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Greening regional development: employment in low-carbon and renewable energy activities

Grant Allan^a , Peter McGregor^b  and Kim Swales^c

ABSTRACT

Greening regional development: employment in low-carbon and renewable energy activities. *Regional Studies*. The promotion of low-carbon and renewable energy (LC + RE) activities has become an important element of development policy in many regional economies. In practice, defining and measuring these activities presents conceptual, methodological and operational challenges. This paper illustrates these difficulties using three recent estimates of LC + RE jobs for Scotland. It proposes that information on the LC + RE sector should be embedded in a set of input–output accounts. This would facilitate the planning, implementation and monitoring of LC + RE-based regional development policy.

KEYWORDS

low-carbon economy; green jobs; renewable energy; Scotland

摘要

绿化区域发展：低碳与可再生能源活动中的就业。《区域研究》。低碳和可再生能源（LC + RE）活动的推广，已成为诸多区域经济发展政策的重要元素。实际上，定义并测量这些活动，引发了概念、方法和操作上的挑战。本文运用对苏格兰LC + RE工作的三项晚近评估来描绘这些困难。本文主张，LC + RE部门的信息，必须嵌入一组投入—产出的解释之中。这将能够促进以LC + RE为基础的区域发展政策的规划、执行与监控。

关键词

低碳经济；绿色工作；可再生能源；苏格兰


RÉSUMÉ

L'écologisation de l'aménagement du territoire: l'emploi dans les activités à faible émission de carbone et dans le domaine des énergies renouvelables. *Regional Studies*. Favoriser les activités à faible émission de carbone et dans le domaine des énergies renouvelables est devenu un élément clé de la politique d'aménagement du territoire dans bien des économies régionales. En pratique, définir et mesurer ces activités-là représente de véritables défis conceptuels, méthodologiques et opérationnels. Cet article cherche à illustrer ces difficultés à partir de trois estimations récentes des emplois à faible intensité de carbone et dans le domaine des énergies renouvelables en Écosse. On propose que l'information à propos du secteur à faible émission de carbone et dans le domaine des énergies renouvelables devrait être ancrée dans une série de comptes des entrées-sorties. Cela faciliterait le planning, la mise en oeuvre et le suivi d'une politique d'aménagement du territoire fondée sur les activités à faible émission de carbone et dans le domaine des énergies renouvelables.


MOTS-CLÉS

économie à faible émission de carbone; emplois verts; énergie renouvelable; Écosse


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ZUSAMMENFASSUNG

Begründung der Regionalentwicklung: Arbeitsplätze in kohlenstoffarmen und auf erneuerbare Energien gestützten Aktivitäten. *Regional Studies*. Die Förderung von kohlenstoffarmen und auf erneuerbare Energien gestützten (LC + RE) Aktivitäten ist in zahlreichen regionalen Ökonomien zu einem wichtigen Element der Entwicklungspolitik geworden. In der Praxis ist die Definition und Messung dieser Aktivitäten mit konzeptuellen, methodologischen und praktischen Problemen verbunden. In diesem Beitrag werden diese Schwierigkeiten anhand von drei aktuellen Schätzungen für LC + RE-Arbeitsplätze in Schottland illustriert. Es wird vorgeschlagen, die Informationen über den LC + RE-Sektor in eine Reihe von Input-Output-Konten einzubetten. Dies würde die Planung, Umsetzung und Überwachung einer LC + RE-basierten regionalen Entwicklungspolitik vereinfachen.

SCHLÜSSELWÖRTER

kohlenstoffarme Wirtschaft; grüne Arbeitsplätze; erneuerbare Energie; Schottland

RESUMEN

Desarrollo regional ecológico: empleo en actividades hipocarbónicas y energías renovables. *Regional Studies*. El fomento de actividades relacionadas con la economía hipocarbónica y las energías renovables (EH + ER) se ha convertido en un importante elemento de la política de desarrollo en muchas economías regionales. En la práctica, definir y medir estas actividades supone un reto conceptual, metodológico y operativo. En este artículo ilustramos estas dificultades mediante tres cálculos recientes de empleos relacionados con EH + ER en Escocia. Proponemos que la información en el sector de EH + ER debería estar arraigada en un grupo de cuentas de entradas y salidas. Esto facilitaría la planificación, la aplicación y el control de la política de desarrollo regional basada en EH + ER.

PALABRAS CLAVES

economía hipocarbónica; empleo ecológico; energía renovable; Escocia

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INTRODUCTION

The pace of renewable energy development in Scotland has accelerated rapidly over the last decade. Scottish renewable electricity capacity rose by 246% between 2003 and 2012 while Scottish output from renewable heat almost tripled from 2008/09 to 2012 (Department of Energy and Climate Change (DECC), 2013; Energy Saving Trust (EST), 2013).¹ Moreover, the Scottish Government (SG) (2011d) has a target for renewable sources to meet the equivalent of 100% of Scottish gross electricity consumption and 11% of heat by 2020 (SG, 2009a).

