Regional electricity generation and employment in UK regions

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Abstract

A number of electricity generation technologies reduce carbon emissions but with different economic and employment effects, partly consequent on how far generation capacity supports regional supply chains. In devolved regions these issues are important because of the role given to renewable electricity generation in economic development strategies. The paper analyses the regional employment supported by different electricity generation technologies, illustrating trade-offs between generation scale and employment-intensity, and shows that the regional employment supported under all pathways is modest compared to the regional economic scale. The policy implications are investigated.

Key words: Regional employment, Electricity production, Wales

JEL: R58 - Regional Development Policy < R5 - Regional Government Analysis < R - Urban, Rural, and Regional Economics, R11 - Regional Economic Activity: Growth, Development, and Changes < R1 - General Regional Economics < R - Urban, Rural, and Regional Economics, Q40 - General < Q4 - Energy < Q - Agricultural and Resource Economics.

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1 Introduction

This paper focuses on the regional employment supported by different types of electricity generation technology. Governments seeking to reduce climate emissions whilst improving energy security have acknowledged that a transformation is required in electricity generation and use, while also identifying an opportunity to stimulate economic demand and hence generate growth and jobs (DECC, 2013). This forms part of a 'green growth' agenda crystallizing around the notion that green industries and the green economy are the basis for a fresh round of capital investment, leading to economic development gains from adapting to climate change effects; mitigating human contributions to climate change; and managing the transition to renewable technologies. A green growth paradigm forms part of many national economic recovery plans.

The economic and employment possibilities of renewable energy have also been highlighted in the devolved regions of the UK (ALLAN and GILMARTIN, 2011). One UK region with a significant renewables opportunity and a measure of political autonomy is Wales, and this is the case examined in this paper. Here there has also been a stress on the potential for the region's natural resource base to promote green economic growth (WELSH GOVERNMENT, 2012, WELSH GOVERNMENT, 2010). Further incentive is provided by a concern that high energy costs, coupled to a relatively energy-intensive industry mix, are a bar to improving regional competitiveness for a region where consumer and industrial demand outside Wales are important drivers of domestic electricity generation and associated carbon emissions (JONES, 2010; TURNER et al. 2011).

While there is regional interest in the transformational potential for new rounds of electricity generation investment, there is limited evidence on how different electricity generation technologies might support regional employment prospects. This type of evidence could be important with, for example, ALLAN and GILMARTIN (2011) showing that the employment claims associated with electricity generation developments can shape policymaker opinion. Moreover, there is an expectation that the regional pattern of employment returns connected to many electricity generation technologies is uneven. GIBBS and O'NEILL (2014) show that the green economy will not develop evenly across space and this is because sustainability transitions will depend on the interplay of actors, networks and institutions available in some places and not in others. Transitions to greener energy and a greener economy will therefore feature regional winners and losers. COWELL et al (2012) argue that the distribution of economic benefits from renewables may favour coastal and rural areas that are relatively deprived, or suffer from geographical isolation, ageing populations and a heavier reliance of seasonal employment. Similarly ALLAN and GILMARTIN (2011) show that the dispersion of renewable resources such as wind and tidal across the UK suggests that a disproportionate amount of activity will occur in areas such as Scotland and Wales, and with new developments linked to more distinct energy policies and renewables targets in the devolved administrations of the UK. A further issue here is that the subsidy and regulatory regime around electricity generation is largely set at a UK level, such that changes in levels of subsidy could have important effects on investment levels in regions close to the natural resources supporting renewables.

There are also issues relating to the industrial sectors and hence types of employment that are supported by electricity generation investment. This is particularly relevant where the local content of capital is low and regional economies are heavily dependent on imports to develop new electricity production infrastructure. This might lead to spatial variations in the returns from employment supported by electricity generation, with lower levels of regional employment concentrated in operations and maintenance occupations, and perhaps greater employment opportunities in the manufacture and development of power generation systems remote from where capacity is installed. In this respect, STROUD et al. (2014) show that one of the shortcomings of debates on green transitions is that they underplay the core role of labour in the process of change and suggest there is a need for debate around 'decent jobs' i.e. featuring adequate wages, skilled and secure jobs, and in safe conditions. Then given the expected dependence of renewable (and conventional) power developers on imported components and skills, an issue is how far new developments have scope to create high-quality, skilled employment, perhaps in more needy places featuring persistent socio-economic disadvantages (COWELL et al., 2012: MUNDAY et al., 2011).

Arising from the above are a number of issues which are of relevance to public policy development regionally and nationally. Public policy can work to prioritise new methods of electricity generation. These technologies have different implications for carbon emissions, but they also have different developmental and employment effects. Moreover, the uneven distribution of the natural resources on which some renewables rely also means that different electricity generation pathways and restructuring encouraged by the subsidy regime will affect the spatial distribution of employment creation (and losses), and the quality of employment that is offered. Importantly this does not just relate to direct employment created in the electricity generation sector, but the extent to which different electricity generation pathways support supply chain activities in regions. Then a policy implication is to consider not just the direct, but also the supply chain opportunities likely to be created by different technologies, and the trade-offs between technologies in terms of carbon emissions, efficient power generation and then employment creation/developmental potential. Different pathways could also, following Stroud et al., (2014), link through to questions about the quality of employment offered and training and skills needs, and whether green transitions related to electricity production are a means of a ‘high road’ or ‘low road’ green transition in terms of ‘decent’ jobs.

