DTI Renewable Energy Innovation Systems Project

The Innovation System for Photovoltaics

Draft 1.1 (by Jeremy Woods)

1. Technology overview/description

Photovoltaics (PV) can be used to generate electricity as stand alone units, grid-connected systems, or when integrated into building structures (BIPV). PV is associated with the 'high technology' end of renewable energy technologies and innovation is occurring in a range of areas from fundamental materials research to developing integrated implementation and monitoring systems. Although PV is one of the best known renewable energy technologies it remains one of the most expensive methods of producing electricity despite receiving governmental development funding.

Projected gains resulting from learning-by-doing in both the scale-up of manufacturing and the increasing size of single project applications are likely to be insufficient in themselves to allow PV to compete directly with existing large scale conventional or renewable electricity production technologies. Therefore, PV proponents have concentrated on highlighting: i) the potential 'step-change' technology developments currently undergoing R&D that are likely to significantly reduce costs in the future, and ii) the perceived 'flaws' in existing markets that discriminate against small-scale decentralised electricity production technologies by distorting the economic framework to favour large-scale centralised generation and distribution.

Even with the relatively low insolation rates of the UK, there are nevertheless a large number of potential sites for developing both large and small scale installations if costs and incentives are right. More importantly, there are significant scale effects that reduce capital expenditure. In addition, the modular nature of PV allows installations to be completed faster and in more remote locations than competing technologies or areas where it is expensive to provide low voltage supplies for low loads. Large-scale PV systems (<10 kWpeak) are rare, but are examples are beginning to occur in the UK, such as the recently completed 106 kWp amorphous PV installation at the Alexander Stadium in Birmingham, installed by Solar Century. This project was installed at just under £4.00 per peak Watt (Wp), but smaller systems which are typically <5kWp and are often installed on single dwellings are likely to cost more than £20 per Wp installed.

Building integrated photovoltaics (BIPV) is another product / market area where the UK could achieve a significant technical expertise. BIPV can be integrated into roofing tiles, facades, cladding and shading materials, or mounted on the building as a separate unit. The advantages of this technology include its ability to be used in urban areas, its highly modular and distributed nature and its low maintenance needs. There is significant academic and industrial interest in BIPV in the UK and elsewhere. Research is also active in novel areas in PV cell development in at least seven universities in the UK, including novel construction methods and materials, the use of organic dyes, high temperature PV and concentrators (see below).

1.1 Resource

In a review of the potential for renewable energy technologies in the 21st Century in the UK, ETSU estimated the technical potential for BIPV to be 266 TWh/yr (958 PJ; ETSU, 1998). This estimate was calculated by modelling predicted electricity generation from PV panels placed on all domestic and non-domestic buildings. Roofs and facades at all orientations were considered.

However, those receiving lower insolation (e.g. north facing or shaded) would only be available at a significantly higher cost. When the possible rate of PV uptake in new buildings was considered, a practical potential of 37 TWh/yr was calculated (133 PJ electricity; ETSU, 1998).

ETSU (1998) also projected the costs of PV to fall from the current value of greater than 70 p/kWh (£194/GJ) to 10-16 p/kWh by 2020 (PIU, 2001h). These projections were based on the historic learning rate for the technology, and therefore do not allow for the significant cost reductions that may result from new technologies e.g. thin film modules or future innovative PV materials. This longer-term trend in innovation is projected to lead to a potential cost reduction to 6–10p/kWh (£16.7 to 2.8/GJ) by 2025 (PIU, 2001h).

1.2 Technology

The range of technologies being explored is briefly summarised below. PV devices may be classified by physical form:

- crystalline
- amorphous

Of which there are four basic types of implementation:

- Mono-crystalline silicon
- Poly-crystalline silicon
- Amorphous silicon i.e. ‘thin film’
- Hybrid – combining amorphous with crystalline (e.g. Sanyo panels)

The primary aim in the development of the photoelectrical materials / cells is to increase the efficiency of converting solar radiation to electricity per unit area whilst at the same time lowering the costs of production. This can occur by developing cheaper photoactive materials either by novel production methods or through changes in composition. A second approach is to improve the efficiency of conversion by using more expensive materials but where the increased efficiency allows the costs of relatively cheap concentration equipment to be offset, thereby lowering the overall costs of implementation.

However, the photoactive materials, the ‘cells’, in a PV system often represent less than half the total cost of system installation (Omer *et al.* 2002) and significant scope for cost reduction is also available in the so-called ‘balance of system’ (inverters, supporting structures, metering, etc).

