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To cite this article: Suhendri and Tri Pratiwi Handayani 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **291** 012028

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House-scale Renewable Energy System Sizing in Liverpool

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Abstract. Renewable energy technology such as solar thermal, PV, and wind have been developed to be building integrated. This exercise is aimed to sizing those three renewable energy systems for a typical house in the UK, specifically Liverpool. The methodologies used in this exercise are load evaluation, resource assessment, and finally sizing the systems. The results from all of sizing calculation show that there will be 6 evacuated tube collectors with 6m² area, 14 PV modules with 20.7 m² area, and 1 wind turbine with 2.5 rotor diameter. The renewable energy systems for electricity sized are predicted to cover 78.47% of the electricity load with PV contribution as many as 54.5% and the rest 24% is covered by wind turbine.

1. Introduction

Household sector shares a significant amount of energy consumption to the world annual energy consumption [1]. Indeed, it also contributes directly or indirectly to CO₂ emission to the atmosphere. Changing the basis of energy source for household sector from fossil fuel to renewable energy can reduce its contribution to world CO₂ emissions [2]. Nowadays, using renewable energy resources for domestic demand has been a phenomenon at least in developed country since the issue of climate change emerge [3].

Renewable energy technology such as solar thermal, PV, and wind have been developed to be building integrated. However, these building integrated renewable energy technologies are not always be a good solution. Under-sizing, bad performance, or misplaced are some of the problems that may happen. In order to work in optimum condition, they need to be assessed and planned correctly. Solar thermal collector, PV, and wind turbine as the common building integrated renewable energy technology are being used in this study. Specifically, PV and wind turbine are used to generate electricity and solar collector is used to domestic hot water. Location of the study is in Liverpool, the United Kingdom.

2. Objectives

This study is aimed at sizing three renewable energy systems for a typical house in the UK. Three renewable energy systems to be designed are solar thermal, photovoltaic, and wind turbine technology. The resulting system size from the research should be reasonable for typical household in the UK in terms of cost, and dimensions as well. Analytical calculation was used to assess the renewable energy sources and sizing the systems. The data from each method supports each other.

3. Methods



As mentioned in the introduction part, using renewable energy technology systems are not always be good especially for the user. Oversized systems make the investment cost high and the systems works inefficiently. Undersized systems lead to unfulfilled energy demand from the user. Therefore, sizing the systems in the right methods is important [4].

3.1 Load evaluation

The purpose of installing renewable energy technology system is to supply the energy demand in more sustainable ways. To supply energy demand is still the main purpose of it, therefore before sizing the system, how much energy load to be covered should be clear. A typical UK house (Figure 1) for a family of 4 people is taken as a case study. More details about the electricity and hot water loads in this case will be elaborate in Part 4.



Figure 1. Case house [5]

3.2 Resource assessment

After location and case study for the load have been set, resource assessment is now being more contextual and relevant. Resources assessment is key information whether it is reliable or not to have any building integrated renewable energy system in order to supply energy demand. Solar radiation data and wind speed data are two resources to be assessed. Solar radiation can be taken from NASA's website. Wind speed data is provided by weather data file of EnergyPlus.

3.3 System sizing

Determining renewable energy system specification and its size can be done if the energy load and resource has been known. Roughly, the system size is a product of energy demand divided by resource available. It is common to slightly oversize the system due to the assumption done in resource assessment, because usually the real condition is not as high as the calculation. In the end, the important information from system sizing is to know the cost of the system.

4. Results and discussions

4.1 Solar thermal sizing

Solar thermal system sizing is based on winter conditions where hot water requirement is high and solar radiation is low. From the calculation it is known that number of solar collector needed is 6. With storage tank volume of 65 litres per collector, the storage tank is sized to be 390 litres. That volume is provided by a 1 m height tank with diameter of 70.4 cm.

Temperature profile of water in the tank during winter period can be seen in Figure 2. Energy from solar collector can maintain the temperature above 30 °C, but it can only increase the water

temperature to about 43 °C. Energy from auxiliary system may be added in this condition to get required temperature (60 °C).