We argue that for devolved regions such as Wales, these questions are important given a focus on the role of renewables in economic development, and with one policy driver (the subsidy regime) being set at a UK level. In this context estimating the regional employment connected to different electricity production technologies in development and operation is one important element to inform proper policy debate, and to understand the likely regional consequences of changes in regulation and subsidy.

It is accepted that a study of the employment supported by different types of energy generation in a region can only be a small part of the puzzle of the system-wide economic consequences of different types of energy development. Renewables are not costless to the public purse and with substantial opportunity costs associated with their installation and operation (see FURCHTGOTT-ROTH, 2013). New electricity generation pathways are also connected to losses in conventional power generation sectors. Furthermore, where new development results in higher energy prices, this could cause complex employment effects through the whole economy, perhaps offsetting employment created around measures to increase energy efficiency, such as retrofit and smart metering (JONES, 2010). However, regional employment supported by different patterns of energy generation is an important part of these system-wide effects, and estimates of these employment effects can influence policy makers, investors and campaigners for and against a different energy technologies.

In this paper we derive estimates for the employment supported by different types of electricity generation technologies for Wales. This allows us to consider what kinds of technologies might have greater or lesser regional employment effects, and to reveal potential trade-offs between the scale of generation and the scale of supported employment. Section Two reviews research that has explored the employment effects connected to electricity production technologies. The third examines the structure of electricity generation in Wales. The fourth outlines the method used and the sources for the analysis. The fifth presents the findings and the final section presents some conclusions and a discussion of policy implications.

2 Electricity production and employment

Studies examining electricity production and employment are often contextualised in terms of understanding the employment consequences of changes in the technology mix for electricity production. There are a number of considerations in associating electricity generation to employment creation. Studies vary in what is counted as employment, and then how far a 'system-wide' account is provided of employment changes (see LEHR et al., 2008, 2012). LEHR et al (2012) argue that in exploring system-wide effects of using different types of electricity generation, one needs to consider both positive and negative factors, for example, not just the new installed capacity itself but also reductions in old capacity, implications for trade and international competitiveness, and also household effects consequent on what are often higher electricity costs from renewable sources. Critiques of 'green job' studies commonly allege incomplete accounting with renewables potentially crowding out other business investment (WEI et al., 2010). FRONDEL et al (2010) suggest the higher employment associated with renewables generation can be touted as a benefit without a clear understanding that any resultant increase in the direct cost of electricity might have less visible (and negative) economic implications.

LLERA et al. (2010, 2013) show the difficulties of comparative analysis of the employment potential of energy developments. They spell out reasons for variation in employment impacts cited across studies linked to data used, modelling method adopted, economy size, technological maturity and scale issues, and importantly what types of jobs are included (i.e. whether direct or indirect).

Common measurement approaches include job ratios in terms of direct employment per Megawatt (MW) of installed capacity during the operational phase of power station life, and then person years of employment during construction and development phases (LLERA *et al*., 2013). This subdivision allows consideration of the shorter term job creation during development and construction, with longer term employment during power station operations. However, such a subdivision can make comparative analysis difficult, with different energy generation technologies associated with different operational lifetimes.

While studies commonly produce employment factors connected to electricity generation these are rarely analysed to explore the distribution between local jobs and jobs for in-migratory workers. Moreover, LLERA et al. (2013) cite the issue of inadequate accounting of the number of jobs associated with imported goods and services. Another issue is that few studies estimate employment linked to the energy produced by different technologies (see WEI et al. 2010).

A variety of methods are used to estimate the employment effects associated with different types of electricity production. Input-Output models are commonly used to account for the indirect and induced effects of the development of new and existing electricity generation capacity (see MARKAKI et al. 2013; CAI et al., 2011; WINNING, 2013). Econometric and computable general equilibrium (CGE) models are also employed to overcome limitations of the basic Input-Output model framework. For example, ALLAN and GILMARTIN (2011) show that an approach grounded in a CGE framework can better describe system-wide spending effects including crowding out and supply side adjustments contingent on developing large new electricity infrastructure in regional economies. In this respect Input-Output frameworks (in the Scottish case) were found to overstate the economic impact of renewable energy expenditures, and failed to consider the legacy effects beyond the period of operational and development expenditures.

In conclusion a series of points can be made. First there is a diverse literature covering the economic and employment impacts of different electricity production methods but with variability in objectives and content. Second, variations in assumptions make it difficult for comparisons to be made between studies; indeed even where better quality case material is available, care needs to be taken in generalising because of specific spatial and economic factors that influence the scale of employment effects. Third, employment multiplier effects, where assessed, do not always take into account differences in the quality or duration of jobs between different energy types.

