UKERC Technology and Policy Assessment

Green Jobs II Project

Scoping review report

Richard Hanna (Imperial College London)
Phil Heptonstall (Imperial College London)
Rob Gross (Imperial College London)

February 2021

Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

UKERC is funded by the UK Research and Innovation, Energy Programme.

Technology and Policy Assessment (TPA) within UKERC

The Technology and Policy Assessment (TPA) team was set up to inform decision-making processes and address key controversies in the energy field. It aims to provide authoritative and accessible reports that set very high standards for rigour and transparency. Subjects are chosen after extensive consultation with energy sector stakeholders.

The TPA has been part of UKERC since the centre was established in 2004 and is now in its fourth phase, which started in 2019. The primary objective of the TPA is to provide a thorough review of the current state of knowledge through systematic reviews of literature, supplemented by primary research and wider stakeholder engagement where required.

Contents

1. The subject of this TPA project

1.1 Introduction: the subject and its importance

In 2014 the UKERC TPA team completed a review on low carbon jobs, examining the evidence for net job creation from policy support for energy efficiency and renewable energy (Blyth *et al.*, 2014). This report examined the economy-wide consequences of policies encouraging investment in energy efficiency and renewable energy. It examined whether, how, to what extent and under what conditions such policies lead to net job creation in the implementing regions. The assessment was confined to OECD economies and covered all relevant policy measures with the exception of carbon taxes and carbon emission trading schemes.

Given the UK net zero emissions target and the economic implications of the COVID-19 pandemic, there is a pressing need to update our previous analysis on net job creation potential and skills requirements in the renewable energy and energy efficiency sectors. A key question is whether investment in the low carbon transition can be combined with, and facilitate, post-COVID-19 economic growth (Figueres and Zycher, 2020; Gross, 2020b). There have been a plethora of calls for investment in green jobs, skills and infrastructure to help kickstart economic recovery from COVID-19, in a way that is compatible with achieving net zero emissions and a societally just transition (Allan *et al.*, 2020; CCC, 2020; EEIG, 2020; Jung and Murphy, 2020; Webb, Emden and Murphy, 2020). In their latest Progress Report to Parliament, the Committee on Climate Change highlight several priority areas for post COVID-19 investment which include low-carbon and climate-resilient infrastructure, reskilling and retraining for a net zero and climate resilient economy, and low carbon retrofitting and future proofing of buildings (CCC, 2020a). The UK Government's Energy White Paper sets out an aim to create up to 250,000 jobs by 2030 as part of a Ten Point Plan for a Green Industrial Revolution (BEIS, 2020).

The current project will provide an update to the 2014 UKERC TPA report on green job creation (Blyth *et al.*, 2014). Our updated analysis considers the question of whether policy driven expansion of specific low carbon sectors actually creates jobs, particularly if the policies in question require subsidies that are paid for through bills or taxes. Employment and economic benefits are often cited as part of efforts to lobby for investment in clean energy projects such as renewables, low carbon heating and energy efficiency (EEIG, 2020; Hydrogen Strategy Now, 2020; McPhee, 2020). Such claims are often backed up by project or sector specific analyses. However historically, other literature has been more sceptical, claiming that any intervention that raises costs in the energy sector will have an adverse impact on the economy as a whole (Huntington, 2009; Michaels and Murphy, 2009; Morriss *et al.*, 2009). One significant change since 2014 is the rapid reduction in costs of leading renewable energy technologies (IRENA, 2020; Jansen *et al.*, 2020), and this changes the economic context that the project will explore.

This topic area has links to related topics including skills and supply chains, transitioning to a low carbon economy, industrial decarbonisation, just transitions,

and local/community energy – all of which were raised as priority areas during the most recent TPA topics consultation exercise.

1.2 Context and earlier work

In some contexts, it is important to explicitly define what is meant by a 'green job'. Some categories of job will be obviously 'green'; installing and maintaining solar panels or wind turbines, for example. Others are less obvious – are the lorry drivers who deliver the solar panels to site carrying out a green job? The issue that UKERC's 2014 report addressed is whether 'green' policies lead to the creation of additional jobs (Blyth *et al.*, 2014). As long as the jobs contribute to fulfilling the aims of the policies, then they count as job creation, irrespective of whether they individually would be considered as being particularly 'green'. To further avoid controversies around definitional issues, the 2014 report focused on a relatively narrow subset of 'green' policies, namely support for renewable energy and energy efficiency. It aimed to address the following specific research question:

"What is the evidence that policy support for investment in renewable energy and energy efficiency leads to net job creation in the implementing regions?"

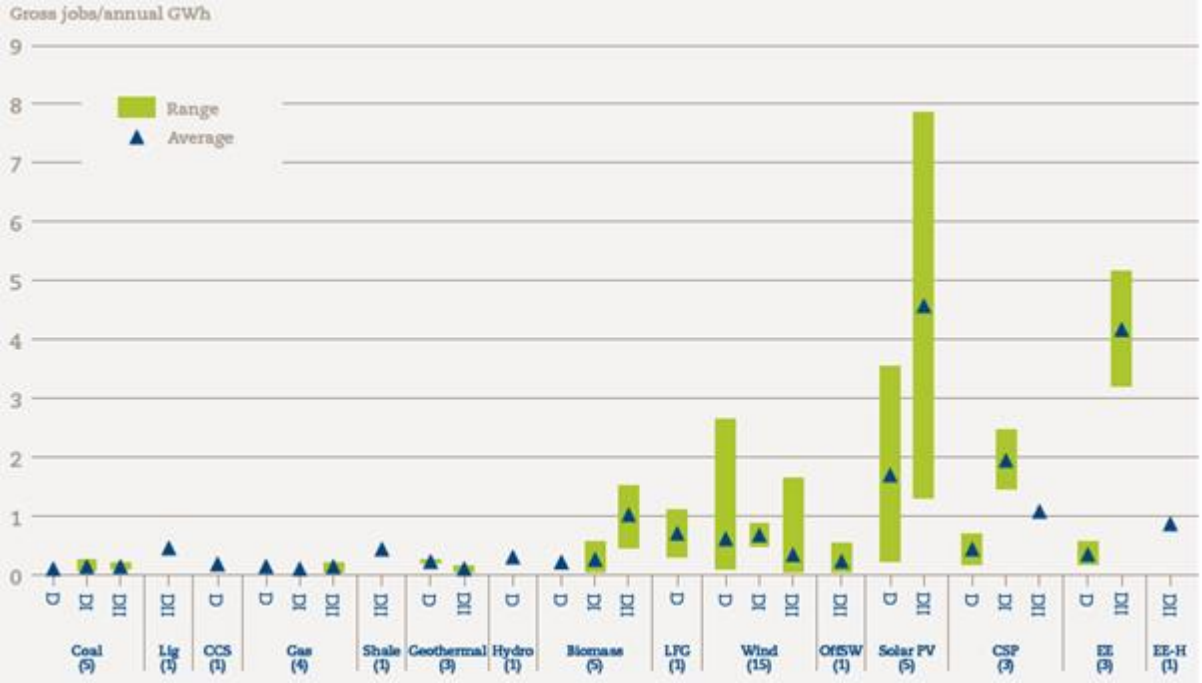
The question reached particular policy relevance at the onset of the 2008 financial crisis when governments were considering how to spend economic stimulus money. At this time, and similar to now with post-COVID-19 economic recovery, issues of how many jobs would be created by different investment pathways were paramount.

Blyth *et al.* (2014) reviewed the pros and cons of methodologies used in the literature to estimate job impacts. Primary data is often gathered through case studies, together with questionnaires and supply-chain surveys. Studies often include not just direct employment impacts, but also the wider ripple-through indirect effects of increased demand in the supply chain, as well as the induced effect of higher spending potential for those households that have benefitted from the higher employment rates. The most common analytical approach for these wider effects is input-output modelling. Studies also address wider macro-economic impacts through computable general equilibrium (CGE) modelling, or macro-econometric approaches.

The quantitative evidence base reviewed in UKERC's 2014 report comes from two main different types of literature. The first (comprising the majority of the literature surveyed) are studies where authors provide estimates of gross job impacts of individual projects for specific types of electricity generation. To get an approximate estimate of net job impacts, Blyth *et al.* (2014) compared across different studies the gross job impacts of investing in renewable energy and energy efficiency with the gross job impacts of investing in fossil fuel plant. In the second type of literature, authors explicitly calculate the net job impacts of renewables and energy efficiency compared to fossil fuels, giving a direct indication of the net impacts. This was a smaller set of literature, but produced a roughly similar result to the first set of literature, giving some additional confidence in the overall conclusion. The review found there to be a reasonable degree of evidence that in general, renewable energy

and energy efficiency are more labour-intensive in terms of electricity produced than either coal- or gas-fired power plant, as illustrated in Figure 1 below.

Figure 1 Gross jobs per annual GWh generated (number of studies in brackets)



Key: D: direct jobs, DI: indirect jobs, DII: induced jobs, CCS: carbon capture and storage, LFG: land-fill gas, OffSW: offshore wind, CSP: concentrated solar power, EE: energy efficiency, EE-H: energy efficiency in households.