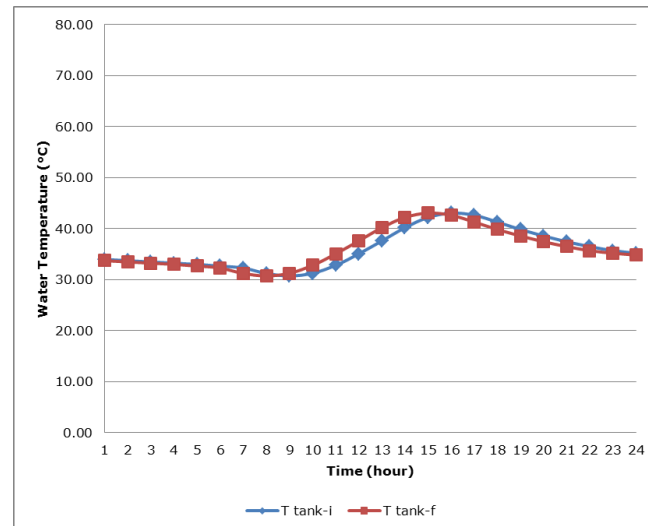


Figure 2. Water tank temperature profile in winter

During summer, to avoid the water to be overheated above 90 °C, 4 collectors are preferred than 6. This variation on number of solar collectors might be overcome by using active valve for the pipeline that passing through the collectors [6]. It can be done because the collectors are connected in parallel [7]. This concept is illustrated schematically by Figure 3. By using 4 collectors, hot water demands in summer can fully covered by solar energy. As it shown by Figure 4, water temperature is maintained to be above 60 °C and also not exceed 90 °C.

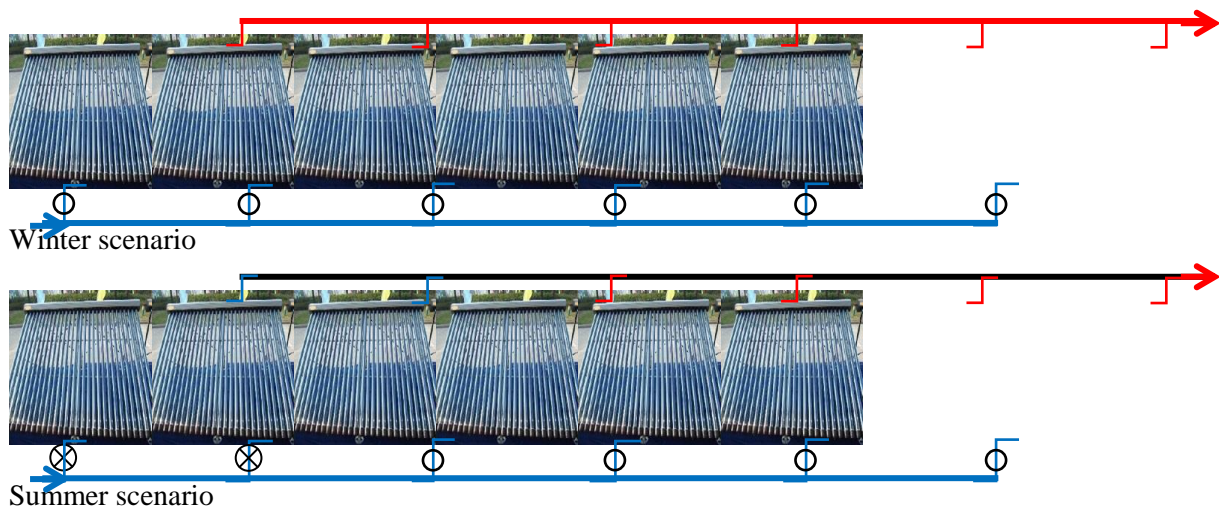


Figure 3. Solar collectors connection scheme

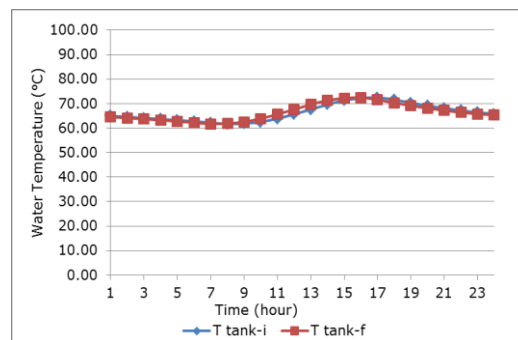


Figure 4. Water tank temperature profile in summer

4.2 *Pv sizing*

For the same reason as solar collectors, PV system sizing is based on winter conditions. From the calculation, it is known that number of PV needed is 14 PV modules, with PV specifications as written in the Table 1. With such number of PV, the energy balance between electricity delivered by PV, the grid, and the electrical load is shown by Figure 5 (winter) and Figure 6 (summer).

Table 1. PV Specifications

Pmax(W)	250	Vmpp(V)	31	Impp(A)	8.07
Temp. coeff	-0.463%	Voc (V)	37.9	Ioc	8.76
Temp. coeff	-0.330%	Temp. coeff	0.030%	λa	10%
Pmax (W)	179.9	Vmpp(V)	27.9	A module (m2)	1.48
Voc(V)	37.1	Isc(A)	7.07	NOCT (°C)	47.5
Vinv(V)	90-550	max Iinv	20	ηinv	97%

