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Renewable energy supply potential of shopping centres

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Abstract

Shopping malls, often centrally located in urban districts, have high energy savings and carbon emissions reduction potential due to their large electrical and thermal loads. At the same time, shopping malls cover important surface areas and are reference points in urban districts for citizens, with possibilities to install renewable energy supply systems as PV and wind power to provide services to both the grids and the community.

This paper studies for 3 different locations in Europe the interaction between shopping centres and the installation of PV and wind power systems with the objective to identify key aspects which allow improving the current electrical grid and identifying the capacities that these types of buildings could give as suppliers/providers of services to the local energy grid. The results will help to optimize renewable energy production integrated in shopping centres by being able to optimize self-consumption, reducing the energy need to generate and deliver additional electricity and allow the participation of the end-users in the management of energy with grid providers.

Keywords: Renewable Energy, PV, Wind Power, Shopping Centres, Electrical Grid.

1. Introduction

In sustainable development of city structures, increasing power consumption requires maintaining power grid safety and reliability with less mismatching between electricity generation and demand [3]. Power grid fluctuations in both power demand and generation induce an effort to supplementary setting on conventional production units and efforts to maintain grid stability. Hence, nowadays with the trend towards more complex, flexible and dynamic systems as well the higher penetration of distributed and decentralized renewable energy systems, the issue of peak reduction of demand/generation mismatch has gained importance [4].

2. Problem identification and basic principle

Shopping malls, often centrally located in urban districts, have high energy savings and carbon emissions reduction potential due to their large electrical and thermal loads. At the same time, shopping malls cover important surface areas and are reference points in urban districts for citizens, with possibilities to install renewable energy supply systems as PV and wind power to provide services to both the grids and the community [1].

This paper studies for 3 different locations in Europe the interaction between shopping centres and the installation of PV and wind power systems with the objective to identify key aspects which allow improving the current electrical grid and identifying the capacities that these types of buildings could give as suppliers/providers of services to the local energy grid. The results will help to optimize renewable energy production integrated in shopping centres by being able to optimize self-consumption, reducing the energy need to generate and deliver additional electricity and allow the participation of the end-users in the management of energy with grid providers.

3. Methodology

Methodology followed consists of four steps:

1 Definition of parameters which characterize the building, the building context and the interaction of building with grid. The characterization of the reference buildings and the building context is based mainly on the parameters defined in [4]. For the characterization of building-grid, Load Match Index and Grid Interaction Index were considered. For the Valladolid democase, an energy grid analyzer was also utilized for measuring the quality of supply electricity fed by the grid to the building. As, this building is located in an urban context, the city centre, with likely high degree of grid saturation, it was assumed that represents the worst conditions,

while the other reference buildings could have better conditions [4].

2 Characterization of shopping centres by the analysis of the data compiled .[4] shows general data from buildings aimed to this analysis, their environment context and share of electricity consumption.

3 Definition of the potential of shopping centres as energy service and identification of the best solutions for each shopping centre. Once the diagnosis of shopping centres is done, it can identify constrains and potentials of buildings for being exploited as energy service. 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) [5; 6; 7; 8].

4 Evaluation of the impact that energy solutions would produce on the local energy 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 using EnergyPlus.The profile is adjusted to the location of reference buildings once it is introduced the climate characteristics of the places where they are located and it is also adapted to the real surface of the supermarket and retail areas.• Evaluation of the energy generation and energy saving potential for the set of solutions proposed by each shopping centre.

- Energy generation for RES solutions (PV and wind) was evaluated with TRNSYS [9]. For the capacity of PV, it was taken into account the available surface of each building, the climate and own restrictions of the building (shadow effect for surrounding building). For the case of the wind energy, it has estimated the production of energy 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).

• 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.

Load Match and Grid Interaction Indexes are represented by the following equations.

