Are 'green' jobs good jobs?

How lessons from the experience to-date can inform labour market transitions of the future

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Contents

Headline messages

- Research on green jobs often uses a narrow definition of the green economy.
- In contrast, we apply a broad approach to the UK and European economies.
- We find that green jobs provide good quality employment and pay higher wages than non-green jobs, especially for middle- and low-skilled workers.
- Green jobs are also at lower risk of automation than non-green jobs.
- Currently there are fewer women than men, and fewer younger than older people, in green jobs.
- Policymakers need to ensure that:
    - training and education programmes build the skills needed in the net-zero transition; and
    - transition policies address regional and demographic imbalances.

Summary

Analysing the 'green' economy

The transition to net-zero will have far-reaching but unequal effects, as 'dirty' jobs disappear while new jobs aligned with or supportive of the net-zero objective – which we refer to as 'green' – are created.

As governments worldwide increase their commitments to tackling climate change, there is a growing need to quantify and characterise the 'green economy', and to identify opportunities to be seized and challenges to be overcome in the transition to the net-zero economy of the future.

To shed light on green jobs and inform policy and future research, we apply a granular analytical approach to quantify and describe green jobs in the UK and EU economies.

Context: what does the literature say on the quantity and quality of 'green' jobs?

There is not yet an agreed definition of what a green job is, making comparing existing research findings difficult. This is despite an increasing number of academic articles and policy reports estimating green jobs and their labour market attributes. 'Top-down' studies that apply a narrow definition of green jobs (based on employment in a set of industries or activities that are directly relevant for decarbonisation) tend to estimate that green jobs account for under 5% of employment in the United States or European economies. Broader definitions, including those that take the 'bottom-up', occupation-based approach that we follow in our analysis (see Box 1), yield considerably higher estimates, since they account for jobs that are both directly and indirectly affected by decarbonisation.

Box 1. Defining 'green' jobs

We apply an occupation-level classification of 'green jobs' developed by O*NET in the United States. This database can be used to classify occupations based on the greenness of their related task content and applies a relatively broad definition of green jobs within 12 sectors that were deemed to be most affected by decarbonisation. O*NET classifies any occupation that will be affected by greening as a green job. A consequence of this is that non-green occupations are not necessarily 'dirty' under this definition; rather, they are occupations that are not directly or indirectly judged to be affected by the zero-carbon transition.

The O*NET database distinguishes three occupational categories that differ regarding the effect of the transition to a climate-neutral and sustainable economy on occupations:

- Green new and emerging (GNE): The transition to a sustainable economy leads to the creation of new occupations with unique tasks and worker requirements.
  Examples: Wind energy engineers or solar photovoltaic installers, for whom all tasks are 'green'.
- Green enhanced skills (GES): The transition to a sustainable economy significantly alters tasks, skills and knowledge requirements for these occupations.
  Example 1: A general and operations manager for whom new green tasks relate to managing the sustainability of operations, or a marketing manager for whom a new green task might be developing business cases for environmental marketing strategies.
  Example 2: A construction labourer who would need to apply weather stripping to reduce energy loss.
- Green increased demand (GID): The transition to a sustainable economy creates higher demand for these occupations but there are no significant changes in tasks or worker requirements due to greening. Such jobs are considered *indirectly green* because they support green economic activity but do not involve any green tasks.
  Examples: chemists, materials scientists, industrial production managers.

Figure 1. Varying greenness of job categories

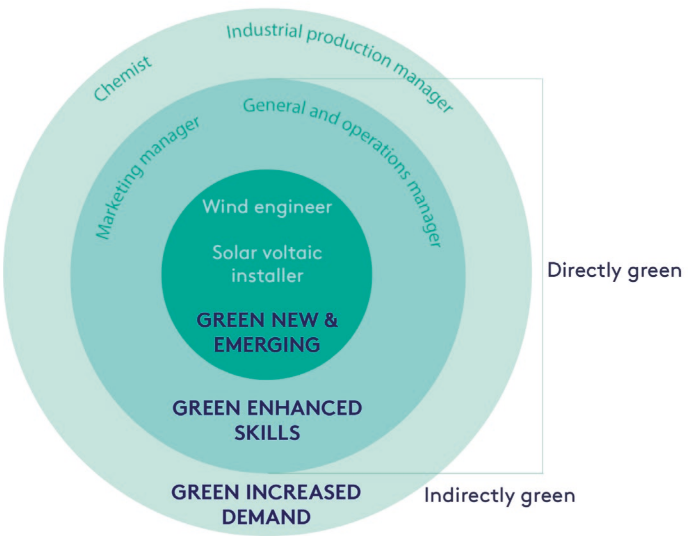


Figure 1 illustrates the 'greenness' of these three categories. The narrowest definition of a green job would focus on the new and emerging category but these, together with enhanced skills jobs, can be considered 'directly green' since they involve explicitly green tasks as defined by O*NET. Increased demand jobs are a broader concept and are considered 'indirectly green'.

Looking to the characteristics of 'green' jobs and how they compare to non-green jobs, a number of studies have found that directly green jobs require more education and involve more non-routine analytical tasks than non-green jobs. Indirectly green jobs tend to be more similar to non-green jobs.

Impacts of net-zero policies and green investments

A broader question concerns how policies that drive the net-zero transition, and the 'clean' innovations that arise because of it, will affect the demand for skills, via impacts on employment and relative wages of skilled versus unskilled workers. **Studies analysing causal relationships find that environmental regulation tends to increase demand for more high-level analytical or technical skills.**

There is evidence (also from the United States) that 'green' investments have created more jobs in areas with pre-existing 'green' capabilities and that such jobs have been manual in nature – though manual labour wages did not rise. A review of evidence in the UK suggests that net-zero-aligned investments – in clean automotive, hydrogen and carbon capture, utilisation and storage, renewable energy, and housing energy efficiency – can create tens of thousands of jobs in the short term, typically in construction and installation. In the medium to longer run, job creation opportunities are related to R&D and production of new technologies. There is less conclusive evidence on the link between firm-level 'clean' innovation and jobs.

A variety of jobs in high-carbon sectors (such as in fossil fuel power plants) provide secure and well-paid jobs in the UK and the EU. Therefore, **the quality of green jobs will need to be considered as a matter of fairness for workers and to secure the willingness of workers to take them up.** The literature analysing related characteristics of 'green' jobs is sparse but indicates that 'green' jobs can provide good quality employment. There is evidence from the US and the UK that 'green' jobs can pay higher wages than the national average.

The UK in focus

We apply O*NET occupational classifications to UK Labour Force Survey data, at the individual level, and estimate that 17% of jobs are 'green'. We observe a slight increase in the share of green jobs since 2011, occurring across all types of green jobs.

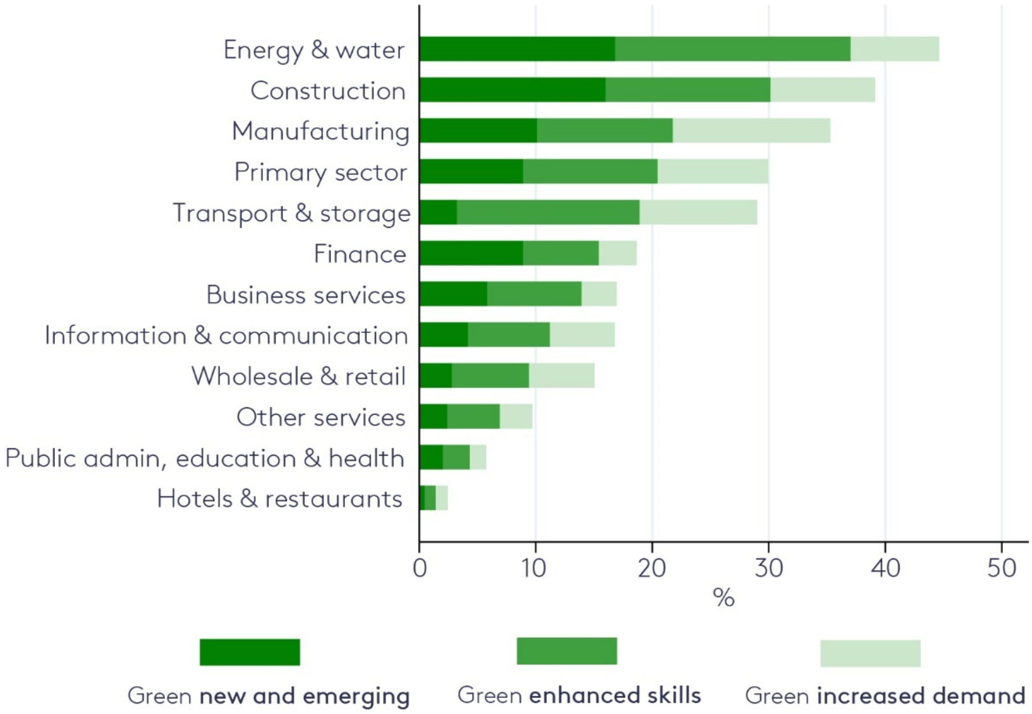
Table 1. UK-wide estimates of the share of 'green' employment in 2019

	Mean
Green (any)	17%
Directly green:	
Green **new and emerging**	5%
Green **enhanced skills**	7%
Indirectly green:	
Green **increased demand**	5%

Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green max and green mean occupational classifications across individuals.

