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Solar Thermal Production of Domestic Hot Water in Public Buildings

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Abstract

This current chapter addresses the energy production situation in the pilot city of Plovdiv as investigated under the iURBAN project co-funded under the FP7 call. The focus of the article is the case study of one of seven public buildings with solar thermal installations realised with national and municipal funding. The pilot buildings are socially significant facilities – public kindergartens, located per urban residential area. Their study draws conclusions over the effectiveness and usefulness of such installations in public buildings and builds upon their role as prosumers in the urban energy balance.

Keywords: Energy production, Prosumers, Domestic hot water, Energy efficiency, Renewable energy resources, CO_2 reduction.

8.1 Introduction

The current chapter addresses the energy production situation in the pilot city of Plovdiv as investigated by the iURBAN project. The focus is a case study of one of seven public buildings with solar thermal installations realized through national and municipal funding. The pilot buildings are socially significant—i.e., public kindergartens, distributed evenly in the pilot city residential areas. The study draws conclusions on the effectiveness and usefulness of solar monitoring installations in public buildings and builds upon their role in detecting prosuming and feeding the information to the urban energy balance.

8.1.1 The Pilot

The city of Plovdiv is the second largest city in Bulgaria, approximately 152 km southeast of the Bulgarian capital of Sofia. The population is over 376,000, and there are approximately 300,000 visitors per year, including 80,000 foreign tourists.

Within the iURBAN project, the pilot city of Plovdiv built energy monitoring and management facilities for both energy consumption and production in 30 public and residential buildings. In the research and development framework of the project, it applied novel ICT and cloud-based services for promoting energy efficiency and renewable energy sources utilization on its territory.

Even though the energy management and monitoring systems in Plovdiv are not new to the residential buildings, only a few public buildings operate such. The mission of the iURBAN project was to expand their use and bring new perspective on the building and urban energy balance. Its integrated and validated ICT energy management systems (Chapter 4) gathered data useful for the local energy planning and development.

Monitoring of energy production was never realized in the city of Plovdiv up till the implementation of the iURBAN project. Putting a new, prosumer perspective on the realization of energy efficiency in the public sector, the seven public kindergartens were chosen—they would produce domestic hot water (DHW) for their own use and thus indirectly reduce the need for centralized hot water provision.

8.2 Public Solar Prosumers Background

8.2.1 Background

Traditionally, solar thermal installations in the city of Plovdiv are realized in the residential sector for single-family houses. Still, their usefulness and effectiveness outreach to the public users.

The seven pilot prosumers were renovated in 2013 with national and municipal funding, i.e., energy efficiency measures were realized—new external wall insolation, change of windows, change of lighting, and refurbishment of heating installation, along with the introduction of solar thermal installations for DHW.

8.2.2 How Is the Energy Management and Monitoring Architecture Established?

In late 2014, an energy consumption and production monitoring and management installation was introduced by the iURBAN project.

The deployed solar prosumer smart metering system is independent and parallel to the utility energy consumption monitoring system. Its architecture is realized so that each prosumer kindergarten has its own smart solar meter with communication facilities to transmit data to a centralized data collection center which forwards the data to the iURBAN Cloud. The equipment includes communication modules and a *blind* PC to manage reading, writing, and transmitting data on site. It is possible to update PC software from only reading and transmission to managing the entire heating system. The *blind* PC then sends the data to a local centralized data collection center where the data are kept and forwarded to the iURBAN cloud.

This type of system reduces the transmission failure risk as the solar meter, the *blind* PC and the buffering server back up data before sending it to the iURBAN cloud. In addition, data granularity can be adjusted to any transmission pattern, which can be defined by both the data receiver and the data sender.

The parallel prosumer smart metering system is connected to the iURBAN data cloud, and though consumption and production data are sent from two different sources, this does not affect the data visualization on the iURBAN platform.

In the future, the prosumer system can be expanded beyond by registering new solar prosumers, so that it forms a regional system for monitoring of the heat production, thus to become municipal prosumer data center, relevant to the local authorities, public end users, and community.

8.3 Case Study of a Prosuming Kindergarten

8.3.1 Introduction

The kindergarten studied is a public kindergarten, with solar panels installed through national and municipal funding. The iURBAN system was built additionally to capture electricity, heating, and DHW consumption from the local utility and production of domestic hot water by solar thermal installation.

The solar system in the kindergarten has 12 solar vacuum pipe collectors, with a total number of 260 pipes in a system of mixed type. All of them are propylene glycol collectors, which influences the metering characteristics of the smart meter for the solar installation.