Load matching equation [10]:

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

where
g(t) is the energy generation at each time step
l(t) is the energy load at each time step
N is the number of samples in the evaluation period

Grid interaction equation [10]:

$$f_{grid} = STD\left(\frac{ne(t)}{max(|ne(t)|)}\right) \qquad (2)$$

where
ne(t) is the net export at each time step

Fig. 1 Location of selected shopping centres (Red points)

4. Results and discussions

A description of potential solutions to provide services to the grid among which are on site RES (PV and Wind Power) can be found in [4]. Other options for load reduction are discussed in [11].

This study has been done for 3 different shopping centres in three different locations (Figure 1), Trondheim (Norway), Klaipeda (Lithuania) and Valladolid (Spain).

Figures 2, 3 and 4 show the base load profiles of the Valladolid, Trondheim and Klaipeda shopping centres for winter, mid- and summer season. For all of them, the total load profiles do not differ significantly in the various seasons. As can be seen in the Figures 2, 3 and 4, the lighting profiles dominate in all cases.

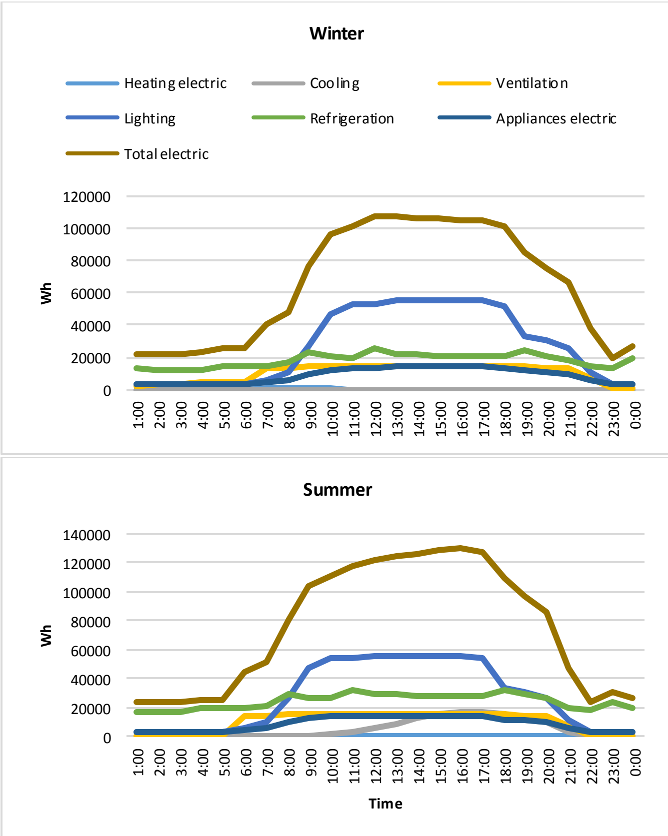

Fig. 2 Valladolid

