A SKILLS AND TRAINING NEEDS ANALYSIS FOR SOLAR PHOTOVOLTAICS A WELSH AND UK PERSPECTIVE

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Abstract
A Skills and Training Needs Analysis (STNA) to review the current delivery of low carbon education within the UK Higher Education Sector, was conducted for Solar Photovoltaics (PV). The PV STNA revealed a sizable University presence in technology development across the different PV technologies, but a lack of existing provision focusing exclusively on Solar PV across the Higher Education Institutions at level 7. Twenty four Post Graduate courses across the UK including ten within Wales were identified, which cover Solar PV content at master's level, but this is mainly delivered as part of a low carbon technology module providing an overview of the main renewable technologies e.g. Solar PV, Solar Thermal, Marine, Hydrogen and Wind. The main areas of interest for new training provision are: PV Systems and Design, Advanced Manufacturing, Emerging PV Technologies, Buildings as Power Stations and End of Life Considerations. The STNA highlighted that the training provision offered by the Welsh Energy Sector Training (WEST) project needs to be demand led and align with the identified training needs of the industry to ensure successful uptake of the new training provision and maximum benefit to the Welsh and UK energy sectors. That said, it is also incumbent upon providers to fulfil a leadership role, by identifying the training that is required to meet future industry needs given the changing context for the UK solar industry.

Key words: *Solar, Photovoltaics, Training, Renewables, Blended Learning*

1. Introduction

The renewable and low carbon sector is one of the few industry sectors that has been growing (Department of Energy & Climate Change, 2012). In the year July 2011 to June 2012, the total electricity generation from renewables in the UK increased by 27%, reaching 37.9TWh from a total of 14.4GW installed capacity (Department of Energy & Climate Change, 2012) The strong performance compared with that of other sectors highlights that a long-term view and investment in renewables would be beneficial in providing opportunities for UK businesses. 2013 was an exciting time for the UK PV sector with the UK accounting for approximately 2 % of global PV installations and was able to scale up and install over 1GW of capacity in less than 12 months.

That said, the sector also faces challenges. Whilst installations of Photovoltaic devices have been growing at a steady rate, the UK only captures the value from part of this supply chain – as many of the devices installed are imported, and few are made in the UK. Crystalline silicon currently dominates the market (Irvine, 2013). In the UK, there is some final assembly of crystalline silicon modules – however, given the low cost of imported PV cells, it is challenging for the UK to compete with China.

A question that has been contemplated about sustainable technologies in general (Harper & Wells, 2012), is whether in the quest for sustainability, a diversity of solutions is desirable – or whether this results in duplication and wasted resources. As both the EU and US struggle to compete with cheap silicon photovoltaic devices from China, can the UK build 'resilience through diversity' (Harper, 2014) and look to other photovoltaic technologies as potentially profitable goods to manufacture in the UK? Can value be created through the generation of new knowledge, insight and innovation.

There are a range of other PV technology trajectories – thin-film cells and excitonic cells which occupy a much smaller proportion of the marketplace. Whilst presently less efficient, they promise the potential of continuous production processes that may enable them to be produced more cost effectively. These new processes will require skilled workers, research scientists and engineers with an appropriate blend of skills and expertise.

In conducting the STNA, there is both an immediate, and a longer term goal. The immediate pressing goal, is to look for how the current industry context informs the development of new courses and training. However, the longer term goal is to look at the context the UK industry operates within, how it might evolve and anticipate the training needs of the future. In this respect, the research adopts the perspective of Van de Ven's (2007) practice of 'Engaged Scholarship', positioning the researcher in an active dialogue with industry and engaging with Key Stakeholders has been adopted in order to produce a piece of work that is relevant to the UK Solar Industry.

