A Regional Approach Towards a Low Carbon Built Environment

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ABSTRACT: Wales has a commitment to the low carbon agenda and has sustainable development identified in its government constitution. The Welsh Government has recently received devolved powers to develop its own energy related Building Regulations. The Welsh Low Carbon Research Institute (LCRI) was set up to help the Welsh Government deliver its low carbon agenda, linking research activities, in renewable and low carbon energy supply with reduced energy demand, across six Welsh universities and five research centres. The market transformation of this research requires a holistic approach across the Welsh region, with partnerships between academia, industry and government. The LCRI's built environment research programme includes work on building integrated low carbon energy supply and energy demand reduction, for new build and retrofit programmes, working at a regional scale. It collaborates closely with industry at a component level, on the development of new technologies. Examples include, the use of timber as a sustainable locally sourced construction material, and developing energy generating building envelopes integrated into metal cladding systems. At a building scale it is developing low carbon building design, with built demonstrations. At a city and regional scale, there is work on large-scale housing retrofit programmes. Simulation tools have been developed to help inform low carbon building design and retrofit options at building and urban scale. This paper reviews the outputs from this research programme, in the light of a regional approach towards achieving a low carbon built environment.

Keywords: Energy, Low Carbon; Built Environment; Regional; Retrofit; New Build; Systems Approach

INTRODUCTION

On the 10th May 2013 the UK's BBC reported that daily measurements of CO2 at a US government agency laboratory on Hawaii exceeded 400 parts per million for the first time in three to five million years. If we continue to burn fossil fuels at a 'business as usual' trajectory, we will cross the 450 parts per million level, taken as the limit for keeping global warming under 2°C, in a matter of a couple of decades [1].

Even though society has been aware of the issues associated with burning fossil fuels since the mid-70's, there has been little lessening of the problem. Since the start of the industrial revolution some 200 years ago, society, especially in the developed world has locked itself into a fossil fuel economy, and the developing countries are rapidly following suit. Change will be difficult. We are now very efficient at being inefficient in the use of resources, and in particular energy. The economy has developed to support the fossil fuel habit. Amory Lovins explains in his recent book 'Reinventing Fire' that the fossil fuel industry receives enormous subsidies both directly and indirectly [2]. Reports from the International Panel on Climate Change (IPCC) have been noted in developing government policy, but this policy is not getting into practice. Even the Stern report on the economics of climate change, which identifies the enormous costs of dealing with climate change, has not changed our behaviour [3].

It is not really surprising that there is a huge resistance to changing to a low carbon economy, and perhaps we cannot expect our 200 year habit to be turned around in the relatively short time we have to avoid serious climate change impacts. The current austere economic period is also frequently stated as an excuse to delay climate change action.

Low carbon technologies have developed considerably in recent years, but the economies of scale are slow to take effect, both in areas of low carbon energy supply and reducing energy demand. Governments tend to look for the 'silver bullet' solution on the supply side rather than the more scattered subject of reducing demand, and they also tend look for 'big industry' solutions. Increasingly nuclear and fossil fuel with carbon capture, seem to be preferred to wind, tidal and solar. To some extent there is 'low carbon fatigue', perhaps association with the overall negative message of climate disaster, rather than focussing on the positive aspects of a low carbon future, such as a clean healthy environment, and the economic and social benefits from a low carbon society.

There has been little attention to how the various issues across policy and practice can be 'joined-up'. An overall low carbon strategy should link government policy to business opportunities, technology advances, training and awareness raising, and, cost and value. This may be best addressed at a regional scale, where there is autonomy, understanding and decision-making that take

account of specific regional attributes. This is currently the subject of a EU COST Action on Smart Energy Regions, which the author chairs [4].

This paper explores the low carbon agenda at a regional scale. It is based around the activities in Wales, which has a devolved government within the UK. The Welsh Government is committed to the low carbon agenda and has sustainable development identified in its constitution. In line with the rest of the UK, it has a long-term commitment to 80% CO2 emission reduction by 2050. It has set aspirations to reduce CO2 emissions by an average of 3% per year from 2011, to be self sufficient in renewable electricity within 20 years, and to work towards zero carbon new buildings. As a country it has a range of future energy options, including renewables, nuclear and shale gas. It has recently received devolved powers to develop its own energy related Building Regulations with the intention of prioritising the move to low carbon buildings.

