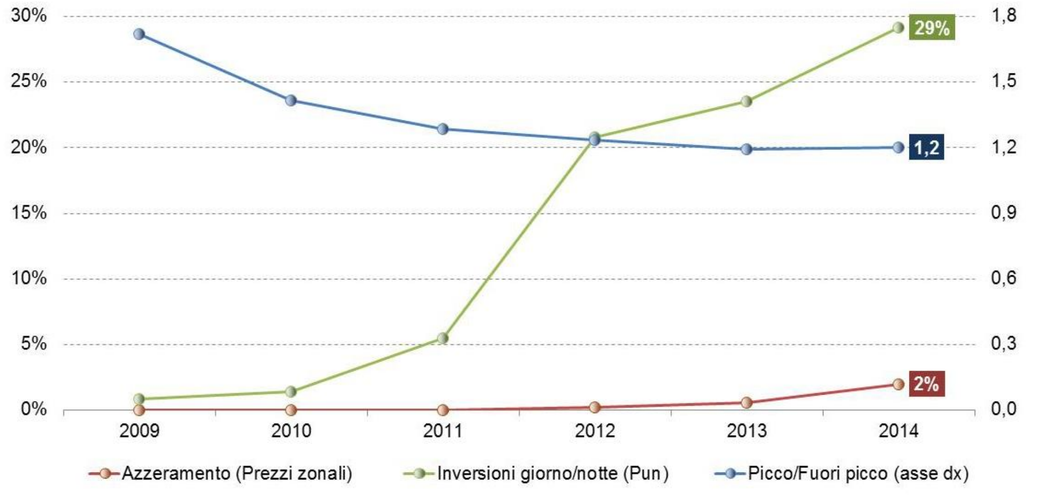


Figure55). Additionally, there are lower price variations between seasons. Interestingly, the decrease in electricity stock market price has not had any impact on the energy bill where the difference between the PUN and the fixed costs has increased. The variable price contracted accounts only for approximately 40% of the total for a retail. The remaining 60% depends on non-negotiable costs decided by the regulators.

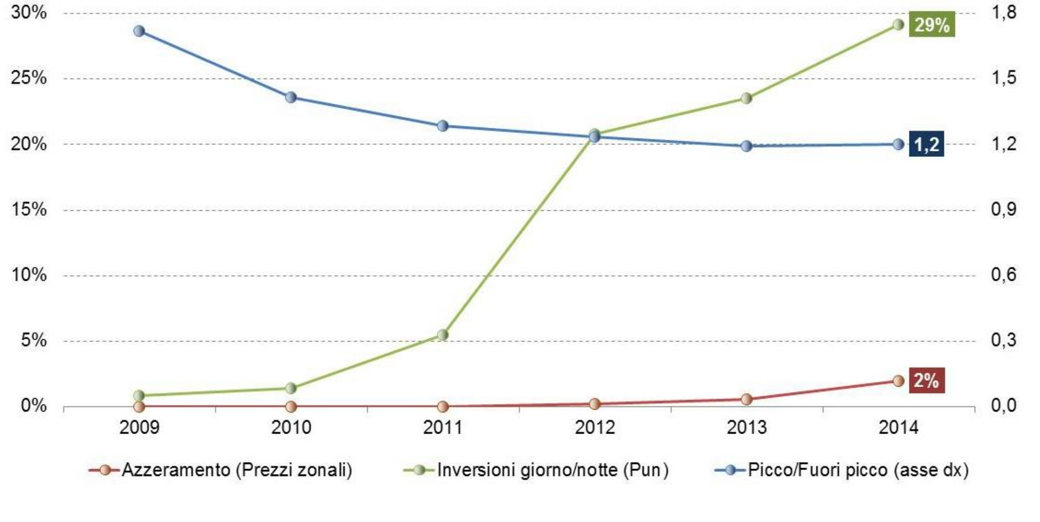


Figure 55: Electricity price trends in the Italian market. Red curve (electricity produced at null marginal costs), green curve (PUN price inversion day/night), blue curve (peak/off peak price difference).

The grid operator is obliged to grant priority transmission to electricity from renewable sources. In detail, priority shall be granted as follows:

If several plant operators offer their electricity at the same price, the transmission of electricity shall be given priority as long as grid security can be maintained.

Electricity generated from intermittent sources (wind, solar and geothermal energy, running waters, biogas) has the second highest priority, after electricity generated by units deemed essential for system security, in the hours in which they are declared indispensable. (www.res-legal.eu).

A5.4 Lithuania

Energy sector

Lithuania imports oil and natural gas from Russia and internally produces electricity from RES and in the recent past from nuclear energy. Currently up to 80% of Lithuanian primary energy mix is provided by import. This phasing out is planned to be offset mainly through an increased share of natural gas, but also through renewable (RES).

In the electricity mix the share of RES amounted to 29% in 2010. Current RES-E production is dominated by hydropower, which generated 540 GWh in 2010. The growth in RES-E production from wind is remarkable: from 2 GWh in 2005, its contribution rose to 224 GWh in 2010.

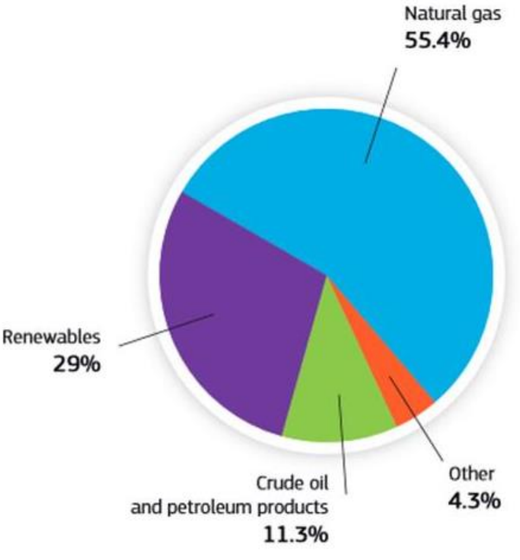


Figure 56: Gross electricity generation in Lithuania (Source: Energy markets in the European Union, 2012)

Policies and normative which regulates the renewable energy sector

Lithuania has significant potential in terms of the development of RES. The National Strategy for the Development of RES (approved in 2010) set a target of 23% of RES in gross final energy consumption by 2020 (Energy Markets in the European Union, 2012). Furthermore, electricity from renewable sources is promoted mainly through a feed-in tariff. Thus, electricity produced from wind, solar and biomass power plants with installed capacities not exceeding 30 kW is purchased at a fixed price (feed-in tariff), which is determined by the national regulatory authority (NCC). Electricity produced from wind, solar and biomass power plants with installed capacities exceeding 30 kW is supported by feed-in premium tariffs and quotas that are estimated by auctions. (www.res-legal.eu).

Grid issues: Priority to renewable energy

The operators of renewable energy plants are entitled to priority connection to the grid. The grid operator shall ensure priority transmission and distribution of electricity from renewable energy sources. The grid operators are obliged to optimise, boost or expand their grids if this is required for RES plant connection (www.res-legal.eu).

A5.5 Austria

Energy sector

Austria has an energy mix with a greater incidence of biomass, waste use and hydropower, while fossil fuels are still the main energy sources. However, for the electricity mix the proportion of renewable is much greater (68%), mostly hydropower.

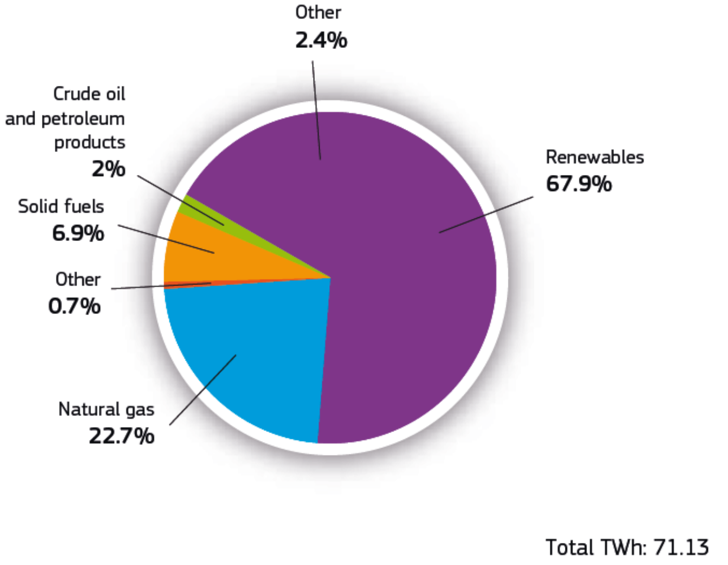


Figure 57: Gross electricity generation in Austria (Source: Energy markets in the European Union, 2012)

Policies and normative which regulates the renewable energy sector

The country intends to achieve that a 45% of final energy was achieved with renewables by 2020 and to add 3GW of wind and solar capacity plus 1GW of hydro and 0.2 GW of bioenergy.