2. The Changing UK Solar Industry Context

The stimulus in the form of 'Feed In Tariffs' has led to a growth in installations of Solar Photovoltaic devices. At the start of 2014 it was announced by DECC (Shankleman, 2014), that under the Feed-In-Tariff incentive scheme, there were now half a million installations of less than 50kW under the scheme. The UK solar industry installs around 1900 new PV systems a week (Shankleman, 2014). The Feed In Tariff scheme has been effective in encouraging the uptake of solar technology in the UK. Alongside this, with the volume of installations, the costs of solar installations have fallen and capacity has been built within the UK supply chain (Irvine, 2013). But, as Lewis (2012) notes *"In the solar energy sector, the countries that lead the world in the production of solar photovoltaic (PV) cells or modules currently are not the same countries that lead in the deployment of solar technology.*

That said, there are still opportunities for growing the UK Solar Industry. Greg Barker MP, Minister of State for Energy and Climate Change has said that *"Great Britain is now the most exciting growth market for solar in Europe. And there are three prime reasons why the UK should be the destination of choice for any solar company looking to invest in Europe First, our UK domestic market has the greatest growth potential in the EU. Second, the UK has a reformed, robust and fully-financed support framework for renewables, set all the way to 2020 and beyond. And third, we are an emerging global hub for advanced manufacturing."*

The final point is moot, whilst there are now robust supply chains to provide the materials for this growing industry, very few PV devices are manufactured within the UK. Far eastern manufacturers have significantly undercut European and US manufacturers in the production of crystalline silicon solar cells. The growth of China's market share in the past few years has been nothing short of spectacular. As Lewis (2012) notes, in 2007, Chinese PV comprised around a third of the market, by 2011 this had risen to 57%. By 2011, no EU or Japanese manufacturers appeared in the top 10 global PV manufacturers, but the Chinese manufacturer Suntech had held the position of the largest solar manufacturer for the second year. This provides a challenging context for UK manufacturing. Some have described this as a 'Solar Trade War' (Traynor, 2012; BBC News, 2013).

Carbaugh & St. Brown (2011, 9) note that in 2011, three large US solar companies entered bankruptcy, which left Chinese firms dominating the marketplace with a two-thirds share. Carbaugh & St. Brown (2011, 9) go on to note, that whilst Western Manufacturers can claim technological superiority to Chinese manufacturers, they are unable to compete on the grounds of cost. Some EU nations, such as Germany, have objected vociferously against what is known as 'dumping', which the Solar Trade Association (n.d) define as, *"charging a lower price in an export market than is charged in the home country of the producer. It is seen as an anti-competitive strategy aimed at capturing market share in the export market using profits made on the domestic market."* There have been concerns in some EU countries that these cheap imported cells, allegedly subsidised by the Chinese domestic market, undermine the competitiveness of European manufacturers.

As a result, there have been moves to impose sanctions and erect trade barriers to cheap imported PV's in the US and EU. Clark (2013) is among many who have criticised this type of response, noting *"transforming trade policy mistakes into energy/environmental and export policy failures."* However, in Britain, there is a different position to the US and some of the other EU nations. This has led Greg Barker MP to comment (Bennett, 2013a) *"Britain – perhaps more than anyone else in the EU – stands for free trade and global competition. We have always done so, and will always continue to do so. That is why we have led the fight against the imposition of damaging and counterproductive anti-dumping EU levies on imports of Chinese solar panels."* Perhaps this is understandable, given the lower levels of PV manufacturing in the UK, there is less of an industry to protect.

The UK has developed experience and a track record of assembly, module manufacture and design combined with coated glass manufacture. This places the UK in a prime position to build its manufacturing capacity, based on innovation, to compete in the global market. PV module manufacturing capacity in the UK was in the region of 600 MW per year. The majority share of this was accounted for by the Sharp Ltd module factory in North Wales and Romag's specialist glass and high quality architectural PV modules.

For the UK, the regional context for this industry is emerging. Competition based on labour-cost is impossible so there is a need to discover distinct regional strengths in order to stay competitive. There is an importance to focusing on products which offer a high degree of Gross Value Added. This means focusing on strategic niches and technologies that whilst not perhaps offering the highest conversion efficiency, offer attractive returns through economic competitiveness.

Furthermore, the technical properties of thin film cells lend themselves to capturing diffuse light, whereas silicon solar cells perform better with direct light. This may be considered a good fit between the technology and the weather of the regional market the technology could potentially serve.