Source: Blyth *et al.* (2014)

The implication of this analysis is that at least in the short-term, building new renewable generation capacity or investing in greater energy efficiency to avoid the need for new generation would create more jobs than investing in an equivalent level of fossil fuel-fired generation. The magnitude of the difference is of the order of 1 job per annual GWh produced (Blyth *et al.*, 2014).

Whilst the evidence reviewed by Blyth *et al.* (2014) seems reasonably robust that renewables and energy efficiency are in general more labour-intensive than fossil fuels, this does not automatically mean that preferential investment in these technologies will lead to higher employment in the economy as a whole. In the 2014 report wider economic factors are also explained, with reference to Keynesian economics. Keynesian economics provides one of the leading theoretical bases for understanding unemployment effects, and explicitly relies on the assumption that economies are out of equilibrium during periods of high unemployment. For example, in a depressed economy in which aggregate demand is low compared to potential supply of goods and services (creating a so-called ‘output gap’), then Keynesian measures of stimulating additional employment in particular sectors, such as through a fiscal or monetary stimulus, are very likely to lead to higher overall employment,

and it makes sense to focus such efforts on more labour-intensive options. On the other hand, in an economy which is closer to ‘equilibrium’ conditions and ‘full employment’, the room for such manoeuvres is more limited: if human and physical resources are fully deployed, then output cannot be increased. Government-led investments may crowd out private investment leading to lower-than-expected net employment results.

Policies that have impacts beyond the time horizon of the current business cycle lock-in the economy to a particular set of behaviours that go beyond their initial stimulus impacts. This is particularly true for decisions in the electricity sector which concern long-lived strategic infrastructure. In these cases, it is important to assess the balance of costs and benefits to the economy in terms of the impact on growth potential. When designing stimulus programmes, it makes sense to support technologies and projects that support technological progress in the long-term, because if they have a persistent impact on the economy beyond the timeframe of the direct stimulus effects, they should also help contribute to long-term growth. In this longer-term context, labour intensity is not in itself economically advantageous, as it implies lower levels of labour productivity (economic output per worker), which could adversely impact prospects for economic growth (Blyth *et al.*, 2014).

Therefore, the 2014 report also cautioned that the employment characteristics that matter in the long-run are not just how many jobs are created per unit of investment, but also whether or not the investment contributes to an economically efficient transition towards the country’s strategic goals, taking account of externalities such as environmental impacts and energy security considerations.

1.3 Work plan

As a 1st task of the current project, and to provide some context for the scoping review report, the project team collated relevant international estimates on gross low carbon jobs (see section 1.4). The 2nd task of this project was to carry out a scoping review of relevant academic and grey literature (see section 1.5). This report presents findings from the scoping review including a preliminary analysis of evidence, and informs our refining of the research questions and search strategies to be used in the full systematic review, which is the 3rd task. The systematic review will build upon the evidence gathering and analysis that has been conducted for the scoping review. Section 2.5 sets out the planned approach for the full systematic review.

1.4 UK and international estimates on low carbon jobs

In order to provide some background to the scoping review, we extracted the latest key statistics on gross low carbon jobs from authoritative sources in the UK and internationally, and we make reference to these here. It is estimated that at least 11 million people are employed in renewable energy sectors worldwide, with the

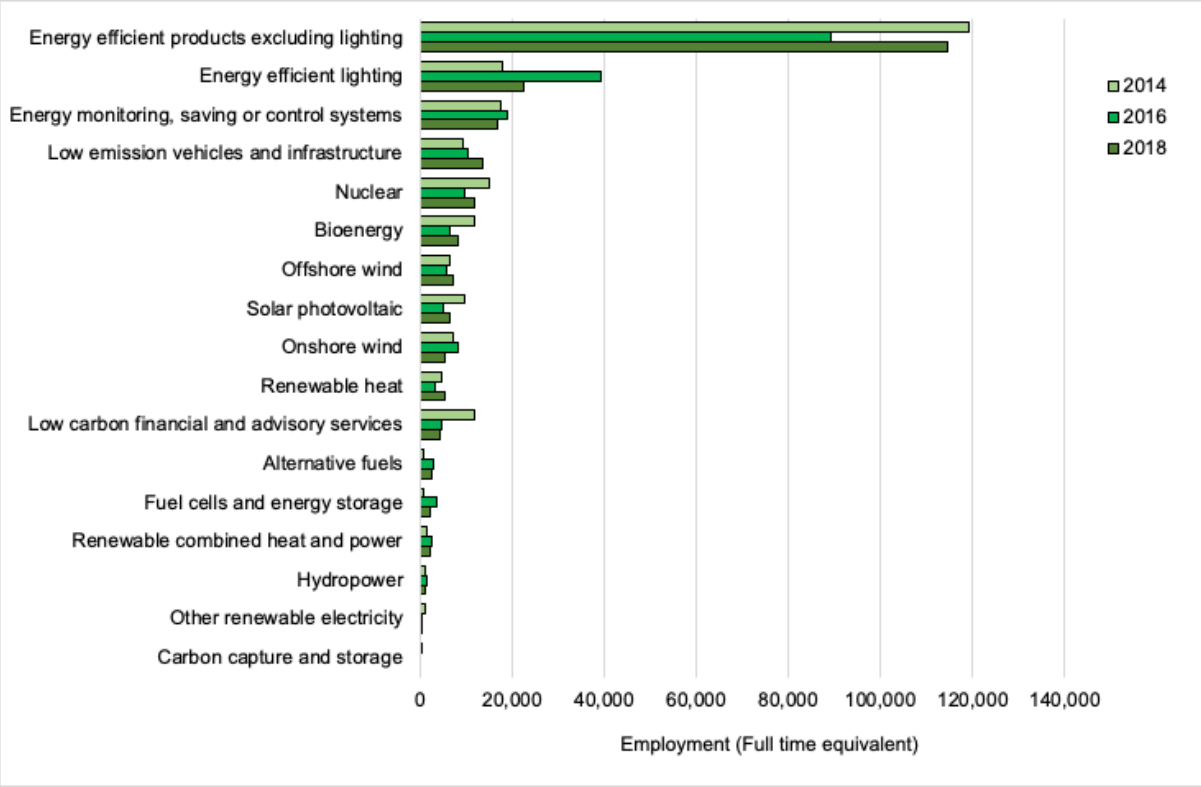
majority of these jobs concentrated in China, the EU, Brazil, the US and India (IRENA, 2019).

Figure 2 shows gross employment estimates for a range of low carbon and energy efficiency technologies, products and services in the UK. In terms of the net jobs outcomes of decarbonisation, some low carbon options may be more labour intensive than the fossil fuel options they replace (and hence create jobs per unit of energy), but the evidence is mixed. Wider economic effects also need to be accounted for, so that if a low-cost, high carbon fuel or energy system is substituted for a more expensive low carbon alternative then overall economic efficiency would be expected to fall. All else being equal this would reduce output and hence employment (Gross, 2020b).

Energy efficiency products and services, including lighting, currently comprise around 150,000 jobs in the UK (Figure 2): this equates to over two thirds of UK employment in low carbon and renewable energy businesses, according to a survey carried out by the Office for National Statistics (ONS, 2020). The Treasury has estimated that the Green Homes Grant, now extended until 2022, could support more than 100,000 jobs (Murray, 2020).

Several reports have been published recently, for example by the Energy Efficiency Infrastructure Group (EEIG, 2020) and the Institute for Public Policy Research (Jung and Murphy, 2020; Webb, Emden and Murphy, 2020), which make a strong case for the co-benefits of investing in home energy refurbishments. The UK has one of the oldest, most poorly insulated and draughty housing stocks in Europe (ACE, 2015). Space and water heating in buildings contributes around 40% of UK energy consumption and 20% of UK greenhouse gas emissions (CCC, 2016). Properly insulating UK homes and replacing fossil fuel boilers with heat pumps can help to alleviate fuel poverty, meet the UK's longer-term net zero climate target, and support a just transition: creating jobs in a distributed way around the country, including "levelling up" in regions most affected by unemployment and lack of investment (EEIG, 2020; Jung and Murphy, 2020; Webb, Emden and Murphy, 2020). Low carbon energy technologies may vary in the extent to which they offer social and economic co-benefits similar to those arising from retrofitting buildings (Gross, 2020a).