The sectors with the highest shares of green jobs are utilities, construction, manufacturing, the primary sector and transport (Figure 2). At a broad level, sectors with a high share of 'green' employment also tend to be higher-emissions sectors, including occupations such as large good vehicle drivers, and production managers and directors in construction and manufacturing. However, some sectors stand out – financial and insurance activities; professional, scientific and technical; and information and communication sectors have relatively high shares of green employment and low emissions. These jobs include financial accounts managers, IT business analysts, architects and system designers.

Figure 2. UK green employment shares across sectors (2019)



Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals by broad sector groupings. 20 SIC [standard industrial classification] sections are grouped into 11 categories as labelled; 'primary' sector contains agriculture and mining.

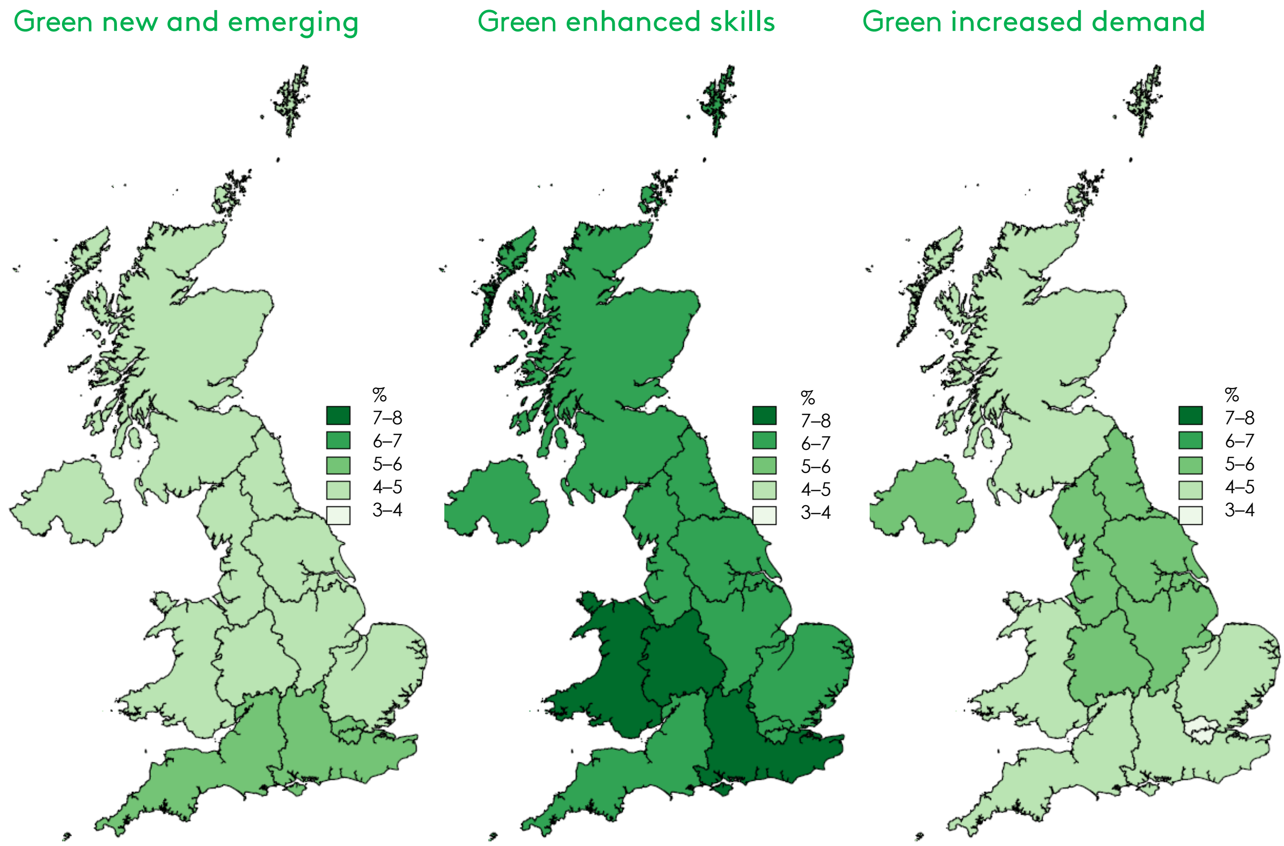
We also consider how the shares of green jobs vary across the UK's regions, reflecting their differing occupational and sectoral structures, and find that the pattern differs for the three green job types (Figure 3). For the directly green jobs, we find that **enhanced skills jobs are more prevalent across Wales, the Midlands and the South East.** This could be driven by the energy efficiency products sector and the Midlands' strong position in the manufacturing of low-emission vehicles. **New and emerging jobs have some concentration in the South of England** but are otherwise spread quite evenly across the country. Contributing factors could be the prevalence of jobs in the low-carbon service sector, and in waste and biomass, in London and the South East, while the South West shows strengths in low-carbon electricity. Areas with relatively higher shares of **increased demand jobs stretch from the Midlands to Northern England, and Northern Ireland**.

We analyse the characteristics of green jobs and those that tend to hold them and find that the 'green' workforce tends to be more male than female across sectors and professions (even after controlling for detailed sector of work). **Directly 'green' jobs in particular tend to be held by older workers who are on permanent contracts** – and, in the case of new and emerging jobs, more educated workers who are more likely to have received training on the job.

'Green' jobs in general appear to be associated with a wage premium, particularly at lower skill levels, even after controlling for the education and work experience of the individual. And in an occupation-level analysis, we find that directly green jobs tend to be at **lower risk of automation** than non-green jobs.

We complement our analysis of the 'stocks' of green jobs with analysis of the 'flows' of new green jobs using data on online job vacancies. This finds a similar share of new green jobs in the UK, at 19%. New green enhanced skills jobs appear to be most concentrated across the Midlands, in a pattern consistent with the stock of jobs, as shown in Figure 3.

Figure 3. UK green employment shares across regions (2019)



Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals at the NUTS1 region level.

'Green' jobs across Europe

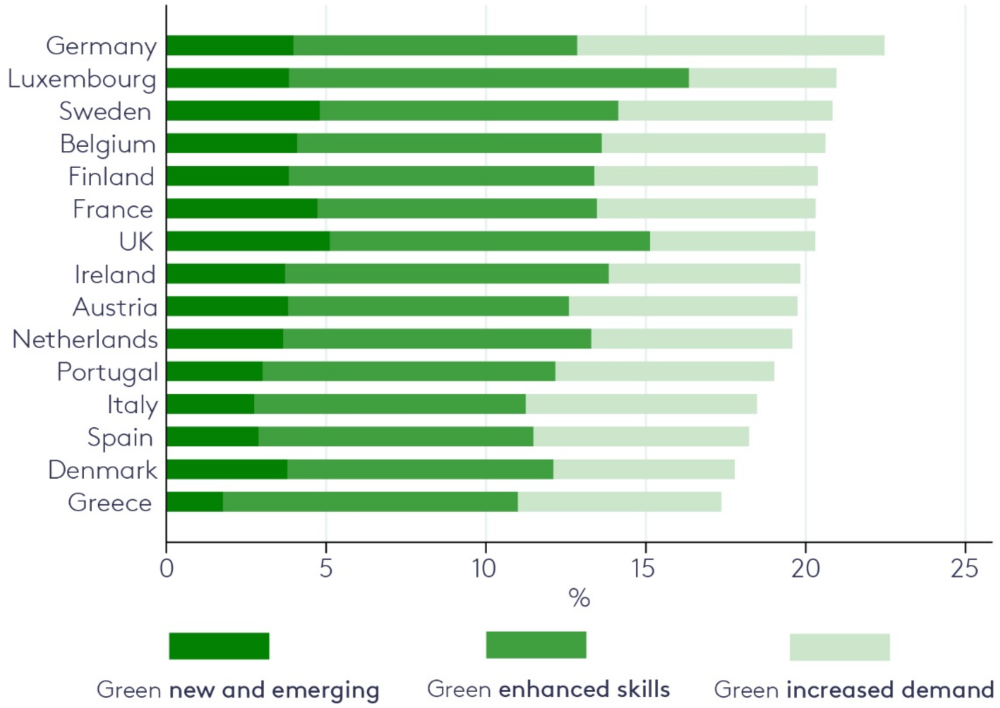
Our analysis of EU Labour Force Survey data reveals a picture broadly consistent with the UK analysis, with the green job share ranging from 17% (in Greece) to 22% (in Germany). The indirect and direct green shares of employment are of similar orders of magnitude as in the UK.

