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Solar Photovoltaics

Solar power has the potential to provide low carbon electricity. This POSTnote discusses the development of solar power in the UK and summarises debate over feed-in tariffs - financial support policies introduced in 2010 to stimulate take-up.

Overview

- Photovoltaic technology (PV) converts solar radiation directly into electricity.
- Since April 2010 UK legislation has required suppliers to pay generators above-market prices for PV electricity, financed through a levy on electricity bills.
- This has led to a 20-fold increase in installed PV capacity but there is debate over the impact of ongoing policy reforms.
- The cost of PV is decreasing due to reductions in manufacturing costs.
- Long-term prospects for PV in the UK depend on its cost compared with other sources, and affordability for end users, as well as other factors such as ease of use and potential for emissions reductions.

Background

Electricity from the Sun's energy is generated either by:

- converting solar radiation directly into electricity (using photovoltaic or 'PV' technologies);
- using the Sun's heat to generate steam to drive turbines. This is called Concentrated Steam Power, or CSP.

Unlike CSP, PV generates electricity in both cloudless and overcast conditions. This POSTnote focuses on PV technologies (see Box 1), because CSP is not considered feasible under the climatic conditions prevalent in the UK. PV systems can be standalone, installed on rooftops, or integrated into buildings (e.g. incorporated into glazing or tiles). They can be employed at a range of scales – from small scale systems such as parking meters and street signs, through to large scale "solar farms" covering many acres and generating electricity for hundreds of homes. Solar PV is used to generate electricity both "on-grid", where it is connected to national electricity infrastructure and "off-grid" (such as in oil rigs and lighthouses). This note focuses on grid-connected PV, which constitutes a rapidly growing share of PV capacity in the UK (see Figure 1).

On-grid PV is more expensive than both conventional generation and some forms of low carbon generation such as wind. Governments worldwide have therefore introduced schemes to support PV and to foster domestic solar industries.

In the UK, "Feed in Tariffs" (FITs) were introduced in 2010 to stimulate uptake of microgeneration technologies.[1] There is much debate over proposed reforms to these tariffs (see pages 3 and 4).

Under the 2008 Climate Change Act the UK is committed to reducing greenhouse gas emissions by 80% by 2050. As part of its European commitments the UK is bound to source 15% of its energy from renewable sources by 2020. In May 2010, PricewaterhouseCoopers estimated that PV constituted 0.3% of renewable energy generation in the UK. The UK's 2010 National Renewable Energy Action Plan suggests that solar electricity from PV could constitute 1.9% of renewable energy generation by 2020 (the majority of the target is expected to be met using large-scale wind).[2] The carbon emissions per unit of PV electricity are less than those of fossil fuels but greater than some other renewables (such as wind, under UK conditions – see POSTnote 383).

UK Solar Resource

The amount of solar irradiation available in the UK ranges from 960 kilowatt hours per metre squared (kWh/m^2) in the far north, to 1240 kWh/m^2 in the south-west. This compares with 900 kWh/m^2 for Norway and 1,900 kWh/m^2 for Spain. A UK field trial (Box 2) found that around 13m^2 of PV panels on a suitable house roof could generate half of its electricity requirements averaged over one year.

Box 1. PV Cells and Systems

PV Cells

PV cells are classed in three 'generations':