Figure 2 Low Carbon and Renewable Energy Economy (LCREE) gross employment estimates by sector in the UK, 2014 to 2018



Source: ONS (2020)

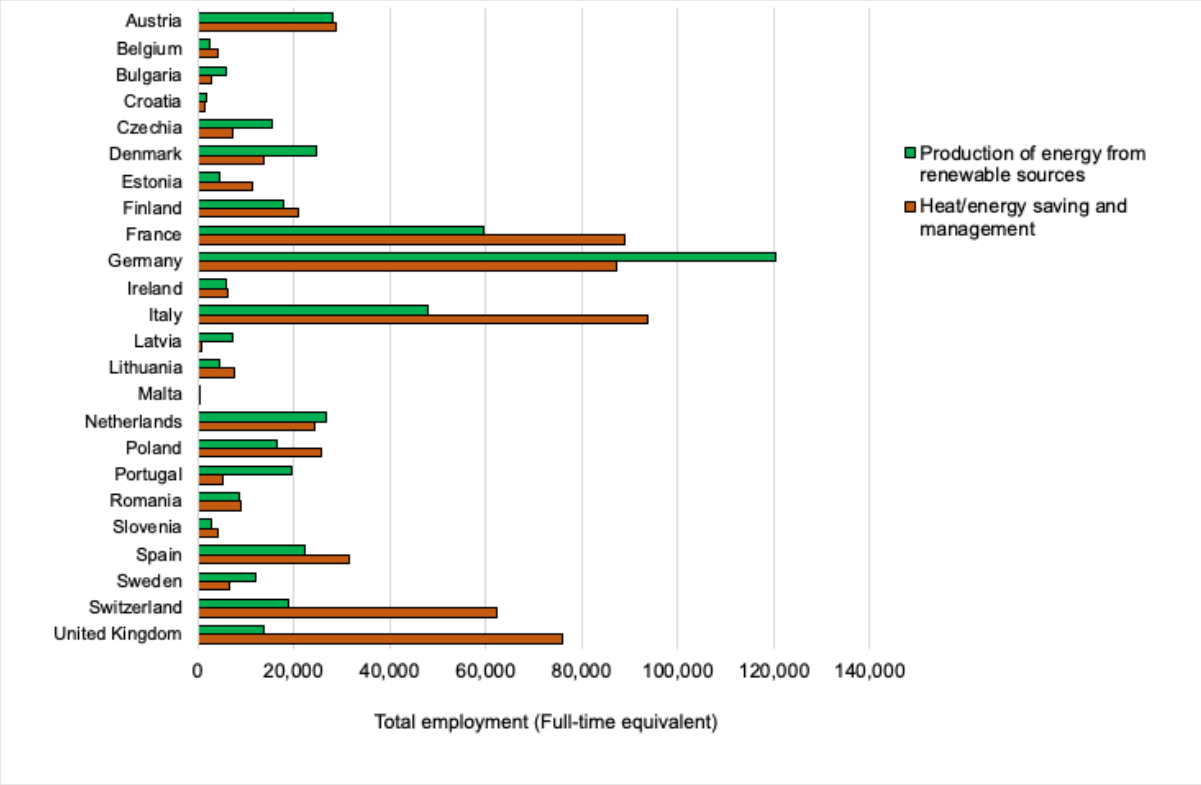
Notes to Figure 2

1. *Employment estimates are full-time equivalents (FTEs) and rounded to the nearest 100.*
2. *For carbon capture and storage in 2016 and 2018, employment was estimated to be less than 100 and is not shown in the chart.*
3. *All employment estimates are subject to uncertainty ranges not shown in the chart: coefficients of variation and 95% confidence intervals.*

The "environmental economy" is defined by Eurostat (Eurostat, 2020b) as including *"activities and products that serve either of two purposes: 'environmental protection' — that is, preventing, reducing and eliminating pollution or any other degradation of the environment or 'resource management' — that is, preserving natural resources and safeguarding them against depletion."* The environmental economy in the EU 28 (including the UK) accounted for 4.6 million full-time equivalent (FTE) jobs in 2017, compared to 3.4 million in the year 2000 (Eurostat, 2020a). In 2017, 1.1 million FTE jobs were in heat / energy saving and management, and 600,000 in the production of energy from renewable sources. Employment in these two energy-specific sectors is shown by country in Figure 3. In terms of total number of FTE jobs, Germany stands out given that around 120,000 people there work in the renewable energy sector. The next highest are France and Italy, with 59,000 and 47,000 renewable energy jobs respectively. All three countries employ more than 87,000 people in heat / energy saving and management, with Italy having 94,000 FTE jobs in this sector in

2017. In the UK, full-time employment in heat or energy-saving is the 4th highest of the countries shown in Figure 3, at 76,000 employees.

Figure 3 Gross employment in renewable energy production and heat / energy saving and management in selected European countries, 2017



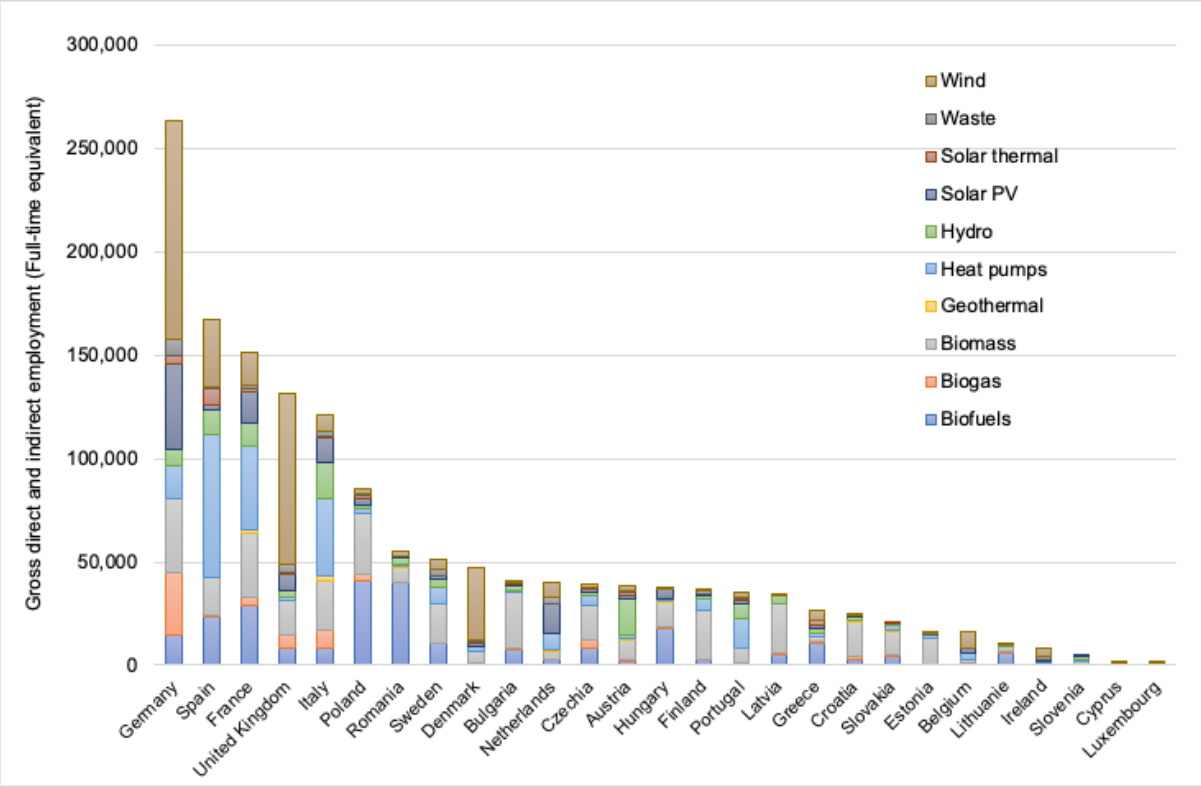
Source: Eurostat (2020b)

Notes to Figure 3

1. *Employment "is measured in full-time equivalents (total hours worked divided by the average annual hours worked in a full-time job)"* (Eurostat, 2020b).
2. *The two economic activities shown in Figure 3 (1. production of energy from renewable sources; 2. heat/energy saving and management - aka energy efficiency) have been categorised according to the Classification of Resource Management Activities (CReMA)* (Eurostat, 2020c).

Figure 4 shows sectoral renewable energy employment estimates produced by EurObserv'ER (2020). These are based on an employment modelling approach in which the economic activity of each renewable energy sector is accounted for and converted to full-time equivalent (FTE) estimates using input-output tables. According to this data, around 1.5 million people were estimated to be directly or indirectly employed in renewable energy in the EU28 in 2018. The UK had 131,900 renewable energy jobs according to this measure, the 4th highest total in the EU after Germany, Spain and France. In the UK, 63% of total direct or indirect renewable energy jobs were in wind power in 2018, equating to 82,800 FTE employees. These employment estimates do not include energy efficiency, energy storage or electric mobility.

Figure 4 Gross direct and indirect employment estimates for renewable energy sectors in EU 28 countries, 2018



Source: EurObserv'ER (2020)

Notes to Figure 4

1. *Employment estimates are full-time equivalents (FTEs) and rounded to the nearest 100.*
2. *Employment data includes both direct and indirect employment, but not induced employment.* EurObserv'ER (2020) *lists examples of direct employment as including "renewable equipment manufacturing, renewable plant construction, engineering and management, operation and maintenance, biomass supply and exploitation"; indirect employment is referred to as "secondary activities, such as transport and other services".*

The estimates presented in this section show gross (not net) low carbon and energy efficiency jobs. A key definitional issue which this project aims to account for is the distinction between 'gross' and 'net' jobs. Gross effects include only the positive impact on employment which may be associated with a particular investment. It is clear that gross jobs can in general be created when money is spent on projects that require manufacturing, installation, operation and maintenance of new equipment. What is relevant to this study is whether net jobs can be created when the potential negative impacts of those projects on the wider economy is taken into account. In particular, it is important when considering the net employment impacts of a renewable energy or energy efficiency investment to consider jobs that might be displaced in other parts of the economy as a result of the investment. For example, the number of gross jobs created through additional renewable energy deployment could be offset by the implied number of jobs that would be lost in other parts of the

power sector due to less power generation needed from gas and coal generation (Blyth *et al.*, 2014).