It is claimed that these major changes in the scale of low-carbon and renewable energy (LC + RE) production and use will deliver significant economic benefits and employment gains for Scotland. The *2020 Routemap for Renewable Energy in Scotland* argues that the target to meet 100% of Scottish consumption is 'necessary to re-industrialise Scotland through 21st century technologies and seize the opportunities to create tens of thousands of new jobs and secure billions of pounds of investment in our economy' (SG, 2011d, p. 2). The earlier *A Low Carbon Economic Strategy for Scotland* more explicitly asserts 'jobs in the low carbon sector in Scotland could grow by 4% a year to 2020, rising from 70,000 to 130,000, over 5% of the Scottish workforce' (SG, 2010c, p. 10).

The emphasis on LC + RE developments reflects the SG's core purpose of increasing sustainable economic growth, encompassing a range of (potentially conflicting)

objectives including stimulating economic growth, but also reducing carbon emissions. Renewables are particularly attractive in this context, and there are few policies that contribute positively to both these policy objectives.² However, it is important to state that international energy and greenhouse gas reduction responsibilities are not devolved and formally rest with UK central government.³ The SG's sustainability policy is, therefore, an ethical and economic one.

There are, however, three core interrelated problems involved in identifying the level and nature of employment in such activities. The first is conceptual and centres around precisely which activities are included or excluded under this heading. The second issue concerns what methods should be used to operationalize this concept. The third issue is accuracy. Even if there were complete clarity about what is meant by LC + RE activities and how these should be measured, there could still be concerns over the accuracy of such measurement.

Three recent studies attempt to quantify employment in Scotland in LC + RE activities. In this paper these reports are used to illustrate the issues that have been raised in attempts to identify LC + RE employment. Appropriate and accurate reporting is particularly important here, given that LC + RE activities comprise a key sector in Scotland's economic development strategy. Whilst the paper uses Scotland as an example, many regional economies have the expansion of LC + RE activities as prominent in their development strategies and the difficulties illustrated

here apply much more widely (e.g., Mayor of London, 2011; Nova Scotia Department of Energy, 2010; Welsh Government, 2012) so that lessons drawn for Scotland should inform methods for measuring LC + RE employment in other regions.

LOW-CARBON ECONOMIC STRATEGY IN SCOTLAND SINCE DEVOLUTION

Table 1 identifies those major Scottish Executive (SE)/SG policy documents published since devolution in 1999 that link LC + RE technologies and economic development. Although the terminology differs over time, this list includes strategies concerning what are known as green jobs and jobs in (or in the transition to) the LC economy. Affirmatives in the second and third columns in Table 1 indicate whether the strategy documents were focused on one or both energy and/or economic objectives.

Table 1 shows the growing focus since 2001 on the employment gains to Scotland from LC + RE technologies. At the beginning of the decade, the 'Smart, Successful Scotland' development strategy made no reference to 'renewables', 'energy', 'emissions' or 'carbon' (SE, 2001). However, within four years, the SE (2005a, p. 6) outlined a 'green enterprise strategy for Scotland' that expressed non-specific expectations for linked employment and economic advantage. This was followed by specific targets for renewable electricity/energy production (SE, 2005b; SG, 2008, 2011b). These targets

are explicitly or implicitly linked to the potential jobs and development outcomes that are expected to accompany stimulating renewables.

The government's economic strategy (SG, 2007) listed 'Energy, with a particular focus on renewables' as one of its key sectors. These are sectors identified as having the potential to be 'internationally successful in areas of global demand', and whose future success could be helped by government intervention (SG, 2007, p. 27). When this strategy was refreshed, the SG (2011c) created an additional strategic priority – the transition to an LC economy. The then First Minister, Alex Salmond, stated that Scotland had the

opportunity to reindustrialise the nation and create thousands of new jobs across Scotland. With the right incentives we now know that the low carbon sector could support 130,000 jobs by 2020 and we are determined to deliver on this ambition.

(SG, 2011c, p. 5)

Whilst this is not a formal target, it is clearly a firm aspiration.

Over this short period of time, LC + RE technologies have become a central plank of the SG's sustainable development strategy with the aim of augmenting (and eventually replacing) oil-related activity. It is central to the SG's economic aims and confident claims are made for its future importance. It is therefore crucial that there is a clear and consistent accounting framework for measuring

Table 1. Major Scottish Executive (SE) and Scottish Government (SG) economic and energy strategy documents, 2001 to 2011.

