Energy and development in the periphery: A regional perspective on small hydropower projects

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Abstract

Investments in renewable energy have been identified as one mechanism for encouraging development in lagging regions, with community owned or operated facilities potentially having a relatively greater impact. The development of small hydropower installations in Wales is examined to establish the economic and community benefits of such schemes. The sector displays a number of locally beneficial economic characteristics that are absent from larger scale renewable investments. However, this is shown to be a fragile sector dependent on a small number of key individuals and institutions, and with an investment model relying on depreciating UK government subsidies.

Following an introduction, the paper first examines why renewables, and small-scale, community renewables in particular, have attracted attention as a part-response to declining economic, social and environmental conditions in rural communities. It then describes the Welsh energy and policy context before describing the data and the method employed in the research. The paper then examines the economic value of small hydropower developments; the nature and scale of impacts on local social capital and on communities; and then the extent to which small hydropower might be considered distinct from other local energy sectors in terms of business behaviours and inter-organisation relationships. The discussion then focuses on factors affecting prospects for the small hydropower sector, and which will limit how far development of the sector can lead to transformative outcomes for communities close to the natural resource.

Key words: community development; cluster growth, community energy, environmental sustainability, sustainable development

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Introduction

Rural communities are often characterised by limited economic opportunity, but these same communities are often co-located with valuable natural resources. The paper examines whether the development of small-scale in-stream hydropower facilities (hereafter small hydropower)[1] can provide a direct or indirect stimulus to community development. We examine the case of small hydropower facilities in Wales, a largely rural region of the UK, to establish the scale of local economic benefits consequent on the construction and operation of such installations, and on the income received from renewables subsidies (here Feed in Tariffs (FiTs)[2]), whether arising from community, third sector or privately owned turbines. We also investigate the wider development potential of the small hydropower sector regionally, showing it displays interesting 'cluster' characteristics, but also very significant vulnerabilities to wider economic conditions.

Wales is an interesting lens through which to explore the local socio-economic contribution of small-scale electricity generation of which small hydropower is a case.

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[1] We use the term small hydropower throughout as relating to installations of less than or equal to 499 kW capacity, but later on in the analysis we provide a further distinction of micro-schemes of 99 kW or less.

[2] Feed-in tariffs are financial supports for selected low-carbon electricity technologies, and aimed at small-scale installations (less than 5 Megawatts). FiTs support new anaerobic digestion (AD), solar photovoltaic (PV), hydropower and wind, by requiring electricity suppliers to make payments (generation tariffs) to these generators based on the energy they generate. An additional guaranteed export tariff is paid for electricity generated that is not used on site and exported to the grid.

At one level devolution processes in the UK have been asymmetric and this conclusion relates particularly to energy matters. Upton (2014) analyses Welsh powers in respect of energy matters compared to other devolved UK administrations. For example, in terms of energy generation Wales has planning and consenting powers for onshore energy generation projects up to 50 Megawatt (MW) onshore (and dealt with under local authority planning powers). However, this limit does not apply in Northern Ireland and Scotland, and with Welsh Government powers will shortly to be extended in this respect. Indeed Upton (2014) suggests Scotland has made more progress than Wales on energy policy with more comprehensive policy documents, more coherence among local authorities and environmental bodies on project development, and with Welsh Government criticised for a cumbersome regulatory system that is perceived as a key barrier to small-scale energy development.

Wales (as other devolved UK administrations) has also placed itself squarely within a green growth agenda that embraces more renewable electricity generation capacity (Welsh Government, 2012, 2014a). However, there is a question on how far different types and scales of renewable electricity investment lever advantages for the communities close to the natural resources employed. In this respect a series of papers have focused in upon the embeddedness of electricity generation investments (for example, Munday *et al*., 2011). Embeddedness is a complex term and can include issues like the intensity of local socio-economic and community linkages supported by energy investment programmes, and the types of activity supported by electricity generation plants once in operation. Existing research in Wales has pointed to trade-offs between large-scale, centralised and often more established electricity generation technologies; and novel (renewable) and more diffuse technologies in terms of employment generated per unit of installed capacity (see Bryan *et al*., 2015). There has been limited opportunity for local firms to engage in technological development or early-phase implementation with many renewable electricity generation technologies. This is in part because the prevailing paradigm of energy generation in Wales has tended to be in terms of capital investment decisions made externally, developers and managing contractors based externally, and then the risks and rewards of new infrastructure development in large measure arising externally to the regional economy. Under this structure, the benefits from local electricity production will be modest and with limits on how far large scale renewables development (for example, onshore wind) might be transformative for host economies. Wales is unlikely to be alone with respect to this problem of capitalising on future opportunities from renewables. This has been a theme in other UK research undertaken around renewable electricity development covering, for example, on and offshore wind in England and Scotland and here with Cowell et al. (2012) exploring linkages between energy generation and local socio-economic needs.

Welsh Government has been keen to better embed new renewable electricity production into the regional economy (Welsh Government, 2012). The development of renewables, particularly small scale, decentralised and community owned renewables, might be seen as beneficial in a number of ways. Renewables reduce greenhouse gas emissions. Meanwhile, such electricity could (theoretically at least) be used by communities and businesses local to its source to offset the cost of power purchased from the grid – and indeed, over recent years provide a reasonably steady income stream through UK level subsidies for renewable generation. Such decentralised energy production can also reduce grid losses. There is also a recognition that the pattern of local social and economic benefits can be different with smaller schemes, especially where there is either full or partial local ownership (see for example New Economics Foundation, 2012). Indeed wider research has examined issues around regional energy governance, and with small-scale community projects seen to have implications for economic development paths, but also with implications for communities in terms of control of projects and revenue generation (see Walker et al., 2007; Harnmeijer et al., 2012). Then different models of ownership of renewable energy developments may have different economic results (see particularly here, Phimister and Roberts, 2012, Capener, 2012), but also social and environmental results, for example, in the latter case relating to perhaps minimising environmental damage around developments where communities own the land on which facilities are placed, and in terms of growing environmental awareness of communities (see Cowell *et al*., 2012).