Statistical estimates of current levels of gross employment in renewable energy and energy efficiency are also difficult to compare between different sources for the UK and Europe. This is due to variations in the way particular categories of technologies or activities are defined, different methods used to estimate FTE employment, and different approaches to including and defining direct and indirect employment.

1.5 Scoping review

For the scoping review, we selected a limited range of key words or phrases shown in Table 1 below, and combined them in search strings applied to two databases: Google Scholar and Science Direct. The search terms were based on those used in the 2014 TPA review or included key words related to recent or current policy concerns. These initial searches were restricted to the years 2014 to 2020, as an update to, and in order to avoid duplication with, the pre-existing review on green jobs. The project team first experimented with a range of search words and terms, applied to Google Scholar and Science Direct, to determine the most productive search strings to use. Two search strings were then selected to be applied to Google Scholar and two to be applied to Science Direct. For each of four search strings we extracted the first 25 results, yielding 100 documents in total. 19 additional (mainly grey literature) documents were included in the scoping review which had come to the authors' attention largely through press releases, news items or peer recommendations. Each document was assigned a relevance rating from 1 to 4[1], with reference to the potential research questions set out in the UKERC project scoping note (August 2020). A total of 62 of these were assigned relevance ratings 1 to 2, or in other words were judged to be directly or indirectly relevant to the research questions, and were included in a summary analysis. The findings from this summary analysis are presented in this section.

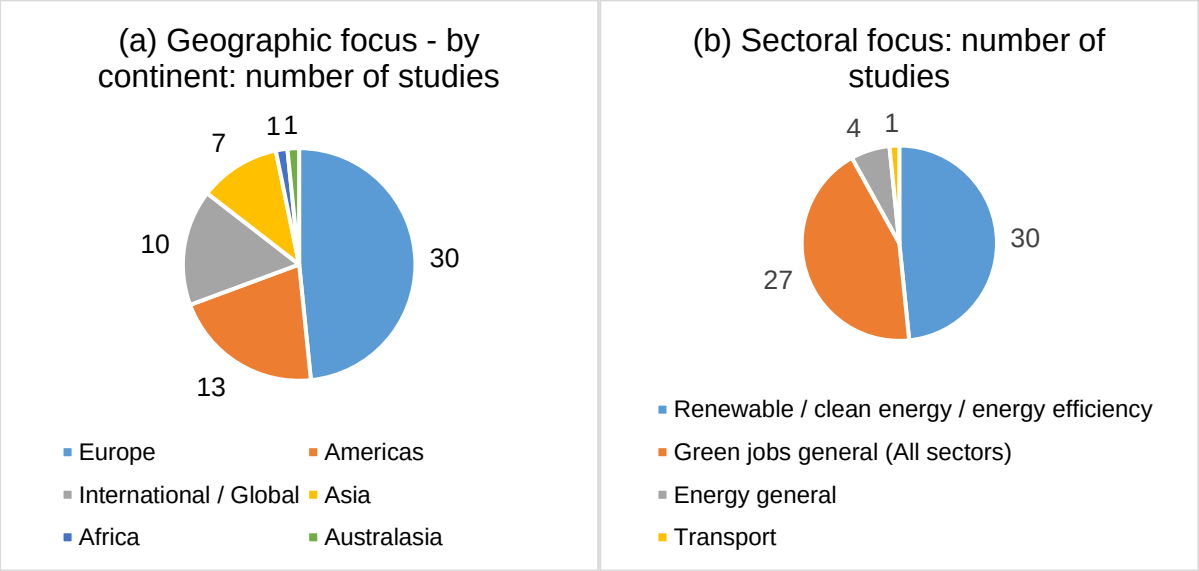
Table 1 Search terms used for scoping review

Employment and Job Creation	Energy and Environment	Policy
job	energy	"net zero"
"green job"	green	"just transition"
"low carbon job"	"low carbon"	stimulus
skill	renewable	
"supply chain"		

[1] The criteria used for assigning each relevance rating is identical to that planned for the full systematic review: see the explanation of each relevance rating in section 2.5.

Figure 5 categorises the 62 relevant documents into geographies and sectors studied. The identified documents are fairly international in scope: while 30 focused on the UK and/or Europe, 20 documents studied countries in either North America or Asia. 10 documents had a generally international focus. In terms of their coverage of green jobs and economic sectors, the relevant studies were approximately evenly split between those which specialise in renewable / low carbon energy or energy efficiency jobs, and those concerned with green jobs in a wider sense or across the whole economy.

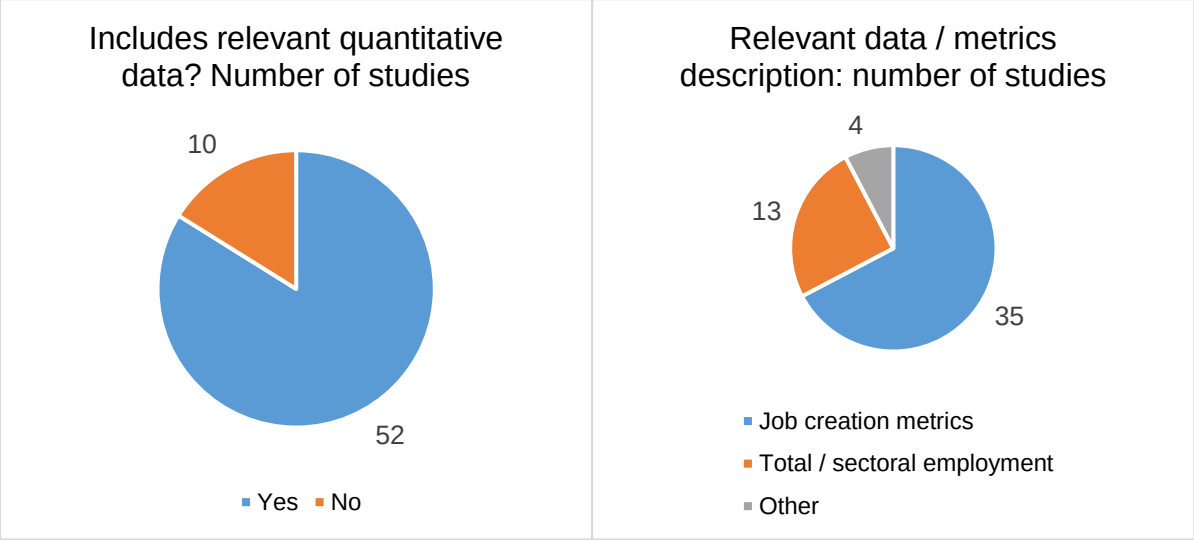
Figure 5 (a) Geographic and (b) sectoral focus of relevant documents



Most of the studies presented quantitative data or analysis, although 10 documents discussed or investigated job creation qualitatively (Figure 6a). The latter studies mostly followed descriptive, synthesis approaches such as literature reviews or in some cases presented data which was not directly related to job creation or green employment. Dsouza (2015) carried out expert interviews / elicitations and qualitative analysis of interview responses, in a study on the standard of living resulting from green job creation in California.

Of the 52 studies with quantitative data, two thirds included job creation metrics, such as jobs per level of investment or jobs per installed capacity or amount of electricity generation from renewables. Table 2 shows examples of methods and metrics used to estimate job creation in some of the identified studies. 13 documents presented total or sectoral employment data, but not job creation metrics specifically. Several studies, represented by the 'Other' category in Figure 6b, included quantitative data and metrics on the relative carbon intensity or environmental protection activity levels of different economic sectors (Bagheri *et al.*, 2018; HMT, 2020; Kapetaniou and McIvor, 2020).

Figure 6 (a) Quantitative data and (b) metrics in relevant documents



Many of the studies which presented job creation estimates derived these from modelling approaches (23 documents). Of these, seven documents used statistical (e.g. regression) models, whereas an additional eight used either input-output models or computable general equilibrium (CGE) models (Figure 7). One study, represented by the 'Hybrid' category in Figure 7b, used an approach combining simulation/CGE and input-output modelling (Baer, Brown and Kim, 2015). Six documents employed other modelling types; these included three studies applying macroeconomic or macroeconometric models (Element Energy, 2019; CCC, 2020b; Arvanitopoulos and Agnolucci 2020).