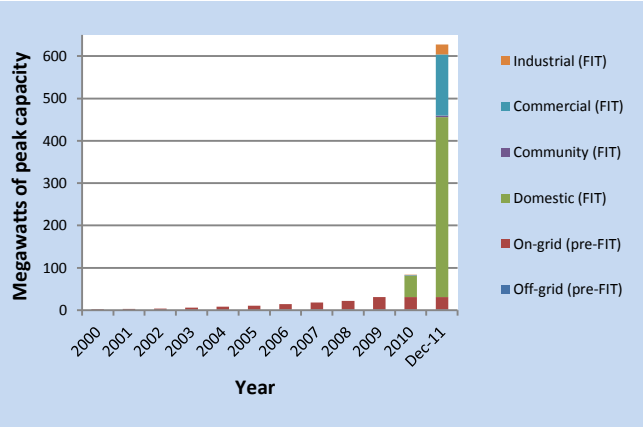
- First generation cells, using crystalline silicon, have dominated the market for over 30 years.
- Second generation 'thin-film' cells use a variety of materials in thinner layers, thus reducing cost. They could constitute up to 35% of the market by 2020.
- Third generation cells are being developed with the aim of harnessing a greater proportion of energy from sunlight than is possible with 1st and 2nd generation.

The percentage of solar irradiation that a solar cell converts into electricity is known as its *conversion efficiency*. Currently efficiencies range between 4% (third generation), 4-12% (second generation) and 13-22% (first generation) although efficiencies change as technologies develop. Production costs vary depending on the technology as well as the scale of production.

PV Systems

PV cells are assembled into a modular system which is connected to electrical hardware called the "balance of system". Peak power is a measure of a system's electrical performance. It is determined according to a set of "standard testing conditions" (STC) which are "optimal" conditions of irradiation, light intensity and temperature. PV systems worldwide tend to generate 15-20% below peak power because of deviations from STC conditions.[3]

Figure 1. UK Cumulative installed PV capacity



Before April 2010, systems were distinguished only by whether they were grid connected. All systems in this figure installed after April 2010 are registered with the FIT scheme and are grid connected.[4,5,6]

An industry estimate claims that covering the entire country's south-facing roofs and facades (~ 1,100 km^2) with standard PV modules could generate 26-35% of total UK electricity consumption.[7] This is theoretical; in practice it would be constrained by factors such as cost, and the technical challenges of integrating large amounts of small scale electricity generation into local electricity networks.

UK Government Support for PV

Since 2000 the government has supported PV in three main ways: funding research and development (R&D), demonstration programmes and market stimulation policies.

R&D Funding

UK public funded R&D in PV is supported by bodies such as the Research Councils.

Box 2. PV Research and Development in the UK

R&D into PV constituted 7.7% of total research council funding into energy in 2008/9, increasing from £2.7 million in 2002/3 to £8.5 million in 2008/9. Some highlights funded by the Engineering and Physical Sciences Research Council include:

- The Research Councils UK (RCUK) SUPERGEN programme. This funds "PV Materials for the 21st Century" (2008-2012; £6.3 million) to improve the cost-performance of first and second generation PV materials ; and "Excitonic Solar Cells" (2009-2013; £3.1 million) to consolidate the UK's research position in third generation PV cells.
- Two joint R&D projects announced in 2010 by the RCUK and the Government of India Department of Science and Technology (running 2010-2013, with £2.5 million per project from both parties). "Advancing the Efficiency and Production Potential of Excitonic Solar Cells" targets commercialisation of third generation solar cells. "Stability and Performance of Photovoltaics" models the behaviour of PV systems under different climatic and grid conditions.

The four R&D projects in Box 2 bring together a range of British universities, private sector and international partners. Projects involve laboratory- and field-based experimentation with different types of PV materials.

Demonstration Programmes

A series of government-led capital grant schemes ran from 2000-2010, targetting PV installation in the built environment. The Domestic and Large Scale Photovoltaics Field Trials (Box 3) investigated the performance of PV under UK climatic conditions. It highlighted the need for professionals such as roofers and electricians to acquire new skills and expertise. Since the trials, the UK skills base in this sector has expanded considerably, although recent reviews of feed-in tariffs for solar PV (see next page) have raised concerns over the future of the sector (Box 4).

Market Stimulation

The Low Carbon Building Programme (LCBP I+II), which ran from 2006 to 2010, was a £80 million programme promoting a range of microgeneration technologies, by providing support towards the capital cost of systems. PV was the most popular technology. However, frequent changes in grant levels, funding cuts and a temporary suspension (March-May 2007) were criticised by industry.