3. The Welsh Context

In Wales, the competitive situation within the solar industry has been given particular poignancy by the closure of Sharp's module assembly in Llay, Wrexham (Pultanova, 2013) – where imported silicon solar cells were assembled into modules. In a statement to the press, Sharp CEO for Europe, the Middle East and Africa, Hiroshi Sasaoka had noted (Hall, 2013) that the 30% fall in European PV prices had created market conditions in which the decision to close the Wrexham plant was unavoidable.

Bennett (2013b) presents a graph, that shows how in the period from the first quarter of 2010 to the third quarter of 2013, the output of the Wrexham plant at one point largely served the European market which purchased over half of its output, over time almost wholly became redirected towards Sharp's domestic Japanese market. Bennett (2013b) cites Finlay Colville, vice president at NPD Solarbuzz, who provides an analysis of the fall of Japanese manufacturers in the EU marketplace. Colville (in Bennett, 2013b) notes that many Japanese manufacturers in the EU carried out final assembly, but imported cells and components from Japan and Taiwan. The EU market has become very competitive and commoditized with Chinese Tier 1 manufacturers cannibalising Japanese market share. By contrast, Japanese manufacturers still command a premium price in their domestic marketplace. Some however, have even abandoned manufacture of crystalline silicon cells in their own marketplace, outsourcing this to China / Japan. Sharp's Wrexham closure is set against this backdrop.

This begs the question given the difficult market conditions, how the photovoltaics sector in Wales can grow. The answer perhaps lies in technological diversity. Crystalline silicon may dominate the marketplace, however, there are other technologies such as thin-film cells, which promise the potential for growth. Thin film cells, whilst currently less efficient than crystalline silicon can offer cost advantages. There is also research within the (solar photovoltaic academic research consortium) SPARC consortium within Wales, which could lead to the production of thin film cells using continuous "roll to roll" processes. One company, BIPVCo in Wales, is already looking at utilising

thin-film cells on metallic substrates These different materials offer a range of opportunities in terms of Building Integration of Photovoltaic devices.

The production of these technologies on continuous processes could lead to significant cost reduction, migrating from "batch" processes to a continuous process. There are already photovoltaic devices being manufactured using continuous processes in Wales. G24i has pioneered the production of excitonic dye-sensitised solar cells, and there are other start-ups such as "DyeSol" in Wales, which are also investigating this technology. Whilst dye-sensitised cells can be produced on "roll-to-roll" processes, there are currently limitations with longevity to this technology which restrict their use to applications which require less durable technologies. For the market share of these technologies to grow installers and specifiers must be aware of the diversity of PV technologies their capabilities and relevance to different situations.

Another consideration that is specific to the Welsh context is that there are some variations in Governance. The Welsh Government (2012) sets out its energy strategy in "*Energy Wales: A Low Carbon Transition"*. Furthermore, there are some variances in the Building Regulations between England & Wales. These changes are set out in National Assembly (2012) of particular note, is the statement by Sargent (2013) relating to Part L of the Building Regulations, which are concerned with the conservation of energy.

4. The Welsh Energy Sector Training Project

The Welsh Energy Sector Training (WEST) project is supported by the Low Carbon Research Institute's (LCRI) Convergence Energy Programme. The main objective of WEST is to develop skills to aid the utilisation and uptake of new technologies developed through the LCRI industrial research projects (Banteli, Gwilliam and Stevenson, 2013). This will ensure that industrial research is disseminated through both traditional educational streams as well as directly to industry through Continuing Professional Development (CPD). WEST developed and implemented a STNA across five themes; Hydrogen Technologies, Large Scale Power Generation, Low Carbon Built Environment, Marine and Solar PV (Banteli, Gwilliam and Stevenson (2013)). The aim of the exercise was to establish the current delivery of low carbon education within the Higher Education Sector in Wales at levels 4-7 of the Credit and Qualifications Framework Wales (CQFW). This paper focuses on the findings of the Solar PV STNA that aimed to identify opportunities to develop training at Level 7 (Masters) of the CQFW that align with the research outputs of LCRI SPARC project.