	Economy	Energy	Short report name	Comments
SE (2001)	Yes		Smart Successful Scotland (SSS)	No reference to renewables, energy or low carbon
SE (2005a)	Yes	Yes	Green Jobs Strategy	Strategic guidance to sectors including renewables and biofuels. Non-specific ambitions for employment
SE (2005b)		Yes	Scotland's Renewable Energy Potential	Sets 40% renewable electricity target for 2020 in GW capacity and concludes that 'there is a need for a better understanding of these potential economic impacts' (p. 11)
SG (2007)	Yes		Government Economic Strategy (GES)	Energy (with a particular focus on renewables) is identified as a key economic sector
SG (2008)		Yes	Framework for the Development and Deployment of Renewables	Sets a target of 20% Scottish renewable energy for 2020
SG (2009b)		Yes	Renewables Action Plan	Detailed short-term actions and objectives to meet SG's targets on renewable energy
SG (2010a)	Yes	Yes	Low Carbon Economic Strategy	Identified 70,000 low-carbon and renewables jobs which could increase by at least 60,000 by 2020
SG (2011a)	Yes		GES	Additional Strategic Priority – 'Transition to a low carbon economy'
SG (2011b)		Yes	Routemap for Renewable Energy	Sets out the background to a new target of 100% of Scottish electricity demand equivalent to be produced by renewable electricity

this activity, so that policies can be appraised, monitored and evaluated.

IDENTIFYING LOW-CARBON ACTIVITIES IN SCOTLAND

There has been much recent debate in the academic literature concerning how best to identify activities that might be considered green (e.g., Furchtgott-Roth, 2012) and also whether green policies, or increases in specific 'green' activities, create net additional jobs (e.g., Blyth et al., 2014). Additionally, there is little agreement on how to measure 'green employment'. Some studies adopt a 'top-down' approach, such as using official aggregate statistics (e.g., Bureau of Labour Statistics, 2010; Yi, 2014; Yi & Liu, 2015) whilst others use 'bottom-up' surveys to measure employment in specific activities (e.g., Blanco & Rodrigues, 2009; Llera, Uson, Bribian, & Scarpelli, 2010).

This section examines three recent studies that produce estimates of Scottish employment in such activities. It has two main objectives. The first is to use these as case studies in identifying the conceptual and practical problems in measuring green jobs. The second is to assess how accurately the studies measure the present and potential future role for the LC + RE sector in Scotland. This is important to policy-makers for monitoring progress and is essential if the electorate is to be enabled to hold the SG to account on its aims for this sector.

The relevant characteristics, strengths and weaknesses of these three studies are summarized in Table 2. These are spelled out in more detail below. To begin, it is important to note that these studies attempt to measure three rather different activity groupings, driven by different objectives. Two of the three reports are generated or funded by the SG: SG (2011) and Innovas Solutions (IS) (2011). Another is produced for an industrial association: Scottish Renewables (SR) (2012). SG is generated specifically to track progress on an individual SG growth sector, whilst SR indicates the size of a particular LC + RE sector.⁴ IS was produced specifically to motivate the SG's Low Carbon Economic Strategy. Although the diversity of the reports

reflects, to an extent, the ambiguity over the notion of green jobs, this paper is more concerned about the validity and the consistency of the results generated by the studies.

SR (2012) seeks to estimate 'employment in renewable energy in Scotland'. First, note that this study covers one area targeted by the SG's Low Carbon Economic Strategy and 'Energy, with a particular focus on renewables' key sector. The study takes a bottom-up approach: employment data were obtained from a survey of more than 200 firms active in RE in Scotland. SR's definition of renewable employment comprises a range of categories, including product design, development, operation and the supply chain, for a number of RE technologies.⁵ The estimate of total employment and the disaggregation of activities is reported in Table 3.

This section begins with conceptual issues concerning the coverage of the individual studies. The SR report only deals with part of the LC + RE sector. However, although one could consider the renewables element of LC + RE the most straightforward to measure, there are further issues raised by this report. The first is that SR includes 152 jobs in the public sector and 757 in higher and further education. These make up 8% of the SR total of 11,136. The inclusion of such jobs is unusual. For example, in an estimate of employment in the finance sector, it would be curious to include finance academics and civil servants working on financial regulation. Serious problems of double-counting can occur when activity clearly in one industrial sector is attributed to another. This having been said, the employment categories are clearly identified, so the user can decide whether to include these figures, though it is often the headline (aggregate) figure that is quoted.

A second conceptual issue is whether investment activity should be included in the estimates. In the SR figures for renewable employment in Scotland, the largest single element is 3223, attributed principally to grid upgrade work driven by onshore wind generation. It might seem curious to some that these are included as LC + RE jobs. Similar concerns relate to elements of the supply chain. This is an area where clarity is absolutely essential. The production of renewable electricity,

Table 2. Key characteristics of three reports.