The Welsh Government has provided European Structural Funds to support a university based Low Carbon Research Institute (LCRI). This paper describes some of the outputs and issues resulting from the government's policy aspirations, and research and development activities, which have taken place over a relatively short period of the last five years. It reviews energy supply and demand, the development of low carbon technologies and processes, and how collaborative research across the region's universities can help government and industry take forward the low carbon agenda**.**

ENERGY OVERVIEW

Wales has a great potential for renewable energy supply, including onshore and offshore wind, tidal energy, bio-energy and solar. It has 1200km of coastline, deep-sea ports and accessible grid infrastructure, which are ideally suited to meet the requirements of the marine energy industry. The proposed Hafren Power Severn barrage proposes to use the renewable energy generating potential of the world's second-largest tidal energy resource, with an 18km long tidal barrage in the Bristol Channel with a capacity of 6.5 GW, producing up to 16.5 TWh per year, equivalent to approximately 5% of the UK's annual electricity demand. Around 80% of the £25bn investment would be injected into the British economy, creating an estimated 50,000 direct and indirect jobs during its nine year construction period. Wales already has major offshore and offshore offshore wind farms and plans to expand on these in the future. The first new nuclear plant to be built in the UK since 1995 will be deployed by Hitachi at Wylfa on Anglesey generating up to 4GW of power. It would generate up to 6000 construction jobs and 1000 long-term jobs. It was recently announced that Wales has enough shale gas to supply the UK for 16 years if developed, although at a environmental cost. This potentially cheap fuel option will challenge renewables, and if developed will need to consider carbon capture associated with burning gas.

The Welsh Government has identified the potential for some £50 billion of investments in large-scale renewables and other low-carbon electricity projects over the next 10-15 years. Figure 1 summarises the current and future energy consumption and the future scenario for renewable electricity supply [5].

Current and future consumption (kWh/d/p)

	2008	2050	
Losses	27		
Electrical	18	18	18
Heat	40	30	12 electricity 12 pumped heat 5 wind 1 solar
Transport	40	20	2 bio-fuel 18 electricity
	125	69	

Future electricity supply 2020/25

	TWh	kWh/d/p
Wind offshore	5	4.5
Wind onshore	21	15.5
Bio-electricity	7	6
Tidal ranger	18	8
Tidal wave	9	8
Local (PV, etc)	1	1
	45	43

Figure 1: Future energy consumption and supply scenarios[5]. The figure presents average energy use per person, which in Wales, as in the rest of the UK, is currently around 125 kilowatt hours per day per person (kWh/d/p).

Wales has also identified priorities to consider electricity networks and storage, smart distribution and demand management technology. In particular the built environment has been targeted for reducing energy demand and promoting low carbon applications. In 2009 the Welsh Government announced it would target all new buildings to be 'zero carbon' by 2011. However, delays in devolving the building regulations to Wales, uncertainly over the definition of zero carbon, and subsequent concerns over costs have diluted these original aspirations. The current target (2013) is 40% reduction in CO2 emissions for new housing (from 2010 levels), to take effect from 2015. Now, even this target is being challenged by the mass house builders in relation to concerns over costs. However, the political aspiration has resulted in innovation in construction, and a number of government subsidised demonstrator low carbon houses are going to be built to see what can be achieved in practice.

It is widely recognised that it is in existing housing where energy savings are most needed. Wales has a sub-standard housing stock relative to the rest of the UK and a high level of fuel poverty. The Welsh Government has invested in domestic energy efficiency and community-scale renewables through its ARBED programme. In its

first phase, completed in 2012, a total £68m was invested in multiple energy efficiency measures to over 7500 households in Wales, including: solid wall insulation applied to over 4000 homes; over 1800 solar PV panels; solar hot water heating to 1080 homes; around 1000 properties switching to cheaper and lower carbon fuels, e.g. from coal or electric heating to high efficiency gas boilers; heat pumps installed in over 100 households off the gas network. A second phase started in May 2012, partly funded by the European Regional Development Fund (ERDF), with a budget of up to £45 million, to improve the energy efficiency of some 4800 existing homes by the end of 2015. This programme is providing opportunities for new jobs and skills across Wales, regenerating communities and developing local supply chains in low carbon technologies.