Figure 7 (a) Extent of modelling and (b) model types in relevant documents

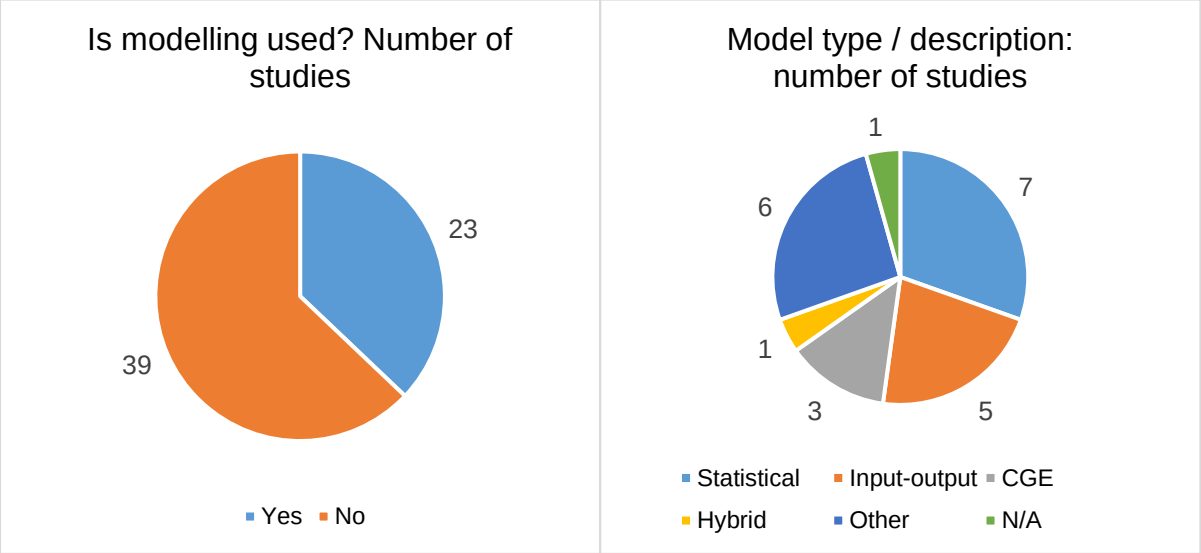


Table 2 shows the variety of approaches used by an illustrative selection of identified documents to estimate green job creation. Methods can vary from literature reviews to extract employment factors[2], collation of data and statistical analysis, to several different types of modelling reflecting the diversity of models shown in Figure 7b above. There is a wide range of metrics and units used in this international sample of literature, and therefore normalising or comparing such estimates is challenging.

Table 2 Examples of job creation methods and metrics identified in the international literature

Study and geographic focus	Methods used to estimate job creation	Job creation metrics
Dvořák *et al.* (2017); Czech Republic	Literature review, statistical collation and analysis	Number of jobs/installed capacity (MW).
Mundaca and Luth Richter (2015); US	Literature review – estimates presented from other sources	Job creation (number/year; job years); direct and indirect jobs created by clean energy spending; jobs supported by clean energy programs (includes induced jobs); total job years; average jobs/year for large wind and solar PV projects; estimated direct jobs in renewable energy industries and clean economy.
Sooriyaarachchi *et al.* 2015); International	Literature review of job potentials created in renewable energy technologies and energy efficiency	Estimated Jobs per $1M spending in energy efficiency sector in US in 2008 (Person-Years of Employment (PYE) per $1M invested); jobs/MW, man-years/MW, job-year/MW, jobs/year/$ Million, person-years/$ Million; direct, indirect and induced jobs.
Gkatsou *et al.* (2014); International	Employment factors from literature	Annual direct labour requirement per TWh of electricity generated; jobs destroyed elsewhere in the economy per every subsidized green job; annual jobs creation by green energy.
Reddy (2016); India	Integrated energy–engineering–environmental–economic system model	Job intensity (no. of jobs/MW); employment creation estimates through various power generation technologies: jobs/MWp (peak MW), jobs/MWa (average MW), job years/GWh, direct, indirect and induced jobs (jobs/GWh/lifetime years); jobs/MW/life time; cost/MW (US$ million); jobs/US$ (million) of investment.
Cameron and Van Der Zwaan (2015); International	Reviews studies including some which use input-output models to derive employment factors	Employment factors (defined as the number of jobs or amount of work generated per unit of electricity production capacity); direct employment factors for manufacturing, installation (person-years/MW) and operation and maintenance (in jobs/MW); direct and indirect jobs per deployment phase (in jobs/MW).
Mu *et al.* (2018); China	Computable general	Employment factors (Jobs / MW); employment impacts (Thousand Jobs/TWh); net employment impacts – direct, indirect and induced jobs (Thousand Jobs/TWh).

[2] Defined by Cameron and Van Der Zwaan (2015) as "the number of jobs derived from a certain renewable technology investment or capacity".

	equilibrium (CGE) model	
Arvanitopoulos and Agnolucci (2020); UK	Vector Error Correction model (Econometric model)	Employment effect of a 1 GWh permanent increase in electricity supply for each type of power generation technology.
Kamidelivand *et al.* (2018); Ireland	Input-Output model	Multipliers of the disaggregated electricity sectors; GHG emissions and employment numbers for each 2% substitution of imported gas and imported coal for electricity with renewable electricity.
Fragkos and Paroussos (2018); EU	Employment factors and CGE model (GEM-E3)	Employment and labour intensity of energy supply activities in EU in 2015; employment associated with 1 GWh of annual electricity production by technology in 2015; changes in EU direct energy jobs; changes in EU employment by sector.

There is also a wide range of estimates in recently published reports on how many jobs could be created or would be needed in order to achieve decarbonisation and meet the UK's net zero target. Table 3 shows different job creation estimates in forward-looking studies focusing on the UK, which have been drawn from our scoping review of the green jobs literature. These estimates vary in terms of timescales and the sectors they apply to, and may or may not include energy efficiency, low carbon heating, energy systems upgrades or industrial decarbonisation and CCS. Several studies highlight the potential for job creation in household retrofitting in relation to energy efficiency and low carbon heat. There is also considerable variation in the way in which metrics of job creation are defined, such as whether they apply to truly additional jobs, jobs created directly by an investment or more widely in the supply chain. It is therefore difficult to compare such job creation estimates, which may be generated by 'input-output', general equilibrium or econometric models, or derived from employment surveys and other literature, or a combination of all of these. Details of methodologies used in different studies are provided inconsistently in the literature and in some reports are absent or vague. For a discussion of terminology and the different methodologies used to estimate job creation see Blyth *et al.* (2014)

Table 3 Examples of recent job creation estimates under UK decarbonisation and net zero pathways

Study	Methods used	Estimated number of additional jobs created	Geography	Sector(s)	Time period
Vivid Economics (2019)	Business opportunities assessment including analysis of the potential for innovation to increase UK competitiveness, GVA, and jobs	500,000 jobs (not all will be additional).	UK	'Energy Innovation Needs Assessment' for a clean energy system	2019 - 2050

BEIS (2020)	N/A	Up to 250,000 jobs	UK	Green Industrial Revolution	2020 - 2030
CCC (2020b)	Based on Construction Industry Training Board (CITB) modelling (unspecified)	Over 200,000 FTE jobs	UK	Energy efficiency / low-carbon heat housing retrofit programme	Late 2020s – 2050
Ecuity Consulting (2020)	Based on other sources and unspecified modelling	997,000 direct jobs	England	Low-carbon and renewable energy economy	2018 - 2050
Element Energy (2019)	Macroeconomic model – using inputs on the demand of goods and services and statistical data to generate UK domestic output, imports, GVA and jobs	43,000 (13,700 direct jobs, 9,000 in operation of newly built facilities, and over 20,000 indirect, supply chain jobs)	UK	Industry decarbonisation using CCS and hydrogen	2020 - 2050
EEIG (2020)	Based on investment needed to deliver EPC C for all homes by 2030	Over 150,000 skilled and semi-skilled FTE jobs	UK	Energy efficiency	2020 – 2030
Webb, Emden and Murphy (2020)	Based on other sources	Over 325,000 jobs	UK	Energy efficiency and low-carbon heat	2020 – 2035
Jung and Murphy (2020)	Based on other sources	More than 560,000 jobs	UK	Energy efficiency, low-carbon heat and zero carbon social homebuilding	2020 - 2030
Johns and Longlands (2020)	Based on other sources including input-output modelling	77,000 direct jobs in the North and 111,000 indirect jobs across the UK	North of England and UK	Household heating, energy efficiency and decarbonisation	2020 - 2035
National Grid (2020)	Estimates generated by Development Economic analysis based on multiple data sources	260,000 new workforce jobs (including self-employment) plus 140,000 replacing those who have left the workforce	UK	Upgrading and operating energy generation, transmission and distribution network infrastructure to meet net zero	2020 - 2050

Figure 8 summarises the diversity of themes identified across the most relevant documents identified in our scoping review. There was a considerable range of issues covered including the role of policies in green job creation and recovery from economic recession, opportunities for youth employment, the nature (and quality) of green jobs, implications for green skills, and locational aspects. In addition, a subset of analyses focus on how a transition to renewable energy from conventional, higher carbon power generation, might affect the number of jobs created in an economy. These analyses commonly conclude that overall, a shift to renewable energy generation from fossil-fuel based or nuclear sources will deliver an increase in jobs, on both a gross and net basis (e.g. Arvanitopoulos and Agnolucci, 2020; Cameron and Van Der Zwaan, 2015; Fragkos and Paroussos, 2018; Ram, Aghahosseini and Breyer, 2020). Furthermore, whilst some of these additional jobs are relatively short term since they relate to the construction and installation phase, Arvanitopoulos and Agnolucci (2020) found that in the UK, there is still an increase in overall jobs in the long term.