The kindergarten has two water tanks of 1 000l each and 2 serpentines per tank—one for propylene glycol and second one for the local utility heat supply. Additional heating of the water inside the tanks could be done through two electric heaters per tank, i.e., four electrical heaters in total.

8.3.2 What We're Interested in and How Data Can Tell It?

The current analysis is pointed toward the effectiveness of introducing solar thermal installations in a public building and the cost benefit of integrating monitoring system to it. We will be also looking at the relations between the usage of centralized DHW and own production of DHW and how this affect the general energy balance of the building. Finally, we will have a look at the overall financial benefits of the case and if they have implications in regard to their role as energy and finance saving measure.

For the purposes of these analyses, we will be using data from the baseline year 2012 and the monitoring year 2015. Data are acquired through distant metering in 2012 and real-time metering in 2015 through the iURBAN platform service. The data sets used for 2012 are electricity and heat energy consumption only. The data sets used for 2015 are electricity consumption, heat consumption divided into two subsets—heating energy and DHW energy, and solar DHW production. Only one data gap in March and April 2015 was identified—data were filled through normal distribution based on the working days. Data in January split into heating and DHW was not present so the distribution was made based on the closest month proportion; this approach was chosen to the annual average one due to seasonal concerns.

Weather data for the two periods are acquired through online service and then used for normalization of the heat data.

The evaluation is based on a comparison between 2012 where no energy efficiency and renewable energy sources measures were realized and 2015 where all measures were fully realized and operational.

8.3.3 What the Results Tell Us for Baseline and Post-retrofit Periods?

8.3.3.1 What was happening when no energy efficiency measure was implemented back in 2012?

The total annual energy consumption in 2012 was 472 MWh out of which 48 MWh (10%) was dedicated to electricity consumption and 425 MWh (90%) to heat consumption.

Figure 8.1 promptly shows the seasonal character of the heat energy use—high in the winter season and low in the summer. The reason for the high winter values is the lack of energy efficiency measures implemented and poor building condition.

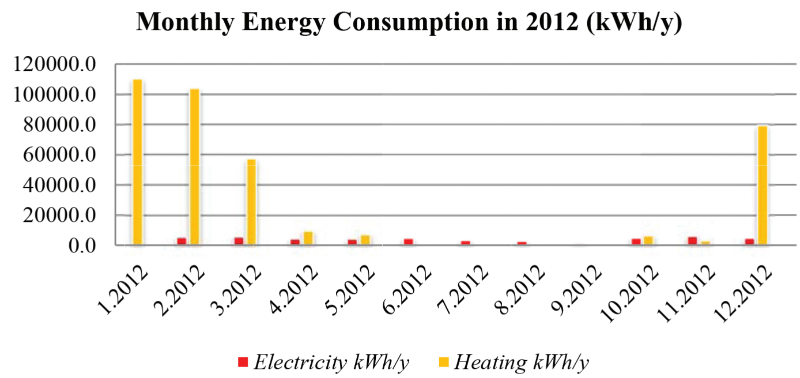

Figure 8.1 Monthly energy consumption in 2012 (kWh/y).

The correlation between outside temperature and the heat consumed in the kindergarten is –0.95, which corresponds to the prediction that with the rise of the outside temperature, the heat demand is reduced.

Figure 8.2 shows the share by energy type of the consumed energy. The share of electricity is 10% and that of the heat energy is 90%. The disproportion is due to the peculiarity of this type of public buildings—kindergartens spend most of their electricity energy for lighting and the kitchen needs, and the heat energy is used for keeping the indoor comfort up to the national requirements and domestic hot water needs in the kitchen.

In 2012, the electricity use in the kindergarten has produced 39.17 t CO_2 (24%) and the heat energy use 123.14 t CO_2 (76%).

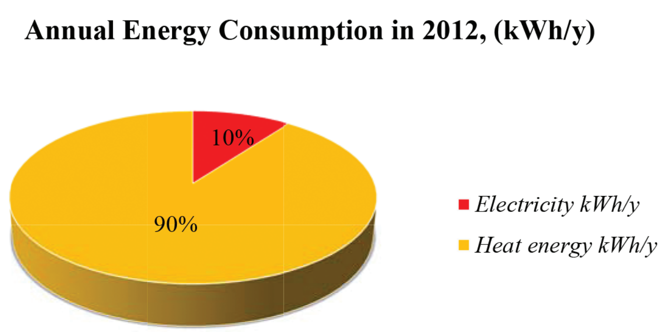

Figure 8.2 Annual energy consumption share by energy carrier in 2012 (kWh/y).