These activities, across energy supply and demand scenarios, have begun to highlight a range of issues associated with the energy future of Wales, which will be typical of many regions. These include:

- how to balance large-scale renewables versus building scale energy efficiency and building integrated renewable;
- the shift to electric, including distributed PV, heat pumps, future electric vehicle charging, placing a huge demand on the grid and the possible need for storage at local level;
- an appropriate balance between renewables versus large-scale power projects (e.g. future nuclear and shale gas);
- the capital cost and cost savings associated with low carbon buildings, and new and retrofit technologies.

There are strong lobbies from mass house builders, the nuclear and energy supply industries resisting what might be called the green approach. The future will eventually be low carbon, possibly evolving from 'cleaning up' our existing energy supply systems, combined with large and small-scale renewables, and demand side management; the problem is not so much about the technology, but more related to the process of transition to a low carbon future. The First Minister of the Welsh Government recently announced that he will chair an Energy Wales Strategic Delivery Group in order to enhance and strengthen the strategic engagement approach needed to deliver the Energy Wales: A Low Carbon Transition ambitions [6].

THE LOW CARBON RESEARCH INSTITUTE

The Welsh Low Carbon Research Institute (LCRI) was set up to help the Welsh Government deliver its low carbon agenda, linking research activities, in renewable and low carbon energy supply with reduced energy demand. It is a consortium of six Welsh university research groups at Cardiff, Swansea, Glamorgan, Glyndwr, Bangor, and Aberystwyth. Working with industry and government, the LCRI's research agenda includes, low to zero carbon energy supply systems, reduced energy demand, knowledge and skills transfer, and dissemination and industry partnerships. The market transformation of this research requires a holistic approach across the Welsh region, with partnerships between academia, industry and government.

Low Carbon Research Institute: Universities and Research Centres

Lead Partner	Cardiff University
Research Themes	**University**
Built Environment	Architecture, Cardiff
Large Scale Power Generation	Engineering, Cardiff
Bio-Energy	Aberystwyth
Hydrogen	Glamorgan
Solar PV	Glyndwr and Bangor
Marine and Power Electronics	Swansea
Research Centres	**Location**
Sustainable Building Envelope Centre (SBECC)	Shotton
Gas Turbine Research Centre (GTRC)	Margam
Institute of Biological and Rural Sciences(IBERS)	Aberystwyth
Hydrogen Research Centre	Baglan
Centre for Solar Energy Research (CSER)	St Asaphs

Figure 2: Structure of the LCRI

The LCRI was launched in 2008 with an initial investment of £5.2 million by government's Higher Education Funding Council for Wales (HEFCW) under its 'reconfiguration programme' to stimulate universities in Wales to work together and pool their strengths. In December 2009 LCRI secured European structural funding of £19.2 million to provide a research base for the Welsh energy and low carbon industry sector. This government funding has built low carbon research capacity in Wales and helped to secure a current programme of some £82 million (2013), including £20.4 million from UK research councils, another £20.2 million from EU framework and other sources, with a further £15.1 million support from industry and the partner universities. There are now over 130 researchers attached to the LCRI on a range of research programmes associated with the high priority research areas identified by the Welsh Government, including, renewable and clean energy supply, energy efficiency and smart living. It has five research centres working closely with industry partners (figure 2), namely:

Sustainable Building Envelope Centre (SBEC): work on energy generating building facades for electricity and thermal energy, together with energy storage.
Centre for Solar Energy Research (CSER) work on new solar PV technologies and integration on buildings.
Hydrogen Centre: work on hydrogen fuel cells, vehicles and hydrogen as an energy storage medium.

Gas Turbine Research Centre (GTRC): work on new fuel mixes and gas turbines carbon capture.
IBERS: work on bio-energy and bio-fuels.

LCRI - LOW CARBON BUILT ENVIRONMENT

The LCRI's Low Carbon Built Environment programme carries out research over a range of scales from new components, to buildings, to communities. At a component level, examples include, the use of timber as a sustainable locally sourced construction material, and developing energy generating building envelopes integrated into metal cladding systems. At a building scale, it is developing low carbon building design, with built demonstrations. LCRI works closely with the steel and timber industry in Wales to develop and demonstrate new products. ECOBUILD 2013 showcased LCRI research products in collaboration with BRE, Zed Factory and other industry partners (figure 3).