Key characteristics of green jobs in the EU are also broadly similar to those in the UK. Green job workers tend to be older, fewer are female, more are higher skill and (for employees) more are likely to be on permanent contracts. New and emerging jobs tend to drive these results, though again the gender result applies across all 'green' job types. There are no discernible differences in training rates, on average.

Some interesting country-level differences emerge, specifically for the education level of 'green' job workers, for example: workers in new and emerging jobs appearing to be more likely to have a university degree in some countries (including Belgium, Greece, Luxembourg, the Netherlands and Spain). In some countries there is a similar relationship for enhanced skills jobs (including

Denmark and Luxembourg). This hints at differences in education and skills systems as well as in demographics across these countries. However, there is less granularity in our classifications of green jobs in EU countries due to data limitations. More in-depth analyses are therefore required to draw firm conclusions regarding differences between countries.

Figure 4. EU15 green job shares by country (2019)



Notes: Sample includes employed and self-employed workers aged 16-65. EU Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals.

What's next?

Our results suggest that based on the experience to-date, greener jobs are 'better' than their less green counterparts across some dimensions of job quality observable in our data. Greener jobs command higher wages – and, controlling for individual-level education and experience, this effect applies in particular for lower skilled occupational groups. Directly green jobs – in particular, those that are new and emerging in the transition – are at less risk of automation.

Our analysis uses data for 2011–19 and reflects the economic and policy environment over the past decade, before the onset of the COVID-19 pandemic. In the context of increasing decarbonisation commitments, these findings can help to inform future policies that can shape the shift to net-zero in a way that will be just and socially equitable.

In the next phase of the transition to net-zero, during this 'decisive decade' for climate action, policymakers will need to ensure equitable access to the new labour market opportunities it brings. Particular attention will need to be placed on regions with significant transition needs that currently have a low green job share and on particular demographic groups that are so far underrepresented, i.e. women and young people.

More granular data and research are needed to understand the ease of transition for certain groups in particular places, and the role of industrial, skills and labour market policies for enabling a just transition, given differing institutional contexts.

Conclusions for policymakers

Training and skills programmes will be key for a just transition.

- Changing skill requirements will have implications for how education systems produce the future workforce. Given the significant technological and economic uncertainties, education programmes must create a balance between general and specific skills, building worker resilience and flexibility to change.
- On-the-job training will be an important route for reskilling or upskilling existing workers that need to transition into green occupations. Firm-level investments in skills will need to be incentivised, for example through making government support packages conditional on training provision or introducing (enhanced) human capital tax credits.

Given current imbalances, targeted transition policies and programmes are likely to be required.

Green jobs are less likely to be held by women than men, and many tend to be held by older rather than younger workers.

- Given the apparent distributional consequences in the transition to net-zero, targeted recruitment policies or information campaigns will be needed for specific sectors, locations or demographic groups.
- Improved clarity on career paths at different stages in the transition (i.e. as construction activity gives way to maintenance) will be required to ensure that new opportunities are available to underrepresented groups, and transitions are managed effectively.

Conclusions for research

While more insights are emerging on the green economy, important gaps remain:

- More information is needed on the ease of transition for specific groups in particular locations.
- Deeper analysis is needed to quantify and describe the jobs within firms that can be classified as green.
- Future research could explore the relationship between national education systems and green job characteristics to identify the most appropriate ways to train or upskill the net-zero workforce in different institutional contexts.
- More research exploring the causal relationship between differences in environmental regulation or 'green' investments across or within countries, and the impacts on labour markets, is also required.

1. Introduction

As governments worldwide are increasing their commitments to tackling climate change, efforts are growing to quantify and characterise the 'green economy', and to identify opportunities to be seized and challenges to be overcome in the transition to the net-zero economy of the future. The aim of this report is to shed light on the quantity and quality of current green labour markets, to inform policy action and future research for the net-zero transition.

The macroeconomic context

The transition to green growth has been called a modern-day industrial revolution (see, for example, Stern and Rydge, 2012), due to its expected large structural impact on labour markets worldwide. Once the transition is complete, all jobs will be consistent with a low-carbon economy. However, during the transition, the shift towards net-zero in economic activities will have far-reaching but unequal effects as 'dirty' jobs disappear while new jobs aligned with or supportive of the net-zero objective – which we refer to in this report as 'green' – are created.

New jobs are likely to be a consequence of efforts to decarbonise existing high-carbon activities but also of shifts towards low-carbon sectors as patterns of demand change. This is particularly the case, in the short to medium term, for countries that are deindustrialised and have a large share of economic activity in low-carbon service sectors, or for emerging economies that might move straight to services in their development process.

Over this coming decade, these changes in labour markets will occur in tandem with broader technological trends such as digitisation, and in the context of labour market displacements in many sectors that have occurred due to the Coronavirus pandemic, plus in the case of the United Kingdom, acute skills shortages.

Past estimates of job creation

Several analyses have sought to estimate the job creation potential in net-zero-aligned investments.[1] Earlier research on the job implications of the transition to net-zero has concluded that it will be "a net generator of decent jobs" (UNEP, 2011), as it stimulates "innovation, job creation and growth" (Fankhauser et al., 2008). More recent analysis, by Montt et al. (2018), finds that most economies will experience net job creation in the low-carbon transition. Blyth et al. (2014) consider the job creation potential in renewable energy and energy efficiency, distinguishing between the short run and the longer run. In the short run, if the economy has spare capacity, the higher labour intensity of low-carbon investments during their construction phase could lead to more jobs than would result from investing in an equivalent level of high-carbon assets. However, the authors caution that in the longer run, 'job creation' ceases to be a meaningful concept if economies are assumed to migrate towards equilibrium conditions.

In a state of near full employment, public investments could only create limited additional net employment benefits and the relevant focus would be on the impacts on real wages and the mix of jobs. The initial conditions in specific countries, regions or sectors are likely to matter: Popp et al. (2020) evaluate the employment effects of the 'green' part of the US fiscal stimulus[2] following the financial crisis and find little evidence of short run employment gains but larger effects over

[1] For a recent review of the evidence in the UK, see Unsworth, Andres et al. (2020). Also on the UK, Corfe and Norman (2021) estimate that the two-thirds of local authorities that are expected to experience relatively high levels of disruption are also expected to experience relatively high levels of opportunity, including through job creation and business formation.

[2] The American Recovery and Reinvestment Act of 2009.

the longer run, although more jobs were created in areas with a higher prevalence of pre-existing 'green' capabilities, and such jobs tended to be manual in nature.

The impacts of environmental policies

Evidence on the impacts of environmental policies and regulations on employment is mixed. While Greenstone (2002) and Walker (2011) find negative impacts concentrated in energy-intensive industries, a number of empirical studies (mainly from the US and UK) have found that the overall employment effects of environmental regulation are negligible (see Gray and Shadbegian, 2013 and Gray et al., 2014 on the US and Martin et al., 2014 on the UK). In a review of the relevant literature, Dechezleprêtre and Sato (2017)[3] find that environmental regulations can lead to small but significant negative effects on trade, employment and productivity in the short run, especially for pollution- and energy-intensive industries, while at the same time enhancing innovation in clean technologies (which can be expected to generate growth opportunities over time). Taking a broad view that considers the social advantages environmental regulation can bring, such as health improvements, evidence suggests that the benefits are likely to outweigh the costs (Deschênes, 2018).

