WELSH ENERGY SECTOR TRAINING: A CASE STUDY OF RESEARCH INFORMING EDUCATION

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Abstract
Many countries report challenges translating research into commercial practice. Although funding is often blamed, lack of appropriate dissemination and engagement with industry can also be an issue. The Low Carbon Research Institute has tackled these issues through Welsh Energy Sector Training. Professional training is being derived from research in the fields of Hydrogen, Large scale power generation, Low carbon built environment, Marine energy and solar PV. Widespread engagement with industry has identified the most relevant research based training topics as well as refining delivery methods.

Key words: *Research, training, continuing professional development*

1 INTRODUCTION

Public funded R&D can be measured in a variety of ways, although commercialisation of targeted technologies is often considered the most important (Kimura, 2010). Knowledge 'diffusion' or 'transfer', the subject of this paper, has been highlighted as an important step on the road to commercialisation by a number of authors (Boehm and Hogan, 2013, Walsh, 2012, Aarikka-Stenroos and Sandberg, 2012) (Balachandra et al., 2010).

The Low Carbon Research Institute Convergence Energy Programme (LCRI-CEP) is partly funded by the European Regional Development Fund through the Welsh Government to lead research to cut carbon emissions. To this end, it has undertaken major research projects in each of the following themes: Hydrogen (H2), Large scale power generation (LSPG), Low carbon built environment (LCBE), Marine energy (Marine) and Solar Photovoltaic (Solar PV) since 2010. As is usual for academic research, the results of this work has been disseminated using traditional routes during the projects, including journal papers, conference presentations, themed seminars and annual conferences.

The Welsh Energy Sector Training (WEST) also funded through the LCRI-CEP has the objective of developing research based training to inform professionals working in or aiming to work in the energy sector. It is argued here that this Continuing Professional Development (CPD) can be considered as an effective alternative knowledge diffusion mechanism.

The need for and provision of CPD, has been acknowledged in many fields since the 1970s with the attendance and participation in either formal or informal education, being required in order to maintain professional registration (Eraut, 1970). For example, RIBA currently requires a minimum of 35 hours per year (RIBA 2014). In order to respond to this need however, any training targeted explicitly at such a professional and employed sector, must consider carefully, a variety of factors, in order to ensure that both the content and delivery mechanism is carefully tailored to the specific needs.

Sections 2 and 3 of this paper will describe how the WEST training strategy was developed through reviewing existing provision and investigating demand while section 4 will summarise the training programme developed as a result.

2 REVIEW OF EXISTING LOW CARBON EDUCATION AT FURTHER EDUCATION AND HIGHER EDUCATION LEVELS

The first stage in developing WEST's strategy was to review the further and higher education and training available to the inhabitants of the Principality of Wales on the subject of low carbon.

2.1 Further Education Review (Rudd et al., 2014)

The majority of low carbon relevant courses offered by further education institutions were found to be aimed at apprentices in the plumbing and electrical trades. Despite this, topics such as solar thermal, photovoltaics, wind, hydro power, geothermal, heat pumps and biomass were available; however, not all of these were available in all geographic areas. The lack of specific renewable energy courses was attributed to insufficient demand. This originates from local employers recruiting traditionally trained and qualified personnel as they consider that this is a sound basis on which to build additional skills such as installing renewable energy systems. Very little e-learning was available as it was considered unsuitable for assessment of such practical skills. It could be argued; however, that awareness raising and fundamental knowledge could be effectively disseminated through such routes, complementing traditional face to face delivery and minimising time "off the job".

Training companies offer installation training on a variety of renewable energy technologies including solar thermal, photovoltaic, heat pumps, biomass, wind and hydro power. These companies were accredited by a range of bodies including the Microgeneration Certification Scheme, Renewable UK, Logic Certification, BPEC, Heating Equipment and Testing Approval Scheme, NIC Certification.