Given the above it is perhaps surprising that the comparative development of UK community owned renewables has been disappointing by most chosen metrics. For example, community renewables in Wales currently represent a small percentage of both electricity generation and new renewable capacity installation (see for example, Community Energy Wales, 2016). Underlying the slow pace of development are various factors including a lack of financial, human and strategic capital in local communities, and tensions with environmental regulators focussed on protecting biodiversity (Cowell *et al*., 2012). Both the supply and demand side environment surrounding community renewables development is uncertain, with government subsidies for small scale renewables delivered via FiTs under increasing scrutiny, and with lower levels of support announced in 2015.[3]

This paper examines the case of community and non-profit-taking hydropower schemes in Wales and addresses three issues. Firstly, we examine the amount of economic activity supported by the development of small hydropower schemes, and consider the extent to which local communities might benefit from their development. Second, we seek to examine whether there is any evidence that such small schemes have provided community resources. Third, we assess whether the small hydropower sector in Wales displays distinctive characteristics compared to other energy sectors regionally in terms of its local orientation, knowledge sharing and other relationships that might benefit both communities and involved organisations. In particular here we address whether the small hydropower sector has any characteristics of a regional 'cluster' (Porter, 2000; Cooke, 2001).

The remainder of the paper is structured as follows. The next section examines why renewables, and small-scale, community renewables in particular have attracted attention as a part-response to declining economic, social and environmental conditions in rural communities. The paper then briefly describes the Welsh energy and policy context before describing the data and the method employed in the

[3] See later Table 3.

research. The paper then presents the findings from the research in terms of the quantitative economic value of small hydropower developments; the nature and scale of impacts on local social capital and on communities; and then the extent to which small hydropower might be considered distinct from other local energy sectors in terms of business behaviours and inter-organisation relationships. The final section of the paper discusses the findings and concludes.

Renewable energy and local development

The need to reduce greenhouse gas emissions has resulted in increased investment in renewable electricity generation and energy efficiency over recent decades. Moreover governments at local, regional and national level have identified renewable energy investments as not only environmentally beneficial, but also having the potential to re-start stalled economic growth and provide much needed jobs (DECC, 2013; Welsh Government, 2012).

For peripheral regions and rural areas the focus on renewables (and especially generation) might have been seen as very welcome. Cowell *et al*. (2012) reveal how some of the most significant wind, wave and tidal resources are close to more disadvantaged communities. Here then were a series of immobile natural resources; overwhelmingly rurally based and, in most of Western Europe, concentrated in economically lagging Northern and Western regions (Clarkson Research, 2012). Renewables development then appeared to be a golden economic opportunity.

Alongside such optimism are a series of economic realities. The gross number of jobs associated with renewables development is modest. Moreover, the nature of renewables in terms of wind, hydropower and solar voltaic also places limits on the number of longer term jobs supported in operations and maintenance (Cardiff

University and Regeneris, 2013; Winning, 2013). Furthermore, a number of studies point to the limited ability of rural areas to capture the economic benefits – and especially non-employment benefits - associated with the use of local natural capital for electricity generation, particularly when the paradigm is that of large-scale development financed by non-local capital. For onshore wind, Munday *et al* (2011) highlight the lack of local supply chain development, especially in manufacturing – as well as the relatively small scale of community benefit provisions from developers associated with large commercial schemes. Of course there is an underlying issue here with undifferentiated rural economies perhaps lacking the skills and firms to provide necessary goods and services to renewables installers (Moreno and Lopez, 2008).

Compared to internationally financed and large scale renewable energy installations, those at smaller scales and with different ownership models may offer a greater opportunity for benefits to accrue locally. However, the evidence is sparse. This is in part due to the slow pace of community-led installations and the difficulties inherent in quantifying employment impacts *ex ante* and locally (Lambert and Silva, 2012). There is a paucity of European studies that comparably relate the benefits of small scale renewables, community owned or otherwise, to larger scale investments (see Santiago and Roxas, 2013). Entwistle *et al*. (2014) examine the economic impacts of community owned renewables (largely wind turbines) in Scotland and identified significant annual incomes from the sale of, and subsidies for, generated electricity, ranging from £125,000 per MW installed to £280,000 in the most advantageous locations. These totals were large in comparison to local incomes from construction spend and land rent and maintenance. This highlights the importance of community ownership in driving local incomes – the subsidies and export monies would leak from the locality in the commercial case and annual community benefit payments from large wind farm operators are much lower than the incomes estimated here – typically in a range from £2,000- £5,000 per installed megawatt and rarely linked to the power generated from plants (Cowell *et al*., 2012; Cardiff University and Regeneris, 2013).

There is also evidence of the potential and actual social and environmental impacts of community renewable developments, albeit by no means a settled picture. In part this is due to some looseness in the very definition of 'community' (Walker, 2008), and perhaps a wideness in the hoped-for benefits that dilutes research effort. Putative social benefits highlighted in studies have included: an increase in the capacity and skills development within the organisation developing the initiative; new social facilities and initiatives subsidised by the newly available revenue streams; strengthening of social and network capital and cohesiveness within the community through the act of developing the initiative; facilitated attitudinal and behaviour change within the wider community, and specifically more positive attitudes towards renewables; an increase the uptake of domestic renewable technologies; and more engagement with climate change and energy issues in general (see for example, Walker *et al.,* 2007; Walker and Devine-Wright, 2008).

One conclusion from reviewed research is that it is more difficult to measure social and community benefit, with few well established, adoptable and practicable techniques, and with commercial models of innovation and growth inappropriate (see for example, Hanley and Nevin, 1999; Hargreaves *et al*., 2013; Slee, 2015). The complexity of the task is highlighted by the New Economics Foundation (2012) whereby identifying social return on investment (SROI) on energy developments had to embrace a very wide range of variables and with consequent difficulties in operationalisation.