SPARC Cymru project was designed to develop new photovoltaic materials for solar energy conversion towards low cost PV modules. The overall aims of the project were to enable grid parity for PV solar energy in Wales by 2015, enhance the adoption of solar PV electricity and help meet the ambitious carbon neutral target for Wales by 2025. The SPARC project aimed to accelerate academic research in new PV materials for solar energy conversion, leading to a new generation of low cost PV module products. SPARC explored both low cost dye sensitised solar cells (DSC) and thin film inorganic materials, whilst also addressing the power electronics used to extract the electrical power from the modules. Three broad areas of research were carried out from the production and testing of novel PV test modules on installations, to developing sophisticated power electronics to support PV and bring it into the domestic sector. The project included collaboration with eight industry partners from across the PV supply chain. The project was split into three work packages each focusing on a different research area; i) power electronics, ii) in line deposition of thin film materials and iii) rapid processing of DSC.

5. Experimental

Data collection was achieved by a combination of desk based research, one-to-one consultation interviews, questionnaire and networking at events with key stakeholders in the UK and Welsh PV supply chain and similar initiatives. Desk-based research was conducted to establish the remit of the existing training provision for Solar PV within Wales. As the UK PV industry is still relatively new

the scope of this research was extended to include the UK as a whole. Increasing the scope to include the UK also provides opportunities to see how WEST could impact beyond its current funding commitment (Banteli et al. 2013).

Consultation interviews were held with researchers from the SPARC project to ascertain the scope of SPARC and the potential training courses WEST could exploit. Details of the training arising from the SPARC project are discussed. To avoid duplication and ensure maximum benefit of WEST project a review of similar initiatives, previous experiences and existing reports relating to Solar PV training was undertaken.

Consultation with the Solar PV industry was achieved primarily through networking at relevant events, one-to-one discussions with key stakeholders including an Industry Advisory Group and a WEST Solar PV questionnaire, made available at WEST events and also online via the WEST project website. Information was also obtained from UK PV Roadmap 2013 (Irvine, S. J. C et al. (2013)) and feedback forms from WEST events. Interviews were aimed at establishing the professionals' interest in training themes that arose from the SPARC project and preferences and barriers to participation in training. In addition to discussions with industry stakeholders at networking events, feedback forms and questionnaires were also developed and sent out to contacts that had registered interest in the Solar PV theme of WEST or attended a WEST event.

Participants of the questionnaire were asked to comment on issues including:

- The value of accreditation for new courses
- The research themes within SPARC and their importance to PV delivery in their work
- Solar PV training themes they would be interested in receiving
- Methods of delivery

Participants were also asked to comment on the most crucial need for PV training within their company. Information gathered from the questionnaires and consultations regarding training themes and appropriate delivery methods are discussed

Consultation with the SPARC work package leaders revealed some potential training themes that they considered relevant to the research work undertaken on SPARC. The opportunities are discussed below for each WP.

5.1 Work Package (WP) 1: Power Electronics

WP1 offers the opportunity to develop training courses on any aspect of power electronics, PV systems and grid connection. These are key elements of WP1 and essential in extracting maximum power from PV modules. Training relating to outdoor environmental testing and performance monitoring is relevant to WPs 1 and 2. WP1 highlighted that research activities incorporated three key technologies within power electronics;

- Inverters
- Smart Metering
- DC/AC conversion

PV system training can focus on the system components, smart meters, inverters, grid connection and storage and also on system design, focussing on siting, inverter and panel choice and system size. Energy use and habits along with smart meters also have a key role to play in the future adoption of all renewable technologies as the grid needs to accommodate an intermittent power source from renewable technologies compared to the current constant power source from fossil fuels. The power generation during the summer days will be considerably higher from PV compared to the winter months. Smart meters also need to ensure that power generated from PV (and other renewables) is utilised before drawing upon the fossil fuels (e.g. mains gas or oil) supply. The issues of storage and smart metering are not unique to PV and apply to all intermittent power generation technologies including, wind and marine and is therefore applicable to a wider audience. WP1 held a seminar on *PV*

in Wales the post Feed-in-Tariff Reduction that was attended by 14 companies and provided a useful platform for the dissemination of information to industry. However, training on finance incentives and legislation falls outside the remit of WEST. These topics will only be mentioned for context rather than be the focus of developed training.