Renewable electricity is mainly supported through a feed-in tariff regime and subsidies (for BIPV or medium size hydropower). On a national level, PV solar system are co-financed in terms of capital investment (200-400 Euros/kWp depending on system size and integration on building) and can also access feed-in-tariffs (10-12.5 Eurocents depending on system size and installation type) through the “Solarstromgesetz” and “Ökostromtarifförderung“ (http://www.pvaustria.at/meine-pv-anlage/forderungen/osterreich/,http://www.pvaustria.at/wp-content/uploads/2013/07/Oekostromtarif_VO-2014.pdf). Building integrated systems benefits from more generous subsidies. As for 2015, PV systems with Pn>200 kWp and systems not installed on infrastructure will be excluded from any type of subsidy. In addition, each Region has specific incentives for solar electricity that cannot be combined with national incentives. In Wien (http://www.pvaustria.at/meine-pv-anlage/forderungen/wien/), only plants producing more than 900 kWh/kWp can be subsidised. Wien incentives can integrate the national contribution for the capital investment. For example, for a plant with Pn=35 kWp, 5 kWp will receive national financial support while the remaining 30 kWp will be co-financed by the Land Wien (400 Euros/kWp up to 40% of the total costs).

Grid issues: Priority to renewable energy

High share of RES in the electricity mix makes necessary a well coordination with the electricity grid operators and flexibility in operation, including time-dependent prices, self-consumption incentives and smarter system for managing supply and demand. Compared to other countries the competitions among electricity providers is low, while the prices are not regulated and have rising; however, customer satisfaction ranks among the top in Europe. Network costs account for 44 %. Interestingly, the network charges have gone down by 28% in the past 11 years, while this has increased or is increasing in other European countries.

The transmission of electricity from renewable energy sources has to be given priority over the transmission of electricity from other, non-renewable energy sources when capacity is not sufficient to meet all demands for use of the grid. Apart from that, the grid operator may deny grid use to electricity from traditional energy sources to prevent electricity from renewable sources from being driven out of the market even though the price for renewable energy is in line with current market prices. In doing so, he is entitled to sell this electricity to third parties (source: http://www.res-legal.eu).

A5.6 Belgium

Energy sector

The energy sector in Belgium is dominated by a high share of nuclear power and natural gas. In 2011, net electricity generation mix originated from 50.4% nuclear power plants, 34.3% came from classic thermal, or co-generation plants (mainly natural gas), 8.3% from solar, wind and other renewables (ENTSO-E, 2014).

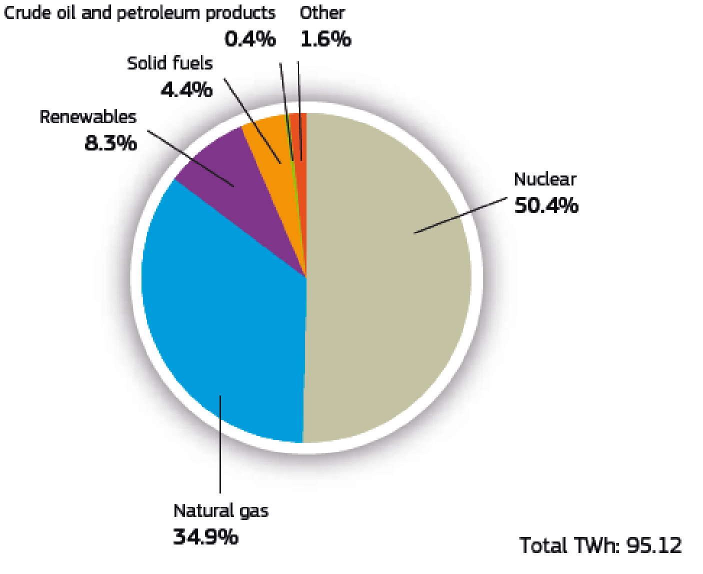


Figure 58: Gross electricity generation in Belgium (Source: Energy markets in the European Union, 2012)

Considering that the average operational hours of nuclear reactors remained on nearly the same level from 2009 to 2011, the operation time of CHP gas turbines and the more expensive peak units is in decline (Figure59). This may indicate the priority that renewables have in the merit order.

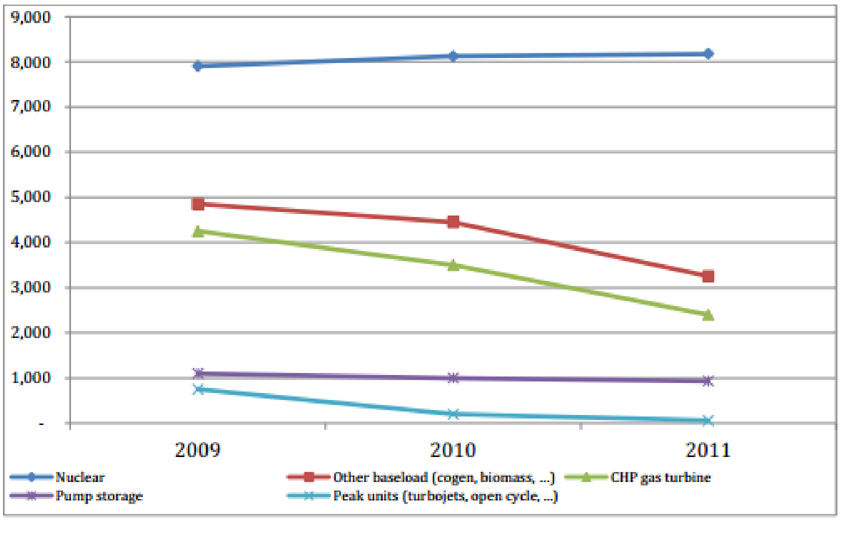


Figure 59: Evolution of the average number of hours of operation for different categories of electricity generation technologies (Source: Wathelet Report, 2012)

Policies and normative which regulates the renewable energy sector

The country's 2020 RES target indicator for the energy sector compiled in The National Renewable Energy Action Plan is 13%, below the EU-27 average of 20%. Moreover, National Reform Program sets a provisional target of 18% reduction in primary energy consumption compared to 2007 levels by 2020.

According to Cantillon (2014), up to recently the debate in Belgium has been divided between Belgium's opportunity to continue to rely on nuclear power and how to adapt Belgium's electricity system to a world characterized by more electricity from renewable sources. Discussions have now shifted from the electricity production to the electricity system, including transmission, interconnections, production, and demand.

Electricity from renewable sources is promoted mainly through a quota system based on the trade of certificates.

Grid issues: Priority to renewable energy

Due to its central location, Belgium is part of an electricity grid with many interconnections. While there are currently connections to France, Luxembourg and the Netherlands projects are also under way on direct interconnections with Great Britain and Germany.

On the other hand, the recent growth of renewables in the electricity production mix (14.8 percent of installed capacity in 2012) has changed the residual load profile that conventional electricity generation plants have to serve. Figure59 shows the development of the residual load profile in Belgium between 2010 and 2012 (Cantillon 2014). As it can be seen, despite an overall impact, the maximum load which is required for a few hours during the year has not decreased in the same manner.

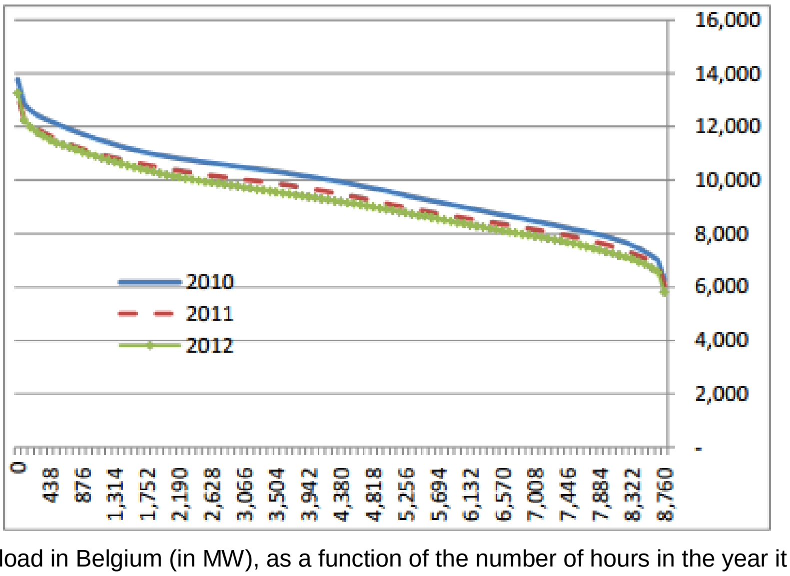


Figure 60: Residual load in Belgium (in MW), as a function of the number of hours in the year it is called (Source: Cantillon, 2014)

Electricity from renewable sources must be given priority access and transmission unless the security of supply is at risk.