Ensuring a just transition

Beyond impacts on the number of jobs, the net-zero transition is likely to lead to a significant change in the mix of jobs. Therefore, analyses of (net) job creation effects of the zero-carbon transition must be complemented by more analyses of the 'distributional' aspects for workers in different sectors and places, and the implications for transitions to new jobs. Job transitions are a common feature in modern economies: for example, in the UK around 9% of workers changed jobs each year between 2000 and 2018 (ONS, 2019a). However, there will need to be particular focus on those who are likely to be displaced or for whom transitions might be more difficult, and on the 'quality' (often measured in terms of wages or levels of job security) of jobs created compared with those that are lost.

The need to build such understanding is urgent in a rapidly evolving policy arena. In the US, the President's Executive Order on Climate Change emphasises the job creation potential of net-zero solutions and highlights the importance of these being "well-paying union jobs" (The White House, 2021). In the EU, the just transition forms a central pillar of the Green Deal programme through its Just Transition Mechanism, which aims to address the social and economic costs of the transition. The goal is to mobilise €150bn by 2027, focusing particularly on the most vulnerable and carbon-intensive regions, industries and workers (European Commission, 2020). Through its *Ten Point Plan for a Green Industrial Revolution*, and its *Net Zero Strategy* the UK aims to "build back better" and "build back greener" from the COVID-19 crisis, support green jobs and accelerate the transition to net-zero. As part of this, the Green Jobs Taskforce published its report in July 2021, outlining recommendations for increasing investment and building up the needed skills for the green transition.

Industrial, labour market and skills policies, and investor environmental, social and governance (ESG) strategies, will need to be informed by an improved understanding of the attributes of jobs that will be lost and created, how patterns vary across and within different countries and regions, and the implications for the relative ease of transition for different groups in the workforce.

[3] See also Consoli et al. (2016) and Vona et al. (2018) for further discussion of the relevant literature.

Structure of the report

In this report we begin by reviewing the relevant recent literature that has attempted to quantify and describe the 'green' jobs already in existence, categorising studies according to the approaches taken (Sections 2 and 3). We then apply what we consider to be the most granular approach, based on the characteristics of occupations, to quantify and describe green jobs in the UK and EU economies based on data over the past decade (Sections 4 and 5). The analysis is based on individual-level microdata so that the characteristics of individuals in 'green' occupations can be analysed and compared with their non-green counterparts.

Using these same classifications and some text-based analysis relating to emerging clean technologies, we analyse trends in hiring activity in the UK (Section 6) to identify certain places or sectors that have experienced rapid growth in the creation of new green jobs in recent years. We conclude with the implications of our findings for future research and policy (Section 7).

2. How can we quantify 'green' jobs?

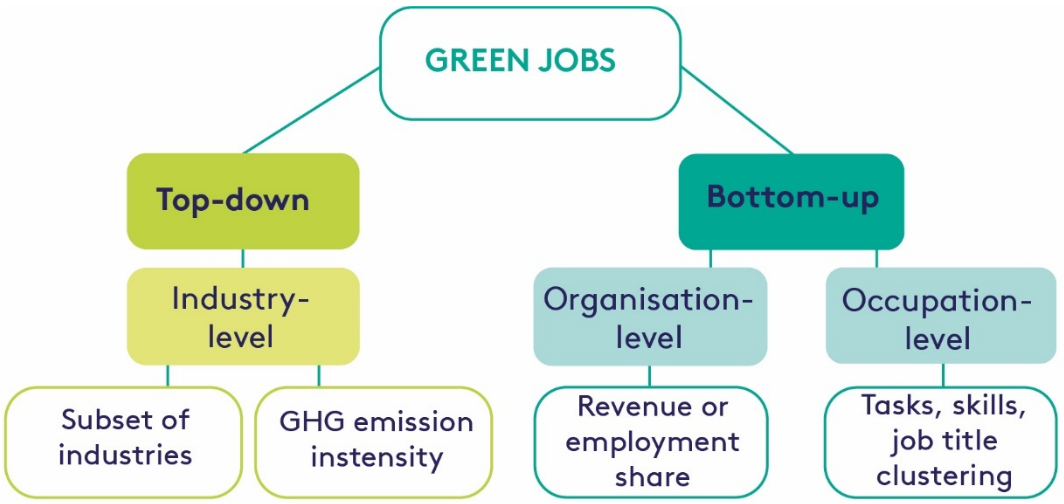
Summary

- There is no agreed definition of a 'green' job but the range of approaches used can broadly be labelled 'top-down' and 'bottom-up'.
- 'Top-down' approaches consider all jobs within specific sectors or activities that are relevant for the zero-carbon transition to be 'green'.
- Narrow top-down approaches tend to estimate that the share of green jobs is between 1 and 2%, and certainly below 5%, in the US or European economies.
- Broader top-down approaches based on sectoral emissions estimate that a much higher share of jobs can be considered green.
- 'Bottom-up' approaches identify specific activities within firms, or specific occupations that can be considered green.
- Within this second group, the O*NET occupational classifications identify jobs as being directly or indirectly green, depending on whether jobs contain explicitly 'green' tasks. These approaches tend to estimate that over 20% of employment can be considered directly or indirectly green.
- Different approaches are complementary and may be more or less appropriate in different settings, depending on the specific policy question.

Broad-based approaches to classifying green jobs

Despite an increasing number of academic articles and policy reports estimating green jobs and their labour market attributes, there is not yet an agreed definition of what a green job is, making the comparison of existing research findings difficult (ONS, 2021). Broadly, two types of approach have been taken in identifying green jobs: we label these 'top-down' and 'bottom-up' – Figure 2.1.

Figure 2.1. Approaches to defining green jobs



- **The top-down approach** is focused on industry-level analysis, classifying sectors, industries and activities as being 'green' and counting all those employed within those sector, industries or activities.
- **The 'bottom-up' approach** uses either organisation-specific characteristics (such as revenues or employment associated with green products or services within companies) or occupation-specific characteristics that apply to individuals (such as job description, occupational skills and task content that can be used to identify some level of 'greenness').

In this section, we describe these approaches in more detail before providing a summary of a selection of studies that have estimated the share of green jobs in the EU, UK or US in Table 2.1. This does not present a comprehensive review but rather highlights the different approaches taken in the literature to classify green jobs and the large range of results available depending on the definition of green jobs.

Top-down approaches

Using the top-down approach, industry-level definitions of green jobs can be subdivided into two further categories:

1. **The first identifies a subset of industries or activities that are considered green – e.g. environmental protection – and all jobs within that sector or activity are subsequently categorised as green.**

The analysis of green industries varies significantly in breadth, ranging from a narrow focus on the renewable energy sector to a broader selection often referred to as the **environmental goods and services sector** (EGSS). The EGSS comprises industries that are relatively easy to define and distinguish in available data, typically focusing on environmental protection activities, related to reducing and preventing greenhouse emissions and other harmful environmental impacts, and resource management activities, which are usually related to energy. Applying this definition in the EU context, a Eurostat (2021) study estimates the EGSS to cover 4.4 million full-time equivalent jobs, a 2% share of total employment.[4]

Some studies have expanded their analysis to activities that reduce greenhouse gas emissions but would not be considered environmental protection activities *per se* – such as the production of electric vehicles. This sector is known as the **low carbon and environmental goods and services sector** (LCEGSS). Georgeson and Maslin (2019) estimate the LCEGSS to account for 4% of employment in the US. Some studies focus exclusively on climate change impacts and exclude activities that have other environmental benefits, such as biodiversity conservation. In the UK, the **low carbon and renewable energy economy (LCREE) survey** (ONS, 2020) takes this type of approach, and the share of jobs in the LCREE is estimated at 1%. Focusing on a subset of relevant industries makes cross-country comparisons relatively straightforward, though taxonomies of green sectors do differ by country (Cedefop, 2019).

The International Labour Organization's definition of green jobs also takes a sectoral approach, covering activities that protect or restore the environment, including climate change adaptation measures. The ILO adds a qualitative element to its definition, requiring green jobs to be 'decent jobs' (ILO, 2016).

Overall, the approach of analysing a pre-defined subset of industries or activities generates a relatively narrow definition of green jobs, and excludes jobs that are already low-carbon and that will play a central role in the transition to net-zero (e.g. in education or consulting).