8.3.3.2 What happened when the building was deeply renovated and RES was introduced in 2015?

In summer 2013, energy renovation took place—insulation and new windows, and solar thermal installation for DHW was introduced. In autumn 2014, the iURBAN energy management system was introduced for energy consumption and production alike. Thus, the impact of energy efficiency measures and renewable energy sources introduction is visible throughout 2015.

The total annual energy consumption in 2015 is 282 MWh distributed as follows in Figure 8.3—electricity (21%), heat energy for heating (58%), heat energy for DHW from centralized heating supply (16%), and DHW from solar thermal production (5%).

The annual energy consumption and distribution in 2015 are shown in Figure 8.4. Winter months are high in heating demand (January, February,

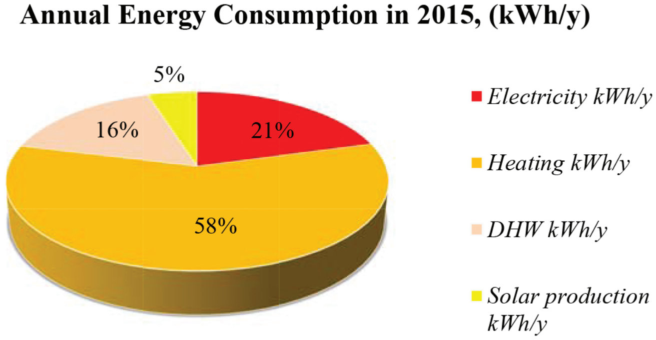

Figure 8.3 Annual energy consumption share by energy carrier in 2015 (kWh/y).

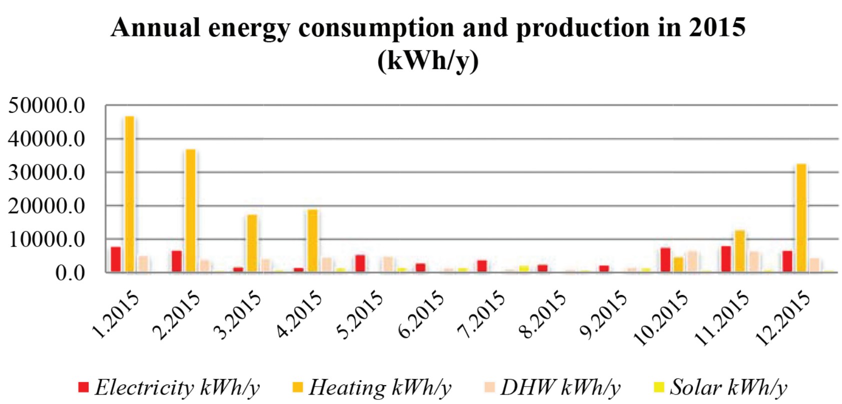

Figure 8.4 Monthly energy consumption in 2015 (kWh/y).

March, April, October, November, December). The correlation between outside temperature and the overall heat consumed in the kindergarten is –0.94, which is slightly lower than 2012, but again corresponds to the notion that the outside temperature and the heat demand are inversely proportional; looking at the heating demand only the correlation is –0.94 and at the DHW is –0.63.

On the other hand, DHW demand is constant throughout the year, but is also dependant on the number of children. In winter, the DHW consumption from centralized heat supply is 85% of the total annual DHW consumption and is due to the high number of children attending and lower capabilities of the solar installation to produce. In summer, the consumption is 58% of the total annual and corresponds to lower number of children attending and the increased capacity of the solar installation to produce.

The DHW produced by the solar thermal installation accounts for 23% of the total DHW consumption. Its RES nature and the technology used define low seasonality of the production—data show that production in the winter season is 44% and in summer season is 56% of the total annual production. Regarding the reduction in the DHW by centralized supply, the solar installation accounts for 15% of the DHW in winter and for 42% in summer. The correlation between the outside temperature and the solar production is 0.76 which shows direct positive effect of the warm weather on the production performance. In 2015, the correlation between DHW usage and solar production is –0.43.

In 2015, the CO_2 emissions by the kindergarten show significant reduction. The electricity use produced 47.81 t CO_2; the heating use, 47.57 t CO_2; and the domestic hot water use, 13.29 t CO_2 including the RES savings. The solar installation produced energy that saved 3.99 t CO_2.