In addition to the above, a review of accounting and economic modeling frameworks reveals few studies that present standardised and hence comparable estimates of employment generation at regional scale, and across a number of fossil, nuclear and renewable technologies. This paper moves towards addressing this issue and applies a common conceptual and modeling approach across technologies to make the employment results as comparable as practicable. We report in terms of employment generation per megawatt installed and in terms of the overall scale of potential regional investment and job creation. Whilst the analysis remains unsophisticated in a number of respects, it does illustrate the trade-off between the scale of electricity generated, and the employment-intensity of that generation. We believe that the focus on employment effects in this paper should be seen as part of the wider investigation into the economic effects of changes in the way we generate energy, and as part of an agenda seeking to develop a holistic understanding of the economic implications of Welsh energy generation and use (JONES, 2010; MUNDAY et al 2011).

3. Energy & Electricity Generation in Wales

The *Digest of UK Energy Statistics* shows that total electricity generated in Wales in 2013 was 26,351 gigawatt hours (GWh). Around 24% of energy generated is from natural gas (see Table 1). Coal generation contributed around 40% of the total in 2013 but with this set to decrease sharply after 2018. Nuclear was the other main contributor in 2013, with this being reduced through the decommissioning of the Magnox Wylfa plant on Anglesey but with the probability of future new nuclear build nearby. Renewables contributed around 9% of generation in 2013, and with over half of this generated in on- and offshore wind, with the balance being landfill gas, hydro, and biomass. Analysis by Turner et al. (2011) shows that a considerable proportion of electricity consumption in Wales is driven by industries that export such as steel and chemicals.

Table 1 about here

Employment attribution to operational power station sites in Wales is problematic. Published data do not always accurately sub-divide employment in production of electricity from that in transmission and distribution. Direct employment in Welsh electricity production in 2012 was estimated in the ONS *Business Register and Employment Survey* (BRES) at around 2,300.

Table 2 about here

Table 2 lists major Welsh power stations operational as at May 2012. The employment total for discrete sites, where some information is available, totals 1,457 and again reveals variation in operational employment across generation technologies. For example, for the two coal fired plants (RWE Aberthaw and SSE Uskmouth) the operational staff per MW of installed capacity varied between 0.2 and 0.3. For the newer gas powered facilities the operational employees per MW installed capacity can be as low as 0.05 (i.e. RWE npower Pembroke Dock).

Following from the above there are problems in analysing employment and activity in electricity generation in official statistics and then problems in relating ‘direct’ employment in power generation to that supported in the regional supply chain. Moreover, official employment surveys major on operational employment at discrete sites and are silent on the employment opportunities supported through development and construction. We seek to address this issue in what follows.

4. Data and Methodology

4.1 Data

This study estimates the regional employment consequent on investments in electricity generation facilities in Wales, both in the development and operation phases. The data that informed our modeling process were developed from studies undertaken during the 2011 – 2013 period covering a variety of technologies, including fossil, renewable and nuclear (see Appendix 1).

To estimate the economic impact of investment on the regional economy, data were required on the level of economic activity (here additional output) consequent on capital spending associated with new electricity generation capacity. In practice, this meant assessing the gross preliminary, development and capital, spend (effectively per facility) and then the proportion that had been, or was likely to be, spent regionally (accounting separately for goods manufactured in part or whole in Wales or just purchased via Welsh distribution channels).

The data were of four types. First, data on past investments were available from the 2007 Input-Output Tables for Wales (JONES et al. 2011) for a number of extant electricity generation sub-sectors (the 2007 Tables report four such sectors, plus hydro pumped storage). Although the Tables only publish current expenditure in detail, the data collection and survey process undertaken for their compilation included capital expenditure inquiries. Secondly, data were available for generation investments post-2007 either from sector specific projects and surveys (see REGENERIS & CARDIFF UNIVERSITY, 2013a for onshore wind, for example) or undertaken ad hoc to inform sector understanding (for example, a site visit to the new RWEnpower 2GW gas fired station in Pembroke undertaken in 2014). In the third case, data on expected levels of capital spending and regional levels of spending for novel technologies were collected from a survey of regionally located developers; this being the case for example with marine renewables (in-stream tidal and wave). The fourth class of data was taken from other regions and nations to triangulate and assess our own gross and regional spend estimates per project, facility or MW installed (for example WINNING, 2013; ALLAN and GILMARTIN, 2011; FRONDEL et al 2010; MARKAKI et al 2013).

A similar process was undertaken to assess the level of operational spend associated with different facilities during their generating lifetime. This process was relatively easy for selected generation technologies already present in Wales e.g. gas, coal, and wind. In the case of novel technologies developers were asked to estimate the likely nature and geographic origin of future operational spend. The data are, inevitably, imperfect. Not only are novel technologies open to question as to their economic characteristics, but other data (e.g. for coal investment) represent technical approaches (and resultant capital spending) that are obsolete. Nonetheless the data represent the clearest possible economic picture of electricity generation in Wales. More detail on the scope and scale of the data collection process is available in Appendix 1.