The following gaps in further education low carbon education were identified across Wales:

- Low Carbon Economy concept
- Importance of Energy Security
- Replacement of existing generation capacity

On a geographical, regional basis, the following content gaps were also identified:

- Reducing carbon emissions to reduce potential implications of climate change
- Costs of not complying with EU requirements for carbon emission reductions
- Education for specifiers on capacities of various renewable energy systems
- Planning permission and renewable energy technologies

2.2 Higher Education Review(Banteli et al., 2014)

Foundation and Undergraduate degrees were generally found to have little low carbon specific content. However, postgraduate qualifications were found to be more relevant and were evaluated in the context of the following themes:

- Hydrogen (H2)
- Large Scale Power Generation (LSPG)
- Low Carbon Built Environment (LCBE)
- Marine Energy (Marine)
- Solar Photovoltaics (Solar PV).

Thirty six relevant modules were identified within twenty two courses currently available in Wales. In general, modules relevant to LCBE and Solar PV were the most widely available, followed by LSPG, Marine and H2. The majority of the Welsh courses were available in the South of the Principality, in particular H2 training was not available at all in Mid or North Wales.

It can be argued that professionals in employment are unlikely to be able to access full time courses, but may be able to access part-time or distance courses and in this context the suitability of the existing provision to this sector was evaluated (Figure 1). It can be seen that a significant proportion of LCBE modules are available on a part-time or distance learning basis. Solar PV and Marine follow the same trend, but with fewer overall modules, while LSPG has some representation in part time and distance modules and two of the three H2 modules are available on a part time basis.

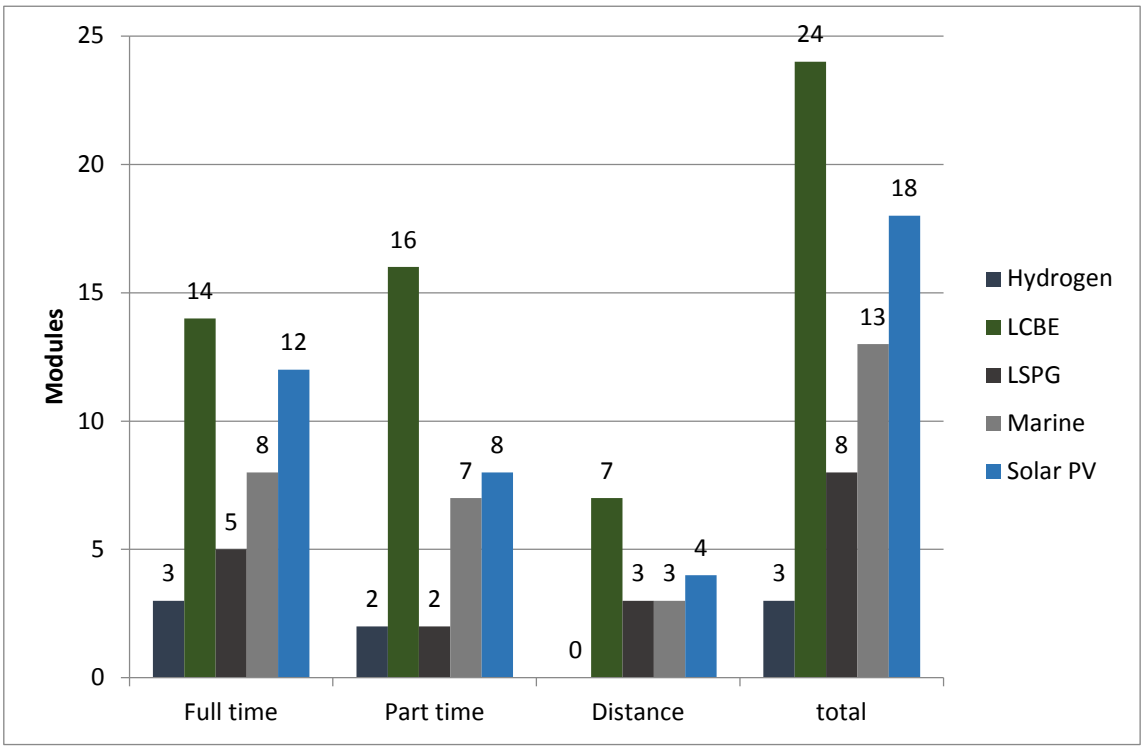

Figure 1. Study options of the modules relevant to the energy themes (NB some modules are available in more than one format)