Figure 3: Welsh timber products at ECOBUILD

Figure 4 shows an example of a low carbon house constructed in Ebbw Vale, South Wales, using indigenous 'Ty Inos' timber system, designed by the LCRI funded Design Research Unit Wales (DRUW), based at the Welsh School of Architecture. The Sustainable Building Envelope Centre (SBEC) at Shotton was established with a £1.5 million investment by Tata (plus £0.5 million support from the Welsh Government) to develop new products associated with energy generating building envelopes. Figure 5 shows the LCRI Tata Sustainable Building Envelope Centre (SBEC), also designed by DRUW, which has within its construction, energy generating facades, such as the Transpired Solar Air Collector. It is a building that demonstrates its research activities and the new products being developed. Kevin Bygate of Tata has estimated that, '*the manufacturing and installation of these new products have the potential to create up to 10,000 jobs over the next 5 to 10 years'.*

At a city and regional scale, large-scale housing retrofit programmes, such as ARBED have been assessed using models developed within LCRI. Retrofit programmes have the potential to significantly reduce CO2 emissions whilst having other positive impacts such as improving health and quality of life. Costs associated with installing measures range from a few hundred pounds for shallow elemental retrofits up to £70,000 for a deep whole house retrofit. The results from a series of assessments of large and small scale retrofit programmes are presented in figure 6. The cost of whole house retrofits, together with disruption factors, have been identified as a major barrier to wide-scale take up. Therefore, UK government's target of 80% reduction in carbon dioxide emissions will be difficult to achieve in relation to housing retrofit within current financial schemes. New finance models are being developed with industry partners, to provide the incentive for large-scale whole house 'deep' retrofit programmes.


Figure 4: A Low Carbon House constructed from indigenous timber using the Ti Inos system.


Figure 5: The LCRI Tata Sustainable Building Envelope Centre (SBEC).

It is important to be able to target the most beneficial combination of packages of energy saving measures and renewable energy supply, for specific house types. To this end, simulation tools have been developed to help inform low carbon building design and retrofit options at building and urban scale. Figure 7 presents the newly developed housing energy 'app' which can be used to quickly assess the energy saving potential for new and retrofit houses.

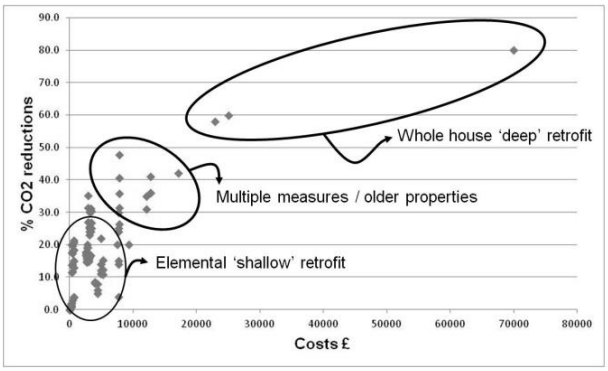

Figure 6: Summary of costs versus savings a range of retrofit programmes in Wales (£1 = 1.15EUR)

At an urban scale, models have been developed that can simulate energy performance of large numbers of buildings at the same time based on the continued development of the Energy and Environmental Prediction (EEP) tool [7]. This originally was developed to assess large-scale energy savings to estates of existing buildings. It has now been developed to address new developments, simulating the impact of neighbouring buildings and natural features on energy performance and solar access (figure 8).

Figure 7: Housing energy 'app'.

LOW CARBON SYSTEMS APPROACH

Most 'low carbon' research is currently centred on technology developments at an individual component level. The main activities of the LCRI to date have been in developing technical solutions for energy demand reduction and supply, which have been mainly based on such a component approach. However, it is the practical implementation of low carbon technologies as part of a system that determines the extent to which they are successful and to what extent predicted targets can be achieved in practice. In particular, it is at the interfaces of supply and demand technologies that often determine performance. Many technologies, when applied, do not deliver their optimum performance and cost, as they are often 'bolt on' solutions, e.g. increasing insulation standards for buildings may reduce the heating demand but may not result in an appropriately reduced capacity heating system. Therefore a more systematic and holistic approach is necessary. The temporal and spatial relationships between demand and supply need to be addressed through new and emerging technologies in order to create an appropriate balance.