5.2 Work Package 2: Thin Film PV Modules

WP2 focuses on manufacturing scale up of thin film materials available in today's PV market, which directly compete with Silicon modules, but are often not selected for installations on small scale such as domestic roofs due to the lower power per unit areas but have been an attractive option for large scale ground mounted PV. WP2 also considers encapsulation technologies for module production as well as real world performance and reliability in partnership with WP1 by utilising environmental testing and outdoor testing in the Welsh climate. Training on PV installations within the Welsh climate could be vital to proving the worth of PV installations in Wales, changing public opinion that the Welsh climate is not suitable for PV. It also highlights that it is the design of the installation, choice of site and panels that ensure a beneficial PV installation, again supporting the opportunity for PV system design training.

With the scale up of manufacturing, consideration needs to be given to materials supply and waste stream in order to improve manufacturing efficiency. This is particularly relevant to PV as the availability of 14 critical raw materials is an industry concern, compounded by low substitutability and recycling rates. In addition training courses on advanced manufacturing, monitoring of PV systems and reliability and life cycle assessment of PV panels could be developed. The latter is particularly pertinent with the recent inclusion of PV modules in the recast WEEE Directive 2013 European Commission (2013a).

5.3 Work Package 3: New Materials for PV

Possible training opportunities suggested by WP3 researchers for WEST to explore include aspects of advanced manufacturing and advanced PV materials. In terms of specific training themes, the WP leaders suggested:

- Chemical, process and mechanical engineering (related to scale up),
- Market analysis and strategy,
- New product development,
- Investing in new technologies,
- Building new business sectors,
- Globalisation,
- Web marketing,
- Technical sales

Several of the identified themes are soft skills which are beyond the scope of the current WEST project. Therefore the relevant themes to develop include: new product development, chemical, process and mechanical engineering (related to scale up), and emerging materials. WP3 focusses on rapid processing and scale up of the emerging PV technologies and a key part to the research undertaken is the analytical and characterisation techniques required to assess the new processes and materials. Training on integration of PV technologies in buildings, particularly of new technologies coming to market and the end of life assessment of new technologies would also fit with this WP.

6. Recommendations / Results

The UK Solar Industry has observed a wealth of positive developments and a steady rate of growth. The market has been heralded as potentially one of the biggest growth markets in Europe, and so therefore if managed effectively there is the potential to create growth and add value.

In this paper we have built the case that there is a need for more in-depth training at Postgraduate level into Photovoltaic technologies. Why is a more in-depth understanding of the technology needed, when the industry already appears to be growing? Looking at the wider context of the UK Photovoltaic industry, whilst there is a steady growth in PV installations, this is only part of the photovoltaic value chain. At present, the UK captures a small fraction of photovoltaic manufacture.

Carbaugh & St. Brown (2011, 9) note that in recent years, there has been a mismatch of supply and demand as stimulus and incentives have encouraged the supply-side of the industry to develop, but with insufficient demand leading to intense price competition. It is clear that Western PV manufacturers cannot compete on cost as far as crystalline silicon PV technologies are concerned. That said, as the SPARC research programme shows, there are numerous opportunities for the development of thin-film and excitonic PV technologies that promise the potential of continuous 'reel to reel' manufacture. Whilst ultimately less efficient than silicon cells, these technologies offer the promise of economies of scale, continuous manufacture and commensurate cost reductions. If the intellectual property and tacit knowledge for developing these technologies can be retained and embedded within the UK economy, then there are interesting future avenues for PV manufacture in the UK.

PV Systems and Design, Advanced Manufacturing of PV materials, Emerging Technology and New Products have been identified as the broader themes for training opportunities within WEST. Of the 10 potential WEST training opportunities, power electronics is clearly the priority training area for WEST to address as 100% of participants ranked this theme as very important. 75% of participants also gave priority to;

- Solar: Scope, technological, environmental and societal perspectives
- Fundamentals of PV
- PV System Design
- Monitoring of PV (Siting and energy use habits)
- Energy Storage and Usage

The main areas of interest for new training provision within Wales that align with the SPARC research outputs are: PV Systems and Design, Advanced Manufacturing of Thin Film and Emerging Technologies and Buildings as Power Stations.