3 SKILLS AND TRAINING NEEDS ANALYSIS

For each energy themed research project, the outputs were assessed for their suitability for development into training with industrial interest being gauged for these identified training topics as well as training delivery methods. In the subsections below, the research is set into context, potential training topics are identified and the view of the relevant industry is presented for each theme.

3.1 H2 (Reed et al., 2014)

The world market for hydrogen as a chemical exceeds $50billion per year; however, hydrogen for energy use is only a fraction of this. Transition to a position where hydrogen is widely used for energy will require awareness raising followed by training for industry. Road transport is likely to be one of the first sectors to use hydrogen energy; this may be followed by boats and ships. Hydrogen in tandem with renewable electricity generation may be used for power by off-grid communities: while fuel cells are seen as a catalyst for the use of hydrogen. Against this background, the key research areas within the LCRI CEP were:

- Hydrogen energy storage development
- H_2 & H_2/CH_4 vehicle and refuelling infrastructure development
- Industrial development of the $BioH_2$ and $BioCH_4$ process
- Experimental development of the recovery and clean up of product gas, intermediates and co products.
- Development of product gas, intermediate and by-product end use and applications
- Economic and life cycle assessment of the above points

The following training needs were identified (many of which relate to more than one of the research areas identified above):

- Building integration of H2 and fuel cell systems
- Control
- Electrical grid connection and grid management
- Electrical safety
- Electrical systems design
- Electrical systems for renewables
- Electrochemical systems
- Electrolyser Development
- Fuel Cell development
- **Gas handling**
- Modelling and simulation
- **Safety in explosive atmospheres**
- Solid state hydrogen storage mechanisms
- Vehicle drive train

Two immediate needs have been identified in the area of hydrogen energy (as highlighted in bold above). The first need is to address the awareness raising requirement identified in the context setting. To meet this, a general introduction to hydrogen and fuel cell technology is planned. The second is a course with a focus on the automotive industry, with due regard to hazard awareness.

3.2 LSPG (Hewlett, 2014)

In 2009 power generation contributed 27% of UK carbon emissions while industry contributed 23%. Both UK industry and power generation have already significantly reduced their carbon emissions despite increasing demand: industry by 46% between 1990 and 2009 and the power sector by 23% between 1990 and 2011 (DECC, 2011). Looking forward, it is expected that fossil fuel combustion will still contribute significantly to the energy requirements of industry and power generation in 2030. For this reason it is essential to further improve combustion efficiency and increase the combustion of biomass and biogas in the short term and implement carbon capture in the long term as well as developing alternatives to combustion. To address this research need, Cardiff University School of Engineering designed and commissioned a generic burner in conjunction with a large scale gas mixing facility capable of producing gaseous fuels representative of sustainable alternative fuels envisaged for future use. Building on this, indigenous fuel sources were evaluated in relation to their use in current gas turbine technology.

The following training options were identified:

- **The nature of fuels**
- Utilisation of waste
- **Energy Conversion Processes (i.e.**
- Gas turbine emissions
- Gas turbine flame stability and combustion noise

combustion, gasification and pyrolysis)

- **Energy conversion technologies**
- **Combustion Science**
- **Improving combustion efficiency and emissions**
- Combustion risks and hazards
- Gas turbines: fuel variability and alternative fuels
- Combustion performance in gas turbines and thermodynamic cycles
- Gas turbine theory, design and performance

A survey of industry representatives found that there was industrial interest for all of the courses, but the strongest interest was shown in the options highlighted in bold above.