8.3.3.3 So how did EE and RES measures bring change in the kindergarten energy balance?

The weather data are acquired through the local meteo online service performance. Based on the values, outside temperatures are normalized and so is the heating energy consumed. The heat consumption is reduced due to the introduction of the energy efficiency measures, including iURBAN energy monitoring, with 337 kWh/m^2 or 68%. Normalized data are presented in Table 8.1:

Normalization for the electrical energy use is not needed as the kindergarten does not heat or cool on electricity. Still, the electricity use has risen from 49.14 kWh/m^2 to 59.97 kWh/m^2 or 22% (Table 8.2).

Table 8.1 Normalized heating energy

Year	Heating Area (m^2)	Heating Energy Consumed (kWh/y)	HDD	HDD for This Climate Zone	Calibrated Heating Energy (kWh/m^2)
2012	973.28	424,630	2552.5	2241.8	496.75
2015	973.28	164, 045	2093.8	2241.8	157.42

Table 8.2 Normalized electrical energy

Year	Heating Area (m^2)	Electricity Consumed (kWh/y)	Calibrated Electrical Energy (kWh/m^2)
2012	973.28	47,826	49.14
2015	973.28	58,371	59.97

Thus, the energy intensity per person per square meter of the kindergarten is 1.82 $kWh/m^2/p$ in 2012 and 1.09 $kWh/m^2/p$ in 2015, i.e., 40% reduction.

Table 8.3 shows that the overall CO_2 emissions produced in 2012 are 162.31 t CO_2 and in 2015, 108.67 t CO_2, i.e., 0.2t CO_2 per kid. This corresponds to overall reduction of 33% of the CO_2 emissions—there is 22% increase in the emission from electricity use and 51% reduction in the emissions from heat energy use. The solar energy in 2015 has 3.99 t CO_2 not realized which is 7% of the heat energy.

8.3.3.4 What is the overall impact of becoming a prosumer?

The solar installation and its monitoring infrastructure contribute significantly to the reduction in energy intensity and overall CO_2 savings in the kindergarten.

The particular solar installation in the studied kindergarten has produced 13.77 MWh energy for DHW in 2015 only. This corresponds to 3.99 t CO_2 saved and has brought a financial benefit of 607.54 EUR in 2015. The investment for establishment of the monitoring system is 1 246 EUR and will

Table 8.3 CO_2 emissions overview

Year	Electricity (t CO_2)	Heat Energy: Heating (t CO_2)	Heat Energy: DHW (t CO_2)	Total t CO_2 Produced (t CO_2)
2012	39.17	123.14		162.31
2015	47.81	60.86		108.67
		47.57	13.29	

require 10% upon-demand technical support cost per year in the future. Its reimbursement will take 2, 4 years with the technical support.

8.3.4 Discussion

The current study brought up real-time data acquired through iURBAN energy management and monitoring platform to show the benefits of introducing energy efficiency measures and utilization of renewable energy resources. The iURBAN architecture and data gathering provide reliable, qualitative, and quantitative approach toward evaluating the introduction of energy measures.

The introduction of iURBAN provides direct observation over the technical status of the installations and the reduction in the energy consumption. The presence of the iURBAN software is valuable for regular check of the technical status of the solar installation and its functioning, i.e., additional setup of the system could bring up to 50% improvement in the solar energy production. In addition, iURBAN could be used to detect energy leaks—lighting left switched on, heating being on during weekends, etc., and thus to reduce energy costs.

Moreover, there could be direct evaluation of the impact—in the case of the studied kindergarten, it is 51% heat energy reduction, 22% increase in the electricity use, and general energy reduction of 33%. The introduction of the solar thermal installations was estimated to account for 23% of the DHW supply and the CO_2 emissions.

Relating to the cost-benefit of the iURBAN architecture and service, in this case, a reimbursement period of 2.4 years was calculated, but this high reimbursement is due to the low readiness of the solar installation system and additional technical setup made. In the future, other facilities could achieve even lower reimbursement period, which ***strongly justifies*** the introduction of real-time energy monitoring and management systems.

8.4 Conclusion

The introduction of the iURBAN architecture and services in the city of Plovdiv proved valuable novel experience for the public users. It proved significant energy reduction results and facilitated for further improvement of their energy status. In the studied kindergarten, iURBAN uncovered energy reduction of 40% and CO_2 reduction of 33%, and 6% contribution by RES utilization to the energy balance and 23% to the CO_2 emission reduction.

It also spurred new setup of the kindergarten energy systems and planning for new energy efficiency measures.

In the future, based on the iURBAN platform feedback, different prosumer profiles will be identified, thus facilitating optimization through prediction models and dynamic and demand response tariffs. The use of the local decision support system by the prosumers engages them, thus bringing them to aim higher at introducing more energy efficiency measures and achieving greater energy savings.