Various studies attempt to associate green policies, including fiscal stimuli, financial incentives and regulations, with numbers of jobs created (e.g. Dsouza, 2015; Dvořák *et al.*, 2017; Mundaca and Luth Richter, 2015; Lim, Guzman and Bowen, 2020; Lee, 2017). Dvořák *et al.* (2017) found that job creation in renewable energy in the Czech Republic has depended upon the continuity of financial incentives, and Lee (2017) reported that regulations mandating action on renewable energy resulted in small positive increases in private sector green jobs in US states. Several documents investigated the role of green job creation policies in boosting employment during times of economic recession. A US-focused study suggests that green stimulus programmes have helped support renewable energy job creation, revenue, manufacturing capacity and supply chains, particular for large wind power (Mundaca and Luth Richter, 2015).

While the circumstances around the COVID-19 economic recession and 2009 financial crisis are very different, evidence focussed on the 2009 crisis indicates that the green measures (e.g. in renewable energy infrastructure) forming part of the recovery stimulus created more jobs than conventional stimulus measures (Allan *et al.*, 2020). The CCC recommend that in the short term, “green stimulus policies can be economically advantageous compared to traditional fiscal stimuli. They tend to have higher short run multipliers and higher numbers of jobs created” (CCC, 2020a). Domestic construction projects such as insulation retrofits or building wind turbines are particularly favourable and less prone to offshoring services overseas. The CCC also suggest that in the long term, “investments in low-carbon and adaptation technologies can lower costs and help to accelerate deployment and innovation in a 'virtuous reinforcing cycle'.” Examples of the latter include rapid falls in cost with increasing scale and deployment of solar PV, wind and potential battery storage technology.

Several studies highlight the importance of ensuring quality of green jobs, and some documents refer to the concept of ‘decent work’. For example, Mattos (2018) writes that “green jobs are, by definition, decent jobs, i.e. a subset of jobs in environmental sectors which provide adequate wages, safe working conditions, safeguard workers’

rights and social dialogue, and which provide social protection." The review of green jobs literature presented by Mattos (2018) suggests that "evidence on green policy impacts on job quality is minimal." In other documents identified in our scoping review, higher job quality is described for example in terms of high wages and full-time employment (Jung, 2015), and permanent rather than temporary jobs (MacCallum, 2016; Mattos, 2018).

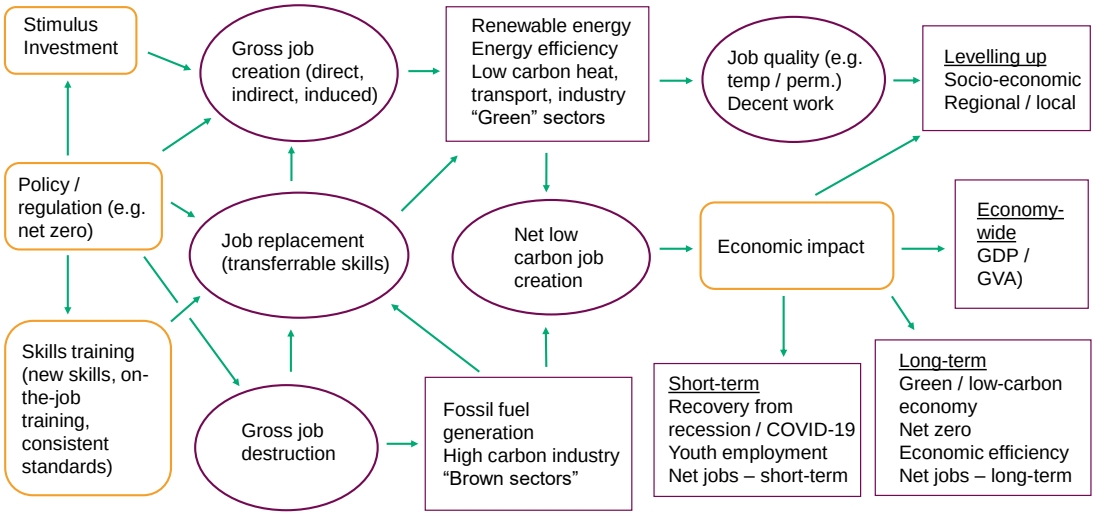
However, green or low carbon energy jobs may not always or necessarily be 'higher' quality jobs. For example, MacCallum (2016) found that in Kingston (Ontario, Canada) some direct employment in renewable energy construction or installation was linked to temporary work, which was no longer needed once renewable energy capacity targets had been met. With reference to data on Scotland, Connolly, Allan and McIntyre (2016) suggest that labour intensity may fall as renewables mature and employment needs shift from construction to maintenance and servicing. The authors observed that "between 2007 and 2012 the number of LCEGS [Low Carbon Environmental Goods and Services] jobs declined whereas the installed capacity of renewable generation in Scotland more than doubled" (Connolly, Allan and McIntyre, 2016).

A cluster of studies was also identified around the issue of skills for green jobs. Based on an analysis of US employment and occupational data, Consoli *et al.* (2016) suggest that "Green jobs exhibit higher levels of education, work experience and job training" and "use more intensively high-level cognitive and interpersonal skills compared to non-green jobs". Vona, Marin and Consoli (2018) also report high skill levels and salaries for green occupations compared to non-green employment in the US. Despite some identified differences in skills levels between green and non-green jobs, Reddy (2016) suggests that the skills required are not new, and Bowen, Kuralbayeva and Tipoe (2018) propose that much retraining in the green economy can occur "on the job". Others contend that the greening of the economy will require new skills, competencies and qualifications, linked to the creation of new markets and activities (Aceleanu, Serban and Burghelea, 2015; Shanghi and Sharma, 2014). Several studies note the potential to train and employ young people in these new areas, while helping to address youth unemployment (Aceleanu, Serban and Burghelea, 2015; Rutkowska-Podołowska, Sulich and Szczygieł, 2016; Sulich, Rutkowska and Popławski, 2020). Green skills supply and demand need to be carefully managed through policies supporting green job creation, and coordination of training activities. Pinninti (2014) suggests that this "will prevent the situation of green skills demand being stimulated by government policy, but not being matched by equivalent action to meet this demand, leading to skills bottlenecks and/or programme failure due to unskilled operators."

Another theme in the literature reviewed relates to the geographic distribution of green jobs and their role in a just transition. Several recent UK-focused publications present estimates of how many low carbon jobs could be created in different regions in order to 'level up' employment opportunities between regions. For example, the National Grid (2020) estimation of a "net zero workforce" for transitioning to a low carbon energy network by 2050 includes "significant employment opportunity in the

North of England[3] where nearly 100,000 jobs will become available, the Midlands (over 50,000 jobs) and the devolved nations of Scotland, Wales and Northern Ireland (nearly 90,000 jobs)." Johns and Longlands (2020) estimate that an economic stimulus to support household heat decarbonisation and energy efficiency could create 77,000 jobs directly in the North of England[2] and 111,000 jobs indirectly across the UK by 2035. According to a study on the US, woody biomass power plants using locally sourced feedstocks can generate more jobs locally than coal or natural gas power systems (Dahal *et al.*, 2020). Vona, Marin and Consoli (2018) present evidence, also on the US, that each additional local green job can create between two and four local jobs in non-green sectors. Elsewhere, it is suggested that green job creation is more likely in areas of higher per capita income and where employment in high-tech manufacturing and knowledge intensive services is concentrated (Vona, Marin and Consoli, 2018). The regional distribution of new green employment can also assist in substituting displaced jobs. With reference to South Korea, Park and Lee (2017) state that "Green industries tend to locate in areas where conventional manufacturing industries were previously concentrated" which "suggests potential strategies for local economic development with green industry sectors in traditional manufacturing cities that have experienced economic decline".

Figure 8 Scoping review: summary of identified themes in literature



Drawing upon the above scoping review of relevant literature on green jobs, and following consultation with our expert advisers (see section 2.4), in the next section we set out several potential research questions for a full systematic review.

[3] The North of England comprises the North West, North East, and Yorkshire and the Humber regions of England.

1.6 Research questions

The overarching research question which this project will address is:

What is the evidence that policy support for investment in renewable energy and energy efficiency leads to net job creation?

Following initial meetings with the project expert advisers in December 2020 / January 2021, we have updated the list of sub-questions which the project may consider to include:

- Which policy instruments can help to maximise net job creation in renewable / efficient energy at least cost to society?
- Does the literature quantify the differences in the rate of job creation between 'low carbon investments' and 'high carbon investments' in the short and long term?
- Quality of jobs: what are the implications of different low carbon job creation polices for the quality of jobs created? Which metrics could be used for the assessment of 'good' jobs under net zero e.g. jobs resilience / sustainability?
- Is there evidence in the literature on metrics for net job creation at a local / regional level, and impacts on local economies? Are jobs created where policymakers and society want them (regionally and nationally)?

The review will also set appropriate boundaries, for example by focusing only on renewable energy, energy efficiency and end use energy demand sectors. The geographical coverage of the review will be international but limited to evidence available in English language.