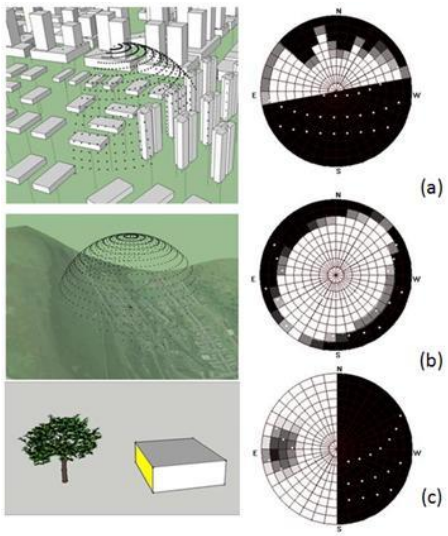

Figure 8: The shading effect on a facade with its resulting shading mask for (a) neighbouring buildings, (b) topography, (c) landscape features.

The LCRI is working across all its thematic programmes to consider how component technologies can be developed through a holistic robust systems-based approach, building on the cross and interdisciplinary capabilities of the LCRI partners. This SOLCER (Sustainable Options for Low Carbon Energy Regions) programme is addressing the immediate short-term implementation of new and emerging technologies. It is investigating demand load profiles for heat and power relating to renewable and low carbon energy supply potential, including the need for storage of both thermal and electrical energy. It considers the grade of energy available from renewable and low carbon energy supply systems and the diversity of demand, and diversifying demand to meet supply availability. It will then address behaviour and household, community and business perceptions of energy alternatives as part of technology market transfer.

SOLCER is developing a matrix of systems some of which are being demonstrated through real applications. Each system has an energy supply, energy storage and energy demand aspect. A number of components have emerged from the various LCRI programme, e.g. energy generating building envelopes, solar PV, LED lighting, hydrogen storage, bio-energy and gas turbine technology. These are being combined into a range of systems at building scale, community and industry scale.

In developing the systems, LCRI academic and industry partners are working together providing a range of cross-disciplinary specialist inputs.

DISCUSSION AND CONCLUSION

Wales is a region that has low carbon policy aspirations, however, like many regions and countries, it experiences difficulties in implementing them into practice. The above experiences throw up a number of reasons for this. Firstly, the energy agenda and the shift to a low carbon economy is a moving target. Priorities change quickly in response to developments in global and local economies. Government policy can change overnight, while industry needs clear longer term targets. The gap between technology development and its application seems to be growing which is a disincentive for innovation. There are uncertainties over cost and skills availability associated with low carbon technologies and processes, especially at the large scale needed. Technology often tends to be of a component 'bolt on' nature, and needs a more systems based 'SOLCER' approach as described above. Technology is being advanced at a number of scales, from energy efficiency measures in buildings, to new large scale energy supply programmes. There is pressure from big industries, such as nuclear and the fossil fuel industries (e.g. linked to future shale gas opportunities). These carry big industry lobbying, and the offer of a 'business as usual' approach. Governments tend to prefer big industry solutions. There is uncertainty over the future split between electricity and heat energy supply (heat being gas, oil, biomass, etc). There are emerging issues with electricity grids, the increase in electrical appliances, the potential shift from heat to electric, and future stresses on the grid from distributed loads (e.g. heat pumps, electric vehicles, renewable energy systems). On the demand side, there are concerns over the costs associated with zero carbon new build and retrofit, and the need for new financial models, which take a more systems and life cycle approach. Building regulations are needed to promote innovation while accepting and dealing with the concern over developers costs.

The economic benefits of a low carbon economy are huge, with opportunities for both wealth and job creation. There are other 'softer' societal benefits through improved quality of life, more efficient resource management and less pollution. However the transition to a low carbon economy is not obvious and we must find a balance between the instabilities that might arise from climate change versus the instabilities from economic change. The current tension between the 'clean' and 'dirty' economies needs to be relieved, and both sides need to work together recognising each other's views. Fossil fuel will be with us for a while, so we must learn to use it cleanly and efficiently, and at the same time develop renewables at all scales. The biggest early win is to reduce energy demand and this could provide the bridge to the low carbon future. Whether the current austere times are an advantage or disadvantage remains to be seen, together with, to what extent the low carbon agenda can drive the economy. We must accept that delivering reductions in energy and carbon dioxide emissions, must also achieve cost and socio-economic 'products' in the development of regional built environment programmes, linking the low carbon agenda with economic growth.

All this seems to be best driven forward at a regional level, linking policy to industry and societal needs for maximum benefit. Institutions like the LCRI, researching new technologies and processes, working with government and industry on skills and training and cost models, can help facilitate the change to a low carbon economy.

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