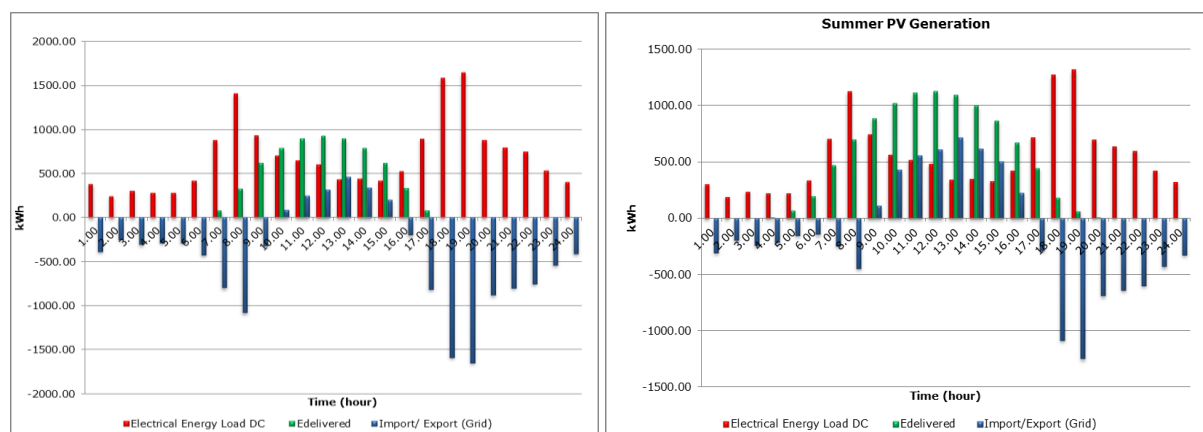


Figure 5. PV electricity energy generation in winter and summer

4.3 *Wind turbine sizing*

Analytical calculation uses 2.5 rotor diameter wind turbine to cover 75% electricity demand from renewable energy resources. Wind local wind speed condition, this wind turbine is predicted to generate 1,296.66kWh electricity per year.

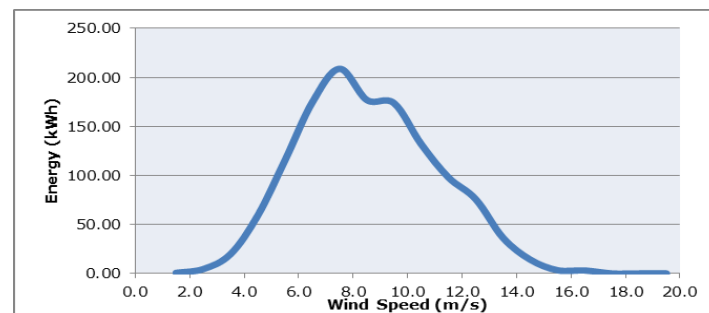


Figure 6. Wind turbine's annual generation

5. Conclusions

Sizing of a house-scale renewable energy system in Liverpool follows three general steps, which are load calculations, resource assessment, and system sizing. It is concluded that a typical house for 4 family members in Liverpool would need at least 6 evacuated tube collectors with area of 6m^2 , 14 PV modules with area of 20.7m^2 , and 1 wind turbine with 2.5 m rotor diameter. The collectors and the PVs will be roof-mounted, hence positioning of these modules should be planned. The position of wind turbine also should be located in the right side of the building. Figure 7 shows the positioning of all renewable energy technologies.



Figure 7. Systems positioning

Calculation is based on two conditions, summer and winter, and optimised according to the two different conditions in the two seasons. PV and solar thermal are affected significantly by the condition in summer and winter. The challenge for the two renewable systems is that in winter condition the load increases, but energy generated decreases. Nevertheless, in average, renewable energy contributions compare to electricity load can be seen in Figure 8. All of the renewable energy systems for electricity sized are predicted to cover 78.47% of the electricity load. PV contributes as many as 54.5% and the rest 24% is covered by wind turbine.

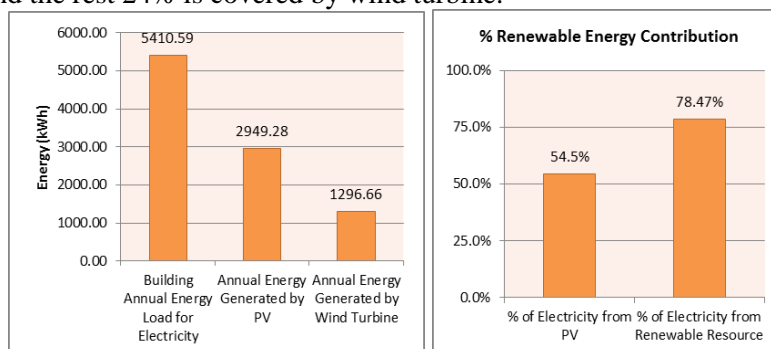


Figure 8. Renewable Energy's Contribution

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Acknowledgments

We gratefully acknowledge the funding from USAID through the SHERA program - Centre for Development of Sustainable Region (CDSR)