2. The UKERC TPA Approach

2.1 Overview

The TPA approach learns from the practice of systematic review, which aspires to provide more convincing evidence for policymakers and practitioners, avoid duplication of research, encourage higher research standards and identify research gaps. This *evidence based* approach is common in areas such as education, criminal justice and healthcare.

The goal is to achieve high standards of rigour and transparency. However, energy policy gives rise to a number of difficulties for prospective systematic review practitioners and the approach is not common in energy. We have therefore set up a process that is inspired by the evidence based approach, but that is not bound to any narrowly defined method or techniques.

This assessment protocol describes this process in detail. It provides a specification of the means by which we will consult stakeholders and solicit expert input, specifications for searching the literature, and criteria against which relevant findings will be assessed.

2.2 Assessment sequence

The TPA has identified a series of steps that need to be undertaken in each of its assessments. These steps, derived from the practice of *systematic review* in non-energy policy analysis, are outlined in Figure 9 below.

Figure 9 – typical process for TPA studies

Scoping prospective issues	Solicit expert input	Define criteria for assessment	Review literature	Synthesis and analysis	Prepare draft report	Consult, peer review and refine	Publish and promote
Questions/issues							
What are key problems and issues	Need to reflect a range of informed opinion	Ensure transparent, rigorous and replicable process	Need to review literature thoroughly	Need to apply rigorous criteria to evaluation of relevant studies	Need to identify key issues and discuss initial findings with stakeholders	Need to seek peer review and gain wide ranging criticism of initial work	Need to ensure report reaches key audience
Actions							
Write scoping note Seek feedback from advisory group Seek feedback from online listing of initial scoping	Appoint expert group Hold expert/ stakeholder workshop	Develop assessment protocols Discuss expert group and AG Place protocols in public domain	Apply protocol to literature search Detailed and transparent 'trawl' Identify relevant sources	Apply protocol to evaluation and synthesis of literature Detailed and transparent assessment of evidence base	Write preliminary draft assessment	Host stakeholder workshop to discuss draft report Send draft report for peer review Make appropriate revisions to draft report	Design and graphics Publication Launch events
Outputs							
Scoping note	Web publication of expert group	Assessment protocols			Draft report	Final report	Published report

While this project will follow this generalised approach, developed for all TPA work, it will be adapted to reflect the fact that one of the aims in this instance is to update the UKERC 2014 report, which may mean that some of the steps in Figure 9 are not appropriate or may need to be revised.

2.3 Stakeholder engagement

The project will seek input and comment from relevant stakeholders in the academic, policy-making and industrial communities. The project scoping note and scoping review report (this document) have been published on the UKERC website.

2.4 Expert advisers

The project team is engaging with a small group of expert advisers who can bring their experience and perspectives to bear on the subject. The expert advisers have been asked to comment on the scope of the project and the proposed approach, advise and assist the project team in the selection of relevant evidence sources, and review draft results. The current expert advisers are:

John Barrett (University of Leeds)

Will Blyth (Oxford Energy Associates and FCDO)

Lucy Geoghegan (Scottish Government)

Mike Hemsley (CCC)

Paul Mathews (HM Treasury)

Alex Price (BEIS)

Karen Turner (University of Strathclyde)

2.5 Research sources and review protocol

A systematic review protocol typically provides a rationale for the choice of sources and lists the main databases, bibliographies, catalogues, personal contacts and other sources that are to be searched. It will also specify the years to be covered and the search criteria that will be used. As identified in the Assessment Sequence section above, the project team will adopt an approach that is consistent with the available timescale. The systematic review will build upon the evidence analysis already conducted for the scoping review.

The initial set of key words, search terms and evidence categorisation are set out in Table 4 below. These search terms are based on those used in the 2014 TPA on green jobs and the scoping review search terms (Section 1.5). The searches will focus on the years 2014 to 2020 in order to provide an update to the 2014 review. The search terms may be revised following any discussion with the expert advisers, and input from stakeholders where appropriate.

Table 4 Potential search terms for full systematic review (Stage 1)

Employment and Job Creation	Energy and Environment	Policy	Job quality
employment	energy	polic*	quality
job*	environment*	subsid*	“decent work”
work*	green	support*	skill*
"green job"	“low carbon”	incentiv*	competenc*
"low carbon job"	clean	stimulus	temporary
"net job creation"	renewable*	regulation	permanent
	efficiency	"net zero"	full-time
	climate	"just transition"	part-time
		“levelling up”	salary
		local	wage
		regional	

Part of the analysis in this study involves comparing low carbon job estimates with estimates of jobs in traditional (fossil-fired) power generation, in order to gauge the net job impacts of renewables and energy efficiency compared to fossil fuels. In

order to reduce any bias that may arise in the ‘green jobs’ literature with respect to job estimates for fossil-fired technology, an additional literature search will be carried out combining search terms related to fossil fuel energy with employment or labour market related key words (Table 5). The policy and quality related search terms will be omitted in order to broaden this additional search (since the focus of the project is on policies to promote low carbon jobs), and to include job estimates for the sector that arise without policy stimulus.

Table 5 Potential search terms for full systematic review (Stage 2)

Employment and Job Creation	**Fossil Fuels**
employment	coal
job*	fossil
work*	“natural gas”
	“shale gas”

Relevance ratings

Returned results will be filtered manually for relevance based on their title and abstract. If this is not sufficient to determine relevance, further inspection of the main text will be performed. This will allow the project team to subsequently focus their attention only on those documents which are most directly useful in addressing the research questions. Each document will be assigned a relevance rating from 1-4 according to the following criteria:

1. Article shows clear discussion and/or data that is directly focussed on some or all of the research questions;

2. Article shows clear discussion and/or data that is related to but is not directly focussed on any of the research questions;

3. Article mentions at least one of the search terms, but is of only limited relevance to the research questions;

4. Article is found to be irrelevant or duplicate on closer inspection.

Databases / sources

Science Direct

Science Direct provides access to Elsevier journals and e-books including on physical sciences and engineering and social science topics.

Google scholar

Note that searches using Google scholar include a range of relevant journal paper databases including Taylor & Francis, Wiley Online and IEEE, in addition to those published by Elsevier.

Google

Searches using google are particularly effective in capturing grey literature which is not obtained using traditional academic journal databases.

3. References

ACE (2015) *The Cold Man of Europe – 2015*. London: Association for the Conservation of Energy.

Aceleanu, M., Serban, A. and Burghelea, C. (2015) '"Greening" the Youth Employment—A Chance for Sustainable Development', *Sustainability*, 7(3). doi: 10.3390/su7032623.

Allan, J. *et al.* (2020) *A net-zero emissions economic recovery from COVID-19*. COP26 Universities Network Briefing, May 2020.

Arvanitopoulos, T. and Agnolucci, P. (2020) 'The long-term effect of renewable electricity on employment in the United Kingdom', *Renewable and Sustainable Energy Reviews*, 134, p. 110322. doi: 10.1016/j.rser.2020.110322.

Baer, P., Brown, M. A. and Kim, G. (2015) 'The job generation impacts of expanding industrial cogeneration', *Ecological Economics*, 110, pp. 141–153. doi: 10.1016/j.ecolecon.2014.12.007.

Bagheri, M. *et al.* (2018) 'Green growth planning: A multi-factor energy input-output analysis of the Canadian economy', *Energy Economics*, 74, pp. 708–720. doi: 10.1016/j.eneco.2018.07.015.

BEIS (2020) *Energy White Paper - Powering our Net Zero Future*. London: Department for Business, Energy and Industrial Strategy.

Blyth, W. *et al.* (2014) *Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy*, *UK Energy Research Centre*. London.

Bowen, A., Kuralbayeva, K. and Tipoe, E. L. (2018) 'Characterising green employment: The impacts of "greening" on workforce composition', *Energy Economics*, 72, pp. 263–275. doi: 10.1016/j.eneco.2018.03.015.

Cameron, L. and Van Der Zwaan, B. (2015) 'Employment factors for wind and solar energy technologies: A literature review', *Renewable and Sustainable Energy Reviews*, 45, pp. 160–172. doi: 10.1016/j.rser.2015.01.001.

CCC (2016) *Next steps for UK heat policy*. London: Committee on Climate Change.

CCC (2020a) *Reducing UK emissions: Progress Report to Parliament*. London: Committee on Climate Change.

CCC (2020b) *The Sixth Carbon Budget: The UK's path to Net Zero*. London: Committee on Climate Change.

Connolly, K., Allan, G. J. and McIntyre, S. G. (2016) 'The evolution of green jobs in Scotland: A hybrid approach', *Energy Policy*, 88, pp. 355–360. doi: 10.1016/j.enpol.2015.10.044.

Consoli, D. *et al.* (2016) 'Do green jobs differ from non-green jobs in terms of skills and human capital?', *Research Policy*, 45(5), pp. 1046–1060. doi: 10.1016/j.respol.2016.02.007.

Dahal, R. P. *et al.* (2020) 'Localized economic contributions of renewable wood-based biopower generation', *Energy Economics*, 91, p. 104913. doi: 10.1016/j.eneco.2020.104913.