A5.7 United Kingdom

Energy sector

Fossil fuels play a dominant role in the energy consumption mix. In 2010, natural gas had a 39.9% share of the energy consumption mix, which was the second-highest share among EU countries after the Netherlands. Renewable energy sources (RES) played a less important role in the energy mix (with a share of only 3.2%). Power generation (in total 381.1TWh in 2010) in the UK was also dominated by gas-fired power plants (with a share of 46.2%) and to a lesser extent by solid fuels (28.3%). RES represented 7.6% of total power production in 2010. (Energy markets in the European Union, 2012).

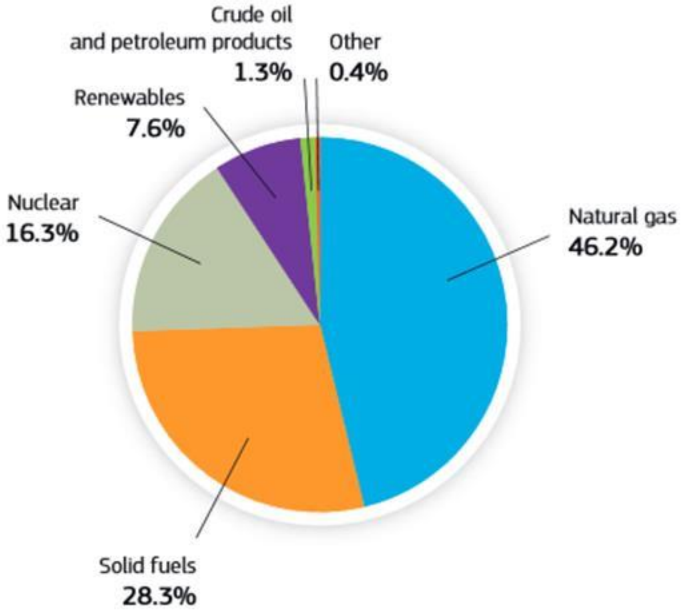


Figure 271: Gross electricity generation in United Kingdom (Source: Energy markets in the European Union, 2012)

Policies and normative which regulates the renewable energy sector

The country's 2020 RES target for the whole energy sector is 15%, which is lower than the EU-27 average (20%).

In the United Kingdom, the generation of electricity from renewable sources is regulated through a combination of a feed-in tariff system and a quota system in terms of a quota obligation and a certificate system. Under the feed-in tariff, accredited producers whose plants have a capacity of less than 5 MW can sell their electricity at fixed tariff rates established by the Gas and Electricity Market Authority (Ofgem). Under the quota system, electricity suppliers of more than 5 MW of capacity are obliged under the Renewables Obligation Orders to supply a certain proportion of electricity from renewable sources

("quota") to their customers. A supplier's quota is deemed satisfied if he presents a certain number of green certificates.
Furthermore, in the United Kingdom commercial and industrial users of traditional energy sources are subject to a Climate Change Levy (CCL), a tax on the consumption of fossil energy, and Carbon Price Floor (CPF), a tax on fossil fuels used for electricity generation. Electricity from renewable sources is exempt from both of these taxes (www.res-legal.eu).

Grid issues

In the United Kingdom access of renewable energy plants to the grid is subject to the general provisions of energy law. Renewable energy sources are not given priority (www.res-legal.eu).

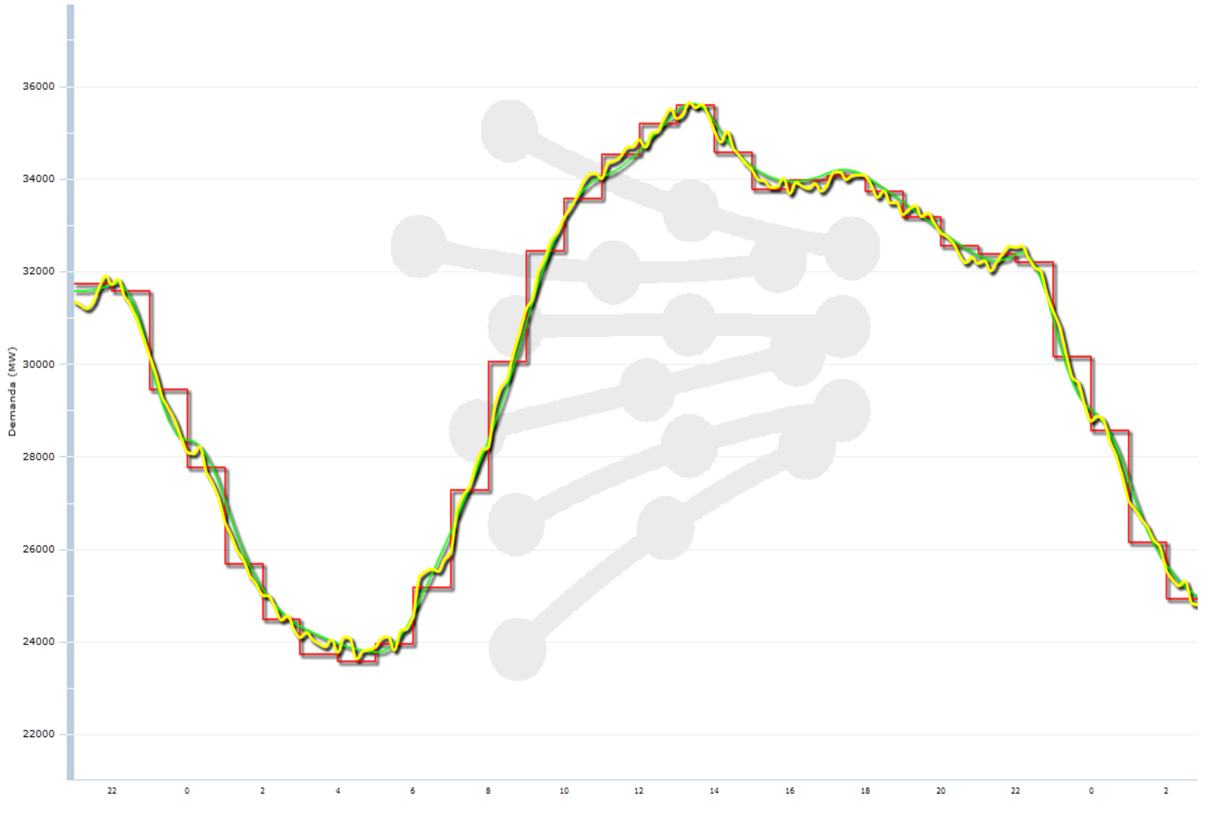
Annex 6: Electricity profile of countries in which reference shopping centres are located

Electricity profiles for the countries where reference shopping malls are located (Spain, Norway, Italy, Belgium, Lithuania and Austria) are characterized here. The idea is to understand possible stress situation for the grid (e.g., significant excess production or excess demand compared to production). With this information we could identify how the shopping mall modification could impact the interaction and which services the buildings could provide to the grids. There is also an exhaustive analysis develop in the frame of this deliverable of the energy sector, policies and tariffs for the countries in which reference shopping centres are located in Annex 5.

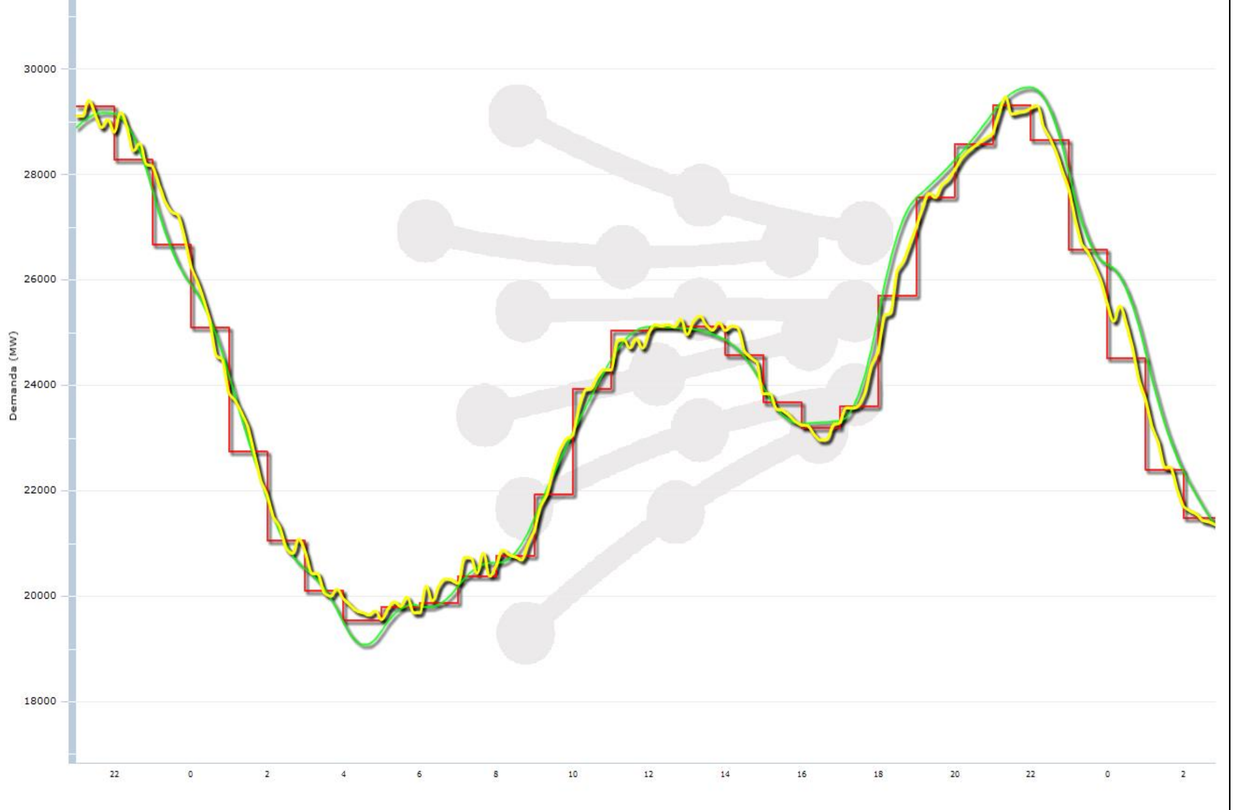
In the following Table4 are shown the electrical profiles of Spain, Norway, Italy, Belgium, Lithuania and Austria for a typical day in summer and winter; these profiles have been taken from the energy managers from each of these countries, respectively REE (Red Eléctrica de España), Statnett, Terna, Elia system operator, Litgrid and Austrian Power Grid.