Much of the material on community energy projects actually speaks to ‘barriers’. Van der Schoor and Scholtens (2015), for example, explore difficulties for community projects in building an adequate local consensus, and encouraging participation over the longer term. Walker (2008) also noted a number of factors faced by community energy projects over other commercial schemes. Included here were issues around the legal conditions under which organisations or projects can operate, the ability to seek expert advice and support, the common requirement to develop a series of funding sources to capitalise projects, and basic issues of community capacity. Johnson and Hall (2014) also flag up an issue of a finance gap for community energy schemes. They cite the centralised structure of the UK banking system as not conducive to servicing ‘civic actors’.

Relevant to our study is also the extent to which successful developments are critically dependent on appropriate public policy, in terms of not just subsidies but also in the provision of a supportive institutional context, and in providing a technical context that enables investments in decentralised generation (e.g. grid access). Here there is a general view that the environment in the UK is not conducive to the rapid uptake of community renewables, with relevant policies inconsistent over time and split between different governments and regulatory authorities (see Walker, 2008; Seyfang *et al* 2013; Cardiff University and Regeneris, 2013). The situation remains fluid.

Much of the previous research on community and decentralised energy has concentrated on its social and technical character. Few papers focus on the economic, and even fewer on economic *impact* rather than economic structure. This is a significant gap. Traditional rural economic activities like agriculture, especially in peripheral areas, are largely in decline, with growth in areas such as tourism insufficient to take up the employment slack and adequately support a diverse and vibrant rural economy and suite of local services (see Allanson and Whitby, 2014). The potential for community (or rather, more *diverse*) economic actors to provide a driver for alternative economic approaches and sector organisation is of interest.

In urban agglomerations, productivity, competitiveness and firm and sector growth is held to depend on a series of factors. These include: shared transport and soft information and communications technology infrastructures that lower costs; shared inputs and suppliers, enabling scale economies, innovation and higher productivity in supply chains; and knowledge spillovers between 'related' firms and labour market efficiency (see Porter, 1998). However, similar processes are held to occur at regional scale and in rural areas, where they can add to wages and productivity and provide an option for rural economic transformation and renewal (see for example, Morgan, 2007; Munnich *et al*., 2003). Given the *a priori* situation for small hydropower and other small scale renewables, with many actors not-for-profit taking, and sharing common goals around sustainable development and rural regeneration, the potential for clustering behaviours to arise within this discrete sector is also worth of study.

Context, data and method

Small and community hydropower in Wales

Hydropower electricity generation makes a significant contribution to the Welsh renewable landscape, comprising 15 % of all renewable capacity in Wales and 10 %

of all renewable electricity generation (Welsh Government, 2014a, b). However, the vast majority of this capacity is (relatively) large and old.

The UK *Digest of Energy Statistics* (2015) lists six larger (greater than 10 MW, and not including pumped storage) hydropower developments in Wales operational in May 2015, totalling 149 MW of capacity. Welsh Government (2014b) estimated that there were a total of 163 hydropower projects in Wales with a combined capacity 152 MW in 2012. OFGEM (2015) revealed 104 hydropower projects in Wales of less than 0.5 MW claiming feed-in-tariff. Total installed capacity of these projects was 3.51 MW, with all but 5 less than 100 kiloWatt (kW) installed capacity, and with 70 schemes listed as domestic schemes, 32 as non domestic commercial and industrial, and just 2 as community. Currently the majority of schemes are in the hands of private developers. For example, Community Energy Wales (2016) revealed that there were 6 community owned/National Trust owned hydropower developments in Wales totalling 1.25 MW of capacity, but with more in prospect, particularly on land within and adjacent to the national forest estate.

The community and third sector element of hydropower comprises a small number of key actors – a handful of community interest companies (CICs) and charities who often have interests and projects, planned in development and complete, across different sites and often extending to other technologies. Meanwhile several commercial operations offer development and installation services to private landowners, with clienteles usually restricted to a part of the region but extending beyond the immediate locality or county.

The Welsh Government is supportive of renewable installation in principle, and with small hydropower very much part of this picture. As recently as Spring 2014, the delivery plan for low carbon transition made plain the importance of distributed generation and the Welsh Government emphasizes its openness to development on its own forestry estate (Welsh Government 2014a, 2014b).

Data

The research for this paper was undertaken with the support of the Wales Hydropower Stakeholder Group.[4] This includes representatives of the British Hydropower Association; environmental lobbying groups; CICs; hydropower developers (commercial, charity and community) and Natural Resources Wales (see Appendix). The support offered by this body assisted in the process of data collection.

Data was gathered during 2014 in the following ways. First, through the Stakeholder Group it was possible to undertake a basic audit of planned and existing small hydropower developments, detailing installed capacity and expected generation, overall levels of funding and costs (including sources of finance and expected FiT and export revenue), and to gather information on the patterns of goods and services purchases by completed and planned projects. Second, there were a series of semi-structured interviews with stakeholders including project developers, regulators, community enterprises and local community representatives (this was supplemented by email and telephone correspondence with three commercial developers regarding their outline business model, local sourcing, scale of installations). Members of the research team also undertook field visits to three communities that had developed

[4] Some of the research underpinning this paper was supported by Natural Resources Wales. We are grateful for this support, but responsibility for the material in this paper rests with the authors.

small hydropower installations to discuss experiences, barriers and social outcomes. Finally, a web based questionnaire was sent out to individuals in the hydropower-experienced communities to relate personal experience of their individual project. Further details of respondents is also given in the Appendix.

The above primary work was supplemented by an examination of relevant company, charity and other websites to glean information on the scale and nature of small hydropower installations.