[4] Using 190 million total employment, based on Eurostat.

2. The second industry classification category of green jobs is based on the greenhouse gas emission intensity of the industry, setting a threshold under which industries are considered 'green'.

Applying this approach, the employment share in the 'green sector' in the UK is estimated at 55% (Kapetaniou and McIvor, 2020). As a result, industries that are already low carbon are considered green under this definition, while environmentally beneficial activities in sectors that generally have high emissions, such as renewables within the emissions-intensive energy sector, can be excluded.

Over- and underestimation

Overall, the industry-level definition takes a sweeping view of green jobs, which can lead to the over- or underestimation of green jobs because of its lack of granularity. Overestimation can arise because all the jobs in a green-defined industry are counted as green, even when the same job in another industry is classed as non-green. For example, security staff for an office focusing on nature conservation research may be counted as green, whereas security staff for an office working on economic research may not be. In addition, this type of approach will miss new jobs created along the supply chain, for example in other sectors that provide goods and services to the specifically identified 'green' sectors.

Underestimation can occur if there are workers specifically focused on sustainability issues in an industry that is not classed as green, for instance a sustainability officer in a fashion company. Moreover, even within sectors, emissions of specific companies or products (or other measures of 'greenness' such as the invention of new zero-carbon technologies) will differ across and within firms. The top-down approach will not capture such differences.

Bottom-up approaches

What we call 'bottom-up' approaches can address some of the issues described above.

Organisation-level

Some studies look within organisations to identify the share of employment that is green. Green jobs are identified as the share of employment connected to the production of green goods or the provision of green services at the organisation. In cases where the share of employment cannot easily be identified, the share of revenues related to green goods and services tends to be used to apportion employment.[5] The US Bureau of Labor Statistics estimated the share of employment related to goods and services that benefit the environment or conserve natural resources to be 2.6%, based on survey data for 2011 (BLS, 2013). Desk research can also identify organisations with these kinds of jobs (see Muro et al., 2011).

Occupation-level

The literature defining and analysing green jobs at the occupation level relies on classifications developed by O*NET in the United States. This database can be used to classify occupations based on the greenness of their related task content and applies a relatively broad definition of green jobs within 12 sectors that were deemed to be most affected by decarbonisation (see Appendix A1 for more detail). O*NET classifies any occupation that will be affected by greening as a green job. A consequence of this is that non-green occupations are not necessarily 'dirty' under this definition; rather, they are occupations that are not judged to be directly or indirectly affected by the zero-carbon transition.

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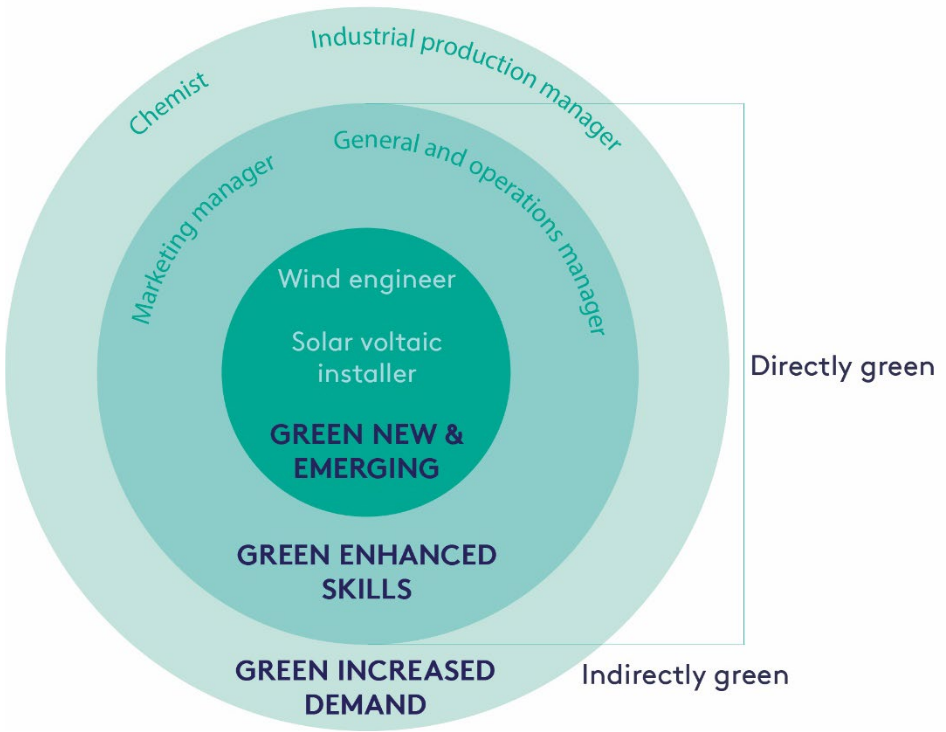
5 Other studies focus on the share of green revenues as the indicator of the share of 'green' activity; for example, Kruse et al. (2020) use a dataset of global listed firms where green revenues are demarcated (FTSE Russell Green Revenues), estimating that environmental goods and services represented 4% of turnover in 2016.

The O*NET database distinguishes three occupational categories that differ according to the effect the transition to a climate-neutral and sustainable economy has on occupations:

- **Green new and emerging (GNE)**: The transition to a sustainable economy leads to the creation of new occupations with unique tasks and worker requirements.
  Examples: Wind energy engineers or solar photovoltaic installers, for whom all tasks are 'green'.
- **Green enhanced skills (GES)**: The transition to a sustainable economy significantly alters tasks, skills and knowledge requirements for these occupations.
  Example 1: A general and operations manager for whom new green tasks relate to managing the sustainability of operations; or a marketing manager, for whom an example of a new green task would be developing business cases for environmental marketing strategies.
  Example 2: A construction labourer, who would need to apply weather stripping to reduce energy loss.
- **Green increased demand (GID)**: The transition to a sustainable economy creates higher demand for these occupations but there are no significant changes in tasks or worker requirements due to greening. Such jobs are considered to be *indirectly green* because they support green economic activity but do not involve any green tasks.
  Examples: Chemists, materials scientists, industrial production managers.

Figure 2.2 illustrates the 'greenness' of these three categories.[6] The narrowest definition of a green job would focus on the green new and emerging category. These, together with enhanced skills jobs, can be considered to be 'directly green', since they involve explicitly green tasks as defined by O*NET. Green increased demand jobs are a broader category and are considered 'indirectly green'.

Figure 2.2. Varying greenness of job categories



[6] For ease of reference within the text, in places we refer to 'enhanced skills', 'new and emerging' and 'increased demand' jobs.

Applying these classifications to country contexts

Applying these classifications to US labour market data, Bowen et al. (2018) estimate that around 20% of jobs were directly and indirectly green in 2014. Since O*NET is based on US data, applying it to other country contexts requires additional steps and assumptions. The US sectoral shares of O*NET-defined green jobs as calculated in Bowen et al. (2018) have been applied to UK sectoral employment aggregates to calculate green jobs across different geographies (Robins et al., 2019; Christie-Miller and Luke, 2021). To apply O*NET classifications to labour-force micro-data in non-US contexts, a 'crosswalk' between classification systems is required, which connects US occupational codes to the codes of the country in the study. A key assumption here is that occupations considered green in the US can be considered so in other contexts. This is the approach we take in Sections 4 and 5, mapping O*NET occupations into UK and EU classifications in turn.

When Bowen and Hancké (2019) adopt this approach across EU countries, the share of green jobs is high – 40% across all types of green job – relative to US estimates in Bowen et al. (2018).[7]

Limitations to the occupational approach

While an occupational approach is indeed more granular and allows the identification of jobs that are both directly and indirectly green, across sectors, it also has its own limitations.

Firstly, the O*NET classifications were generated in 2010, and – as discussed – are based on the US labour market and a group of sectors that were considered key for the transition at that time. Therefore, this type of approach might miss jobs that have emerged more recently, and that might exist in other countries where the occupational mix and transition needs are different.

Secondly, such approaches would consider an occupation as being equally green regardless of the firm it occurs in. For example, some of the 'indirectly green' occupations (e.g. 'chemists') will exist in polluting firms and might be of a very different nature to their counterparts in low-carbon firms. Moreover, jobs that are not explicitly impacted by the transition, but that apply across firm types (such as security guards) would not be counted even in the broader, indirectly green category. Ideally, it would be possible to combine information on occupations within firms with firm-level information on zero-carbon products, services or processes. Building datasets that would enable such an approach is left to future research.