3.3 LCBE (Ruiz del Portal et al., 2014)

"*Almost half of UK CO_2 emissions are connected to our built environment*" (Sector Skills, 2009) but "*By 2050, all buildings will need to have an emissions footprint close to zero*." (DECC, 2011). There are several aspects of the built environment which can contribute to reducing future carbon emissions. For this reason, research in this field, undertaken as part of the LCRI CEP was divided into the following sections:

- Sustainable Building Envelopes
- Energy efficient lighting solutions
- Use of timber in building construction
- Design of Low/Zero Carbon Buildings
- Urban scale energy demand and supply
- Monitoring the performance of low energy buildings
- Innovation, technology deployment and market development

The following training options were identified:

- Energy generation technologies
- Energy storage / release
- **Sustainable building envelopes**
- **Transpired solar collectors**
- Phase change material for thermal buffering
- Radiant wall and ceiling systems
- **Low carbon building design (from inception to maintenance)**
- **Low carbon building fabric solutions (airtightness, insulation, thermal bridges)**
- **Sustainable building procurement**
- Methods for assessing the environmental performance of building fabric / systems
- Effective use of monitoring building
- Energy and environmental prediction model (EEP) simulation tool training
- Efficient lamp types, luminaire types
- Key properties of light and lighting
- Design (space / occupancy lighting requirements) and maintenance
- How to implement the energy and effective lighting criteria
- Lighting controls
- Lighting calculations, software packages
- Applications and industry standards
- Integration of renewable energy generating technologies in low carbon building design
- Low carbon design including basic principles

performance

- Post occupancy evaluation and assessment of occupant comfort
- **Basic principles of using timber in construction**
- **Timber construction products**
- **Joinery products**
- **Using Sketchup to simulate building/urban energy performance**
- **Embodied energy at an urban scale**
- **SAP rating of building typologies**

of artificial lighting design

- Integration of timber in low carbon building design
- Low carbon building fabric solutions – methods for assessing the energy and environmental performance of fabric
- Sustainable building procurement – gap between "as design" and "as built"
- Assessment of low carbon building solutions at urban scale

Industry representatives were surveyed for their levels of interest in the potential training topics. In addition, the topics were compared against (Essex and Hirst, 2011) review of the low carbon skills required for the Welsh built environment sector. From this assessment the following training topics were selected:

- Holistic design of low carbon buildings
- Welsh timber in building construction
- Energy simulation: building and urban scale

These cover the majority of the favoured training topics highlighted in bold above.

3.4 Marine (Potter, 2014)

The UK has the best marine energy resource in the European Union, which is predicted to be worth up to £6.1 billion to the UK economy by 2035, creating nearly 20,000 jobs. Since marine energy is still at a very early stage in the UK, the research foci within the LCRI CEP were:

- Implementation – undertaking strategic site appraisal for selected marine energy projects. The appraisal includes low carbon analysis and economics
- Far field modelling – ensuring the marine renewable energy devices provide the maximum possible energy extraction whilst having minimal impact on the aquatic quality environment and nearshore morphology.
- Near field modelling – developing a validated tool which can be used in the decision making process with respect to the environmental effect of device installation
- Data acquisition – developing baseline information around the Welsh coast to help understand and predict future impacts.

The following training topics were identified:

- **Site selection**
- Resource study
- **Environmental surveys**
- Design of wave marine renewable energy devices
- Design of tidal marine renewable energy devices

- Marine wildlife surveys
- Project feasibility studies
- Strategic project planning
- CAD design
- Oceanographic fluid mechanics
- Coastal hydrology

Industry representatives were surveyed for their levels of interest in the potential training topics. These results were also considered in relation to the wider marine energy supply chain and the findings of the Low Carbon Energy and Marine Power Institute Project: Skills Needs Research in the Energy Sector in Wales (Miller Research, 2013). From this assessment the following training topics were selected:

- Tidal energy conversion
- Wave energy conversion
- Long-term wave analysis

These cover the training topics highlighted in bold above.