Balance of system (BoS) areas/devices under development include:

- Building Integrated PV (BIPV) e.g. Solar Tile, glazing, etc
- Modules
- Street furniture (street lamps, bus shelters, parking meters, road signs, etc)
- Production of dedicated silicon
- Collateral PV related products, e.g. Maximum Power Point PV controllers

2. Recent history/background

The PV systems currently being installed in the UK range from R&D to commercial implementation, although nearly all systems currently being installed are heavily reliant on capital grants. A preliminary investigation of the RD&D infrastructure in the UK appears to highlight an almost complete lack of basic manufacturing / supply chain capability in the UK. With the exception of Crystalox (a silicon production developer; www.crystalox.com), there are no silicon supply, cell manufactures or module assemblers currently active. Three are a number of universities carrying out a range of R&D activities related to PV development from fundamental materials research through to BIPV and systems development (see academic research below).

Recent developments:

- Dual-string extrusion (Evergreen Technology; USA)
- Triple-junction amorphous.
- Spherical crystalline- originally developed by Texas Instruments in 1990s.
- New manufacturing techniques which automate production e.g. using robotics.
- Optical concentrators with precise solar trackers e.g. Ammonix.
- Back pin electrical contacts for crystalline devices, e.g. used for computer chips with real-world efficiencies exceeding 23% e.g. Ammonix.
- Product integration, e.g. PV-specific water pumps, communication and lighting products.
- Balance of System (BOS) product development.
- Achieving higher efficiency per installed kWp (both in terms of more efficient modules and more efficient energy conversion devices) and Thyristor-based DC power sharing between large banks of grid-tie inverters.
- Demand-side energy reduction e.g., LED lighting.
- Wireless PV (avoids junction boxes, bypass diodes, and DC cabling).

3. The industry

3.1 Overview

This has been a rapidly growing sector in the UK over the last 3 to 5 years stimulated by continued technology developments and a range of government grants and incentives. However, the national industry is dominated by systems integration and development companies with very few supply chain companies managing to survive. The world-wide PV industry is characterised by established energy industry players (e.g., Shell, Kyocera, BP-Solar, RWE, Sharp, etc.) that have long term visions of market development and are able to cope with the risks involved in such an innovative industry in the early stages of development. More recently in the UK, the private sector has been willing to provide funding to the PV industry and several PV system designs are being developed entirely by the business sector with private venture capital.

Various research community developments may prove to be major breakthroughs, but must first be proven in the real world. Examples of these include non-silicon organic dye based solar cells, as well as other non-silicon metallic wafers. There are a wide variety of competing technical approaches, roughly divided between amorphous and crystalline technologies, but this is rapidly changing, with many manufactures such as Shell doing both.

However, changing economic conditions have greatly affected manufacturing costs and markets and there have been many recent incidents of PV companies going into receivership including the UK based Intersolar and the Germany-based Antech Solar Gmbh.

3.2 Leading countries

The UK is not a leading supply chain development country in the area of PV – see below. USA, Japan and Germany are amongst the world leaders; although several UK university research groups are believed to be involved (see below) and one company (Crystalox) is developing innovative solutions to silicon production. A detailed global synopsis of the PV industry can be found on www.solarbuzz.com and for the UK on the British Photovoltaic Association's website: http://www.pv-uk.org.uk/index.html.

3.3 Main players of relevance

A number of companies have reasonably well developed devices and commercial development strategies. Front runners include:

- Shell Solar (now includes Siemens; US and Germany)
- BP Solar (UK, Spain)
- Solar Century (UK; www.solarcentury.co.uk)
- Kyocera (Japan)
- Sanyo (Japan)
- Sharp (Japan)
- RWE Schott Solar Gmbh (US and Germany)
- Evergreen Solar Technology (USA)
- Crystalox (UK; www.crystalox.com)
- Flaberg (Germany)
- Sundog (UK)
- Romag (UK)?
- Wind and Sun (UK) ?

The list of companies active in the UK will be further developed once either Gary Shanahan or James Marsh from the DTI have been contacted.

Leading universities and institutes with research activities in this area include:

- Imperial College London (Organic dyes; Ga-As with solar concentrators; thermoPV)
- Salford
- Cambridge
- Reading
- Southampton (http://www.serg.soton.ac.uk/solar/solar.htm)
- Sheffield Hallam University
- Loughborough (CREST; BIPV)

Imperial college is one of the leading research institutes in this field and contacts with relevant researchers are being established.

4. The innovation system

Innovation in the PV sector is occurring throughout the production, supply, installation and monitoring & maintenance stages of the chain globally. RD&D in the UK appears to be much more limited and is being focussed on the front and back ends of the chain with very little supply chain development occurring. Fundamental materials development is occurring in UK Universities and systems integration / development and monitoring is occurring in both the academic and private sectors. Although venture capital is emerging to support the existing private sector it is believed to be high risk and may be mostly originating from outside the UK. The relatively small scale of the existing industry is likely to mean that continued government support will be essential to maintaining or expanding the R&D base as the industry itself will be unlikely to generate sufficient funds.
The industry itself supports this view having submitted a statement of advice to the DTI (3.02.2002), as part of the Energy White Paper consultation. It called for more Government

investment in photovoltaics (PV) as part of Britain's future sustainable energy mix. The industry group responsible for the submission spans nine sectors: transportation (BAA), energy (Centrica), insurance (CIS), banking (Co-operative Bank), architecture (Foster and Partners), engineering (Halcrow), chemical (ICI), retailing (Kingfisher), property development (Land Securities) and the Corporation of London.

