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Technical and policy challenges of wide-scale integration of domestic PV systems into UK homes.

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Introduction

This research investigated the technical viability and policy impact of domestic Photovoltaic (PV), based on real system performance and household electrical energy consumption data, recorded:

- in five minutely intervals
- for a period of six years from 2005 to 2010
- for 18 PV systems and households
- from dwellings at a new residential development site in the West Midlands.

It involved identifying trends and patterns in the energy demand and supply, and determining how well one can offset the other.

Background

Solar PV can help meeting the renewable energy generation and CO_2 (carbon dioxide) emission targets of the UK. However, the UK lags behind the other developed nations in terms of its uptake (Figure 1.)

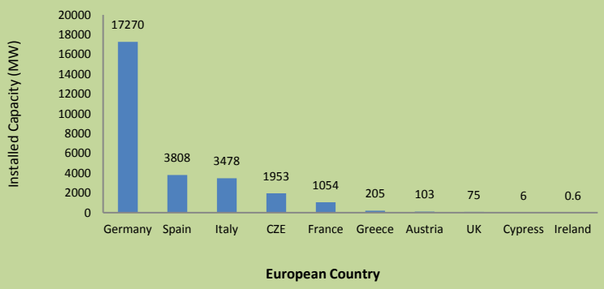

Figure 1. Comparison of installed PV capacity in the UK and other European countries (Source: Photovoltaic Barometer, 2010)

The reason for this is the relatively high cost and various misconceptions associated with the technology, concerning its ability to produce electricity given the UK climatic conditions (Solar Facts, 2008). This research focused on providing an insight into the effectiveness of PV in the UK, based on measured and long-term performance data.

Aims & objectives

The research aims were to explore:

1. the policy options affecting PV uptake
2. the electrical energy generation & consumption characteristics
3. the linkage between the PV energy supply and demand of the households

The objectives were to generate:

1. electrical energy generation patterns.
2. electrical energy consumption patterns.
3. comparison of the supply and demand patterns highlighting the differences.
4. estimates of the economic benefits based on the Feed-in-Tariff (FIT) in terms of Payback and Net Present Value (NPV).
5. methods to improve the match and onsite use of the generated energy.

Methodology & source of data

The methodology included a combination of:

- Literature reviews.
- Data analysis in Excel and SPSS to create average electrical energy consumption and generation profiles

The source of data was Building Energy Research Group, Loughborough University. PV systems design and data recording was as per the PV domestic field trial guidelines (DTI, 2002)

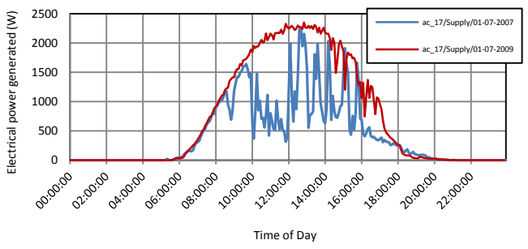

Figure 2. Illustration of intermittency in the electrical power generation pattern of a 3kWp PV system recorded on 1st July 2007 and 1st July 2009

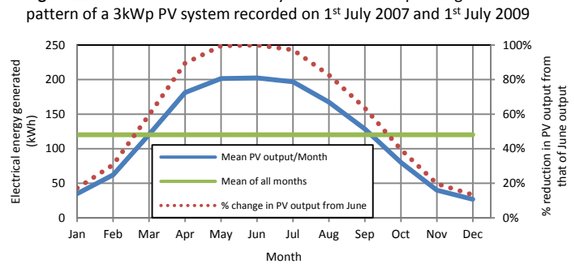

Figure 3. Average monthly electrical energy generation pattern of 18 PV system with a mean system size=2.33kWp, indicating percentage variation relative to the best performing month of June

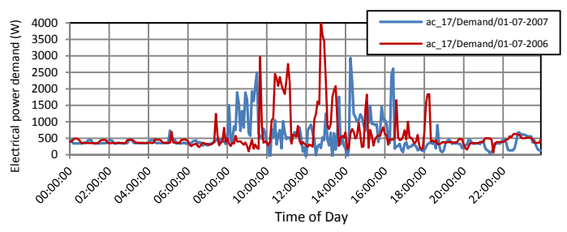

Figure 4. Illustration of unpredictability in the electrical power demand within a single household for the days of 01-07-2007 and 01-07-2006

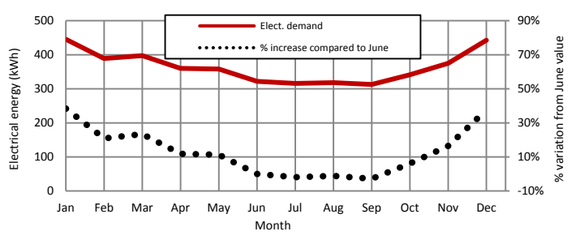

Figure 5. Average monthly electrical energy consumption for 18 households, for 2005 to 2010, indicating percentage variation relative to the month of June.