In summary the economic analysis that follows is based upon technical and financial information from 16 for profit and not-for-profit-taking small hydropower schemes, ranging from 10 kW installed capacity to multiple-100 kWs. Partial information was recorded for a further 22 schemes. The information developed is sufficient to provide some analysis of the not-for-profit sector given its overall small size – the information obtained covers the majority of planned or operational non-privately owned small hydropower schemes operating in Wales. However, it should be remembered that the information covers schemes planned, in development and completed (the last further divided into cases where the social dividends are, or are not yet, being enjoyed). Additionally, the voice of the commercial sector is rather subdued. Those contacted in the for-profit sector were able to provide only outline financial information for their schemes, usually due to stated time or resource constraints.

Economic impact method

One element of the research relates to the economic impact of small hydropower development in terms of employment and gross value added. There are difficulties inherent in modelling the *local* economic impact of small hydropower generation projects. Here the approach was to use the framework provided by Input-Output Tables for Wales to assess the *regional* economic impact of new developments (Jones *et al.,* 2010). This is clearly a significant limitation. Local communities lose much of the economic impact from local projects to larger within-region conurbations, and the figures presented in this paper should therefore be viewed as indicative.

There are, however, benefits to using this framework. Firstly, it has been widely used in the assessment of the economic effects of different types of electricity generation (see for example, Markaki *et al*., 2013; Winning, 2013, Allan and Gilmartin, 2011). The method also allows an assessment of construction, maintenance and FiT/export impacts to be made using common employment and gross value added (GVA) metrics, showing where the drivers of impact arise. However, the general limitations of the input-output modelling framework need to be considered, although these limits in terms of supply side assumptions, and fixed technical coefficients may be less of an issue with small-scale hydropower in Wales (see Miller and Blair, 2009).

The formal analysis here is complemented by the qualitative data collection when assessing local economic impact. Following the data collection process the data were arranged in a way which represents additional spending in Wales arising from project developments, and to present this in terms of a 'typical' project, although this is slightly misleading for what is a very heterogeneous sector. Our assumptions are detailed in Table 1 following, and refer to a 20 year guaranteed FiT payment period. In what follows (see earlier footnote 1) we consider micro-hydropower as a sub set of small hydropower (i.e. schemes up to 99 kW installed capacity). Our typical scheme (or bundle of schemes), at 99 kW and 499 kW, were chosen to represent the break points beyond which the FiT reduces (per kWh). No rational developer would submit a scheme just over this limit, and our stakeholder interviews suggest that schemes (or bundles of schemes) much below 100 kW are uneconomic for community investment. Practically the selection of FiT break points may result in projects being squeezed into one category or other which can lead to poor design choices.

Table 1 about here

Using the developed assumption set it was possible to model the economic impact of a ‘typical’ micro- and small hydropower development on the Welsh economy.

Impacts and character of hydropower developments in Wales

Regional economic impact

This section presents estimates of the regional economic impact of a micro (99 kW) and small (499 kW) hydropower project development. In summary, activity occurring ‘onsite’ and in Welsh suppliers (of raw materials and services) is included in the estimates, as well as the impacts that occur as workers spend their wages in Wales.[5] Our indicative 499kW scheme is large in terms of third sector or community development.

All economic effects (see Table 2) are presented per annum – averaged across the 20 year FiT period in terms of both GVA and employment arising. This includes planning and construction impacts. In reality the investment and hence impact will be front loaded, occurring mostly as the facility is built (or during maintenance spikes). However, community income from FiTs will be more evenly distributed as this will be dependent on the frequency and distribution of annual rainfall in a given year. Part

[5] The approach is then based on an estimate of Type 2 multipliers; see Miller and Blair (2009) for further technical explanation.

of these results relate to *all* small hydropower investments – development and operations – and part to only *community owned* small hydropower – impact of FiT-consequent community funds.

The impact arising from the planning, development and operational phases (combined) of a micro-hydropower scheme (99 kW) is about £18,000 of GVA to the Welsh economy (annualised over the FiT period). This equates to around 0.5 full time equivalent jobs supported per annum for that period. The typified small hydropower scheme (at 499 kW) drives higher levels of GVA and employment generation. However the levels of activity supported are significantly lower per installed MW. This is due to a number of factors including the economies of scale leveraged for larger projects, which have the benefit of being more resource efficient (for example, in building facilities and turbines); and a somewhat lower level of local sourcing, especially with respect to the turbine (a hydro turbine up to 100kW could at this time be purchased in Wales).

The impacts of the development and operations spending are spread across the Welsh economy, albeit varying by project (e.g. depending on the location of specific contractors and purchased inputs). There were a number of key findings here. First, there was a wide range of impact across a number of sectors. Around 60% of impact is related to initial development and set up and 40% to ongoing maintenance and operations. It is estimated that 40-50% of development impact occurs in manufacturing and engineering activities and products, driven by the cost of materials and machinery (see Table 1 for assumptions on local sourcing propensities which is a key driver of the modelled sectoral development impacts). The construction sector attracts an estimated 20-30% of development-phase economic impact.

During the operational period, significant costs included land rent and rates, with the former providing important and potentially 'local' incomes to land owners. These costs can together comprise between a half and three quarters of all ongoing (post-development) costs. Direct maintenance costs are relatively small, even including an assumed refurbishment of a turbine and/or ancillaries once during the 20 year period. The results suggest that a mix of different hydropower developments totalling (just under) 1MW capacity, and comprising one 499kW facility and five 99kW facilities, would support £150,000 of GVA and 5.5 FTE jobs annually (Table 2). It is difficult to assess how much of this regional impact will be 'local' to the development site – some of which are quite some way from population and employment centres. However, both qualitative and quantitative evidence gathered suggested that developers are typically sourcing services from close to the project, and that this was very much part of the development rationale. For example, the majority of the feasibility and other work is done either 'in house' or contracted locally, and it is estimated that between 40-60% of construction spending is local.[6] High levels of local spending carries through into the operations and maintenance phase, emphasizing hydropower in Wales as an embedded and localised activity.