The LCBPs were discontinued when Feed in Tariffs (FITs) came into force in the UK in April 2010. FITs are used across Europe (Box 3). In the UK they were intended to provide a fixed and guaranteed price for electricity from eligible small-scale technologies in England, Scotland and Wales. The aim is to encourage "non-traditional electricity generators", such as households, communities and small business. In the UK the tariffs were originally designed to provide a return on investment of 5-8%. PV systems are paid a tariff for every kilowatt hour that they generate, depending on the size of system, whether it is attached to a building and whether it is a new or existing building. Generators may receive an extra payment of 3 p/kWh for any unused electricity exported to the grid. Tariffs are paid by energy utilities for a set period following installation depending on the technology (25 years for PV). Utilities finance the tariff through a levy on all energy consumers'

bills. Up to 1st August 2011 the tariff was between 30.7 and 43.3 p/kWh but these rates have since been reduced (see below). In DECC's initial impact assessment the cost to households was estimated to be £8.5 per household annually for the period 2011-2030.[8]

Prospects for Solar Power in the UK

The introduction of the FIT increased take-up of PV from around 32 MWp by early 2010 to over 400 MWp by November 2011, with domestic PV being the fastest growing PV sector (Figure 1). Future take-up by end users, and the growth of the domestic UK PV industry, will depend on:

- the technology's cost compared with grid electricity;
- the technology's cost compared with other low carbon electricity technologies;
- affordability to end users;
- ease of access to the technology.

Thus the ongoing review of FITs will influence prospects for solar PV in the UK.

Fast Track Review of Feed-in Tariffs

In February 2011, DECC announced a comprehensive review of FITs and as part of this, a "fast-track" review of the tariff levels for >50 kW PV and anaerobic digestion. The review was prompted by concerns over meeting FIT-related saving commitments of 10%, announced during the 2010 Spending Review. For generators with installations above 50 kW (the statutory definition of 'microgeneration'), the reviewed tariff levels are roughly half of their original value. This applies only to those becoming eligible after August 2011. Two key justifications were cited for the review.

Firstly, the original FIT rates did not take into account recent reductions in manufacturing costs of PV systems. Stakeholders across government, industry and civil society agree that FIT levels need to reflect these in order to foster a competitive PV industry. Secondly, DECC said there was a risk that the levy on consumer electricity bills might rise above the original figure of £8.50 per households per year. This was due to the perceived popularity of large scale "solar farms", originally eligible for the tariff. Industry disagreed with this projection. Based on pre-review FIT rates, the Solar Trade Association claimed that costs to households through electricity bills would average less than £7 per year.[9]

Opponents of the review argue that medium-sized PV schemes (50kW-250 kW), which have attracted housing associations and local authorities, may become financially unviable as a result of this reform.

Comprehensive Review

The first phase of a two phase comprehensive review of FITs opened for consultation in October 2011. It focuses on solar PV and centres on the following proposals: [5]

- reduced tariffs for installations of 50 kW or less;
- further reductions for installations 50-250 kW already affected by the Fast Track Review;
- introduction of multi-installation tariffs applicable for those who receive payments from more than one installation;
- introduction of new energy efficiency requirements.

More information can be found in House of Commons Library Standard Note 6112.[5] The government's justifications for the proposed tariff reductions echo those put forward during the fast track review: namely, that the current tariffs for solar PV are resulting in significantly higher returns than originally intended and are thus threatening the overall affordability of the scheme.