Additionally, another theme that was highlighted, was the need to provide awareness about the End-of-life considerations for photovoltaic materials. This has been driven by changes in European legislation. (European Commission, 2013a).

7. Conclusions

A Skills and Training Needs Analysis (STNA) was conducted to establish the basis upon which the WEST project could develop prospective training provision in PV at HE levels 4-7, as well as CPD for up-skilling the workforce in the Welsh energy sector in relation to the research outputs of the SPARC project. Of the 10 Welsh PG courses only three have solar specific content in their syllabus beyond a simple introduction to solar PV incorporated into a larger introductory module to renewable technologies. Surprisingly there are no master's level courses that focus specifically on Solar PV available at UK HEIs. All postgraduate courses that feature Solar Energy, do so as part of either a broader curriculum looking at Renewable Energy Technologies more widely. There is also a gap in the existing provision that WEST could exploit for research informed solar PV training within Wales. Currently the most comprehensive course within Wales on solar PV, which is not directly aimed at

installers trying to achieve MCS accreditation, is the Photovoltaic Systems six day course offered by the Centre for Alternative Technology (CAT). This covers solar geometry and resource, PV technologies (types and characteristics), stand alone and grid linked systems, mounting systems, modelling and building integration. CAT also offers training in photovoltaics at Postgraduate Level, with its MSc in Renewable Energy in the Built Environment, but again, Photovoltaics are featured as part of a wider renewable energy offer.

One notable development is the EPSRC Centre for Doctoral Training in New and Sustainable Photovoltaics (2014). This initiative draws together the Universities of Liverpool, Bath, Sheffield, Loughborough, Southampton, Oxford and Cambridge in a bid to provide Postgraduate research opportunities to doctoral students. This initiative is supported by £8million pounds in funding, and will provide opportunities for 65 doctoral students. There are also 12 industrial partners engaged with this initiative.

For Wales and the wider UK to develop and grow the domestic photovoltaic industry, we propose that there is a need to provide postgraduate taught courses, which cover Photovoltaic technology in more detail and depth as would befit a full Masters' course specialising in Photovoltaic technology. To this end, through the support of the WEST project, and building on the training developed within the project Glyndwr University developed and validated an exemplar MSc. Photovoltaics programme.

There is already a well-developed system in the UK for training and regulating installers of photovoltaic systems. It was identified that from a CPD perspective, there was insufficient training, targeted at others working within the Built Environment in order to familiarise them with PV technologies. In particular, there is a lack of familiarity with those technologies which are either new to the market, or only occupy a small portion of the market. These are the thin-film and excitonic technologies, which could potentially help the UK regain competitive advantage in PV manufacturing.

For PV technology to develop and gain acceptance in society, there is room for a diversity of solutions, and there are still significant challenges with public acceptance – especially as far as large scale ground mounted PV is concerned. The bulk of building mounted PV installations comprise "retrofit" or 'bolt-on' installation of PV devices, which is not always aesthetically pleasing. Greater dissemination of options for Building-Integration of Photovoltaics will firstly help to improve the quality of the built environment; but may also help in creating a market for the more unusual, custom or bespoke PV technologies which have a higher degree of value-added. Here, there are opportunities for UK manufacturers to engage with integrating PV technologies into buildings, in ways that target a more premium segment of the market through enhanced quality and aesthetic improvement.

In terms of the methods and modes of delivery, engagement with industry suggests that traditional face-to-face delivery combined with digital files on a website that can be revisited and updated with new information provides the most desirable learning experience. A blended learning approach is the most popular delivery method and gaining a qualification is the second highest reason given to undertake a course. Cost is the greatest barrier to attending training therefore WEST is well placed, through its support from the European Union to address these barriers and deliver blended learning courses free to people living or working in the convergence areas of Wales.

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