In addition to the 'industrial' impacts of small hydropower developments detailed above, community-developed hydropower brings an additional benefit in that the FiT payments and any payment for exported electricity are placed into community benefit

[6] In the questionnaire 'local' was defined as within 10 miles or within the same Planning Authority (Unitary Authority or National Park). The local sourcing assumptions for construction were derived from interviews and questionnaire returns – see Table 1.

funds, net of the repayment cost of capital.[7] These funds have their own impact (dependent on their use) in that they can support additional employment and activities in the reference communities (geographic or ‘communities of interest’) – and with potential ‘multiplier’ impacts as more activity is supported outside those communities but inside Wales. The nature and scale of this additional economic impact will depend on the level of FiT/export surplus (and see Table 3 for prevailing FiT rates), and the ways in which funds are employed. Following the programme of primary research our respondents suggested that a mix of educational, community retail and recreational activities were most likely to be supported by community funds, along with a good proportion of physical refurbishment and ‘pump priming’ for further low carbon investment. We estimate that the ‘typical’ micro-hydropower project might here generate £12,000-18,000 surplus per annum, and the small 499kW project perhaps £40,000 - £60,000 per annum. The impact results at the bottom of Table 2 use the mid-point of these ranges and apply a mix of relevant activities/sectors for the modelling of results.

With multiplier impacts included, FiT and export-related surpluses deliver some £13,500 of GVA per annum, across Wales for the scenario 99 kW micro hydropower project, and £39,000 for the 499 kW small hydropower project. Levels of supported employment are very similar to the development and operations case i.e. 0.5 FTEs for the micro project and 1.5 FTEs for the small. On a per MW basis the small

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[7]Note these are not to be confused with community benefit funds that result from developers (typically in respect of large scale energy projects) placing monies voluntarily into communities to support various local causes (for the rationale behind these schemes see for example, Cowell et al., 2012).

hydropower project does not perform as well as the micro project. This is no longer due to differences in the economic and sourcing profile, but rather due to the lower level of FiT that is payable per kW for installations of above 100 kW.[8] (Table 3 summarises the rates of FiT for hydropower prevailing both before and after the December 2015 government review of the scheme.) It is far more difficult here to judge how far these impacts are 'local' to the site(s) in question. This will depend markedly on the nature of the projects undertaken as a consequence of the community benefit fund. Some funds are intended to be directed very closely at a geographic community (hence with likely high local impacts), others are more 'thematically' oriented across a wider spatial area. The relative evenness between the economic impact arising annually, per MW from development and operations (£150,000 and 5.5FTEs) and from FiT/export income (£110,000 and 4.5FTEs) is notable.

Table 3 about here

For community hydropower the 'industrial' and FiT impacts are additive at scheme level. Therefore Table 2 presents the overall economic impact for community hydro, revealing a total impact, per MW, of £260,000 in GVA and 10 FTE jobs. It should be noted that the income from FiTs that accrue to private and commercial developments will also be spent in part in Wales although with no information gleaned from commercial projects on this, it is difficult to say how much. Therefore the indicative

[8]The FiT Tariff levels are reproduced here https://www.ofgem.gov.uk/ofgem-publications/89098/fitpaymentratetableforpublication1october2014nonpvtariffs.pdf - with schemes studied falling into one of a number of past, present or future tariff time periods, we take our lead from the survey and effectively assume 20p per kWh for up to 100kW and 15p for over 100kW; and 4.5p per export kWh in both cases.

impacts from commercial developments will in reality be somewhere between the figures reported in the top and bottom panels of Table 2.

The Input-Output tables for Wales have, in recent years, been used to model the regional employment impacts of different energy investments, with these standardised to report per MW installed.[9] Together, the results of these studies comprise a suite of numbers that is at least indicative in representing the employment impact of different generation technologies in Wales – per MW installed. Different technologies are at different stages of evolution: gas versus marine renewables for example. There are different relevant operational periods: a planned tidal lagoon in Swansea Bay may be in place for a century; most Solar PV and onshore wind for perhaps a quarter of that time. Critically here, different technologies imply different scale and hence require a contextualized reading of per MW impacts. Despite this the comparative employment generation data per MW across technologies and on a 'lifetime' basis is of some interest. Figure 1 does just this for the overall, annualized, impacts of energy investments. On this measure it is no surprise that small hydropower does extremely well as a generator of regional employment per MW installed compared to other technologies, even excluding community income from FiTs and exports. This is because firstly, hydropower is relatively expensive to install. The estimated cost per kW for development ranges from £5-8,000, and this is at the very high end of costs

[9] We do not of course underplay the issues in comparing technologies at different stages of development, very different scales, ex ante and ex post, and with different development and generation profiles.

across generation technologies.[10] We underline again here that comparing capital costs per MW or kW installed for different technologies at different stages of technical development is fraught with problems. The high cost of small hydropower comes despite the application of mature technology. This is due to (in Wales) the absence of large economies of scale and bespoke and often complex installation approaches and locations. Second, small hydropower is an ‘embedded’ economy. Energy developments in Wales are usually typified by the import of high value materials, machinery and often services. Because small hydropower is ‘small’, the characteristics of the industry are quite different, including ongoing, high-trust customer-supplier relationships and interactions. These relationships drive a higher than usual level of regional and local sourcing, and a higher level of regional economic impact. As revealed earlier, the FiT/export related benefit of community hydropower is almost as significant as spending on development and operations. Other technologies benefit communities in similar ways. For example the FiT arising from other qualifying renewable technologies, and the community benefit funds paid to local communities (at up to £5,000 per MW in the case of onshore wind – see Cowell *et al*., 2012) by commercial developers in Wales.

