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A3_5 Investigating the feasibility of Solar Energy in the UK

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Abstract

This paper calculates that the total amount of electrical energy which could be produced by a photovoltaic solar panel array the size of London, with solar tracking, is 417 GWh per year. This is 0.280% of the total energy demand of London alone and a long way from the nationwide target of 15% renewable energy production by 2020.

Introduction

In Germany photovoltaic solar panels have been integrated into the architecture of buildings either through rooftop installations or on the façade of buildings. This has helped to increase the percentage of energy produced through renewable sources. This paper will therefore look at the viability of rooftop mounted solar arrays in London for electrical energy production in the UK. London was chosen as it is the largest city in the UK and therefore has the largest number of available rooftops. This will be done by simplifying the problem and assuming that the solar array is the size of Greater London.

Analysis

In order to work out the energy production of a photovoltaic solar panel array the size of London with solar tracking, so that the solar radiation is incident normal to the panel, first the solar irradiance has to be worked out. This can be done using equation 1 below.

$$I = \frac{L_{\odot}}{4\pi R^2} = \frac{3.839\times10^{26}}{4\pi\left(1.496\times10^{11}\right)^2}, \qquad (1)$$

$$I = 1370\ \mathrm{Wm^{-2}},$$

where L_{Θ} is the luminosity of the Sun [1] and R is the distance from the sun to the Earth in metres. This gives a power per unit area at the top of the atmosphere. In order to get the power per unit area of the solar irradiation in London the atmospheric absorption and the latitude of London need to be taken into account. This is done in the application of equation 2:

$$r_b = I(\cos Z)\,\tau^m\,, \qquad (2)$$

where r_b is the direct solar irradiance, I is the value for the incident solar irradiance, previously calculated, Z is the zenith angle, and is equivalent to 90 minus the latitude, τ is the transmission coefficient of the atmosphere and m is the air mass [2]. The air mass m can be calculated using equation 3 below,

$$m = \frac{c_2}{(c_1+\cos Z)} + c_3\,, \qquad (3)$$

where c_1 = 0.008307, c_2 = 1.021 and c_3 = -0.01259 and are taken from Bemporad's paired air mass zenith angle values [2]. The direct solar irradiance in London (latitude 51.5°N) at solar equinox, taken to give an average direct solar irradiance during a year, can therefore be calculated as,

$$r_b = 1370(\cos(90-51.5))\times 0.75^{1.28} = 740\mathrm{Wm^{-2}}.$$

A value of 0.75 was taken as the transmission coefficient and takes into account the absorption of light from ozone, clean dry air and water vapour at unity air mass [2]. From the value for direct solar irradiation at latitude of 51.5°N the incident power on a solar array the size of London can be calculated by multiplying the direct solar irradiance by the area of London (2263 km^{-2}) [3]. This gives a value of $1.67x10^9$ W. Solar panels coated with and antireflective coating absorb 96.2% of the incident radiation [4]. This gives an absorbed solar power of $1.61x10^9$ W.

Typical terrestrial solar panels are 17.3% efficient [5]. Using this value an output power of $2.79x10^8$ W of electricity could be generated.

On average there are 4.1 hours of direct sunlight a day in London [6]. Using this figure and equation 4 below, it is possible to calculate the electrical energy produced on average every day and therefore the average electrical energy produced over a year.

$$\begin{aligned} E &= Pt = 2.79\times10^{8}\times4.1 \\ &= 1.14\times10^{9}\ \text{Wh/day} \\ &= 4.17\times10^{11}\ \text{Wh/yr} \\ &= 417\ \text{GWh/yr} \end{aligned} \tag{4}$$

Discussion

The UK has a target to produce 15% of its energy demand from renewable sources by 2020 [7]. In 2008 the energy use of London alone totaled 148,780 GWh [8], 15% of this is 22,371 GWh. This value is much larger than the 417 GWh that could be produced in a year by a solar array the size of London.

Conclusion

The use of photovoltaic solar panels is not a viable option for obtaining the renewable energy production target alone. This is due to the high levels of attenuation of the incident solar radiation through the atmosphere due to the high latitude of the UK. Therefore a wider range of renewable sources will have to be used, such as wind power generated by offshore wind farms, which currently look very promising.

References

[1]http://www.universetoday.com/42248/luminosity-of-sun/ (14/02/11).

[2] X. Yin, Meteorology and Atmospheric Physics, **63**, 227, 228 and 231, **(1997)**.

[3]http://www.aviewoncities.com/london/londonfacts.html (14/02/11).

[4]http://www.science20.com/news_releases/reflective_coating_silicon_solar_cells_boosts_absorption_over_96_percent (13/02/11).

[5]http://us.sunpowercorp.com/downloads/product_pdfs/Panels/sp_215wh_com_en_ltr_p_ra_ds.pdf (14/02/11).

[6]http://www.weatheronline.co.uk/weather/maps/city?LANG=en&PLZ=&PLZN&WMO=03772&CONT=ukuk&R=160&LEVEL=162&REGION=0002&LAND=UK&MOD=tab&ART=SON&NOREGION=1 (12/02/11).

[7]http://www.publications.parliament.uk/pa/ld200708/ldselect/ldeucom/175/175.pdf (13/02/11).

[8]http://www.decc.gov.uk/en/content/cms/statistics/regional/total_final/total_final.aspx (14/02/11).