4.2 Methodology

Following data collection, the resulting information was restructured to comprise a positive expenditure shock to the regional economy. This involved, first, reclassification of reported spending categories (capital and operational) into the relevant 88 industrial sectors reported in the Input-Output Tables for Wales. This was based on a matching that drew upon the expertise of the research team and industry interviewees. In most cases, the allocation was straightforward and even spending associated with nascent technologies could be apportioned to a suitable fabrication or electrical sector: more problematic was whether the economic character of the technology at hand is properly captured by the extant Input-Output spending vector for supplying sectors. A regional spending propensity was then estimated for each of the spend categories, based on our best estimate of existing and potential local sourcing based on technological demands and the current and future constraints of regional supply. The summation of all sectors, less relevant taxes, then comprised the input to the Input-Output model.

Table 3 summarises local sourcing assumptions for relevant technologies. It should be noted that these exclude the re-entry of earlier leakage. For example, grid connection charges or seabed lease monies (to Crown Estate Trust) may have future, positive implications for Wales if the relevant UK-national organisations re-invest some of that money in Wales. However, the relevant numbers are uncertain and not included here. Clearly, a priori, the higher the percentage of local sourcing, the higher the level of Welsh employment, but with this dependent on the level of initial spending and the labour intensity of the relevant supplying sector.

Table 3 about here

Development and capital expenditure was modelled, implicitly, as a one-off 'immediate' shock to the economy with no programming of capital expenditure (or consideration of time-discounting effects). This was because of uncertainty related to the likely start and scheduling of capital works (even for reasonably well known technologies like nuclear), and a desire to compare economic effects on a 'like' basis across technologies. For example, application of a discount rate to the far-off economic potential consequent on commercialisation of marine renewables would have depressed impact totals in comparison to more readily available technologies, but would have rendered the analysis less useful for policymaking groups who understand fully the relevant timescales involved and are attempting to actively plan for them. There is the additional constraint inherent in working within a static Input-Output framework, whereby temporal impacts (and then relevant feedbacks) are very poorly dealt with (see ALLAN and GILMARTIN, 2011 for modelling alternatives here). A limitation of our modelling approach is an inability to modify our assumptions to investigate the potential implications for regional economic impact of developing future energy infrastructure concurrently rather than consecutively in a region with a relatively limited construction supply side.

A similar approach was taken for assessing the impact of operational expenditure (and employment); with spending averaged over the expected life of a facility but in the knowledge this ignores scheduled maintenance blocks where spending and employment would be concentrated. Following restructuring of the data, development/capital and operational spend vectors were inserted as a positive economic shock to the Input-Output framework using the Leontief Inverse matrix. Here, the Input-Output framework endogenises payments to regional labour such that the wage-induced effects of additional economic activity can be assessed, and Type 2 multipliers potentially produced (MILLER & BLAIR, 2009).

4.3 Presentation

The results of the analysis for development and capital expenditure are presented in terms of person-years of employment, and for operational impacts, in terms of annual full time equivalent (FTE) employment supported within a generating year. We report the aggregate of direct, indirect (supply chain) and induced impacts for capital and operational elements (following LLERA et al., 2013; MARKAKI et al., 2013) but with significant disaggregation of generation technology within this structure (see e.g. LINDNER et al., 2013; WINNING, 2013).

The focus here is employment rather than financial (output or gross value added-GVA) elements. This arguably somewhat softens the uncertainties around time-discounting (although a future job is still probably worth less than a current job). The electricity generation sector is almost wholly non-Welsh owned and thus with more tenuous links between the non-wage elements of gross value added and regional welfare. A GVA comparison would be further complicated by the fact some energy sectors are subject to significant UK or EU subsidies, others are subject to environmental taxes which may in part be GVA relevant. Here then comparison is limited to employment totals, albeit we accept that investments may utilise peripatetic or non-regionally resident labour to a greater or lesser extent, based on perhaps skills requirements or (in the case of new nuclear build) a limitation in the size of the local labour force in the face of significant demand. The possibility of extra-regional employment leakage should be considered when considering the Section 5findings.

The reader should note we do not report separately the direct, indirect and induced elements of supported employment, or any employment multipliers. This is due to considerable uncertainty around the relative size of direct and indirect impacts. Energy investments in both development and operational phases in Wales include onsite subcontracting that is extensive; varies by developer and technology; and is very uncertain for novel generation. The extent of such activity fundamentally drives the scale of the economic multiplier (i.e. ‘total’ divided by ‘direct’ impact), albeit with no impact on the overall level of employment or economic activity generated in Wales.

5. Regional Employment and Electricity Generation

5.1 Development and Construction

Table 4 shows the estimated regional economic impact of different technologies during the development and construction phase. In employment terms these range from 4.5 jobs per MW for gas, up to 35.3 jobs per MW for tidal stream. The scale of the estimated all-Wales employment effects per installed MW during development phases are determined by a series of factors. For example, levels of absolute spend per MW installed tend to be greater for novel technologies and where prototypes are still being developed (e.g. wave and tidal stream). Meanwhile, more established technologies (e.g. Solar PV) can have a high level of employment impact, driven by the high proportion of development cost that is physical installation (often reliant on local labour), and the local sourcing of some device and ancillary elements. Table 5 shows the estimated distribution of person years of employment by Welsh industry associated with the different electricity generation technologies. Inevitably the supply side in Wales for some technologies is limited by economy size, regional (and UK) demand thresholds, skill issues and then simple scale economies. Another driver of employment effects is the amount paid to Welsh households in wages and salaries, and then the extent to which supported household incomes lead to spending on Welsh goods and services.