Summary of green jobs estimates from previous studies

Table 2.1 below summarises a selection of studies that have estimated the share of green jobs in the EU, UK or US. This does not present a comprehensive review but rather highlights the different approaches taken in the literature to classify green jobs and the large range of results available depending on the definition of green jobs.

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[7] This is because a more aggregated EU occupation is considered green if at least one green O*NET code is mapped to it. We discuss methodological issues further in Section 4.

Table 2.1. Selection of studies quantifying green jobs

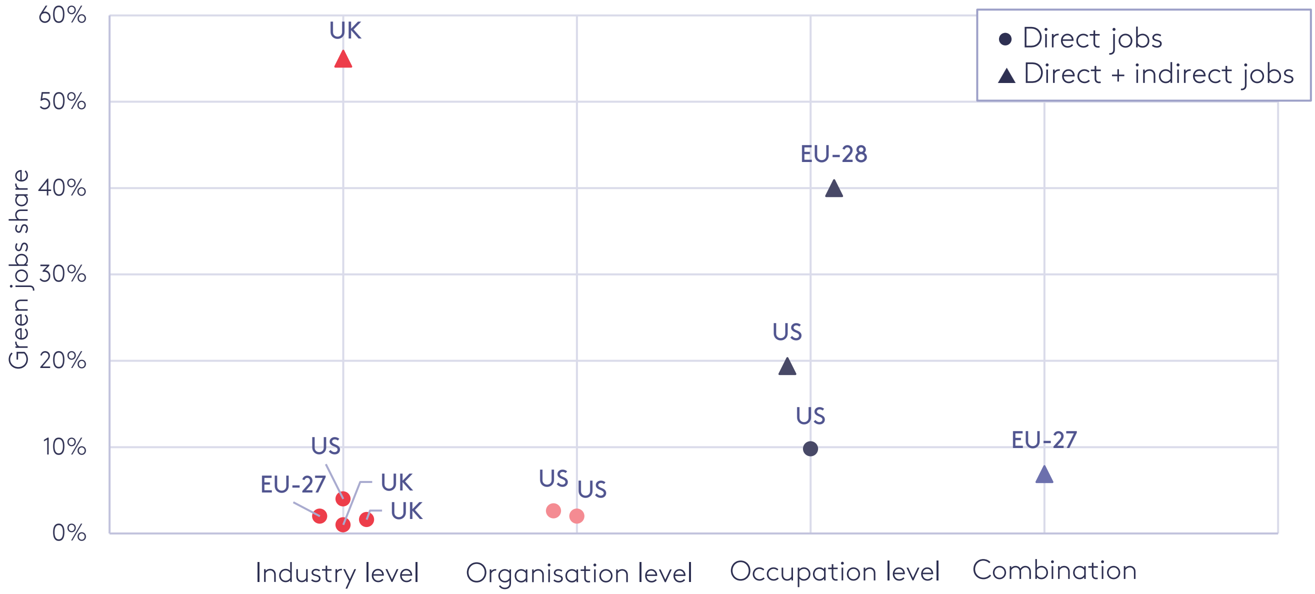
Approach	Report title	Authors (year)	Country/ region	Green employment share and year
Top-down				
Subset of industries	Environmental economy – statistics on employment and growth	Eurostat (2021)	EU-27	2% in 2018 (direct)*
	Low carbon and renewable energy economy, UK: 2018	ONS (2020)	UK	1% in 2018 (direct)
	The size and performance of the UK low carbon economy	BIS (2015)	UK	1.6% in 2013 (direct)
	Estimating the scale of the US green economy within the global context	Georgeson and Maslin (2019)	US	4% in 2015/16 (direct)
Sectoral carbon emissions intensity	Going Green – Preparing the UK workforce for the transition to a net-zero economy	Kapetaniou and McIvor (2020)	UK	55% in 2018 (direct + indirect)
Bottom-up				
Share of employment or revenue share related to green goods and services	Employment in Green Goods and Services, 2011	BLS (2013)	US	2.6% in 2011 (direct jobs)
	Sizing the Clean Economy	Muro et al. (2011)	US	2% in 2010 (direct jobs)
Occupational classification based on tasks, skills and clustering of job titles	Characterising green employment: The impacts of 'greening' on workforce composition	Bowen et al. (2018)	US	19.4% in 2014 (10.3% GES, 1.2% GNE) (direct + indirect)
	Do Green Jobs Differ from Non–Green Jobs in Terms of Skills and Human Capital?	Consoli et al. (2016)	US	9.8–12.3% in 2011/12 (direct jobs)
Application of O*NET to occupations in country in study	The Social Dimensions of 'Greening the Economy'	Bowen and Hancké (2019)	EU-28	40% in 2016 (22.5% GID jobs, 20% GES, 17.4% GNE) (direct + indirect)
	Studies on Sustainability Issues – Green Jobs; Trade and Labour	Cambridge Econometrics et al. (2011)	EU-27 (incl. UK, excl. Croatia)	25% GID, 20% GES in 2009 (direct + indirect)
Application of O*NET US-based green employment shares	Investing in a Just Transition in the UK	Robins et al. (2019)	UK	10% GID, 10% GES in 2011/13 (direct + indirect jobs)
Combination				
Based on job title, job description, job category, firm, occupation, and industry	Green Jobs in Europe and the Increasing Demand for Technical Skills	Colijn (2014)	EU-27 (incl. UK, excl. Croatia)	3.25% in 2011/12 (6.89% when including near-green jobs) (direct/direct + indirect jobs)

Notes: GNE = green new and emerging. GES = green enhanced skills. GID = green increased demand.
** Using 190m total employment, based on Eurostat.*

Figure 2.3 plots the range of estimates in these studies, grouping by approach. Given the narrow definition of green jobs, studies looking at a subset of industries and those looking at the organisational level find very low shares of green jobs. In the US, results from the above selection of studies using these definitions range from 2% (Muro et al., 2011) to 4% (Georgeson and Maslin, 2019), while they are estimated at 2% in the EU (Eurostat, 2021) and between 1% (ONS, 2020) and almost 2% (BIS, 2015) in the UK. Due to the broader definition, occupation-level analysis yields higher green job shares. Among these studies, the EU is estimated to have a relatively high share of green jobs at around 40% (Bowen and Hancké, 2019), with the US between 10% (Consoli et al., 2016) and 19% (Bowen et al., 2018). There is one study in our selection that uses carbon emissions intensity to identify green jobs, resulting in the highest green job share, at 55% in the UK (Kapetaniou and McIvor, 2020).

In addition to the differences in definitions, the different time frames further complicate the comparison of results. Time frames analysed range from 2009 (Cambridge Econometrics et al., 2011) to 2018 (Kapetaniou and McIvor, 2020) in the selected studies.

Figure 2.3. Review of green jobs estimates based on definition



Note: Depending on the study scope, EU-27 can include the UK and exclude Croatia or exclude the UK and include Croatia. Where a finding was available including direct and indirect jobs, it was used for the chart.
Source: Authors' analysis summarising estimates outlined in Table 2.1.

Analysis of green jobs in other territories

The US, EU and the UK are not the only jurisdictions where analysis of green jobs in required. With their specific social challenges and opportunities of the net-zero transition, emerging markets present interesting areas of study. Only a handful of reports have so far explored this, summarised in Appendix C. Data constraints have been a limiting factor so far, and more research is needed to give a holistic picture of green jobs across regions.

Forward-looking analysis of the job impacts of the green transition

The analyses we have summarised so far in this section have attempted to quantify existing green jobs in the economy. But in this next phase of decarbonisation, which will require significant acceleration of climate action across the economy in order to meet net-zero commitments, forward-looking analyses of the likely impacts on labour markets will be required, estimating jobs that will be created and those that will be lost. This type of exercise is a challenge due to uncertainties about decarbonisation pathways and policies, technology take-up, business model success, future market shares and demand patterns.

Some studies have attempted to forecast job impacts of the net-zero transition by focusing on direct job creation in specific sectors and jurisdictions. Box 2.1 describes two examples of 'deep-dives' – for zero-emission passenger vehicles and for carbon capture, usage and storage in the UK – where the forecasting evidence is brought together and analysed.