3.5 Solar PV (Rowlands-Jones, 2014)

Global installations for PV stood at 102GW by the end of 2012, showing that PV already has the electricity generating capacity of 16 coal fired power stations. The PV market is predicted to be worth $155 billion by 2018 (Jones, 2013).

At the end of 2013, the UK had exceeded 3.0GW of PV installations and was placed 6th in the world for large (Colville, 2014b) and small (Colville, 2014a) PV installations. This places the sector in an excellent position to achieve 7-20GW of PV in the UK by 2020 (DECC, 2012). By 2020, the UK could have up to 63,000 jobs in PV manufacturing and 150,000 in installation and services (Jones, 2013). The increase in large scale PV projects (Colville, 2014b) has changed the training emphasis from installation to PV System design as well as electricity transmission and storage.

It should also be noted that the recast of the Waste Electrical and Electronic Equipment (WEEE) Directive (European Commission, 2013) now includes PV modules. This means that the EU PV industry will have a legal obligation in relation to waste associated with the production and end of life of PV modules.

The research directions in this sector were:

- Power Electronics (particularly inverters, smart metering, DC/AC conversion). These issues are also relevant to other intermittent renewable power generation technologies.
- Thin Film PV Modules
- New materials for PV

The related training topics identified were:

- **Solar: Scope, technological, environmental and societal perspectives**
- **Fundamentals of PV**
- Building Integrated PV (BIPV): buildings as power stations
- **PV System design**
- **Monitoring of PV (Siting and energy use habits)**
- Cost reduction routes in Manufacturing
- New and emerging technologies
- The role of nanomaterials in PV
- **Energy storage and usage**

- **Power electronics (inverters, smart meters)**
- Life cycle assessment of PV

Industry representatives indicated that all of the potential training topics were important, but placed particular emphasis on the topics highlighted in bold. Although such emphasis was not placed on "BIPV: buildings as power stations" this topic is likely to increase in importance over the next few years following the recent DECC Solar Strategy (DECC, 2014) which has emphasised the potential for large scale building integrated PV and the commitment of the UK government to install 1 GW of PV on government owned buildings. This is expected to grow the demand for skills relating to building integrated PV technology, design and architecture. Although "Life cycle assessment of PV" was not initially considered a priority by industry, the recent change in the WEEE directive (European Commission, 2013) was considered to be a significant development which merited the development of training in this area.

3.6 Other training topics

The industry consultation which took place for LCBE found a need for training that was not specifically related to the technical topics being offered. These needs focussed around:

- Low carbon economy and policy
- Enterprise in the Low Carbon Economy

Although this need was identified through the LCBE consultation, these topics are relevant to all five energy sectors. Therefore, training on this topic is planned to utilise research information from all five training partners.

3.7 Potential Beneficiaries

Potential training beneficiaries have been identified for each theme and are illustrated in Figure 2. Although consultants, contractors, developers and engineers are linked to multiple themes, these are likely to be separate groups within those professions. However, architects, installers and planners are common to Solar PV and LCBE.

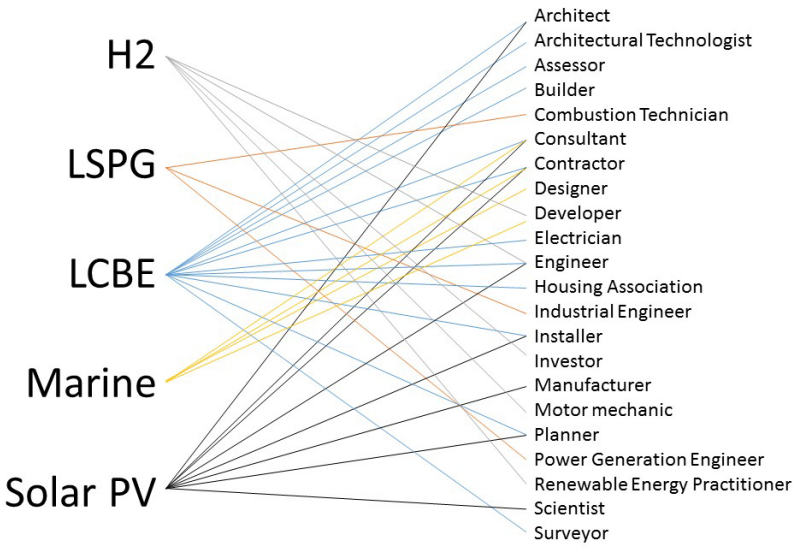

Figure 2 Potential training beneficiaries identified for each theme.