	Scottish Renewables (SR)	Scottish Government (SG)	Innovas Solutions (IS)
Method	Bottom-up	Top-down	Bottom-up
Sponsor	SR	SG	SG
Sectoral coverage: conceptual	Part of low carbon and renewable energy	Energy (including renewables)	Low carbon and environmental goods and services
Sectoral coverage: actual	Includes regulation and Higher education	Based on Standard Industrial Classification (SIC) codes. Too wide and lacking precision	Very detailed, low threshold for establishment inclusion
Investment	Yes	Some	No
Supply chain	Some	Some	Some
Transparency	Medium	Complete	Limited

Table 3. Scottish Renewables (SR) definition of employment in renewable energy in Scotland, disaggregated by technology.

Technology	Employees
Bioenergy	1410
Grid	3223
Solar and heat pumps	161
Hydro	503
Onshore wind	2235
Offshore wind	943
Wave and tidal	521
Working across multiple sectors	1231
Higher and further education	757
Public sector	152
Total	11,136

Source: SR (2012).

bioenergy or renewable heat requires direct employment. But these activities also require intermediate inputs whose production requires workers. Further, these intermediates themselves have intermediate demands generating a multiplier process. Should such intermediate activities be, in part or whole, included in the estimate of the size of the RE sector? These issues are dealt with in more detail in the next section, but there is no clear conceptual account of how these issues should be treated in these studies. In this case some elements of the supply chain are included but only where these seem to have a specifically RE orientation. The method adopted in SR is straightforward and the sectors relatively easy to comprehend. However, there is some ambiguity as to what exactly would be counted as relevant supply-chain production, so that the study is not completely transparent.

'Energy (including renewables)' is one of the six growth sectors identified by the SG in the 2011 Government Economic Strategy (SG, 2011). Each growth sector is defined and monitored using Standard Industrial Classification 2007 (SIC07), which is the basis for official statistics. There is more than one source for these data, but they are curated from official surveys such as the annual Office for National Statistics (ONS) 'Business Register and Employment Survey'. The SG (2013) report draws on information for the relevant sectors from the SG's regularly updated 'Growth Sector Statistics Database'. This estimate therefore adopts a top-down approach.

The categories identified within 'Energy (including renewables)', together with the employment in each of these categories in 2012, are shown in Table 4. The total level of employment identified is 63,400. Clearly, this definition is much broader than that used by SR (2012): it includes, but is not restricted to, the renewables subsector of energy activities. The largest number of employees is actually in the category 'Mining support service activities'.

Two key problems with this approach arise: First, all employment under each SIC sector is identified as being engaged in 'Energy (including renewables)' work. This could be an appropriate assumption for workers employed

Table 4. Scottish Government (SG) definition of 'Energy (including renewables)' growth sector, disaggregated by Standard Industrial Classification (SIC) sectors.

SIC 2007 code	Sector	Employment, 2012
05	Mining of coal and lignite	1800
06	Extraction of crude petroleum and natural gas	9100
09	Mining support-service activities	18,700
19	Manufacture of coke and refine petroleum products	500
20.14	Manufacture of other organic-based chemicals	1000
35	Electricity, gas, steam and air-conditioning supply	14,600
36	Water collection, treatment and supply	3200
38.22	Treatment and disposal of hazardous waste	1500
71.12/2	Engineering-related scientific and technical consulting activities	12,300
74.90/1	Environmental consulting activities	700
	Total	63,400

Source: SG (2013).

in the extraction of fossil resources (SIC 05). However, it will not be the case that all workers employed in 'Engineering-related scientific and technical consulting activities' (SIC 71.12/2) will be employed solely by energy activities, since it is known that this category includes land surveying activities, geological surveying, etc. Secondly, the selection of categories for inclusion in the 'Energy (including renewables)' grouping demonstrates the difficulties in using SICs to classify energy and renewable activities to specific sectors. Activity in renewable electricity, for instance, which would be expected to be included in these definitions – and will be part of SIC 35 – are not separately identified in the SIC categories listed. Moreover, it is difficult to know where some elements included in the SR study, such as bioenergy, would be counted in this estimate. Finally there are sectors here, such as SIC 38.22 'Treatment and disposal of hazardous waste', that seem inappropriately attributed as energy sectors. Furthermore, although this growth sector is defined with particular relevance to renewables, separate figures for renewables are not available from this data source. Clearly there are big advantages to linking the employment estimates to SIC sectors; however, these have to be further disaggregated to properly identify LC + RE activity.

The SG's Low Carbon Economic Strategy, and the subsequent employment ambitions, were informed by IS

(2011). This is a method also used by the UK Department of Energy and Climate Change (DECC) (kMatrix, 2012). This study covers the low-carbon and environmental goods and services sector so that its scope is explicitly wider than the LC + RE sector. Its estimate for the number of LC jobs in Scotland in 2008/09 is 73,950.