Table 4 & 5 about here

Table 4 reveals the relatively low level of offshore wind impact (compared to onshore wind). This is in part due to a lower level of local sourcing that arises from non-Welsh companies' involvement in the development of existing farms that are considered to be off the coast of Wales but are also close to England, illustrating that marine developments may be more difficult to 'embed' economically in a single region. Meanwhile, low levels of employment impact per MW for gas (and nuclear) are in part related to the use of well-established and non-Welsh technology and inputs, but also the very large power outputs per site or development – and hence with significant economies of scale – compared to selected renewables.

Building on the per-megawatt estimates, Table 4 also presents the employment impacts associated with the likely scale of development at a single site. This shows that in terms of employment effects installation size matters. The construction of a single nuclear site (here with two reactors totaling 2GW, but with this scale open to some debate) might support over 16,000 person years of employment in Wales, whereas employment (and indeed) generation at this scale for renewables would imply many installations over a wide area.

The foregoing analysis refers to total person-years of employment across Wales. Clearly, this investment is uncertain in timing. It is not possible to be definitive here, especially in regard to new technologies. Furthermore, conversations with developers suggested that the timing of construction activity and demand for related employment (peak and average) will likely vary significantly between individual projects. However, there is some evidence from on-going and recently completed projects that can illuminate the likely timescale of construction activity in Wales. For example, the 576MW Gwynt y Mor offshore wind facility was completed around 5 years after the inception of works, while the onshore, the 120MW Pen-y-Cymoedd scheme near Neath took around three years to construct and commission.

5.2 Operational Phase Impacts

Table 6 presents the employment effects in Wales estimated for the operational phase of generation installations. Here, we report the number of FTE jobs supported across Wales per annum on-site, in supply chains, and via wage-effects (these numbers do not include employment related to the sale of the electricity itself).

Some technologies are very capital intensive with few direct labour requirements during normal operations. For example, on-site employment in gas is very low in comparison to the installed capacity. On-site employment can however increase during scheduled outages. Also important is the extent to which operational phases involve the employment of regional staff (or subcontractors), and the incomes earned by them whilst employed at power stations and/or in routine maintenance. Another issue is whether major maintenance turnarounds involve local contractors or specialist teams brought in from outside Wales or the UK. Finally of interest is the extent to which charges and payments relating to grid infrastructure, land rents etc. leak from the local economy.

Table 6 about here

As with the development phase there is some variation with the employment effects, and again, gas is the lowest, supporting 0.29 FTEs per MW. Here, the story is linked to large, efficient and well-tried turbines producing significant electricity with low maintenance requirements – and indeed often under warranty for initial years and hence with limited need for on-site repair staff. There are, of course some upstream jobs associated with the handling of gas, in Wales' case largely at LNG terminals at Milford Haven (but not examined here). Similarly low maintenance requirements drive a low employment impact for Solar PV (0.38 FTEs per MW).

Despite the longstanding implementation of various nuclear technologies in Wales (and of course zero local fuel supply), the employment generated by nuclear power in operational phases is relatively high, related largely to onerous maintenance, monitoring and safety regimes (0.73 FTEs per MW). This is indeed somewhat higher than the employment required to monitor and maintain geographically spread wind installations. The best information for marine renewables suggests jobs-per-MW at the high end of the scale, but with developers consulted suggesting there is scope for significant reductions in related maintenance and monitoring costs (and hence employment) over time.

Clearly employment supported annually through construction and development phases tends to be much larger than that in operations. However, operational phase jobs are supported over a period of 20-60 years depending on the underlying technology and potentially over an even longer period where decommissioning processes are costly and/or protracted. The final two rows of Table 6 apply the estimates of FTE jobs per MW installed to estimates of the electricity generation capacity installed in Wales in 2012. This suggests around 5,400 FTE jobs were supported directly and indirectly by electricity generation in Wales in that year, with the majority of opportunities associated with coal and gas. Recall that the estimates of direct employment in electricity production from the Business Register and Employment Survey in 2012 were around 2,300.

6. Discussion and conclusions

The analysis reveals a number of methodological difficulties which affect the accuracy and reliability of estimates produced, and which are relevant for policy. First is employment and energy generation. The analysis presented figures in terms of employment in relation to the amount of capacity installed – hence larger installations give a larger employment number (an estimate of FTEs per gigawatt hour would be preferable were load factors for novel technologies clearer). The implication of a linear relationship between capacity and employment (either in development or operational phase) is false. This is demonstrable with reference to a large gas turbine where generation capacity depends wholly on the size of the turbine and hence gas input, but where control systems might not change between two differently rated turbines – and hence with operational employment largely unchanged also. The analysis here, based as it is on a number of installation case studies, should be considered as relating to a 'typically sized' installation of the technology referred to (although with even this uncertain for many novel technologies) rather than a 'hard' ratio that holds as the scale of generation increases.