This comparison does however need to be treated with a little care. In a limited number of cases, benefits from the sale of electricity (and the increased price brought

[10] There is likely to be strong variation around these figures. For example, ARUP (2011) reported on relatively high hydropower capital costs ranging from £2,797 to £9,507 for schemes below 1 MW installed capacity. Capital costs fell as schemes grew in size. For example for projects from 1-5 MW installed capacity, capital costs ranged from a low of £2,423 per MW to £4,982.

by contract for difference or FiTs) would accrue to Wales but are uncertain, and not included here. The overwhelming majority of generation capacity in Wales is however non-Welsh owned and with incomes from electricity sales leaking from the region.

A hydro cluster?

Small hydropower in Wales displays a number of characteristics that distinguish it from other renewable energy sectors in Wales. There are a number of industry characteristics from the literature on clustering, proximity and productivity enhancements (see Porter, 1998, 2000; Cooke, 2001, Ellison and Glaeser, 1999) that would seem to be relevant in the small hydropower case.

First there is a predisposition to source inputs locally and within Wales, even when the short term cost is higher. This tendency was cited by respondents from the commercial, third and community sectors and arose, variously, from a desire to guarantee (or develop) local inputs for future projects, and to maximise regenerative benefits locally. Second, intra-region input-sharing for important inputs helps develop the supply chain (Ellison and Glaeser, 1999). For example a number of community and third sector developers have purchased turbines from the same Welsh manufacturer, and have been instrumental in that firm's ability to grow and innovate through technical and financial partnerships. Then there appears to be a deliberate and consistent attempt by a number of developers to upskill elements of the supply chain.

Third industry figures appeared to have a proactive, multi-faceted and continuing relationship with a number of regional institutions, including governments and higher education. This extends far beyond the need to interact on (often contentious) regulatory issues. Fourth, learning from hydropower developers is shared widely and freely and across different technology developers, and with little concern that there may be competition for scarce investment funds or government attention. For example a hydro CiC said of a community solar development: 'We tried to give them a bit of help, on how to structure and sell the community share offer for example. We've been there and done that and it's not easy.'

These characteristics might reveal the small hydropower sector as an evolving regional cluster, or in some senses it might be more correct to frame it as part of a small renewables cluster, as opposed to one centred on a single technology. The drivers of these behaviours are largely not internal to the firm or organisation. Numerous respondents cited wider, shared objectives around climate change and ensuring the sustainability and viability of rural (and post-industrial) communities as the rationale for their attempts to grow the sector and renewables more generally. It is also worth remembering that the sector and Wales are both small. The behaviours displayed can be traced to a group of individuals who are well networked. Such interactions may simply wither at 'industrial' scale.

Illustrative community impacts

Two case studies reveal the community uses of FiT and export income. Cases described are the Cwmclydach hydro in the post-industrial South Wales valleys (55 kW; development trust owned on municipal land); and then a scheme in Talybont-on-Usk in rural East Wales (35 kW; Company Ltd by Guarantee). Each scheme's activity generated between £15-£30,000 per annum, and with this applied to locally distinctive projects.

In Cwmclydach, a very deprived community, the income was used to subsidise staff at the local day care and nursery with the explicit intention of enabling the re-entry of (particularly) single mothers into the labour market. In Talybont supported schemes had a distinctly climate change and environmental focus, with the objective of reducing community energy use and transferring as much of the remainder as possible to renewables (for example, promoting the installation of solar PV and the purchase of a community electric car). Drawing from the two case studies, associated field visits, and online individual questionnaires, a number of findings are highlighted.

All developer organisations reported that they had acquired new skills, knowledge and expertise as a result of developing their hydropower initiative. Most obviously these included knowledge of the practical application of renewable energy technology, which, while usually focussed primarily on hydropower technology, often also encapsulated other renewable technologies that the organisation had explored. It also included the development of technical knowledge and expertise of supply and demand within energy markets and the functioning of the National Grid.

Organisations also cited a better understanding of the often complex process of acquiring the various permissions needed from different government departments and the various regulatory codes which applied not only to the technology itself, but to funding regimes and ownership models. Skills developed here not only included hard knowledge of navigating the complex mechanisms of local, Welsh, UK and even EU government, but what might be termed the 'soft skills' of knowing who to talk to and how to exert effective influence.

Whilst the development of small hydropower initiatives had a positive effect on the organisations' capacity, this impact was considered precarious and fragile with hard worn knowledge and experience lost through shifting policy and funding priorities and/or the departure of key personnel. This was particularly evident in Cwmclydach where the reconfiguration and scaling back of the local EU funded Communities First Programme, under whose auspices the project had been developed, resulted in the loss of key personnel, capacity and a considerable dilution of the organisation's focus on community energy initiatives. The end result was that there is a strong sense that the hydro-initiative now represented the endpoint of the organisations ambitions towards community renewables, as opposed to its initial intention for it to be a springboard for more wide ranging actions.

The case hydropower initiatives acted as a source of long term 'no-strings' income that allowed the organisations to develop with a greater degree of autonomy than would be possible from income streams such as grant funding, loans or service level agreements. Equally, the income generated by the schemes was seen to be acting as a valuable source of 'clean money' for programmes with a match funding requirement and so enables flexible and innovative responses to the particular conditions and needs identified within relevant communities.

While the developing organisations reveal significantly increased internal capacity, knowledge and networks as a result of hydropower investment, there is also evident development of new community 'hard' resources. How far such impacts and investments are of benefit to the wider geographic community is however unexplored here (but see Walker, 2008 on this issue).

5. Discussion and Conclusion

Research into the small hydropower development in Wales revealed a sector which is full of engaged, dedicated individuals, many with strongly altruistic motivations, and only too willing to share their experiences and knowledge with the inquisitive researcher. The research has shown (with caveats) that small hydropower features high levels of local sourcing, ongoing knowledge transfer (vertical and horizontal), innovative technical and financial approaches and partnerships, and a genuine desire on most involved to see the whole sector grow and socio-economic impacts increase. Meanwhile, something of the community and social return on such investment was evidenced in the research.