IS (2011) is a bottom-up study where the identification of activity is not restricted by SIC codes. The report states: ‘These technologies are often “cross cutting”, and in the past have been seen and measured as part of other sectors through the SIC coding system which traditionally has a time lag before being implemented’ (p. 4). Whilst it is accepted that the LC + RE sectors will not be wholly defined along existing SIC classifications, clearly some linking to standard sector classifications is desirable and the operationalization will be important. Third, the approach incorporates ‘supply chain companies as well as those which are considered specialists in the sector’ (p. 4). Again, what exactly is included within ‘supply-chain activities’ is not clear.

The operationalization of the IS measure is particularly problematic. The report disaggregated activity to 2400 (‘level 5’) sectors with market and firm-specific data collected from enterprises involved in each of the categories defined at this lowest possible level. Firms are included if they are active either as a specialist firm, with primary activities in an identified and defined category, or if they are assigned to the supply chain. The threshold for including a company is if at least 20% of sales can be directly attributed to the low-carbon, renewable energies or environmental sectors, but how this is determined (and why this threshold is used) is less certain. The estimated Scottish employment data are aggregated into three main (level 1) sectors, disaggregated into the 23 (level 2) subsectors shown in Table 5. Under the IS classification these comprise 73,960 employees. Of the level 2 categories, the largest is Alternative fuels, with 17,780.

It is useful to compare the figures across the type of employment, i.e., sectoral or by activity, which are included in the three studies. First, as noted already, each covers different aspects of energy, LC, renewables and environmental goods and service activity in Scotland. For instance, the SG measure includes activities that are explicitly non-renewable and non-LC, while SR focuses on RE, with a particular focus on electricity, and IS has a broader coverage of activities. Additionally, the reports differ in terms of the extent to which they capture the employment embedded in the LC + RE supply chain.

Figure 1 highlights these differences in coverage. The outer box equates to all employment in Scotland, with employment captured within each report covering a subset of this total. Four overlapping areas between each pair of studies, plus activities that are common to all, can be identified:⁶

- Area 1: activities common to all three reports.
- Area 2: activities common to IS and SG reports (i.e., but not SR).
- Area 3: activities common to SR and SG reports.
- Area 4: activities common to IS and SR reports.

Table 5. Innovas Solutions (IS) employment by activity: level 2 subsectors, 2008/09.

		Employment	
Environmental subsectors	Air pollution	1010	
	Environmental consultancy	570	
	Environmental monitoring	110	
	Marine pollution control	90	
	Noise and vibration control	120	
	Contaminated land	815	
	Waste management	3650	
	Water and waste water	6200	
	Recovery and recycling	5810	
	Renewable energy technologies	Hydro	305
		Wave and tidal	55
		Biomass	6060
		Wind	8030
Geothermal		4910	
Renewable consulting		360	
Photovoltaic		2440	
Low-carbon technologies	Alternative fuel vehicle	4890	
	Alternative fuels	17,780	
	Additional energy sources	980	
	Carbon capture and storage	505	
	Carbon finance	120	
	Energy management	1150	
	Building technologies	8000	
	Total	73,960	

Source: IS (2011), table 3.2, p. 37.

Each area of Figure 1 is populated with examples of employment activities that are counted within the combination of reports to which that area relates. For instance, employment in Scotland’s two nuclear facilities are counted within area 2.⁷ It is also interesting to note those activities in non-overlapping areas, i.e., which feature in only one of the three measures.

Given the differences in coverage, one does not expect the headline figures in the three studies to be the same. However, even for comparable categories, the employment estimates vary widely. For example, it may be expected that the employment identified by SR should be included in all