The new tariffs are planned to be introduced from 1 April 2012 and will affect all solar PV installations with an eligibility date on or after 12 December 2011. A report by the House of Commons Environmental Audit and Energy and Climate Change Committees highlights the controversy surrounding these proposals.[11]

- It says that although it is clear that solar subsidies need to be reduced, the consultation has been rushed, undermining confidence in energy policy and damaging the solar industry. It also says the consultation is based on an inadequate impact assessment.
- It raises concerns over the potential impact on community based schemes and calls on the government to design a "community" tariff to address this issue. Phase 2 of the consultation will explore how "genuine" community projects can benefit fully from FITs (at the time of writing Phase 2 has not yet been launched).
- The 2010 Spending Review set a budgetary cap on the amount that could be levied on energy bills (for all policies

Box 3. PV in Europe

By late 2010, Europe hosted 80% of installed PV capacity worldwide. This met around 1.2% of the EU's electricity demand in 2010, according to the European Photovoltaic Industry Association. In early 2011 the UK ranked in 19th place across Europe in terms of per capita capacity. Germany (which has similar levels of solar irradiation to the UK) was 1st, with an installed capacity around 100 times the UK.[10]

The development of PV in Europe has been closely linked to feed-in tariff policies. As of 2009 these were the main policy tool in 20 out of 27 European Union Member States. As in the UK, the level of the reward is generally dependent on system size and/or the extent to which the system is integrated into a building. Some FITs encourage large ground-mounted installations (e.g. in Spain) while others focus on the medium and smaller scale sectors and building-integration (e.g. in France, Germany, the UK). The future of PV in northern Europe is often thought to lie in the latter sector. This reflects a widespread opinion that PV is most suited to the built environment, while other technologies, such as wind, geothermal and marine renewables, are more suitable to less built-up areas.

Many countries are cutting their tariffs after experiencing higher than expected uptake, amid concerns over the cost to consumers and the need for tariff rates to reflect the falling costs of installation. In the Czech Republic, as of 2010, tariff levels were around 42p/kWh for a plant of under 30 kW. By the end of 2010 installed capacity had reached 1650MW and had exceeded government projections. The rate has been almost halved and a 26% tax on PV introduced. At the other end of the spectrum, in Denmark, where total installed capacity is only 3MW, no changes are envisaged. Any installation above 6 kW receives a fixed feed-in tariff of DKr 0.60/kWh (about 7p/kWh) for 10 years and DKr 0.40/kWh (about 4.5p) for the following 10 years.

funded in this way including FITs). Because of the high uptake of solar FITs there were concerns that this cap would be exceeded. The report says that this "levy funded spending cap" needs to be better managed.

- The report also states that the proposal that all homes must achieve a 'C-rated' energy efficiency standard to qualify for the full feed-in-tariff subsidies could have a "fatal impact" on the solar industry.

Note that on 21st December 2011 the High Court ruled that implementing the proposals by the 12th December deadline (which fell before consultation ended) was unlawful. DECC are seeking permission to appeal.

Box 4. The UK PV Industry

In 2010 PV was in the top ten "high growth sub sectors" of a broader set of low carbon and environmental goods and services, with the sector's value estimated at £4.7 billion in 2008/9 (projected to reach £6.9 billion in 2015). Industry estimates that 30 jobs are created for every MW of PV installed. In Autumn 2011 the solar industry estimated that ~25,000 were employed in the sector. In 2011 there were over 3,800 PV installers accredited to the Microgeneration Certification Scheme (Box 3).However the FIT review is raising concerns about the future of the UK PV industry. A survey of 139 companies by the Solar Trade Association and Renewable Energy Association in November 2011 found that 90% felt the current cuts were too deep and fast, and 1 in 3 feared they may be forced to close.

Cost Competitiveness of Solar

Capital Costs

In 2010 consultancy firm Mott McDonald estimated the capital costs of PV to be £2,600-£2,850 per kilowatt of 'peak' power (Box 1) installed. A 2011 Ernst & Young report estimated reductions in PV module costs of between 13 - 17% annually up to 2013. These are related to efficiency improvements and reduction in silicon usage. Also, the price per module is expected to come down as the scale on which they are manufactured increases.