3.8 Methods for training delivery

During the project, two key aspects to training delivery have been considered: 1) logistics and 2) learning experience. These will be discussed below:

Logistics

For industry participants, the training location and timing are key factors in deciding whether or not to attend a training course. This often relates to the employer needing to justify the time and cost of releasing staff for training. Previous training projects had noted that industry attendees often have difficulty in committing in advance to training events due to the rapidly changing nature of their work environment. This view was reinforced by a survey of Solar PV industrial representatives who indicated that cost, time and distance (in that order) were barriers to attending training. In a previous project a number of participants expressed a desire for delivery via e-learning or training on site, thereby reducing the time cost to employers. However, in this survey participants considered face to face training to be an essential requirement to allow students the opportunity to meet an expert in the field and ask questions. Few surveyed participants expressed interest in the use of smart phones and tablets to access course content.

When combined, this research supported the selection of a blended learning approach, which allows participants to access training material flexibly, but have the support of face to face time with an expert (Rowlands-Jones, 2014, Ruiz del Portal et al., 2014, Potter, 2014). Similar findings were reported by the other themes, although in some instances qualified by the requirement of face to face teaching to allow in depth interaction with experts as well as hands-on experience (Reed et al., 2014).

Learning Experience

It is essential that the range of preferred learning and cognitive styles of the audience are acknowledged and responded to during the training design and delivery (Riding and Rayner, 1998, Adey et al, 1999, Cassidy, 2004, Coffield et al, 2004). For example Kolb's Experiential Learning model (Fig. 3) and learning style inventory is widely acknowledged as the overriding approach to teaching and learning in architectural education, calling for opportunities to make meaning from direct experience (Itin, 1999).