Table 24: Electrical profiles for countries in which reference shopping malls are located

Spain – REE (Red Eléctrica Española) (Source: www.ree.es)



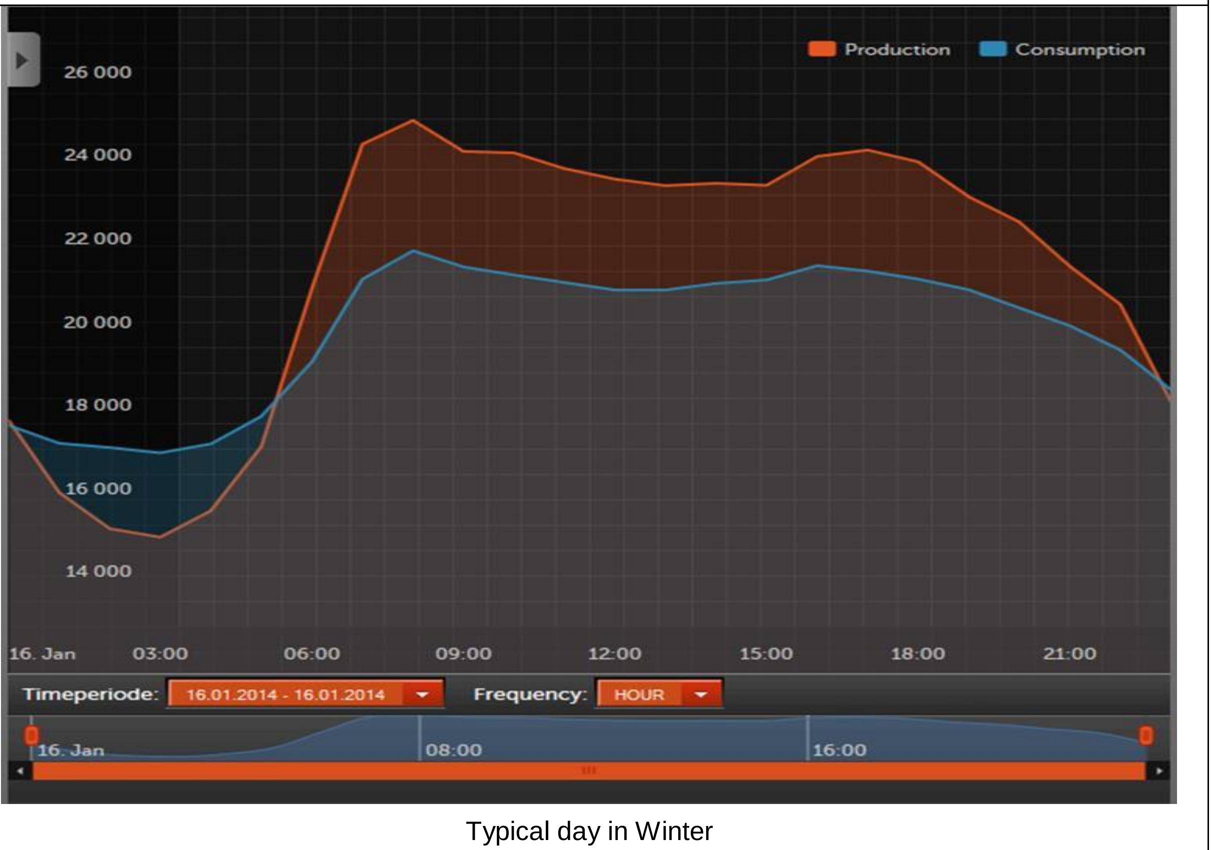
Typical day in summer



Typical day in winter

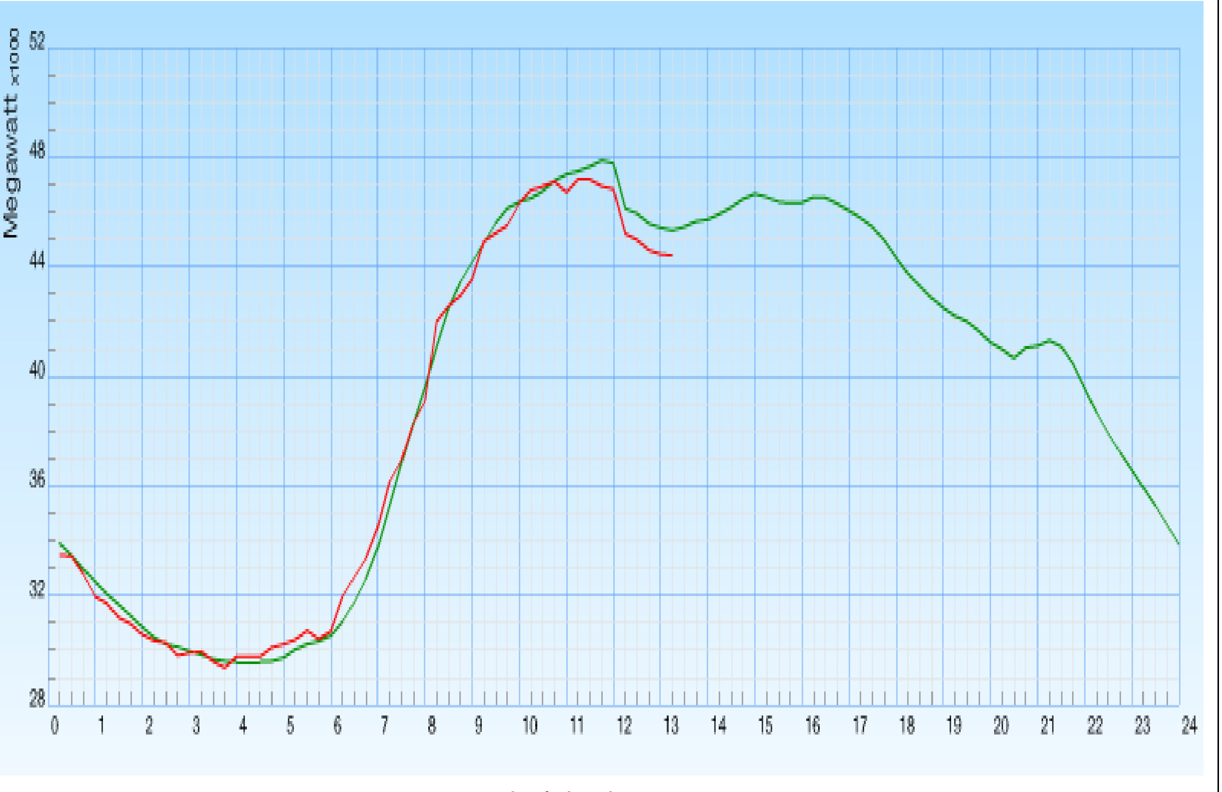
Norway – Statnett (Source: www.statnett.no)