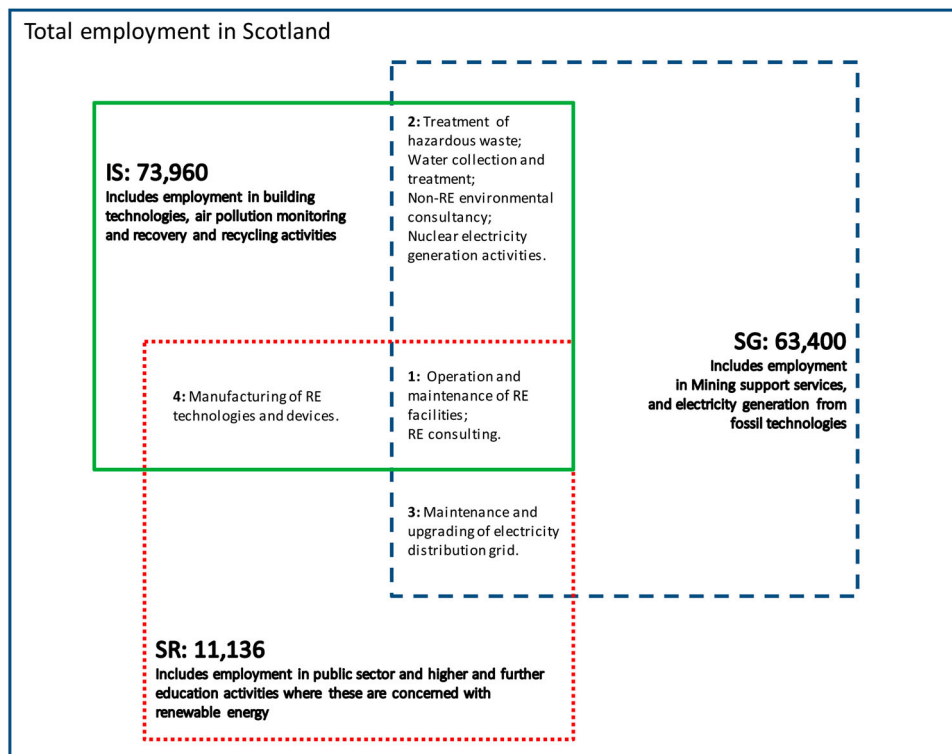


Figure 1. Schematic of the overlaps in employment among definitions.

three studies, as its focus on RE is a subset of that covered by IS estimate, and appears in the nomenclature for the SG measure. However, significant elements of SR's figure – specifically employment in public/higher education and extensions to the grid – are not included in the other two studies. Subtracting non-comparable elements from the SR estimate, one obtains an employment estimate of 7004, which is less than one-third of the IS estimate for employment in the 'Level 1: Renewable energy technology' category (22,160). Furthermore, the IS and SR studies estimate employment in 'Wave and tidal' as the widely divergent 55 and 521 respectively. Remember, both these are bottom-up approaches. Moreover, in the top-down SG study, renewables are not separately identified. However, the SG employment given for 'Electricity, gas, steam, and air conditioning supply' (14,600) is lower than the figure for the renewable electricity generation alone given in the IS report (16,890). This situation is highly unsatisfactory and confusing and stems from lack of a clear, common method for compiling data on employment in LC + RE activities.

AN IMPROVED METHOD FOR IDENTIFYING LC + RE EMPLOYMENT

The second section documented the increased importance of the LC economy in Scottish industrial policy. However, in order to have effective policy-making and monitoring, there is a need for clarity concerning the data that are being used and confidence in their accuracy.

From the discussions in the third section, there are three main practical problems in constructing these data.

The first is to identify which activities are to be treated as falling under the LC + RE heading. This includes the issue of whether both investment and operational activities should be covered. The second is to locate these activities in the existing SIC framework. The third is to deal appropriately with the supply chain. At present uncertainties and inconsistencies in the treatment of each of these issues severely undermines the value of the Scottish data collected on this sector.

The most effective way of dealing with these challenges is to adopt a mixed top-down/bottom-up approach and embed the elements of the LC + RE sector within a set of input-output (IO) accounts (Miller & Blair, 2009). Such accounts present, in a matrix form, the detailed purchases and sales of all industries within a particular geographical area. They identify sales both to final demand (including exports, government, investment and consumption), and to other industries, which use the good as an intermediate input. Similarly IO accounts detail the purchases by individual industries of labour and capital services, as well as intermediate inputs and imports. Finally, standard techniques can be used to measure the multiplier impacts of changes in final demand for the output of individual industries. That is to say, the multiplier process identifies the whole supply chain. For an individual sector the aggregate output, employment or value-added impacts can be calculated, but equally this aggregate figure can be disaggregated to impacts on individual sectors. There is an extensive literature on this form of IO analysis with a standard terminology and set of techniques.

However, official IO tables are typically not disaggregated in a way that separately identifies the LC + RE sector,

so that the tables need to be adjusted using supplementary information. Ideally, this should follow a bottom-up procedure. A crucial point, however, is that supplementary data should be collected in a manner that is compatible with IO tables (where they exist) and that the conventional national accounting principles (that, for example, preclude double-counting) apply.⁸

This hybrid IO approach has a number of strengths. First, the IO sectors map to standard SICs. This means that the LC + RE sectors can be linked and compared with other standard industries. Also, because the IO is a set of balanced accounts, this adds accounting rigour to the identification of LC + RE activity.

Second, the treatment of intermediate demand means that it is possible to give a flexible response to the questions raised in the third section about the appropriate specification of the supply chain. When concern is with the demand-induced impacts of LC + RE developments, then the total impact is most relevant. That is to say, a measure of the full supply chain is required. For example, if Scotland is generating RE for export, then the total of the additional indirect and induced jobs generated by the multiplier effect are the appropriate figures to consider.