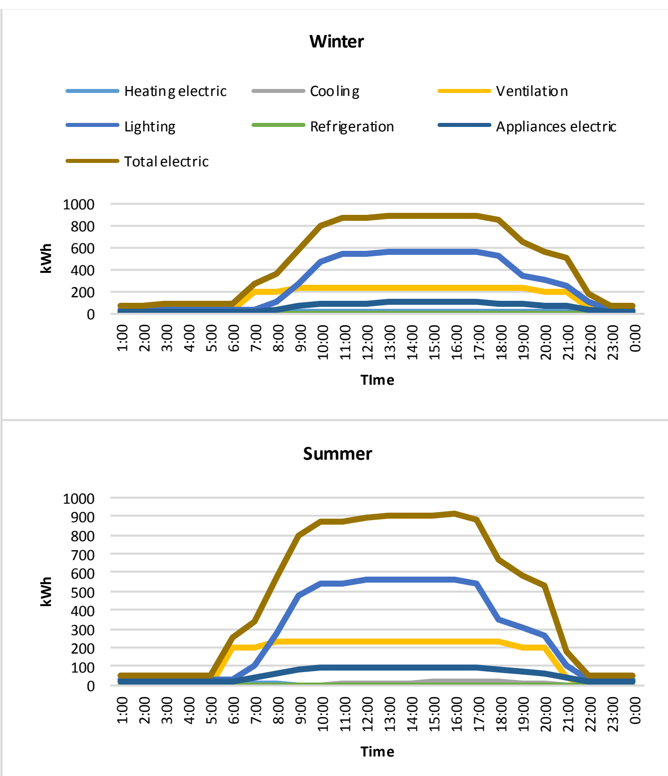

Fig. 3 Trondheim

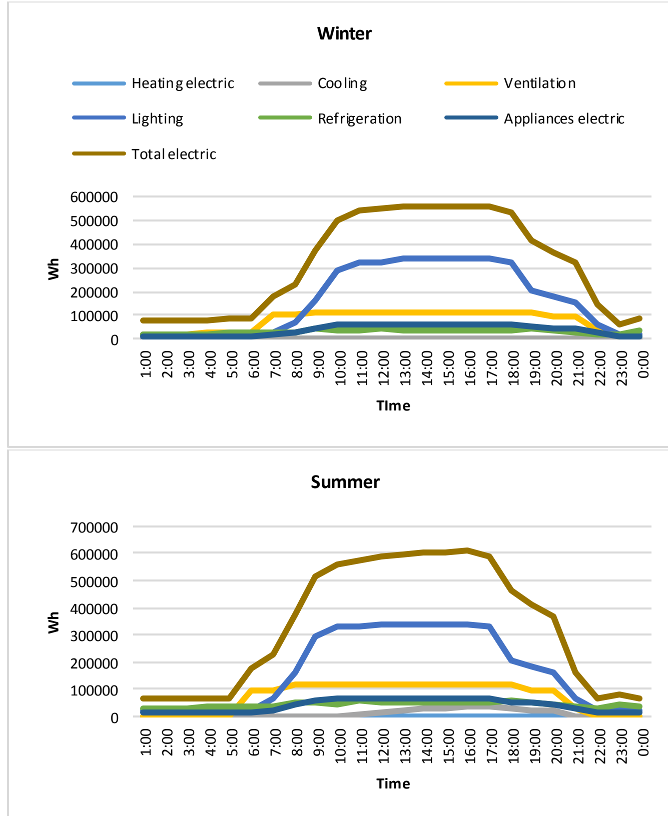

Fig. 4 Klaipeda

Photovoltaic installation

Valladolid

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 architectonical and aesthetic restrictions, it could be also considered the photovoltaic tiles. 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.

The shopping centre in Valladolid is considered a heritage building which difficult the integration of renewable facilities. Therefore has been considered an installation of photovoltaic roof tiles with a power density of 112 W/m^2.

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

Trondheim

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.

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, has been considered a surface free of shadows of approximately 4500 m^2, with a deviation of 0 degrees respect to the south.

Klaipeda

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

For the assessment of photovoltaic production, have been performed a dynamic simulation in TRNSYS, 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.

In Figure 5 the results for the hourly energy production from PV for the three shopping centers and for the different seasons are shown.