Typical day in summer

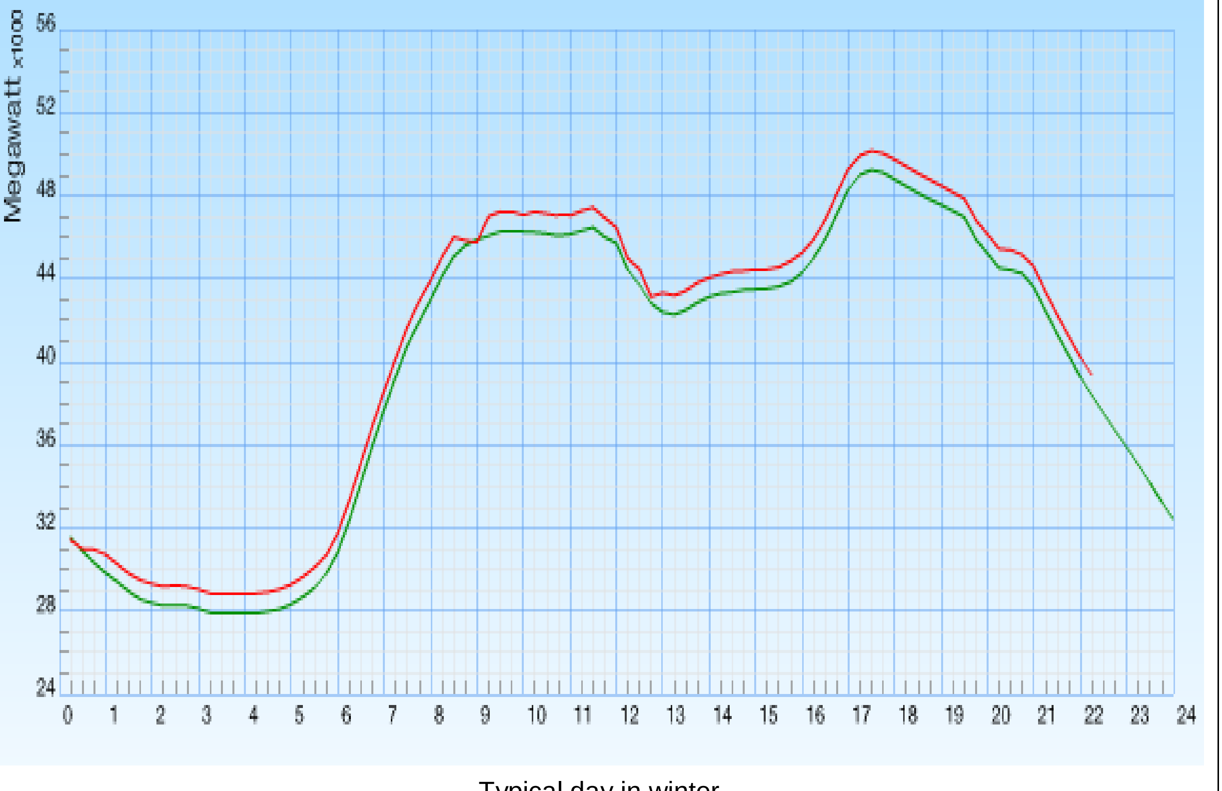


Typical day in Winter

Italy – Terna (Source: www.terna.it)

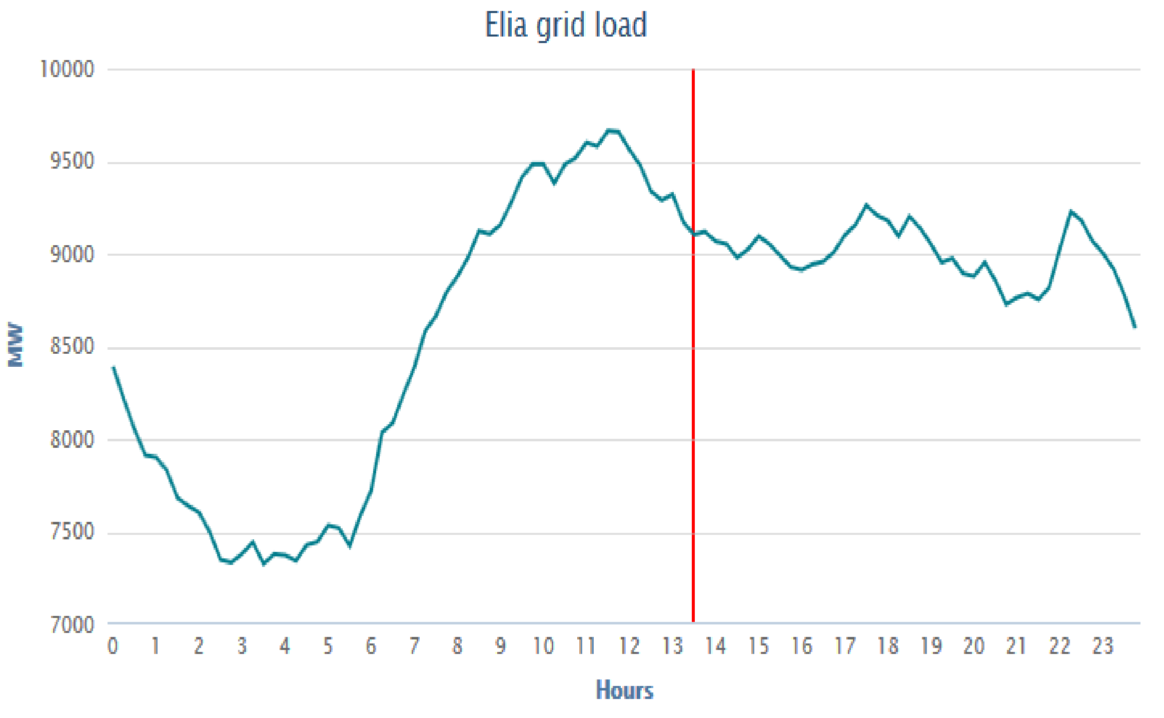


Typical day in summer

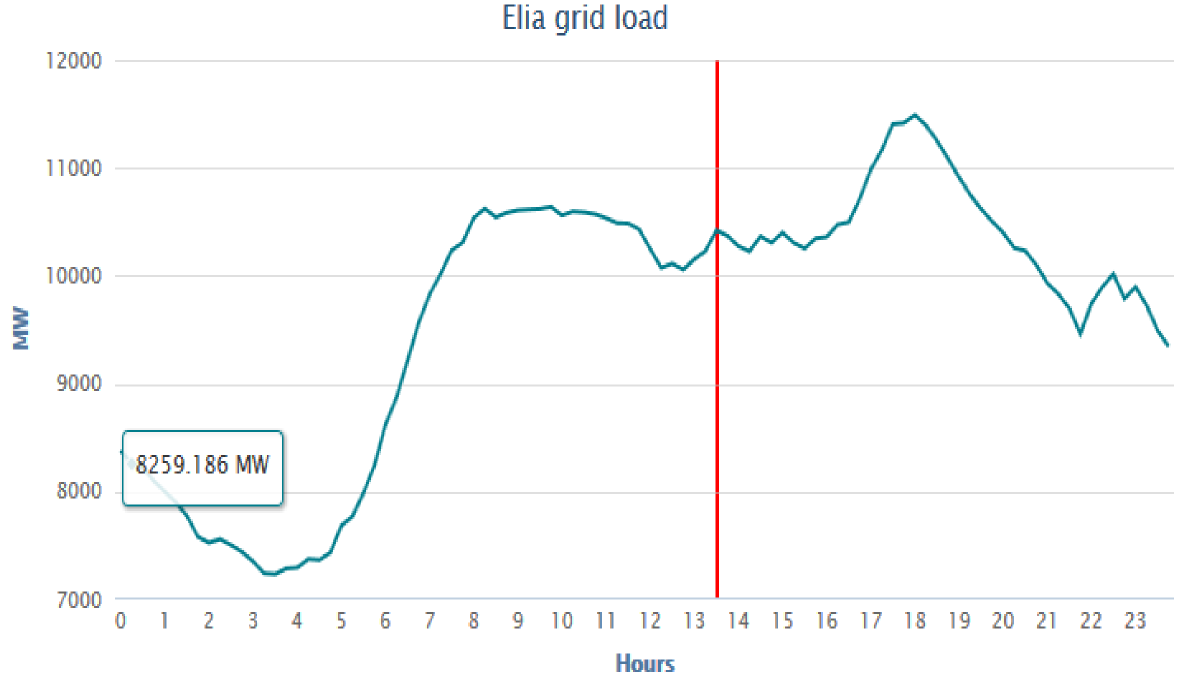


Typical day in winter

Belgium – Elia system operator (Source: www.elia.be)