Box 2.1. Forecasting the impact of the net-zero transition on green jobs

Zero-emission passenger vehicles

In a report estimating job impacts in the zero-emission passenger vehicles market in the UK, Unsworth, Valero et al. (2020) find that while the UK's manufacturing competitiveness is decreasing, the right government incentives supporting supply, demand and a conducive regulatory environment could form an employment opportunity. In that case, the UK could sustain almost 80,000 component production jobs in the sector, generating considerable additional employment, upstream and downstream. Upstream, electric vehicle component production would be likely to receive inputs from a domestic chemicals supply chain. Downstream, net-zero-emission vehicle assembly is likely to benefit from UK component production.

Carbon capture, usage and storage (CCUS)

In a recent report on CCUS, Serin et al. (2021) emphasise the need for a quick roll-out of the technology, to reduce greenhouse gas emissions and realise its potential to contribute significantly to sustainable growth. CCUS is likely to preserve up to 53,000 jobs in energy-intensive industries in the UK by 2030 and lead to further benefits in UK CCUS supply chains. The job creation potential in the sector is estimated at 31,000 jobs by 2030 in the UK, mainly in construction activities in this time frame. If a strategic approach is taken in supporting the industry, CCUS has considerable levelling-up opportunity, given the geographical spread of related activity.

Unsworth, Andres et al. (2020) review ex-post and ex-ante evidence of the job-creation potential across key net-zero-aligned investments in the UK. They find that investments in clean automotive, hydrogen and CCUS, renewable energy, and housing energy efficiency can each generate tens of thousands of jobs across the UK relatively quickly, while building productive capacity for innovation-led growth in the medium to longer term.

The complementarity of approaches

Among the range of approaches taken to quantify green jobs, certain approaches are complementary to one another, and different approaches might be more or less appropriate in different settings. For example, when analysing the impacts of new sectors that are growing, or old ones that are in decline, the sectoral approach – counting all related jobs even if they are not 'green' from a task perspective – is important for understanding the scale of the opportunity or challenge for a particular place. The occupational approach, on the other hand, helps to identify the specific types of job that are relevant for a green economy when considered holistically, and allows for a more granular comparison of the skills content of associated tasks (we discuss how this has been done in the literature in the next section), and the characteristics of workers currently engaged in them.

Therefore, the fact that the percentage of green jobs identified varies so widely is not an indication of contradictory findings but rather of diverging definitions of green jobs, which generate different interpretations and conclusions.

3. What are the characteristics of green jobs?

Summary

- Developing an understanding of the net-zero transition needs of particular groups in the labour market requires a comparison of the characteristics of green jobs with those of their non-green counterparts, using a particular definition of 'green job'.
- Most studies that have used O*NET occupational classifications conclude that directly green jobs require more education and involve more non-routine analytical tasks than non-green jobs.
- Research on the impacts of environmental regulations on the demand for skills tends to conclude that regulations increase the demand for higher- or more technically-skilled workers.
- Studies that consider wages or measures of job security suggest that green jobs can provide good quality employment.
- Green jobs tend to be male-dominated.
- But in general, the literature analysing characteristics of green jobs beyond skills is very sparse.

Specific and general skill characteristics of 'green' jobs

Once a green job is defined in a particular way, it is useful to ask how it differs from its 'non-green' counterparts in terms of observable characteristics such as skills requirements or tasks.

Several studies have focused on making this type of comparison, using the O*NET green jobs classifications and details about occupations and their task content that are available in the O*NET database.

Studies tend to find that directly green jobs require more education and involve more non-routine analytical tasks than non-green jobs.

Using data on US occupations, Consoli et al., (2016) compare the human capital and task-based skills attributes of the green enhanced skills and green new and emerging occupations with those of non-green jobs. They find that green occupations exhibit higher levels of formal education, work experience and on-the-job training than non-green occupations – but that these are more prominent among the green enhanced skills occupations. For more recent green new and emerging occupations, greater training seems to be the most important factor. Green occupations are more likely to require non-routine analytical tasks (such as creative problem-solving) and are less intensive in routine cognitive tasks. However, such differences tend to be smaller once occupational exposure to technology is controlled for.

Another approach (Vona et al., 2018) isolates green tasks within occupations (provided by O*NET; see Appendix A1 for discussion) to calculate a 'greenness' indicator for each occupation, based on the share of such tasks. The authors then identify sets of 'green general skills' – i.e. the general skills associated with greener occupations. They highlight two core sets of green skills for which green jobs differ from non-green jobs: engineering skills for the design and production of technology, and managerial skills for setting up and monitoring environmental organisational practices.

Vona et al. find that the importance of managerial/monitoring green skills is greater in occupations that require more education and are less routine. Similarly, they find that occupations with high scientific green general skills also require more education and are less routine in nature. In contrast, green engineering and technical skills appear both in occupations that require a high level of education (e.g. architecture and engineering) and those that require less education (construction, extraction, installation and maintenance).

Vona et al. then focus on the comparison between green and 'brown'[8] jobs within broad occupational groupings and find that skill differences are small. Broadly, the general skill requirements of brown jobs are closer to those of green jobs than the general skill requirements of other jobs. But the authors highlight exceptions – for example, the importance of green engineering skills within the architecture, construction and extraction fields. These findings therefore have relevance for the transition of workers in oil and mining industries.

Bowen et al. (2018) apply the O*NET classifications to quantify (see Section 2) and analyse green employment in the United States. They also use O*NET similarity matrices (see Appendix A1.2 for more detail) to split non-green jobs into 'green rival' jobs and 'other' jobs, where 'green rival' jobs are considered similar to one of the three O*NET green job categories, either because the tasks are similar or because they require similar skills and worker attributes.

In line with Consoli et al. (2016), Bowen et al. find that green new and emerging and enhanced skills jobs require the most education and experience. But overall, the authors consider that new and emerging jobs appear to require less training than the other green job types – and as we might expect, enhanced skills jobs require the most training. But all green job types require more training than green rival and other jobs. The authors also analyse task-based measures of skills and find that new and emerging jobs require more non-routine tasks (in particular, non-routine analytical and interactive) compared with other types. And on average, new and emerging jobs rely less on manual skills while increased demand jobs rely the most out of all the job sub-categories on manual skills. Based on skill content, Consoli et al. (2016) conclude that green rival jobs are more similar to increased demand jobs. However, these only differ from increased demand and enhanced skills jobs in a few specific dimensions, which implies that transitions into these jobs may only require on-the-job training, whereas transitions to new and emerging jobs may require additional education to supplement on-the-job training.

In summary, papers that have examined the occupational characteristics of green jobs conclude that 'directly green' jobs – green enhanced skills and green new and emerging – tend to require more education and involve more non-routine analytical tasks than non-green jobs, as they concentrate in macro-occupations that are intensive in abstract skills such as management or business and financial operations (Consoli et al., 2016). **Indirectly green jobs tend to be more similar to non-green jobs.**

The impact of net-zero policies on the demand for jobs and skills

The previous discussion sets out the specific skills and tasks associated with 'green' occupations as defined by O*NET. A broader question concerns how policies that drive the net-zero transition, and the technological and organisational changes that arise because of it, will affect the demand for skills, via impacts on employment and relative wages of skilled versus unskilled workers.

There is evidence that in recent years, technological change has been 'skills-biased', i.e. that the type of technological progress we have witnessed in information and communications technologies has increased the demand for educated workers (and hence their relative wages).[9]

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[8] Defined as jobs that are likely to be harmed by environmental regulation. They identify occupations that are prevalent in carbon-intensive industries, and compare the importance of green general skills in these occupations with their importance in green occupations within the same broader occupation classes.

[9] See Violante (2016) for a summary of the skill-biased technical change literature.

A key question is whether the technological innovations associated with decarbonisation, and the environmental policies that have induced these, might also be skills-biased in some way, and might disproportionately benefit higher-educated workers. Despite the growing literature and current policy debate on green jobs and a 'just transition', empirical research on the skill-biasedness of environmental policies is limited and focuses on the US (Martinez-Fernandez et al., 2010; Deschênes, 2013).

Studies (largely) based on the US find that environmental regulation tends to increase demand for higher- or more technically-skilled workers.

Cross-sectional studies have offered some evidence of the skills-biasedness of green production. Becker and Shadbegian (2009) and Elliott and Lindley (2017) used the US Green Goods and Services Survey (2010 and 2011) and found that plants producing green goods and services employ a lower share of production workers than plants in other sectors. However, Becker and Shadbegian did not find any evidence that plants producing green goods had higher wage growth.