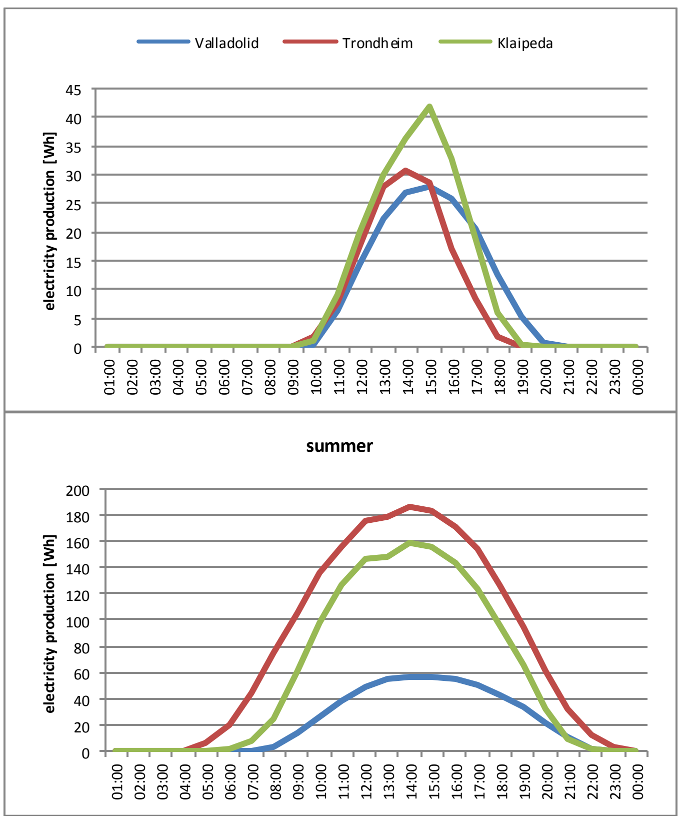

Fig. 5 Energy production from PV

Wind power

Valladolid

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.

It has been considered the production with a wind power installation 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

Trondheim

As in the case of Valladolid mini-wind system presents great troubles with the installation both at aesthetic level and urban environment noise, therefore it is almost discarded.

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

Klaipeda

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

It has been considered a wind turbine installation 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.

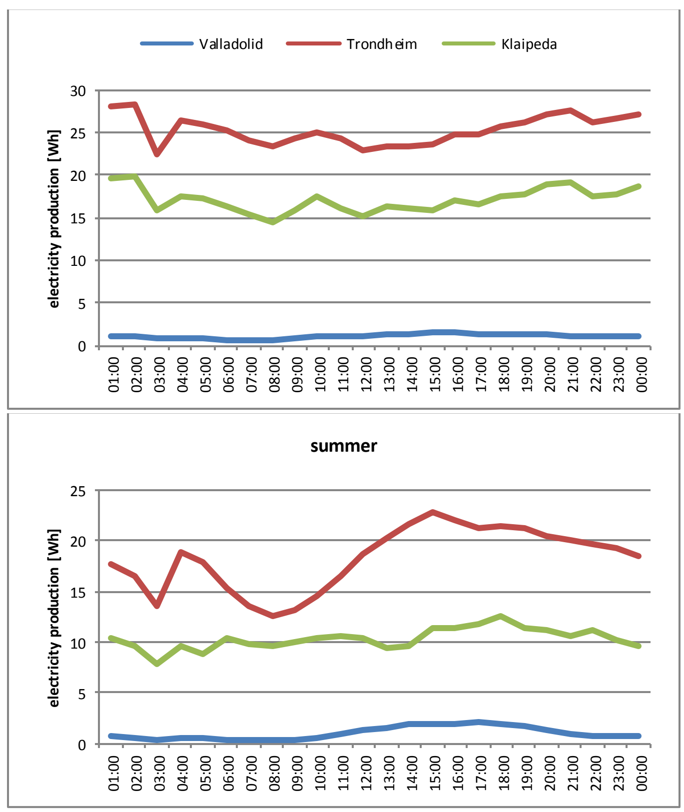

Fig. 6 Energy production from wind power (WP)

In Figure 6 the results for the hourly energy production from wind power for the three shopping centers and for the different seasons are shown.

From the evolution of the power produced by the wind turbine through simulation in TRNSYS it is possible to appreciate how is not possible to reach the highest power, existing a large variation in the power from one days to others.

It can be seen from figures 5 and 6 that energy production from PV is much larger than from wind power. However, the profiles differ but the PV profiles match better the load profiles of the shopping centres.

Based on load matching and grid interaction indicators the results are shown in Figures 7 and 8. It can be seen that RES energy supply options (PV and WP) have a very large influence. The retrofitting solutions concerning energy improvements (lighting, envelope, HVACn) combined with PV show the highest LMavg values for reduced lighting loads (LG) in the case of Valladolid and Trondheim. The load match indicator is sensitive to the time resolution considered, i.e. the higher the time resolution, the higher is the load match and vice versa.