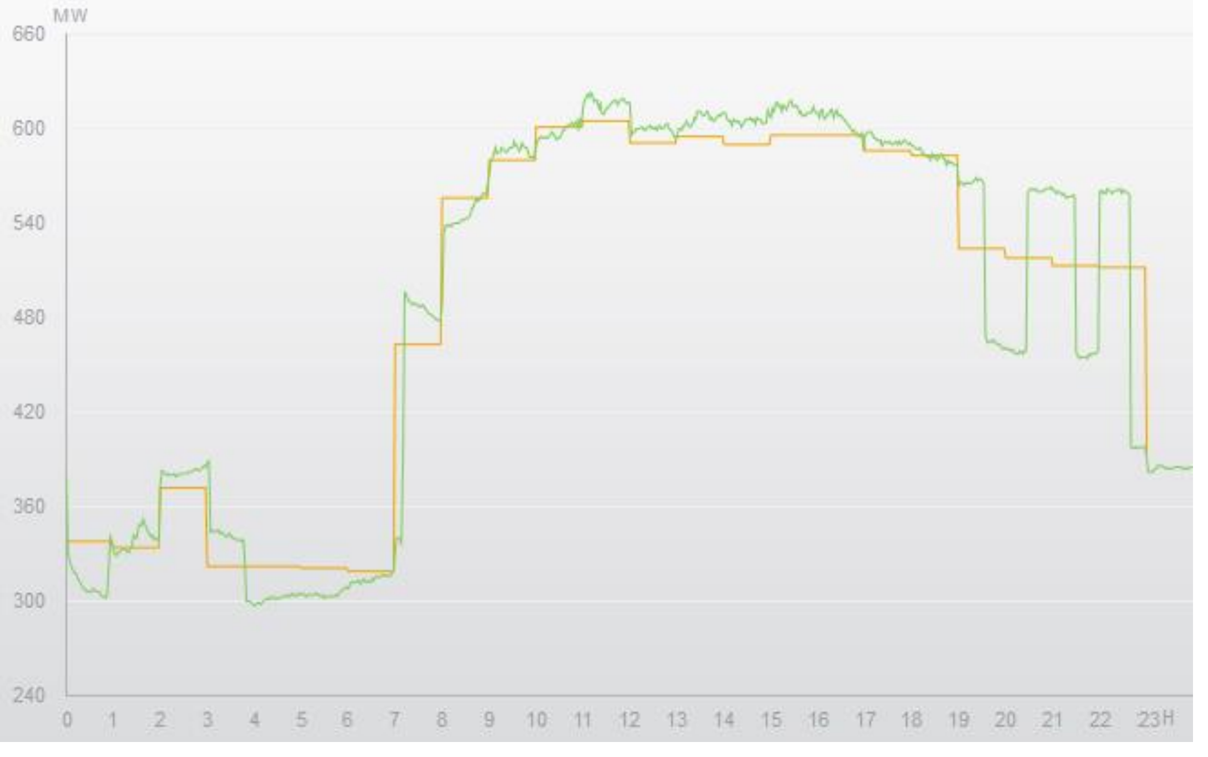


Typical day in summer



Typical day in Winter

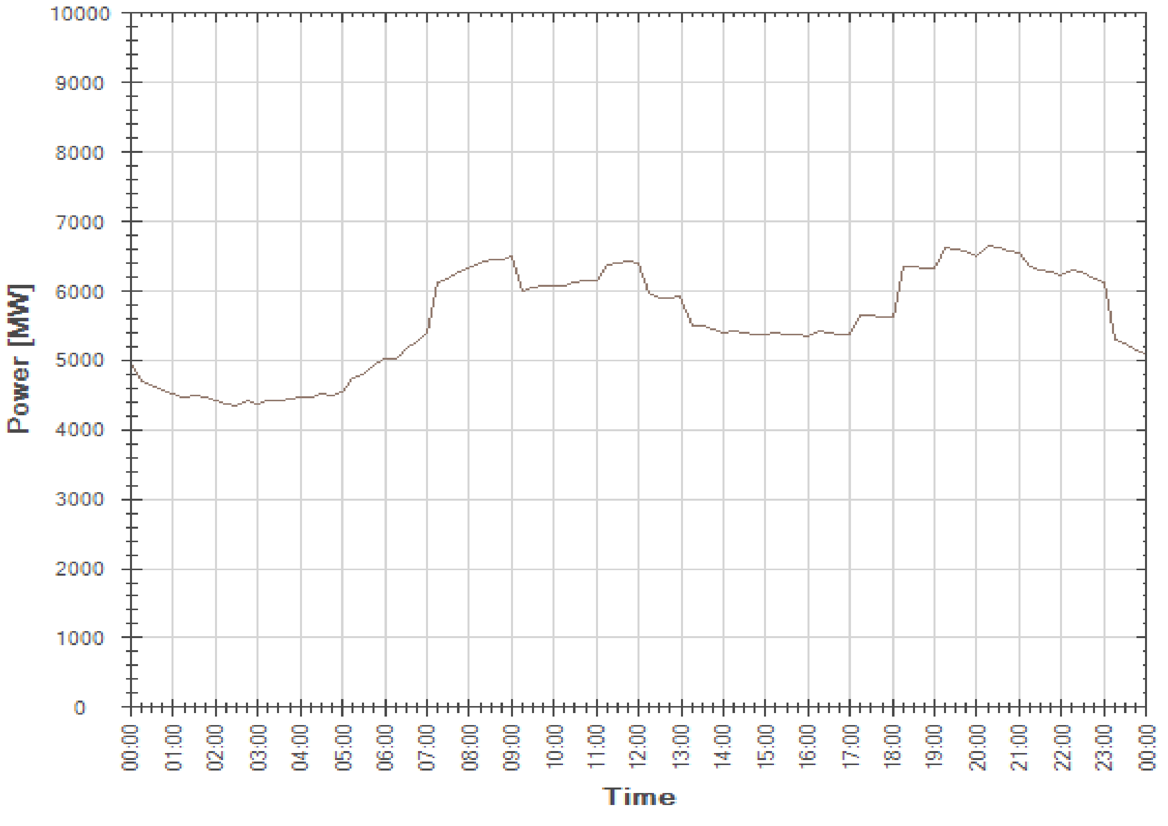
Lithuania – Litgrid (Source: litgrid.eu)



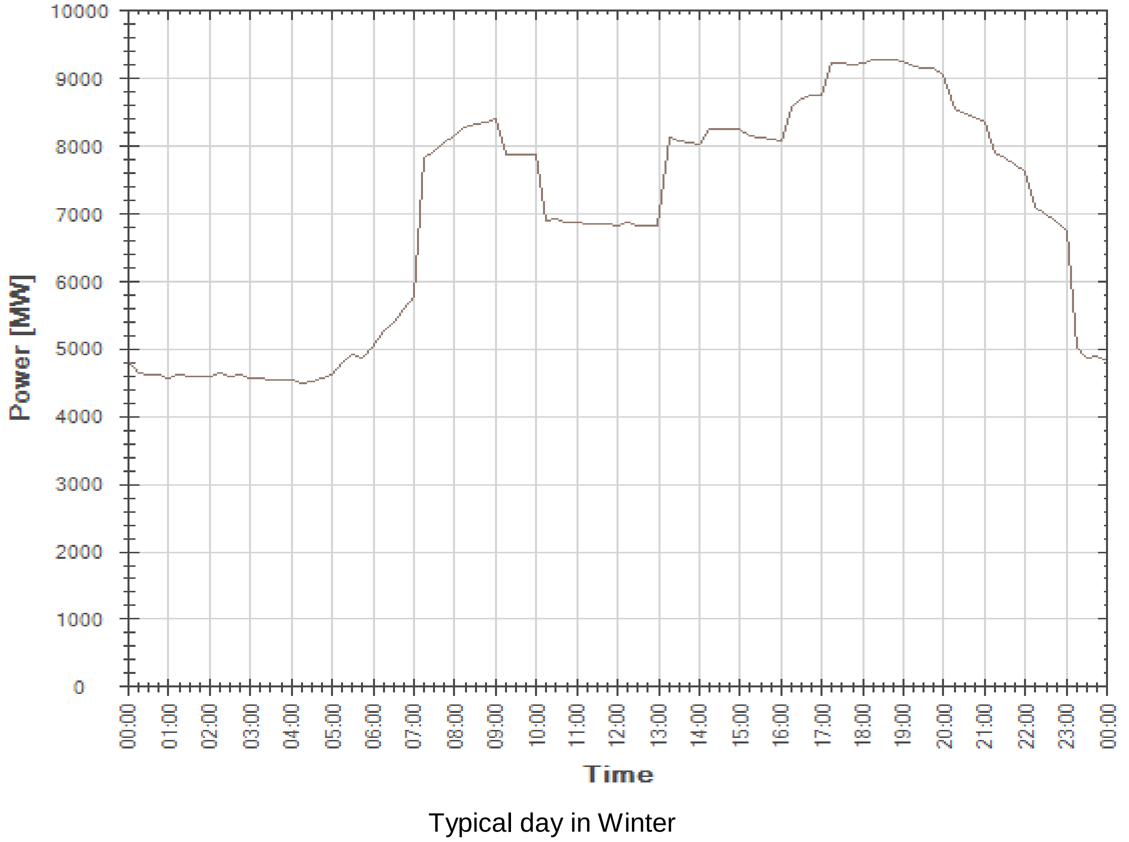
Typical day in summer

Typical day in Winter

Austria – Austrian Power Grid (Source: www.apg.at)



Typical day in summer



Typical day in Winter

A typical week day, starts with low demand around midnight, then starts climbing in the early morning hours, achieving their peaks in the hours in-between depending on the season and country before falling off again toward midnight. As can be seen in Table peaks in summer in Spain are achieved at around 2 pm while in winter are achieved in two periods, the first one between 12 – 14 pm and the second one between 8 – 10 pm. In Norway peaks are achieved around 10 am and 16 pm in summer and around 8 am and 6 pm in winter. In Italy peaks in summer are achieved at noon m while peaks in winter are achieved at 10 - 11 am and 5 – 6 pm. In Belgium the peak in summer is achieved at 11 while in winter is achieved at around 6 pm. Lithuania in summer peaks cover a wide range of hours from around 10 am to 4 pm and in winter between 6 – 7 pm. In Austria peaks in summer are distributed in two periods between 8 and 11 am and then between 7 and 10 pm, in winter peaks are again distributed in two periods between 8 – 9 am and between 5 – 8 pm.