Cost Comparisons

Levelised cost is the total lifetime cost of a technology (scaled to today's prices) divided by its expected life-time output of electricity. It is a way of comparing the overall costs of low carbon technologies. For PV, levelised costs ranging between 202 and 380 £/MWh are cited for 2010 in the government's Renewable Energy Roadmap.[12] This is high compared with costs for on- and off-shore wind (75-127 and 149-191 £/MWh) or biomass (94-165 £/MWh). The roadmap cites levelised costs of 136 £/MWh to 250 £/MWh by 2020. This is closer to other renewables than current costs (102-176 and 71-122 £/MWh for on-and off-shore wind respectively). However there are many uncertainties in making projections, particularly for technologies at early stages of commercial development. Note that these figures represent costs met by the generator and do not incorporate wider costs such as the need to maintain backup capacity due the intermittent nature of a given energy supply.

Grid Parity

Retail 'grid parity' refers to the point in time at which the costs of generating one unit of PV electricity are equivalent to, or become cheaper than, the retail price of one unit of electricity. It is thought that grid parity will be reached through a combination of decreasing manufacturing costs of PV systems and rising electricity prices. Recent evidence suggests that grid parity in the UK will be reached before 2020 for domestic, commercial and industrial PV systems. These estimates are based on OFGEM's "Project Discovery" estimates of future retail electricity prices.[8] Estimating grid parity is difficult because of uncertainties over future policy development, as well as electricity prices and module cost reductions in the industry.

Affordability

Prior to the introduction of FITs it was estimated that the time it would take for a PV system to 'pay back' its upfront investment costs to end users would exceed systems' lifetimes of 25-30 years. Payback time is determined by factors such as system output and retail electricity prices. Government's continued FIT support to microgeneration schemes below 50kW means that a standard domestic PV system should pay back in 10 to 20 years, depending on money saved on bills. Proponents of PV argue that this figure is closer to 10 even with proposed reductions in tariffs. Following this payback period, PV system owners begin to make a net profit on their investment.

A key concern is that the high upfront costs of PV may exclude low-income households, even though they still pay for the FIT scheme through the levy on electricity bills. There are currently no tailored low-interest high street banking products for the financing of PV systems. However, there are ways to spread benefits to low-income households. Housing associations can pay for the installation and receive the FIT, while tenants benefit from reduced bills. One example is Birmingham Council's project of fitting solar panels on 10,000 council homes. "Rent-a-roof" schemes are another possible option for those unable to afford a system. These involve a company renting roof space and then financing, installing, maintaining and insuring a PV system on it. The company receives the FIT, while roof owners benefit from renting their roof and tenants benefit from reduced electricity bills. Before the FIT review, Consumer Focus said that owning a system could be up to fifteen times more profitable than renting. However, there are uncertainties over the future of such schemes as a result of the ongoing review of FITs.

Endnotes

1 Broadly defined as any installation with generating capacity <50 kW.
2 Department of Energy and Climate Change (DECC), 2011 National Renewable Energy Action Plan, July 2010.
3 Department of Trade and Industry, PV Domestic Field Trial Final Technical Report, 2006.
4 International Energy Agency, PVPS UK National report 2008.
5 House of Commons Library: Feed-in Tariffs – Solar PV, Standard Note 6112.
6 OFGEM FIT statistics December 2011.
7 UK Photovoltaic Manufacturers Association, 2020 Vision: An up to date and accurate analysis on the investment case for solar PV in the UK, 2009.
8 DECC, Impact Assessment of Feed-in Tariffs for Small-Scale, Low Carbon, Electricity Generation (URN10D/536), 2010.
9 Solar Trade Association, Our solar future, the solar revolution. 2011.
10 http://www.eurobserv-er.org
11 House of Commons Energy and Climate Change and Environmental Audit Committees, Solar Power Feed-in Tariffs, Session 2010-2012.
12 DECC, Renewables Roadmap, July 2011.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Anne-Christine Maassen and Marc Warner for researching this briefing, to and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Chandrika Nath.