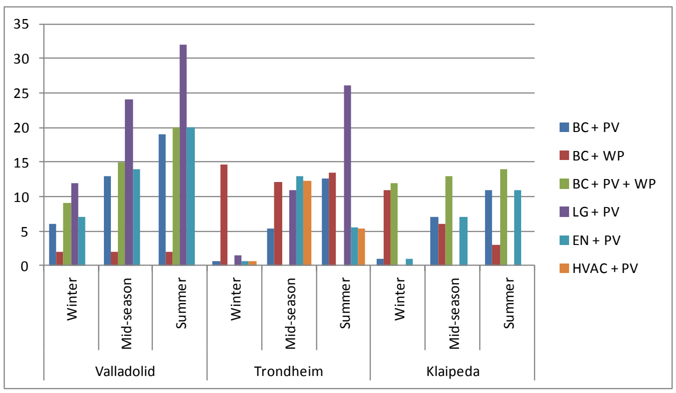

Fig. 7 Load matching indicators (f_{load}) for the three cases (BC: Base Case; PV: Photovoltaic; WP: Wind Power; LG: Lighting improvement; EN: Envelope improvement; HVAC: HVAC improvement).

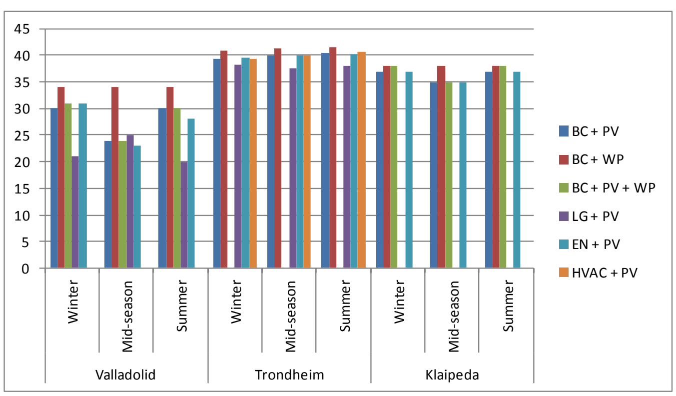

Fig. 8 Grid interaction (f_{grid}) for the three cases. (BC: Base Case; PV: Photovoltaic; WP: Wind Power; LG: Lighting improvement; EN: Envelope improvement; HVAC: HVAC improvement).

5. Conclusions

After studying 3 reference shopping centres throughout Europe it was possible to verify that there is a significant potential for improvement in the interaction between the centres and the power grid. Moreover, key aspects which allow improvements of the current interaction and the capacities that these types of buildings could give as suppliers/providers of services to the grid were identified and quantified.

- The replacement of low efficiency, old or bad dimensioned components, such as lighting or HVAC systems, allow to improve the energy efficiency of the building, in this way there is a great potential of improvement in terms of electrical reduction.
- This is also possible through the improvement of the enclosures reducing the thermal losses and thus the electrical consumption of HVAC systems and through control and management systems which allow to manage the demand in each period of time optimizing the way in which the shopping centre consumes/distributes the electricity, all these measures allow to reduce the electrical consumption of the shopping centre in terms of lighting, heating, cooling, etc.
- Other alternatives such as the energy storage allow to store energy in case a surplus of energy in renewables energies or when the grid is in "valley period" with low electricity demand and then use it in periods when is needed by the shopping centre itself or by injecting it back to the grid in peak periods.
- With the integration of renewables is possible to reduce the energy consumption and thus the electrical demand from the grid to which the shopping centre is connected through self-consumption.
- Cogeneration systems wolud be also very useful in terms of self-consumption and reduction of demand from the grid, producing at the same time electricity and thermal energy which allow also to decrease the electrical consumption in case of electrical HVAC systems.

The results will help to optimize RES energy production integrated in shopping centres, by being able to optimize self-consumption, reducing the energy need to generate and deliver additional electricity through while also being able to benefit from 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 and 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 arose regarding RES integration, energy management and grid support. It would be interesting to analyze the load match according to the electricity price slots. For example in Italy and in Spain, the cost of electricity is lower over the weekends and at night.

Abbreviations

RES = renewable energy system
SC = shopping centre
LM = load matching
GI = grid interaction
PV = photovoltaic system
WP = wind power system
HVAC = Heating Ventilation Air Conditioning
BC = base case
CHP = combined heat and power
EN = envelope
LG = lighting system

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The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:
Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.
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