From these electrical profiles, is possible to conclude, that they have a similar behaviour both in summer and in winter regardless the country with a little variations regarding to where electrical demand peaks occur, and therefore the final considerations regarding the possible improvements in the interaction with the electrical grid could be considered practically the same for all. This behaviour could be extrapolated for the rest of countries in which shopping malls could be located.

With the typical electrical profiles defined and generated for shopping malls in different context shown in Table 1, and considering the typical day electrical profiles of the countries described before, is possible to conclude, that the shopping centres, in addition to influence in the overall electrical profile in terms of consumption due to their high electrical loads (refrigeration, lighting, ventilation, etc.), are going to influence also in the peaks of the overall electrical profile of the countries where they are located due to their similar electricity profile, where the peaks identified before normally coincide with the maximum electrical demand of the malls, having therefore a good opportunity to act on them reducing these peaks and therefore improving the interaction with the grid.

Annex 7: Reference buildings: Energy profile, Climatology and Urban Context

Reference shopping centres have been selected with the aim to cover several important criteria, as described in Deliverable 2.1. In this Annex, a characterization of the energy profile, climatology and urban context of each of the democase and reference building is presented. This information will be relevant for the identification of potentials and solutions to be implemented in buildings in order to reduce the energy demand from the grid (see chapter 4).

A7.1 MERCADO DEL VAL (SPANISH DEMOCASE)


Characterization of shopping mall	
Location	Valladolid (Spain)
Environment context	Urban
Surface	2,168 m^2 (Supermarket area: 844,5 m^2)
Schedule of opening	From 7 am until 5 pm
Schedule of appliances	From 6 am until 4 pm
Characterization of energy consumption	
Total electrical consumption (kWh/m^2 year)	226.7
Lighting consumption (kWh/m^2 year)	22.1
HVAC consumption (kWh/m^2 year)	62.8
Refrigeration consumption (kWh/m^2 year)	69.7
Building capacities for RES & energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	Not allowed by heritage normative
Building surface already utilized.	No
Climatologic data	Irradiation: 1,700 kWh/m^2 Peak sun hours: 1,275 kWh/kWp Wind speed: 5.5 – 6 m/s
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters	No

A7.2 CITY SYD (NORWEGIAN DEMOCASE)

Characterization of shopping mall	
Location	Trondheim (Norway)
Environment context	Suburban
Surface	Net floor area approx. 20,000 m^2 (Storebrand part). Primary floor space: 17,382m^2 (tenants + common areas) + Storage area (ventilated, but mainly unheated): 2477 m^2
Schedule of opening	09-21 (09-20)
Schedule of appliances	06-21 (06-20) on weekdays
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	Total energy consumption: 6,055,683 kWh (year 2011) Electricity shared: 1,711,355 kWh (year 2011) Electricity tenants: 3,284,040 kWh (year 2011) District heating shared: 1,060,288 kWh (year 2011) Total energy consumption: 310 (kWh/m^{2}year)
Lighting consumption in summer (kWh/m^2 year)	130 kWh/m^2
Lighting consumption in winter (kWh/m^2 year)	130 kWh/m^2
HVAC consumption in summer (kWh/m^2 year)	25 kWh/m^2
HVAC consumption in winter (kWh/m^2 year)	25 kWh/m^2 for fans and pumps
HVAC services	The heating needs are covered by 2 heat pumps, supplemented by district heating when needed and connected to the ventilation system (air to water dual heat pump). Cooling is provided via the ventilation system and in addition there are fan coils in most of the stores.
Refrigeration consumption in summer (kWh/m^2 year)	22 kWh/m^2
Refrigeration consumption in winter (kWh/m^2 year)	13 kWh/m^2
Refrigeration services	35 kWh/m^2 over the year
Building capacities for RES and energy management	

Available flat surface free of shadow for being covering by renewable facilities in a building	< 10,000 m^2
Building surface already utilized	0 m^2 utilized for PV, approx. 1,000 m^2 for HVAC, 1,000 m^2 for roof lights
Climatologic data	Irradiation: 1,100 kWh/m^2 Peak sun hours: 825 kWh/kWp Wind speed: 2 – 4 m/s
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters	Able to control and monitor operation/energy use of heating, cooling and ventilation plants, but not lighting systems.

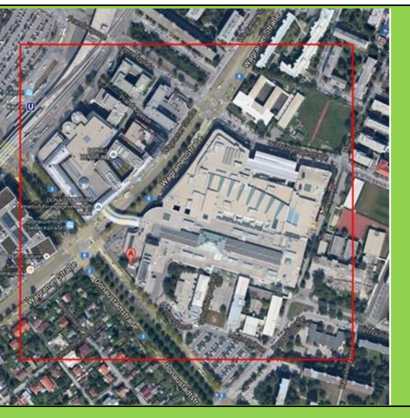
A7.3 Ex OFFICINE GUGLIELMETTI (ITALIAN DEMOCASE)

Characterization of shopping mall	
Location	Genoa (Italy)
Environment context	Urban: On the right there is the current shopping mall that will be expanded to also include the industrial building on the left.
Surface	Gross floor area: 25,048 m^2 (Supermarket: 6,352 m^2)
Schedule of opening	8:30 -19:30 everyday
Schedule of appliances	Some (e.g.: setbacks, security) are always on. Others only from a little before opening to a little after closing. In general 7:00 am to 21:00 pm
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	139.1
Lighting consumption in summer (kWh/m^2 year) Lighting consumption in winter (kWh/m^2 year)	· Total: 35.5 · Summer: 18.4 · Winter: 17
HVAC consumption in summer (kWh/m^2 year) HVAC consumption in winter (kWh/m^2 year)	· Total: 33.7 · Summer: 24.8 · Winter: 14 * Electrical and thermal together.
Refrigeration consumption in summer (kWh/m^2 year)	40.3
Refrigeration consumption in winter (kWh/m^2 year)	29.5
Refrigeration services	69.9
Building capacities for RES and energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	The entire roof will be used as parking lot; park or PV installation on top of the parking sheds. · Parking lot: 22,445 m^2 · PV on top of parking lot sheds. · 2,891 m^2 (on the new roof). · 1,296 m^2 (on the existing roof). · Park: 4,026 m^2 · Others: 14,232 m^2
Climatologic data (peak sun hours, average velocity of wind at 30 m, etc.	· Irradiation: 1,700 kWh/m^2 GTI 35º · Irradiation: 1,450 kWh/m^2 GHI · Wind speed: 3 – 4 m/s (25 m) · Wind speed: 4 – 5 m/s (50 m) · HDD: 1831 · CDD: 44
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.	Able to manage and control the energy consumptions based on schedule, needs, conditions such as indoor T, RH, Lux, occupancy and outdoor conditions (meteo station). Possibly also based on forecast.
Capacity of storage (kWh)	40 kWh for lights and 20 kWh for data.

A7.4 KATANE (REFERENCE BUILDING)

Characterization of shopping mall	
Location	Catania (Italy)
Environment context	Suburban
Surface	14,911 m^2 (GLA) (Supermarket: 8,285 m^2)
Schedule of opening	9 am – 21 pm
Schedule of appliances	7 am – 22 pm
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	2,537,000 kWh (170.14 kWh/m^2 GLA)
Lighting consumption in summer (kWh/m^2 year)	34.03
Lighting consumption in winter (kWh/m^2 year)	
HVAC consumption in summer (kWh/m^2 year)	57.85
HVAC consumption in winter (kWh/m^2 year)	
Refrigeration consumption in summer (kWh/m^2 year)	34.3
Refrigeration consumption in winter (kWh/m^2 year)	
Building capacities for RES and energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	2,000 m^2
Climatologic data (peak sun hours, average velocity of wind at 30 m, etc.	· Irradiation: 2,100 kWh/m^2 (GTI 33º) · Irradiation: 1,840 kWh/m^2 (GHI) · Wind speed: 4 – 5 m/s (25 m) · Wind speed: 5 – 6 m/s (50 m) · HDD: 1578 · CDD: 141
Power provided by renewable sources	23.6 % (2012)
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.	· Able to manage and control the energy consumptions. · Capacitors of batteries.