In terms of local and regional economic impact, small hydropower offers a number of advantages over both large scale power generation *and* other small scale renewables. The characteristics of the industry are shown to drive a relatively high level of regional and local sourcing, and a higher level of regional economic impact. Job creation (per MW installed) is significant, due to the large proportion of inputs sourced regionally – surveying, ground works, maintenance, and even some turbine fabrication for example – and the relatively bespoke (and hence high expenditure) nature of each installation. While overall job numbers are currently small, this needs to be seen in the context of a series of other social effects for communities developing schemes, and the paper also reveals the potential for local economies to internalise much of the economic benefit of schemes, although with more research needed to explore how far monies are retained in actual communities surrounding the developments as opposed to in a wider local economy context. Indeed there may be an issue of how far the incomes leveraged by successful schemes can be used as leverage for further local renewables development.

However, the paper also revealed that this sector is extremely vulnerable and unlikely to see much growth, at least in Wales and certainly in terms of community elements. There are several reasons for this, only in part related to the relatively high cost of development.

Firstly, small hydropower is subsidy-enabled. Only the payment for exports and of FiTs, guaranteed over a 20 year period, makes investment in such expensive electricity generation possible. FiTs for small hydropower were cut substantially in early 2016, and are currently depreciating (for new investments) at a rate of 5% per annum, and this is one factor affecting the viability of projects. This reduces the return on investments. Due to the mature technology employed on run-of-river hydropower, and the bespoke installation requirements, costs per unit cannot fall far, as has happened for Solar PV, protecting surpluses. This has both a direct impact, as potential developers are dissuaded from undertaking projects, and an indirect one as potential investors find other investments more attractive. Should the interest rate increase from its currently very low level, the level of available investment capital will probably decrease. Community led projects, with the need to produce a worthwhile community fund, and with higher organisational overheads (explicit or given *pro bono*) will probably feel the pinch before private developments.

A second issue relates to the tension between energy generation and environmental impact. The Welsh Government through Natural Resources Wales is attempting to implement an ecosystem services approach to nature management with often inadequate data and falling staff resources. The default position (it is claimed by hydropower proponents) is a slow and inefficient water abstraction application process, inconsistent policy across space, insufficient weighting of the climate benefits of renewables, and an overuse of the precautionary principle when hydropower is proposed for upland streams and with impacts on biodiversity unknown. Whilst Natural Resources Wales defends its remit to deliver balanced and appropriate development, it recognises its licensing and institutional approach has been lacking, and the Wales Hydropower Stakeholder Group is a response to this.

Finally the sector is vulnerable because it is so small. Much of the progress made in developing projects and levering community benefits can be traced to a relatively few individuals in CiCs, development organisations and the charity sector. The loss of this human and associated network capital to age, disenchantment or other factors could stymie further developments. Moreover, because the sector is small in generation terms (in aggregate and for individual turbines) it cannot claim to provide a significant contribution to the Welsh Government's decarbonisation targets, having instead to rely on more nuanced and harder to evidence arguments around community engagement and rural regeneration to prove its worth.

To conclude, the paper demonstrates that small hydropower, particularly if community owned or led, is of considerable economic interest and community benefit. The paper revealed an embedded sector which explicitly supports the development of local supply chains. It is a sector where high-trust and enduring relationships are shown across a range of organisations and organisation types, and where agents are motivated by a mix of environmental concern, social altruism and a simple desire to see their locality prosper. It is also distinct from other electricity and energy investments in peripheral regions in that there is a high incidence of local ownership and control of capital (see Bryan *et al.*, 2015) with concomitant benefits in terms of the retention of surplus (and this extending in large part to the private landlord/commercial part of the sector). In many ways hydropower is an excellent example of what the Welsh Government would like to see to other parts of the economy that suffer from a high level of external control, low levels of autonomy, repetitive and low value occupations and a dearth of social and economic innovation.

Despite such interesting facets, small hydropower attracts a lower level of policy interest and support (regionally and nationally) than other more novel renewable technologies such as wave and in-stream tidal generation. This is despite the fact that these technologies are just as regionally insignificant, economically and terms of climate mitigation, as is small hydropower (Cardiff University and Regeneris, 2013). One is left with the impression that small and community projects are just very *difficult* for governments and their regulatory agents to deal with. The Welsh Government's interaction with multinational energy companies on the siting of onshore wind, or of test arrays off the coast are not unproblematic of course, but it is the sort of dialogue – around the attraction of private sector and mobile activities, jobs and capital – with which they are only too familiar.

The depreciation of FiTs and a potential increase in the interest rate and returns from competing investments may then effectively halt new community hydropower development in Wales. For specific communities, and particular engaged, committed and valuable individuals the impact could be stark and life changing, and for some organisations, existential. The loss of the sector, the embedded expertise and its quirky character might be deemed not very important. However, Wales is a region where innovative economic activity and rural resilience is at a premium, and where the sustainable exploitation of natural resources for local benefit is of increasing importance. A future Wales might well regret its demise.

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Table 1 Modelling Assumptions

Factor	Assumption	Notes
Scheme Typology/ Capacity	Small - 1x99kW Large - 1x499kW	Chosen at just below FiT break points.
Load Factor	3,500 kWh per kW per annum	Averaged across a variety of schemes. No obvious correlation with size or location of scheme. Covers a variety of abstraction regimes (% of flow).
Community Funding & Benefit	100% community share funded 50:50 capital repayment: community fund. Non-metered for export	Based on conversations with community and other developers, and reflects the current norm.
Project Total Cost	Small – £7,500 /kW Large - £5,000 /kW	Appropriate mid-points chosen from a variety of sites and data points. Includes all feasibility, development and maintenance costs over the 20 year FiT window including one major scheduled mechanical overhaul.
Local (Wales) Sourcing %	Industrial/mechanical: 50%-70% Turbines – 0% (Large): 80% (Small) Construction: 70% - 90% Professional Services: 70% - 90% Specialist (e.g. plastics): 0% - 20%	Based on interviews and questionnaire returns. Note assumed most turbines here are sourced from within Wales (up to 100kW) as the respondents indicated this, but there is only one company (an SME) currently supplying in Wales so this number in reality is volatile and may be an overestimate for the industry as a whole.
Community Fund	£100-£200 per kW per annum	Surplus over investment cost/repayment. An appropriate mid-point chosen but this will depend in reality on FiT window, costs, topography, water flow etc.