4.1 Innovation stimuli

The UK Department of Trade and Industry (DTI) currently provides the following funding which is applicable to PV:

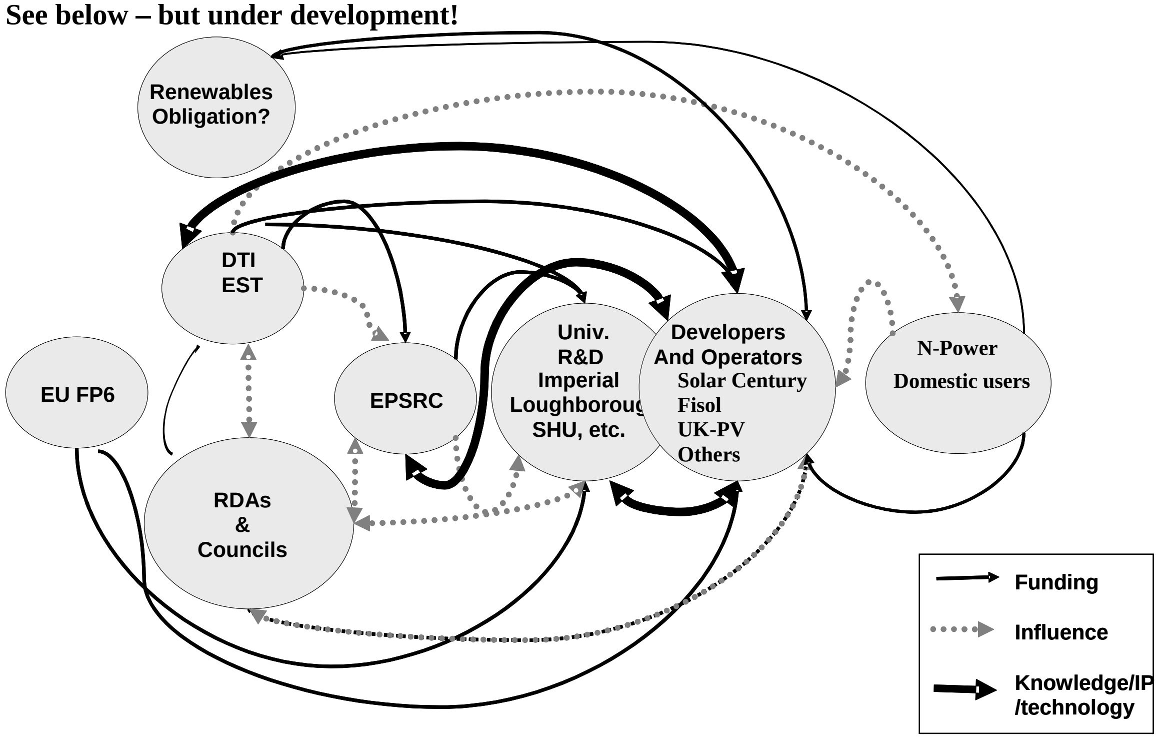
- Industrially led match funding (managed by EST)
- Early demonstration / Major Demonstration Programme
- Capital Grants Programme
- Renewables UK
- Community Renewables Initiative
- Clear Skies Programme (in Scotland)

DTI is awarding £2 million of funding for 18 photovoltaic projects throughout the UK under the major demonstration programme. This follows on from last year's DTI grants of 50% contribution to the capital / installation costs of grid-tied PV systems.

In addition, the EPSRC has awarded grants for equipment purchases by Academic research institutions and Regional Development Associations (RDAs) and councils may also provide community development funding.

4.4 UK innovation map

See below – but under development!



Contacts for Consultation / Interviews:

- PV-UK (01908 442291)
- Crystalox (Tel: 01235 770044)
  - Barry Garrard interviewed 15apr03- e-mailed 10apr03
- Imperial College London (Jenny Nelson and Tom Tibbits)
  - Tom e-mail for informal response 10apr03
  - |Jenny Nelson: 7594 7581, called and e-mailed 10apr03
    - interviewed 3:00pm 14th April
- Solar Century (Seb Berry, Dan Davies or Jeremy Leggit?; +44 (20) 7735 8101)
  - phoned and e-mailed questions 10apr03 for interview next week
- DTI (James Marsh or Garry Shanahan)
- Cambridge Display Technology (not really necessary)
- BP-Solar (Ray Noble (01932 779543; nobler12@bp.com) ask Chris Hedley to set up meeting)
  - phoned and left message 10apr03 am and e-mailed him.
- Sundog or Wind and Sun??
- London Business School (Andrea Masini (72625050 ext. 3851), learning curves).
- Lambeth Council (Colin Monk, Energy & Housing Officer);
  - meeting and interview agreed for 10th April 2003 after CHPA meeting.