A7.5 DONAUZENTRUM (REFERENCE BUILDING)



Characterization of shopping mall	
Location	Vienna (Austria)
Environment context	Urban (Vienna city)
Surface	133,000 m^2 (floor area). 2 floors
Schedule of opening	Monday-Friday: 9 am - 20 pm Saturday: 9 am - 6pm
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	· 243.54 kWh/m² year · Common area 15.4 GWh and 35.7 GWh for the whole shopping centre in 2013 · The building had a specific energy consumption of 268 kWh/m²a (average 2011 - 2013).
Building capacities for RES and energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	Roof: Total roof area: 58,863 m^2 Façade: Total external wall area 19,560 m^2 No Free area around the building
Building surface already utilized	Photovoltaic: app. 1300 m^2 (Calculation according to: 174 kWp, 170,000 kWh) Solar: 310 m^2 Solar Panels
Climatologic data (peak sun hours, average velocity of wind at 30 m, etc.	· Irradiation: 1,400 kWh/m^2 (GTI 36º) · Irradiation: 1,220 kWh/m^2 (GHI) · Wind speed: 2 – 3 m/s (30 m) · HDD: 3555 · CDD: 41
Power provided by renewable sources	RES installed consist of solar thermal and photovoltaic system. The yearly consumption from the photovoltaic system, located on the roof, is 170 MWh. However, they cover a very small portion of the centre's energy demand. The heating energy demand is mainly covered by Vienna's district heating system, which is available in most parts of the city. The centre offers parking decks with three free electric car charging points. A solar thermal system and heat recovery of the ventilation supplemented by Vienna's district heating cover the heating energy demand. 170,000 kWh electricity is produced on-site with a photovoltaic system installed on the cinema centre's roof, which covers less than 1% of the total annual energy demand. Off-site electricity is supplied by 100% hydropower. Ground- and rainwater serve as source for toilets and waste water is recycled for the car wash one of the parking decks. Moreover, there is a continuous modification and replace-ment of the technical installations by state of the art solutions and an ongoing installation of LED illumination.
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.	Building energy consumption is entirely monitored.

A7.6 STUDLENDAS (REFERENCE BUILDING)


<table>
<tr><td colspan="2">Characterization of shopping mall</td></tr>
<tr><td>Location</td><td>Klaipeda (Lithuania)</td></tr>
<tr><td>Environment context</td><td>Urban</td></tr>
<tr><td>Surface</td><td>12,647 m^2 (Supermarket area: 1,500 m^2)</td></tr>
<tr><td>Schedule of opening</td><td>
<table>
<tr><th>Type of service</th><th>Week day</th><th>Opening hours</th></tr>
<tr><td>Cafes</td><td>Monday - Sunday</td><td>10am – 11pm</td></tr>
<tr><td>food store (IKI)</td><td>Monday - Sunday</td><td>8am – 11pm</td></tr>
<tr><td rowspan="2">Other</td><td>Monday-Friday</td><td>10am - 8 pm</td></tr>
<tr><td>Saturday</td><td>10 am – 6pm</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Characterization of energy consumption</td></tr>
<tr><td>Total energy consumption (kWh/m^2 year)</td><td>260.6</td></tr>
<tr><td>Electricity consumption (kWh/m^2 year)</td><td>211.9</td></tr>
<tr><td colspan="2">Building capacities for RES and energy management</td></tr>
<tr><td>Available flat surface free of shadow for being covering by renewable facilities in a building</td><td>Roof: app. 2,000 – 3,000 m^2
Facade: no info
Free area around the building: no info</td></tr>
<tr><td>Building surface already utilized.</td><td>There are no installed solar panels on the flat surface.</td></tr>
<tr><td>Climatologic data
(peak sun hours, average velocity of wind at 30 m, etc.</td><td>· Irradiation: 1,300 kWh/m^2
· Peak sun hours: 975 kWh/kWp
· Wind speed: 5 – 6 m/s</td></tr>
<tr><td>Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.</td><td>They can monitor building energy consumption. Consumption of some equipment can be controlled.
There are light sensors installed in all SC areas. Electricity consumption can continuously be monitored. For the lighting, the LED is installed in the parking areas. The waste heat coming from the food refrigeration is used for the heating purpose.</td></tr>
</table>

A7.7 PAMARYS (REFERENCE BUILDING)

<table>
<tr><td colspan="2">Characterization of shopping mall</td></tr>
<tr><td>Location</td><td>Silute (Lithuania)</td></tr>
<tr><td>Environment context</td><td>Suburban</td></tr>
<tr><td>Surface</td><td>6,020 m^2 (Supermarket area: 1,625 m^2)</td></tr>
<tr><td>Schedule of opening</td><td>
<table>
<tr><th>Type of service</th><th>Week day</th><th>Opening hours</th></tr>
<tr><td>Cafes (bowling/billiards club)</td><td>Monday - Sunday</td><td>10am – 11pm</td></tr>
<tr><td>food store (IKI)</td><td>Monday - Sunday</td><td>8am – 11pm</td></tr>
<tr><td rowspan="2">Other</td><td>Monday-Friday</td><td>10am - 8 pm</td></tr>
<tr><td>Saturday</td><td>10 am – 6pm</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Characterization of energy consumption</td></tr>
<tr><td>Total energy consumption (kWh/m^2 year)</td><td>Yearly energy demand for space heating and hot water: 293.16 MWh
Yearly total electricity consumption: 1568.6 MWh</td></tr>
<tr><td colspan="2">Building capacities for RES and energy management</td></tr>
<tr><td>Available flat surface free of shadow for being covering by renewable facilities in a building</td><td>· Total roof area: 6,097 m^2
· Façade south: 818 m^2
· Façade north: 818 m^2
· Façade east: 327 m^2
· Façade west: 327 m^2</td></tr>
<tr><td>Climatologic data
(peak sun hours, average velocity of wind at 30 m, etc.</td><td>· Irradiation: 1,300 kWh/m^2
· Peak sun hours: 975 kWh/kWp
· Wind speed: 5 – 6 m/s</td></tr>
<tr><td>Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.</td><td>They can monitor building energy consumption. Consumption of some equipment can be controlled.</td></tr>
</table>

A7.8 WAASLAND (REFERENCE BUILDING)

Characterization of shopping mall	
Location	Sint-Niklaas (Belgium)
Environment context	Suburban
Surface	Gross building area: 69,000 m^2 45,000 m^2 (only shops within the mall)
Schedule of opening	10:00-20:00 (Friday until 21:00), Sunday closed
Schedule of appliances	Lighting: service 6:00-23:00 Decorative lighting: 10:00-20:30 HVAC: closed water circuit 8:00-21:30, cooling groups: 10:00-19:00 Instant electric DHW but not so much (just cold water in the mall)
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	4 GWh electrical 1GWh gas
Lighting consumption in summer (kWh/m^2 year)	40% for lighting
Lighting consumption in winter (kWh/m^2 year)	
HVAC consumption in summer (kWh/m^2 year)	55% for HVAC
HVAC consumption in winter (kWh/m^2 year)	
Building capacities for RES and energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	There is any flat surface available
Building surface already utilized.	No surface already utilized for solar panels
Climatologic data (peak sun hours, average velocity of wind at 30 m, etc.	· Irradiation: 1,200 kWh/m^2 · Peak sun hours: 900 kWh/kWp
Power provided by renewable sources	100 %
Total capacity of grid for renewable sources	Probably
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.	Able to manage and control the energy consumptions for lighting and heating There are condensation batteries.
Capacity of storage (kWh)	No storage
Capacity of energy storage/energy consumption [kWh/kWh] at several temporal scales (daily, weekly and seasonal)	No apply

A7.9 GRAND BAZAR (REFERENCE BUILDING)

Characterization of shopping mall	
Location	Antwerp (Belgium)
Environment context	Urban
Surface	18,708 m^2
Schedule of opening	From 10 till 18:30 (opening hours from the different shops)
Schedule of appliances	From 6:30 till 21 (opening hours from the shopping)
Characterization of energy consumption	
Total energy consumption (kWh/m^2 year)	34.27
Lighting consumption in summer (kWh/m^2 year)	5.3
Lighting consumption in winter (kWh/m^2 year)	
HVAC consumption in summer (kWh/m^2 year)	9.62
HVAC consumption in winter (kWh/m^2 year)	
Building capacities for RES and energy management	
Available flat surface free of shadow for being covering by renewable facilities in a building	No possibilities
Climatologic data (peak sun hours, average velocity of wind at 30 m, etc.	· Irradiation: 1,200 kWh/m^2 · Peak sun hours: 900 kWh/kWp · Wind speed: 3 – 4 m/s
Power provided by renewable sources	0
Total capacity of grid for renewable sources	0
Existence of devices for control and regulation: managers of consumptions, capacitors of batteries, harmonic filters.	Able to manage and control the energy consumptions. Harmonic filters.
Capacity of storage (kWh)	0

A7.10 BRENT CROSS (REFERENCE BUILDING)


Characterization of shopping mall	
Location	London (UK)
Environment context	Suburban
Surface	84,200 m^2 GLA