The second relevant issue is the regional supply side. For established technologies and fuels, existing economic relationships can be examined to develop employment scenarios. This is not possible for technologies not yet at commercial scale. Here there is an element of estimation and assumption on the part of developers and stakeholders. The extent to which opportunities will be captured locally will depend on the level of flexibility and responsiveness of existing Welsh companies in the face of such opportunity, and perhaps the likelihood of inward investment being attracted to Wales to service new power generation. At present the extent of this supply side flexibility is unknown.

Third is technological progress and interdependence. It is not possible, across novel generation types, to ascertain the likely level of cost savings made as technologies develop. The impacts of each generation types are therefore based on *current* production and installation methodologies but with the expectation that some of these must change for technologies to become commercially viable, with consequent impacts on regional employment. There is also an issue around substitution and crowding out between technologies. It is unlikely that all technologies will progress together in the same region: they will compete for capital investment, subsidy and space. It is difficult then to assess how far technology-specific employment impacts might be additive or displacing across the piece.

Fourth is the notion of ‘Welsh’ employment impacts. As far as possible, employment generated on-site at Welsh locations during capital and operational phases, combined with off-site impacts across Wales, is reported. This will include some workers that are peripatetic or short term migrants, and indeed some who may commute daily from outside Wales. For developments offshore of Wales, where developers and operators are also (likely) non-Welsh, the link between related employment and economic activity, and regional outcomes needs careful consideration.

The above issues noted there are a number of implications for policy development. In the case of Wales (and other devolved regions) there has been some focus on the role of green transitions in economic development. While the ways in which electricity is generated form only one part of green transitions, the findings of this paper suggest limits in how far changes in the technology of electricity production will be transformational for Wales. Direct and indirect employment creation resulting from changes will likely see as much employment lost as that which is gained. An issue raised in the introduction to the paper related to how far green transition can lever a 'high road' or 'low road' transition in terms of the quality and level of employment created, and whether policy resources can be used to improve the level and quality of employment returns. These issues are pertinent in Wales where there are significant opportunities to develop renewables on Welsh Government land. However, it is suggested there are real limits on how far policy developed in Wales can lever better quality economic returns, and indeed whether there is even any place for regional level supports for selected electricity production technologies where so much benefit leaks away from the 'host' economy on the different technology pathways.

The paper revealed some trade-off between large-site, centralised and often more established technologies; and novel (renewable) and more diffuse technologies in terms of employment generated per MW installed. With some caveats, the latter have higher employment impacts per MW (taking development and operations together) but with these likely to be spread across a number of sites as technologies move to scale. The current pattern is then that new opportunities in renewables combine with lost activity in conventional power generation, some of which is relatively labour intensive (for example, coal). The extent of skills spillovers between sectors is uncertain and could be exacerbated because future electricity production employment in Wales will be more spread out, more mobile and focused in construction engineering companies as opposed to on-site in power stations. These changes have implications for policy seeking to develop the labour skills for new electricity production technologies, and with fundamental skills mismatches in terms of the requirements of selected renewables with more conventional electricity generation.

A further corollary of the above is that it also becomes far more important for policy makers examining competing developments to look at the entire employment supported by project regional operational spending rather than attempting to differentiate direct and indirect employment in what are relatively capital intensive operations. In the case of new development a recurring theme is whether there is any regional supply chain opportunity to meet developer requirements both in development and operation. Indeed the paper highlights the significant opportunities that are involved in development and construction phases. For policy makers examining the merits of competing proposals there is a need to consider local content during each life cycle phase of different technologies, and how this can be improved. Here policy resources could be used to: encourage inward investment in elements of the electricity production supply side; encourage local firms to respond to the procurement exercises of larger developers; encourage developers to explore local purchasing options; or indeed assist firms to diversify to meet the needs of power generation firms. This issue of employment potentially supported in local supply chains has been addressed at UK government level in strategies on selected renewables. For example in the UK BIS (2013) offshore wind strategy the point is made that the government would support the UK supply chain to this industry, and encourage inward investment in that supply chain, and that this would involve active measures to monitor the UK content of offshore wind both in development and operations.

However, opportunities for public policy to develop the regional supply side may be severely constrained. Wales has lost opportunities because of the absence of capacity in terms of the ‘high value’ added elements surrounding device manufacture. Pervading the analysis is an environment where major decisions on capital investment are made elsewhere, developers and managing contractors are based elsewhere, and then the risks and rewards of new infrastructure development are in large measure internalised elsewhere. Consequently regional impacts largely come as returns to labour (directly or in subcontractors) rather than returns to capital employed or land/sea owned (with some exceptions in terms of monies paid to Natural Resources Wales and private landowners for onshore wind leases). Inevitably for more capital intensive developments, returns to capital are likely to significantly outweigh returns to labour. Proximity to abundant natural resources is unlikely to leverage abundant returns to Welsh labour, and with this again relating to the argument on whether this element of green transition in Wales will bring higher quality returns to labour i.e. the ‘high road’ returns considered by STROUD et al. (2012).