On the other hand, supply-side issues might be the primary concern, with the SG wishing to exploit economies of scale and scope and thereby create an LC + RE cluster. In this case, the focus should be on those elements of the supply chain that are defined as being LC + RE. However, the IO multiplier procedure can separately identify those elements of the full supply chain. Furthermore, the impact of changes in the production of other sectors on employment in LC + RE is again straightforward to estimate.

Additionally, IO accounts can be augmented so that environmental indicators, such as pollution or waste, are assigned to specific economic activities, such as sector output or energy use (e.g., Turner, 2006). With an IO system disaggregated to identify LC + RE activity, the policy-maker can quantify the direct and indirect carbon content of each sector. This is not restricted to the carbon intensity of the sector itself, but can also take account of the sector's links to other parts of the economy (and the carbon embodied in those connections). This could be used to identify and verify the status of LC sectors.

Scotland produces regular and timely IO accounts (e.g., SG, 2014), but these accounts do not separately identify the LC + RE subsectors. An attempt partially to augment the official Scottish IO accounts along these lines is performed by Allan, McGregor, Swales, and Turner (2007). They disaggregate the one electricity sector in the official Scottish IO tables into generation and non-generation activities. Generation activity is then further disaggregated to eight technologies (nuclear, coal, hydro, gas, biomass, wind, landfill gas and marine) with the appropriate direct economic linkages. Economic activity in the fossil fuel coal and gas electricity generation would clearly be excluded from the LC + RE sector. Of the other generation technologies, hydro, wind, biomass, landfill gas and marine are included in the SGs targets for renewable electricity generation, while nuclear is not.

Constructing the electricity generation data in this way has two advantages. First, as argued already, there is a discipline imposed by the existing IO accounts. When summed, the output in the disaggregated electricity sector must replicate that in the official accounts. This acts as an important check on the accuracy of the information on the renewable sectors. Second, it gives the user flexibility. For example, there is often disagreement as to whether nuclear energy should be regarded as green. It is LC but not renewable and has significant safety and waste disposal issues. However, in this approach the user can decide whether or not to include nuclear activity (and all the nuclear supply chain) as LC + RE.

The disaggregation in Allan et al. (2007) is indicative of how the approach could be developed. It is limited in that it did not have access to official plant-level data and only tackled one aggregate sector. However, the argument here is that LC + RE-led economic development plans should be accompanied by systematic official disaggregation of the IO accounts so as to ensure compliance with national accounts and consistency across sectors/subsectors, and over time.

Up to this point the analysis has focused on all sectors' operational phases. It is comparatively straightforward to use the static IO framework to analyse the impact of construction (and development) expenditures once its sectoral distribution and domestic content is identified (since imported inputs have no impact on the host region). As an example, Allan, Cui, Lecca, and McGregor (2015) applied this approach to the development of offshore wind.

An appropriately disaggregated set of economic accounts would also allow the identification and tracking of the causes of LC + RE activity, e.g., the drivers of the level of employment in the LC + RE sector. Two dimensions are worth noting: the time period over which the stimulus will apply, and its spatial source. For instance, it would be useful to know if the estimated employment is due to activities that are likely to persist or ones which are temporary in nature. There may be significant employment that is supported by the installation of LC technologies (as in the construction phase of project development), for instance, while other drivers, such as maintenance of existing (operational) capacity, are more likely to be permanent. This is helpful for understanding the build up and expected duration of employment. Additionally, if construction/installation of capacity is projected to continue into the medium-term, the employment implications are likely to be quite different.

The second dimension concerns whether LC + RE employment is derived from domestic or overseas sources. Whilst the domestic market might provide a natural pre-commercial and early development area for new technologies, SG policy certainly aspires to enhancing export activity through LC + RE technologies and services. Quantifying the share of LC + RE employment and activity supported by non-domestic drivers would facilitate better predictions of the impacts that changes in the type and levels of drivers could have on employment. For renewable

electricity, for example, information on exports of electricity as well as exports of the technology would be profoundly helpful for policy-makers.

Finally, such a set of environmentally extended economic accounts would provide the basic dataset for multi-sectoral economic modelling. A range of modelling approaches, including IO, social accounting matrix (SAM) and computable general equilibrium (CGE) models use IO accounts as the basis for more complex analysis of the consequences for the economic system of policy and non-policy disturbances. These methods have been used to analyse the impacts of carbon taxes (Allan, Lecca, McGregor, & Swales, 2014), the consequences of investment expenditures on marine energy capacity (Allan, Lecca, McGregor, & Swales, 2013; Gilmartin & Allan, 2015) and the 'recycling' of non-wage incomes from RE back into the local economy where a facility is locally owned (Allan, McGregor, & Swales, 2011). Such modelling approaches become more valuable with increased devolution of responsibilities for industrial development.