Dsouza, J. (2015) 'The Environmental Revolution: But does Labour Reap the Benefit from Green Jobs?', *E-Journal of International and Comparative Labour Studies*, 4(2).

Dvořák, P. *et al.* (2017) 'Renewable energy investment and job creation; a cross-sectoral assessment for the Czech Republic with reference to EU benchmarks', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, pp. 360–368. doi: 10.1016/j.rser.2016.11.158.

Ecuity Consulting (2020) *Local green jobs – accelerating a sustainable economic recovery*. Local Government Association.

EEIG (2020) *Rebuilding for resilience - Energy efficiency's offer for a net zero compatible stimulus and recovery*. Energy Efficiency Infrastructure Group.

Element Energy (2019) *Hy-Impact Series Study 1: Hydrogen for economic growth*. Equinor.

EurObserv'ER (2020) *The state of renewable energies in Europe: 2019 edition*. Paris: EurObserv'ER.

Eurostat (2020a) *Employment in the environmental goods and services sector*. Luxembourg: European Commission. Available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_egss1&lang=en.

Eurostat (2020b) *Environmental economy – statistics on employment and growth*. Luxembourg: European Commission. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_economy_-_employment_and_growth#Employment.2C_production_and_value_added_in_the_environmental_economy.

Eurostat (2020c) *SCL - Classification of environmental protection activities (CEPA)*

and classification of resource management activities (CReMA). Luxembourg: European Commission. Available at: https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CL_CEPAREM&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC.

Figueres, C. and Zycher, B. (2020) 'Can we tackle both climate change and Covid-19 recovery?', *Financial Times*.

Fragkos, P. and Paroussos, L. (2018) 'Employment creation in EU related to renewables expansion', *Applied Energy*, 230, pp. 935–945. doi: 10.1016/j.apenergy.2018.09.032.

Gkatsou, S. *et al.* (2014) 'The Impact of Green Energy on Employment: A Preliminary Analysis', *International Journal of Business and Social Science*, 5(1), pp. 29–41.

Gross, R. (2020a) *The co-benefits of energy efficiency stack up; and they do for other low carbon options too*. UK Energy Research Centre. Available at: https://ukerc.ac.uk/news/the-co-benefits-of-energy-efficiency-stack-up-and-they-do-for-other-low-carbon-options-too/.

Gross, R. (2020b) *We need an evidence-based approach to clean growth and stimulus*. London: UK Energy Research Centre. Available at: https://ukerc.ac.uk/news/we-need-an-evidence-based-approach-to-clean-growth-and-stimulus/.

HMT (2020) 'Net Zero Review: Interim report'. London: HM Treasury.

Huntington, H. (2009) *Creating jobs with 'green' power sources*. United States Association for Energy Economics.

Hydrogen Strategy Now (2020) *The case for a UK-wide hydrogen strategy*. Available at: https://hydrogenstrategynow.co.uk/.

IRENA (2019) *Renewable Energy and Jobs: Annual Review 2019*. Abu Dhabi: International Renewable Energy Agency.

IRENA (2020) *How Falling Costs Make Renewables a Cost-effective Investment*. International Renewable Energy Agency. Available at: https://www.irena.org/newsroom/articles/2020/Jun/How-Falling-Costs-Make-Renewables-a-Cost-effective-Investment.

Jansen, M. *et al.* (2020) 'Offshore wind competitiveness in mature markets without subsidy', *Nature Energy*, 5(8), pp. 614–622. doi: 10.1038/s41560-020-0661-2.

Johns, M. and Longlands, S. (2020) *Northern powerhomes: A green recovery plan to decarbonise homes in the North*. Manchester and Newcastle: Institute for Public Policy Research North.

Jung, C. and Murphy, L. (2020) *Transforming the economy after Covid–19: A clean, fair and resilient recovery*. London: Institute for Public Policy Research.

Jung, Y.-M. (2015) ‘Is South Korea’s Green Job Policy Sustainable?’, *Sustainability*, 7(7). doi: 10.3390/su7078748.

Kamidelivand, M. *et al.* (2018) ‘A comparative analysis of substituting imported gas and coal for electricity with renewables – An input-output simulation’, *Sustainable Energy Technologies and Assessments*, 30, pp. 1–10. doi: 10.1016/j.seta.2018.08.003.

Kapetaniou, C. and McIvor, C. (2020) ‘Going green: preparing the UK workforce for the transition to a net-zero economy’. London: Nesta.

Lee, T. (2017) ‘The effect of clean energy regulations and incentives on green jobs: panel analysis of the United States, 1998–2007’, *Nat Resour Forum*, 41, pp. 145–155.

Lim, T., Guzman, T. S. and Bowen, W. M. (2020) ‘Rhetoric and Reality: Jobs and the Energy Provisions of the American Recovery and Reinvestment Act’, *Energy Policy*, 137, p. 111182. doi: 10.1016/j.enpol.2019.111182.

MacCallum, A. M. (2016) *Employment associated with Renewable and Sustainable Energy Development in the Kingston Region*. Queen’s University.

Mattos, F. B. de (2018) *Greener growth, just transition, and green jobs: there’s a lot we don’t know*. Geneva, Switzerland: International Labour Organization .

McPhee, D. (2020) ‘Around 1,500 jobs created with every gigawatt of clean energy installed in Scotland, trade body claims’, *Energy Voice*.

Michaels, R. and Murphy, R. P. (2009) *Green jobs: fact or fiction? An assessment of the literature*. Washington D.C.: Institute for Energy Research.

Morriss, A. P. *et al.* (2009) *Green jobs myths. University of Illinois Law and Economics research paper series*. Illinois: University of Illinois College Of Law.

Mu, Y. *et al.* (2018) ‘Employment impacts of renewable energy policies in China: A decomposition analysis based on a CGE modeling framework’, *Applied Energy*, 210, pp. 256–267. doi: 10.1016/j.apenergy.2017.10.086.

Mundaca, L. and Luth Richter, J. (2015) ‘Assessing “green energy economy” stimulus packages: Evidence from the U.S. programs targeting renewable energy’, *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, pp. 1174–1186. doi: 10.1016/j.rser.2014.10.060.

Murray, J. (2020) ‘“Significant down payment”: Chancellor to unveil £3bn green building upgrade package’, *Business Green*.

National Grid (2020) *Building the Net Zero Energy Workforce*. National Grid plc.

ONS (2020) *Low carbon and renewable energy economy, UK: 2018*. Office for National Statistics. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2018.

Oyewo, A. S. *et al.* (2019) ‘Pathway towards achieving 100% renewable electricity by 2050 for South Africa’, *Solar Energy*, 191, pp. 549–565. doi: 10.1016/j.solener.2019.09.039.

Park, J. Il and Lee, S. (2017) ‘Examining the spatial patterns of green industries and the role of government policies in South Korea: Application of a panel regression model (2006–2012)’, *Renewable and Sustainable Energy Reviews*, 78, pp. 614–623. doi: 10.1016/j.rser.2017.04.061.

Pinninti, K. R. (2014) ‘Climate change adaptation and local development: The new imperatives for green skills development’, in *Greener Skills and Jobs* . Paris: OECD Publishing.

Ram, M., Aghahosseini, A. and Breyer, C. (2020) ‘Job creation during the global energy transition towards 100% renewable power system by 2050’, *Technological Forecasting and Social Change*, 151, p. 119682. doi: 10.1016/j.techfore.2019.06.008.

Reddy, B. S. (2016) ‘India’s energy system transition-Survival of the greenest’, *Renewable Energy*, 92, pp. 293–302. doi: 10.1016/j.renene.2016.02.027.

Rutkowska-Podołowska, M., Sulich, A. and Szczygieł, N. (2016) ‘Green Jobs’, in *International Conference on European Integration*. Ostrava, Czech Republic .

Shanghi, S. and Sharma, J. (2014) ‘Local development strategy, green jobs and skills in the Indian context’, in *OECD Green Growth Studies Greener Skills and Jobs*. OECD, European Centre for the Development of Vocational Training.

Sooriyaarachchi, T. M. *et al.* (2015) ‘Job creation potentials and skill requirements in, PV, CSP, wind, water-to-energy and energy efficiency value chains’, *Renewable and Sustainable Energy Reviews*, 52, pp. 653–668. doi: 10.1016/j.rser.2015.07.143.

Sulich, A., Rutkowska, M. and Popławski (2020) ‘Green jobs, definitional issues, and the employment of young people: An analysis of three European Union countries’, *Journal of Environmental Management*, 262, p. 110314. doi: 10.1016/j.jenvman.2020.110314.

Vivid Economics (2019) *Energy Innovation Needs Assessment for the Department for Business, Energy and Industrial Strategy*. London: Department for Business, Energy and Industrial Strategy.

Vona, F., Marin, G. and Consoli, D. (2018) ‘Green employment: What, where and how much? An exploratory study on the magnitude, geographical distribution and effects of green employment in the United States’, *OFCE, Le Blog* .

Webb, J., Emden, J. and Murphy, L. (2020) *All hands to the pump: A home improvement plan for England*. London: Institute for Public Policy Research.