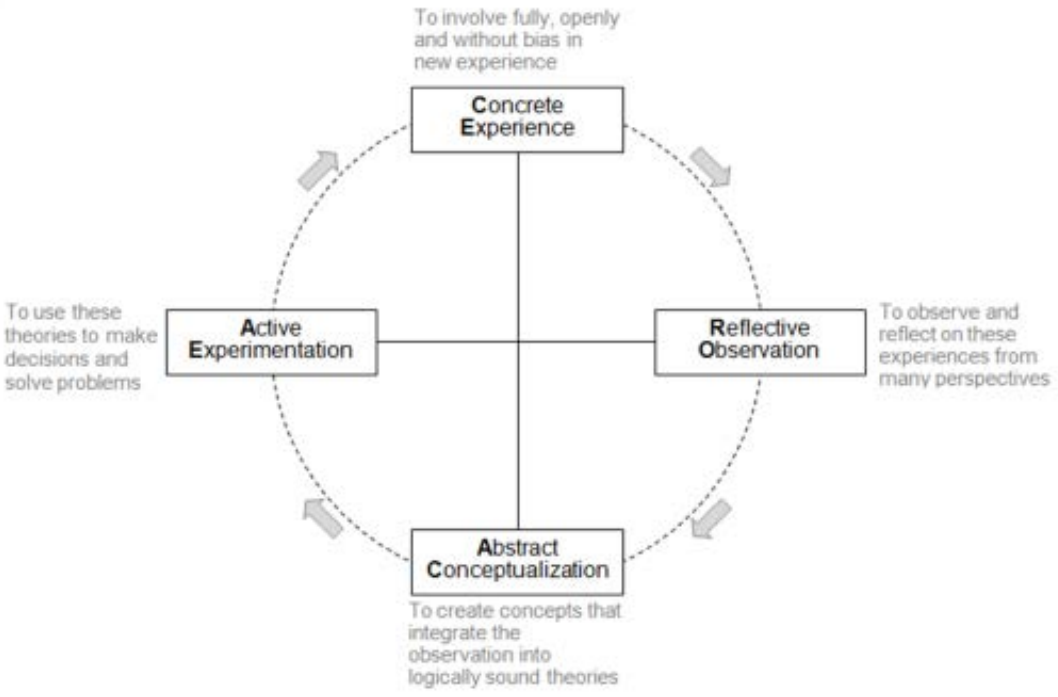

Fig 3. Experiential Learning Model (Kolb, 1984)

Further, the training must also provide for the specific learning drivers of employed adults, as against those typical for children, and perhaps to some extent early entrants to new careers (Suires, 1993). Here, literature relating to approaches to education and training for adults, termed andragogy, rather than pedagogy, suggests that adult learning, particularly in relation to careers, is typically focussed on problem solving for work based concerns. Further, literature asserts that adult learners are also considered to be self-motivated, requiring clarity as to an understanding of why they should undertake learning, considering positive or negative outcomes of learning and then applying their time and energy to obtaining new knowledge they consider to be of value (Hill, 2001).

A simple analysis of these two fields of literature, hereby suggest that CPD for professionals should largely aim to enable an inter-relationship within the training session between the acquisition of new knowledge and its application, linking information with practice.

4 TRAINING PROGRAMME

Initially the training is focussed on CPD, so small units (generally 10 hours student time) are being developed across the five themes. In some instances these can contribute to larger units (100 hours student time). The units under development are illustrated in Table 1.

Table 1. WEST Training Units Being Developed

Theme	Small Units (10 hours)	Large Units (100 hours)
H2	Essentials of hydrogen and fuel cells	
	Hydrogen and alternative vehicles (Hazard awareness)	
LSPG	Basic combustion science	Low carbon combustion
	Nature of fuels	
LCBE	Welsh timber in building construction	Building with timber in Wales
	Low carbon building principles	Holistic design of low carbon buildings
	Energy simulation: Building & urban scale	
Marine	Long term wave analysis	
	Wave energy conversion	
	Tidal energy conversion	
Solar PV	Buildings as power stations	
	PV system design	
	PV end of life	
Enterprise & Economy	Low carbon economy	
	Enterprise in a low carbon economy	

The next stage will be to incorporate the training in higher education courses relevant to each theme:

- A Master of Science in Hydrogen and Fuel Cells at the University of South Wales (Reed et al., 2014)
- A post graduate certificate in combustion science which is under development at Cardiff University (Hewlett, 2014)
- A Master of Research with the option of a post graduate certificate in Low Carbon Built Environment which is under development at Cardiff University
- A Master of Science in Marine Renewable Energy at Swansea University (Potter, 2014)
- A Master of Science in Photovoltaics at Glyndŵr University (Rowlands-Jones, 2014).

5 CONCLUSIONS

Research has been carried out by the Low Carbon Research Institute in the themes of Hydrogen, Large Scale Power Generation, Marine Energy and Solar Photovoltaics. In addition to traditional dissemination methods, the research results were developed into training through the WEST project. This was aimed to transfer the knowledge to the energy sector based professionals most likely to be interacting with these new technologies.

In order to prioritize the training development, reviews of existing further and higher education were carried out, followed by a skills and training needs analysis. This ensured that the training developed met the requirements of industry. Considerations of both the wider literature on learning styles and learning preferences and in particular the drivers for uptake of education and training for employed professional adults has informed the approaches taken for CPD and consequent more substantial course development and delivery.

The training has initially been developed to meet the continuing professional development needs of the relevant industries. It is now being further developed and embedded in post graduate courses across Welsh Universities to ensure its use continues after the closure of the WEST project and to enable support of the widening access agenda to increase skills and knowledge in the low carbon sector across professionals in Wales.

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