Another public policy issue is the extent to which selected electricity production pathways prioritized by policy and subsidy may work to displace other opportunities for regional power generation that could lever better quality developmental returns. Large centralised development has a number of planning, electrical-technical and, potentially, public acceptance benefits. However, the very ease of large developments close to grid capacity may slow the development of decentralised technologies, and the smart, diffuse grid that might support them. This may in time be seen as a lost opportunity. For example community-owned schemes in Wales which do seek to work closely with local suppliers and where a relatively high proportion of rents are returned to local communities already have real problems gaining cheap access to the grid, and similarly access to grid capacity is viewed as a problem in the nascent marine renewables sector (see REGENERIS and CARDIFF UNIVERSITY, 2013b).

Ultimately policymakers grapple with a tension between economic impact and viable power generation. The ‘best performers’ in terms of regional employment generation are the novel technologies of wave and tidal, but they are still by far the most expensive to install per MW. It is this cost which to a large degree drives regional economic impact in both development and operational phases. Novel technologies will not be viable unless they remain specifically subsidised or can be made whole-cost competitive. If returns to capital largely leak from the host region, as is the case in Wales, as cost per kWh diminishes, so will regional economic impact. Moreover the subsidy regime is wholly outside the devolved remit such that changes made in Westminster could have serious trickle down effects to investment intentions in the regions. This noted given that the nature of supporting activities, developers, owners and ‘technology group’ does not vary much between generating types, one might expect regional economic impact to be reasonably convergent between technologies over time, and with the overall trend of impact (per MW) downward as cost savings are made, and the balance shifts from installation to maintenance.

In summary, given the paucity of economic benefits evidenced so far from large electricity investments in Wales, across fossil and renewable technologies, it is unlikely that development of this sector will be in any way transformational for the Welsh economy without a parallel transformation in underlying economic and proprietary relationships. Welsh companies are largely absent from the research and innovation process, albeit with some university activity, and with some scope for the development of a Welsh supply chain. Other benefits are hard to discern. Returns to capital and seabed are, under the current legislative structure and ownership models, almost wholly leaked from Wales. Other benefits, for example local payments from onshore wind generators to land owners, or to communities in compensatory 'benefit' schemes, are small compared to the value of the electricity generated (MUNDAY et al., 2011). Sitting, as it does within a highly regulated UK market for electricity and a UK national supply grid, Wales will see few price or energy security benefits flowing from local generation which might then have positive impacts on fuel poverty, competitiveness or inward investment (JONES, 2010). It would seem, for the UK regions at least, that a preponderance of natural resource, which is increasing in value, is no guarantee of increased prosperity.

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Table 1 Electricity Production in Wales (2013)

	GWh	% Welsh generation
Coal	10,824	40.8
Oil	56	<0.1
Gas	6,292	23.7
Nuclear	4,141	15.6
Renewables	2,434	9.1
Other (pumped storage, other non-renewable thermal)	2,810	10.6
Total	**26,558**	**100.0**

Source: Derived from DIGEST OF UK ENERGY STATISTICS, 2013

Table 2 Major Power Stations in Wales and Estimated Operational Employment 2012

Company	Fuel	Estimated Investment	Installed MW	Estimated employment
Baglan Generation	CCGT	£300m	510	c.32
Beaufort Wind (N Hoyle)	Wind (offshore)	£80m	60	
Centrica (Barry)	CCGT	na	230	c.36
Dong Energy (Severn)	CCGT	£600m	848	c.40
EDF (Aberdare)	Gas	na	10	na
EON (Connahs Quay)	CCGT	£580m	1380	c.80
GDF Suez (Shotton)	Gas CHP	na	210	c.32
IP/Mitsui(Dinorwig & Ffestiniog)	Pump storage	na	2088	c.130
IP Mitsui (Deeside)	CCGT	£200m	515	c.50
Magnox Wylfa	Nuclear	na	490	c.580
RWE npower (Aberthaw)	Coal	na	1586	c.270
RWE npower (Pembs)	CCGT	£1000m	2180	c.100
RWE npower renewables	Hydro x 3	na	42	na
RWE Rhyl Flats	Wind offshore	€216m	90	na
SSE Uskmouth	Coal/biomass	na	363	107
Statkraft (Rheidol)	Hydro x 3	na	49	na

Source: DIGEST OF UK ENERGY STATISTICS 2013, Jordan FAME, and research team estimates.
Note: na- not available

Table 3 Example: Regional Sourcing Assumptions

	Coal	Gas	Nuclear	Onshore wind	Offshore wind	Solar PV	Tidal energy	Wave
CAPITAL & DEVELOPMENT COSTS								
Grid connection & installation		60%	30%	50%	30%	70%	70%	50%
Nacelles / turbines /device manufacture		0%	0%	0%	0%	50%	30%	30%
Other Electrical (inc. solar cells)		20%	10%	40%	30%		20%	20%
Metalworks		10%	10%	50%	40%	80%	10%	10%
Foundations, mooring & other site & port works		50%	35%	80%	30%	90%	40%	70%
Planning, project management, surveys, consultancy		60%	20%	55%	50%	90%	70%	90%
OPERATIONS								
Maintenance inc. port operations & on-going surveys	70%	70%	50%	80%	50%	100%	90%	70%
Grid connection charges	0%	0%	0%	0%	0%	0%	0%	0%
Insurance	10%	10%	0%	30%	20%	20%	0%	0%
Other	50%	45%	40%	50%	50%	50%	0%	0%
Rates/seabed lease etc.	100%	100%	100%	100%	50%	100%	0%	0%

Note: These percentages and classes of expenditure should be considered indicative only due to differences in the nature of developments across technologies. They comprise our best estimate of most likely regional sourcing behaviors in aggregate and do not relate to specific current or future developments.
Sources: REGENERIS AND CARDIFF UNIVERSITY, 2013a, JONES et al., 2011; Authors' own calculations.