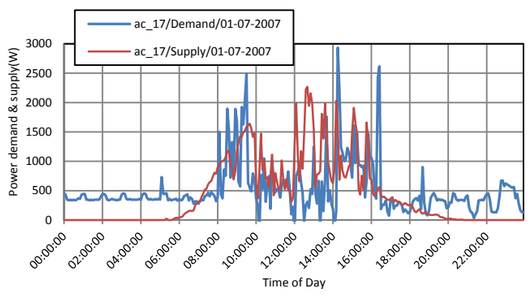

Figure 6. Comparison of the 5 minutely generation and demand patterns of a single household for: a) the days of 01-07-2007

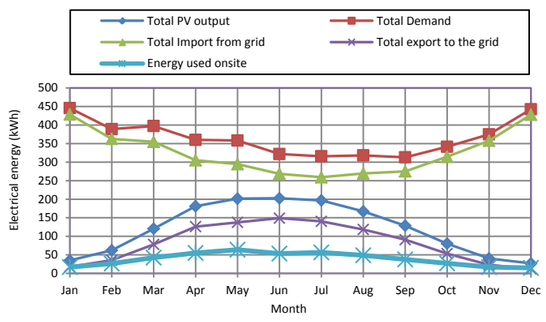

Figure 7. Comparison of the average monthly electrical energy demand, PV generation, electricity import and export of 18 households with a mean installed PV system size of 2.33kWp.

Results

PV electrical energy generation

1. Highly intermittent even in the summer months when the PV output is expected to be at its highest (Figure 2)
2. The average system output reduced by approximately 4.2% p.a.
3. The PV output energy reduced by 90% in December (worst performing month) from that of June (best performing month) (Figure 3).

Household electrical energy consumption

1. Highly intermittent and unpredictable (figure 4).
2. Average consumption was 4035kWh (National average ~5000kWh)
1. Consumption varied from 2036kWh to 8163kWh
2. Energy consumption increased by 35% in December compared to June (figure 5)
3. Frequency analysis indicated that 83% instantaneous peak demand was below 500W.

PV output and household energy demand matching

1. Instantaneous demand and supply highly intermittent and unpredictable (figure 6), therefore have poor real-time match.
1. PV can satisfy 36% of the average annual energy needs.
2. PV output is higher than 50% of the demand for 5 consecutive summer months (April to August) (Figure 7).
3. 68% of the generated energy is exported to the grid and only 32% used onsite.

Economic Analysis

1. Annual return[1]: £1066, £528 and £489 for 3kWp, 2.5kWp and 2kWp systems respectively.
2. Payback time[1] with FIT is 13 years (90 years without FIT)
3. NPV[1] positive for 25 year life time for the 3.5kWp systems at 5% interest (but negative for smaller system)
4. Economic benefit[1] of greater onsite use is small. (It would be £55, £56 and £113 per year for the 2kWp, 2.5kWp and 3kWp system respectively, for 100% onsite use and with zero export)

[1] Basen on a FIT for new development of 36.1p/kWh and electricity cost price of 12p/kWh as at 03-09-2011 (British Gas)

Conclusion

- "Install and Forget" concept of PV may not be accurate and performance should be monitored.
- Over 36% of the household electrical energy need can be satisfied by PV systems.
- The generated energy is not utilised onsite effectively.
- Post-installation support and monitoring is necessary for encouraging greater onsite use.
- FIT provides a good alternative investment option provided the required capital is available.

Recommendations for further study

1. What caused the PV output reduction observed?
2. What are the effects of tenancy type and building ownership on energy consumption behaviour?
3. How the ownership or tenancy type affect onsite use of PV output?
4. To what extent can temporal variation in domestic appliance use improve the onsite use of energy?

References
Solar Facts, (2008). Solar Photovoltaic Technology; Common Misconceptions About Photovoltaics. Solar Century.
DTI. (2002). *DFT tender documentation Annex 6*. Retrieved from www.dti.gov.uk.

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