CONCLUSIONS

The energy sector, and especially the LC + RE sector, plays an increasingly important role in the SG's industrial strategy. Although RE is seen as offering particular opportunities for the Scottish economy, the LC + RE sector features in the economic strategies of many local development agencies, both in the UK and the rest of the World. However, a clear procedure for measuring the level of activity in this sector is required for sound policy-making and monitoring. This review of existing attempts at measuring LC + RE employment in Scotland suggests that there are significant difficulties; existing estimates from the SG and industry bodies lack transparency and are inconsistent. An alternative approach is suggested here.

The proposal is to embed the measurement of the LC + RE sector within a set of IO accounts. Such an approach has a number of key advantages for policy-makers committed to an economic development strategy based (wholly or partially) on the LC + RE sector. First, it provides an essential data source that is constructed on national accounting principles and identifies not only employment but also output and value added in the individual elements of the LC + RE sector, and associates these with conventional headings in the SIC. This makes it more straightforward to compare the contribution of the LC + RE subsector as against other sectors and to monitor the development of the subsector over time.

Second, the IO framework explicitly reveals supply chain relationships. Rigorous methods for calculating the indirect and induced activities associated with a developing LC + RE subsector can be derived from the matrix of intermediate purchases. These supply-chain (and consumption) effects can be presented in terms of both their aggregate and sectorally disaggregated impacts (including the LC + RE subsector) which are automatically generated by the

IO approach. This allows policy-makers to focus on, for example, indirect and induced effects within the subsector as well as their impact on the economy as a whole. The IO accounts also identify the sources of final demand for each commodity, so as to improve projections for future demand.

Third, the augmentation of IO accounts to incorporate environmental variables linked to production facilitates environment–energy–economy accounting. This allows policy-makers to develop rigorous production- and consumption-oriented measures of carbon emissions, for example, and assess the contribution of the LC + RE sector to these measures. So, for example, as the LC + RE sector grows relative to fossil fuel-based technologies, this should reduce both territorial emissions (that Kyoto emphasizes) and carbon footprints, but the proposed approach would allow the government to quantify this contribution rigorously.

Furthermore, the databases could be used to calibrate models that are rather more flexible than IO in that they can accommodate a non-passive supply side. In fact, the SG is already making use of CGEs, though mainly in the context of exploring the consequences of greater fiscal autonomy. Energy–economy–environment CGE models could be used to assess the likely impact of a whole range of possible demand and supply-side policies/disturbances on the LC + RE subsector.

The proposal here is most obviously directly applicable to those regions that already possess IO tables, whether officially produced or not. Where these tables do not exist there are methods available for simulating them, although the accuracy of these methods is more questionable the smaller is the target region. In such instances, one could advocate the same basic principles, namely: adopt methods that are compatible with national accounting principles, identifying links to SIC sectors and subsectors. Adoption of this approach will ensure a systematic and comprehensive database of the LC + RE subsector be developed that would also allow meaningful regional (and national) comparisons.

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NOTES

1. In 2012, 2500 GWh of heat, equivalent to 4.1% of Scottish non-electrical heat demand, was produced from a renewable heat capacity of 0.561 GW (EST, 2013).
2. Renewables might also make a contribution to security of supply, another objective of energy policy, by reducing dependence on imported fuels.
3. In the Scottish Climate Change Act 2009, the SG set targets of 42% and 80% reductions in domestic greenhouse gas emissions by 2020 and 2050 respectively. However, these targets in no way bind the government on international emissions reduction objectives.
4. SR has released updated figures for 2013 (O'Herlihy & Co., 2014). The method adopted appears to be equivalent to that used in its earlier publication. The present paper refers to the 2012 SR report throughout as it is closer in time to the other two reports and therefore makes the comparison of results more straightforward. The update for 2013 gives full-time equivalent (FTE) employment in Scotland's renewable energy industry as 11,695, an increase of 5% on the 2012 estimate.
5. For a discussion of the difficult question of what is, and what is not, part of the supply chain for these technologies, see the fourth section.
6. Figure 1 is simply a topographical representation. Where part of Scottish employment is included in only one of the studies, it is labelled with the abbreviation for that study, e.g., SR, SG or IS. Figures are employment totals identified by the corresponding reports.
7. In neither study is the employment figure for nuclear separately identified; however, anecdotal evidence suggests that each nuclear power station employs a workforce of around 400.
8. A satellite account approach might have added useful information to this analysis. However, these are concerned purely with direct measures of activity. Therefore, they can be an extension of, but not an alternative to, an appropriately disaggregated set of IO accounts; and they cannot undertake an analysis of the supply chain for identified activities (Jones & Li, 2015).

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