Table 4 Estimates of Person years of Welsh employment per installed MW connected to development and construction phases of electricity generation technologies

	Gas	Nuclear	Biomass	On-wind	Off-wind	Solar/PV	Tidal stream	Wave
Job years in Wales per MW installed	4.5	8.6	14.8	12.8	8.3	20.8	35.3	32.3
Scenario (typical) facility MW installed	500	1,900	50	100	300	30	30	30
Job years scenario for typical facility	2,250	16,340	740	1,280	2,490	624	1,059	969

Note: Figures here include job directly and indirectly connected to construction and development.

Table 5 Estimated distribution of total person years of employment by Welsh industry (Construction phase).

	Gas	Nuclear	Biomass	Onshore wind	Offshore wind	Solar/PV	Tidal stream	Wave
Construction & Manufacturing	65%	50%	58%	84%	68%	70%	67%	68%
Wholesale, retail etc	18%	15%	6%	5%	6%	10%	7%	6%
Transport & comms	2%	2%	2%	2%	2%	4%	5%	4%
Financial services	2%	2%	2%	2%	2%	3%	2%	2%
Professional services	12%	27%	32%	6%	19%	11%	18%	18%
Other	1%	4%	1%	1%	2%	2%	2%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 6 Full time equivalent Welsh employment supported per MW installed capacity during operational phase

	Coal	Gas	Nuclear	Onshore wind	Offshore wind	Solar/PV	Tidal stream	Wave
FTE jobs per MW installed	1.4	0.3	0.7	0.6	0.6	0.4	0.9	0.8
Scenario facility MW	500	500	1,900	100	300	30	30	30
FTE jobs in Wales pa in Scenario facility	700	150	1,330	60	180	12	27	24
Estimated 2012 MW installed	1,949	5,883	980	254	150	46	0	0
Estimated Employment supported 2012	2,729	1,706	715	160	84	18	0	0

Note: Figures in this table in first row are rounded up to one decimal place.

Appendix 1: Data sources for analysis

Selected information used in this paper derives from three pieces of research undertaken in Wales on the power generation sector (see REGENERIS CONSULTING and CARDIFF UNIVERSITY (2013a, 2013b) and, CARDIFF UNIVERSITY and REGENERIS (2013). In the case of REGENERIS and CARDIFF UNIVERSITY (2013a) onshore wind cost estimates were derived from a 2012 survey of developers and operators of onshore wind farms in Wales. The achieved response covered 66% of all existing and proposed capacity in Wales. The consultees (in addition to the survey of developers) which aided the research are found in Table A1.

For marine and tidal energy (REGENERIS and CARDIFF UNIVERSITY, 2013b) there were fewer contact points because of the early stage of the technology. Here focus was on device/project developers and consultations took the form of structured interviews as well as the use of a proforma to gather data on costs and sourcing (see also Table A1).

The CARDIFF UNIVERSITY and REGENERIS (2013) study examined a wider set of technologies and initially comprised structured research reviews of the employment and economic effects of different electricity technologies. The research also included a series of consultations with developers/operators to gain information on spending patterns and employment (see also Table A1).

Table A1: Firms and Organisations Surveyed/Consulted

Regeneris Consulting and Cardiff University (2013a): On shore wind	Regeneris and Cardiff University, 2013b: Wave and tidal stream	Cardiff University and Regeneris (2013): Other power generation technologies
Welsh Government (Sustainable Futures, Energy Wales) RenewableUK RWE npower renewables Vattenfall West Coast Energy Falck Renewables Wind Limited Tegni Neath Port Talbot Council Denbighshire Council Mabey Bridge	Welsh Government DECC RenewableUK Carbon Trust The Crown Estate Scottish Enterprise Marine Current Turbines/Siemens Tidal Energy Ltd Marine Power Systems Marine Energy Pembrokeshire University of Swansea	Bangor University Biffa Centre for Alternative Technology Cogent Sector Skills Coleg Menai Dwr Cymru Welsh Water Dulas Wind EDF Energy Energy and Utility Sector Skills Horizon Nuclear Power Kelda Services Low Carbon Research Institute (Cardiff University) National Nuclear Skills Academy Pembrokeshire College Renewable UK Cymru RWE n power (Pembroke Dock) South West Wales Procurement Hub Scottish and Southern Energy Summit Skills Swansea University Welsh Centre for Excellence Anaerobic Digestion, University of Glamorgan Welsh Government (Waste and Resource Efficiency Division)