Table 2 Economic Impact of Micro- and Small Hydro Power in Wales

All per annum (20 years)	Project			Per MW		
	Output/ Spend	**GVA**	**Emp (FTE)**	**Output (£m)**	**GVA (£m)**	**Emp (FTE)**
2A Development and Operations						
99kW	£ 43,000	£ 18,000	0.5	0.45	0.20	6.5
499kW	£ 111,500	£ 45,500	1.5	0.22	0.09	3.5
Per MW Installed (mix of 1 499kW & 5 99kW)				**0.37**	**0.15**	**5.5**
2B Community FiT and Export Income						
99kW	£ 25,000	£ 13,500	0.5	0.26	0.14	5.5
499kW	£ 71,000	£ 39,000	1.5	0.14	0.08	3.0
Per MW Installed (mix of 1 499kW & 5 99kW)				**0.20**	**0.11**	**4.5**
2C Total Impact						
99kW	£ 68,000	£ 31,500	1.0	0.71	0.34	12.0
499kW	£ 182,500	£ 84,500	3.0	0.36	0.17	6.5
Per MW Installed (mix of 1 499kW & 5 99kW)				**0.57**	**0.26**	**10.0**

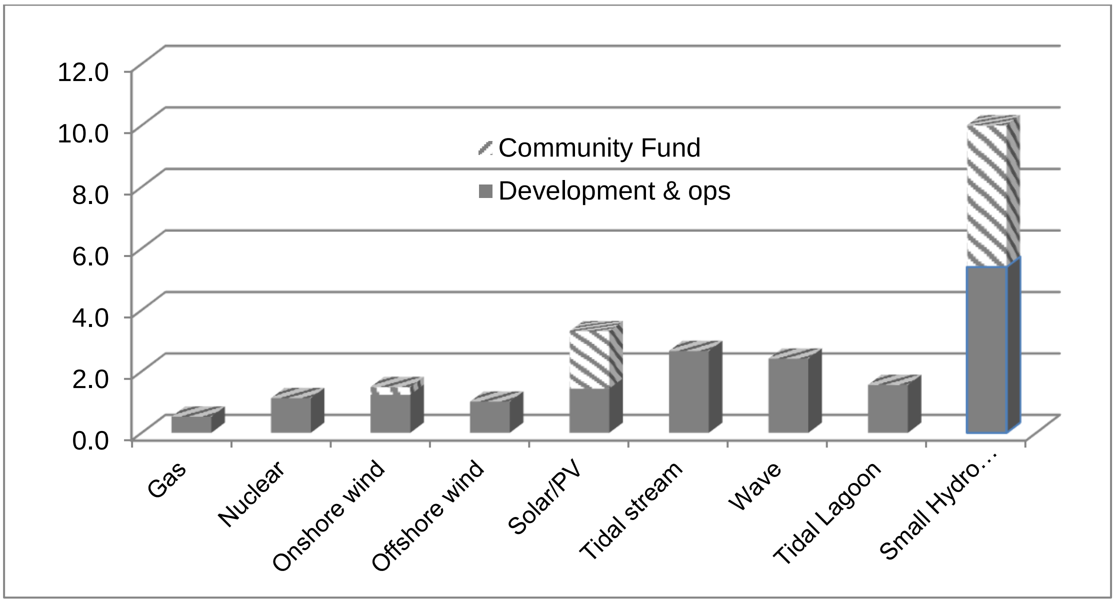
Note: Some columns may not sum exactly due to independent rounding

Table 3 DECC Past and Future Renewables Generations Tariffs (Selected Tariffs (pence/kWh)

	Pre-Consultation to August 2015	Consultation: Sept-Dec 2015	Final April 2016	Change
Solar PV 10-50kW	11.3	3.7	4.6	-59%
Solar PV 50-250kW	9.4	2.6	2.7	-71%
Wind 100-1500kW	10.9	4.5	5.5	-50%
Wind >1500kW	2.5	0	0.9	-64%
Hydro <100kW	15.4	10.7	8.5	-45%
Hydro 100-500kW	11.4	9.8	6.1	-46%
Hydro 500-2000kW	8.9	6.6	6.1	-31%

Notes: For sources: see https://www.gov.uk/government/news/changes-to-renewables-subsidies. Figures rounded to one decimal place. Table ignores changes in banding for reasons of clarity.

Figure 1 Annual Regional Employment Effects of Generation Investments in Wales (FTEs)



Source: In part derived from data in Cardiff University and Regeneris, 2013.

Appendix 1 – Survey Respondents

Wales Hydropower Stakeholder Group – Membership

Natural Resources Wales

Micro-Hydro Association

National Farmers Union, Cymru-Wales

Wales Environment Link

Energy Savings Trust

British Hydropower Association

Welsh Local Government Association

Afonydd Cymru

The Green Valleys

Interlink

Salmon & Trout Association

Welsh Government

Community Energy Wales

Face-to-Face Interviews	**No.**
Hydropower developers – Community	2
Hydropower developers – Charity	1
Community Interest Companies	2
Voluntary/Community Representative Organisation	1
Regulator	1
Email Responses	
Hydropower developers – Community	1
Hydropower developers – Commercial	2

Telephone Interview

Hydropower developers – Commercial	1

Detailed Site Visits

CwmClydach, Rhondda Cynon Taff

Tal-y-Bont, Powys

Individual Questionnaire Responses 25

(Hydro-power located communities)

Note: Individual and organisational details suppressed to protect anonymity and to respect commercial sensitivities.