Vona et al. (2018) test the causal effect of amendments to environmental regulation (the US Clean Air Act[10]) and differences in environmental stringency on skill demand in US regions over the period 2006–2014. They find that environmental regulation does not impact on overall employment but that it triggers technological and organisational changes that increase the demand for high-level analytical, technical, engineering and scientific skills.

Marin and Vona (2019) look at the impact of climate policies and skill-biased employment dynamics. They examine the associations between climate policies, proxied by energy prices, and workforce skills for 14 European countries and 15 industrial sectors over the period 1995–2011. Using an instrumental variable estimator and controlling for the influence of automation and globalisation, they find that climate policies have been skills-biased against manual workers and have favoured technicians. Furthermore, they find that the pronounced bias towards 'abstract' occupations – broadly defined as high-skilled occupations such as managers, professional and technicians, as opposed to manual or routine occupations (Autor et al., 2006) – is concentrated among technical occupations such as physical and engineering science technicians, process control technicians and government regulatory associate professionals.

There is less conclusive evidence on the link between firm-level 'clean' innovation and jobs.

Many have argued that clean innovation and its diffusion are key to achieving and shaping the net-zero transition (see Stern and Valero, 2021, or Martin et al., 2020 for discussion on the UK). A large literature established the relationship between environmental policy and innovation on the one hand and innovation and employment on the other (e.g. see Calel and Dechezleprêtre, 2016; Calel, 2020; or Popp, 2019 for a review of the evidence on the former and e.g. Van Reenen, 1997 and Harrison et al., 2014 on the latter). However, the literature is sparse on the types of jobs and skills that will benefit from green innovation.

Some studies have looked at the impacts of different types of environmental innovation on employment. The adoption of upstream clean production methods has been found to have a positive employment effect (Pfeiffer and Rennings, 2001), and downstream solutions a negative effect (Rennings et al., 2004). Other scholars distinguish between green and non-green innovation, but the evidence is inconclusive. Horbach (2010) and Gagliardi et al. (2016) find positive effects for environmental innovations, while Licht and Peters (2013, 2014) find

[10] This analysis adapts an empirical strategy previously utilised by Greenstone (2002) and Walker (2011) to estimate the impacts of environmental policies on employment. Such studies have found negative impacts concentrated in energy-intensive industries. More broadly, the evidence on the employment effects of environmental policies is mixed, as discussed in the Introduction.

positive effects but no significant differences between environmental and non-environmental product innovations.

Elliott et al. (2021) are the first to examine empirically the link between different types of clean innovation (total, product and process 'eco-innovation') and employment. They use matched employer-employee data from the Netherlands and show that over the 2006–2010 period, firms that eco-innovated had 12 more green employees on average than non-eco-innovating firms. However, they show that the increase in the share of green workers was due more to a falling number of non-green workers rather than a rise in the number of green employees. A small number of studies have tested whether firms' stated motives for clean innovation have differential impacts on employment. Using Spanish data, Kunapatarawong and Martínez-Ros (2016) find that there is a positive relationship between voluntary clean innovation and employment, but no effect when clean innovation is policy-driven.

Another related concept to estimate the impact of the net-zero transition on skills is job polarisation – or the hollowing out of middle-skill manufacturing and clerical occupations that has been documented in the US and European economies (Autor et al., 2006; Goos and Manning, 2007; Goos et al., 2009) as a consequence of routinisation (Autor et al., 2003). It could be that a greening economy counters the job polarisation trend in the labour market. For example, Martinson et al. (2010), Dierdorff et al. (2009), and Cedefop (2010) argue that green jobs are currently largely technical and focused on Science, Technology, Engineering and Maths (STEM), and will favour both high-skilled and medium-skilled workers. In their evaluation of green investments in the US, Popp et al. (2020) find that nearly all job creation has been in manual occupations, but that wages in such occupations have not risen (which the authors attribute to deteriorating bargaining power of manual workers). They also highlight that most of the increase in manual work was among workers that had more than a high school education, highlighting the importance of technical skills in such jobs.

The findings of these studies, however, sharply contradict the conclusions reached by Cambridge Econometrics, GHK and Warwick Institute for Employment Research (2011): that the potential for green jobs lies primarily with both high- and low-skilled jobs.

Other characteristics of green jobs

A variety of jobs in high-carbon sectors (such as in fossil fuel power plants) provide secure and well-paid jobs in the UK and the EU. Therefore, the quality of green jobs will need to be considered as a matter of fairness for workers but also to secure the willingness of workers to take them up.

The literature analysing characteristics of green jobs beyond skills is very sparse but studies that consider wages or measures of job security suggest that green jobs can indeed provide good quality employment. They also tend to be male-dominated.

Muro et al. (2019) find that mean hourly wages in the US clean energy economy are 8–19% higher than national averages and are more equitably distributed, with hourly wages for low-income workers $5–10 higher than in other sectors. Similarly, studies in the UK observe that wages in 'net-zero industries'[11] are 18% higher than the national average and 30% higher than in carbon-intensive industries (Christie-Miller and Luke, 2021).

Using the broader definition of green jobs as defined by O*NET, Bowen et al. (2018) find that low- and medium-skill green jobs tend to pay higher wages than other jobs with the same skill level, but that for high-skill jobs, the picture is mixed. Increased demand jobs tend to have lower wages than non-green jobs, but new and emerging jobs tend to have higher wages, irrespective of skill level.

[11] Net-zero industries are defined as sectors within the Low Carbon and Renewable Energy Economy (LCREE).

Looking beyond wages, an older analysis of green jobs in the EU in 2009 found them to be less likely than non-green jobs to be part-time and slightly less likely to be temporary (Cambridge Econometrics et al., 2011). **The same study found that green jobs were more likely to be occupied by males than females. This is consistent with sectoral analysis in the UK that estimates that employment in 'net-zero industries' is around 82% male** (Christie-Miller and Luke, 2021). However, there is also evidence that the gender pay gap is lower in 'net-zero industries' than in the UK workforce in general (ibid.).

In terms of ethnic diversity, less than 10% of the workforce in clean energy production and energy efficiency in the US is black (Muro et al., 2019). The UK's Green Jobs Taskforce also points to evidence of a lack of representation of ethnic minorities in industries with a high share of low-carbon and renewable energy activity (BEIS, 2021).

Some have also highlighted health and safety concerns associated with some types of green job, an issue that applies in the development and installation of new technologies more generally.[12]

[12] See, for example, European Agency for Safety and Health at Work (2020).

4. The UK in focus

Summary

- Around 17% of jobs in the UK are directly or indirectly green.
- The distribution of green jobs varies across sectors and regions.
- The sectors with the highest shares of green jobs are utilities, construction, manufacturing, the primary sector and transport.
- Wales and the Midlands stand out in terms of green enhanced skills jobs.
- While some high-emitting sectors tend to have high shares of green jobs, there are also low-emissions service sectors that have a relatively high share, such as finance.
- Green jobs are more likely to be held by men across the board, while directly green jobs tend to be held by older workers.
- Green new and emerging jobs in particular appear to be held by individuals with higher levels of education, training, wages and more secure work contracts.
- Green jobs in general appear to be associated with a wage premium at lower skill levels – even after controlling for education and years of experience.
- Directly green jobs are associated with lower risk of automation.
- Analysis of the 'flows' of new jobs using data on online job vacancies finds a similar share of new green jobs in the UK.

Using the case study of the UK, this section explores how green jobs, as defined using the O*NET approach, correlate with several educational and socioeconomic characteristics.

To quantify and describe green jobs in the UK we apply the O*NET green job classifications to Labour Force Survey (LFS) data from the period 2011 to 2019.[13] The occupation codes (which allow for a more accurate mapping from O*NET), and additional variables (in particular, hourly wages) in the UK LFS data are more granular than those in the EU LFS, which we analyse in Section 5. Previous studies have analysed features of green jobs at the occupation level using O*NET data, as outlined in Section 3. Our approach here differs in that we analyse individual-level microdata, which enables us to describe the characteristics of individuals in green jobs versus their non-green counterparts.

Our mapping requires the assumption that what is considered a green occupation in the US is also a green occupation in the UK. Further, while the O*NET classifications focused on certain sectors, we consider that any occupation that is identified as green in such sectors can be considered green in other sectors too (Bowen and Hancké, 2019). The occupational mapping is complex due to the 'many to many' correspondences – i.e. O*NET occupations tend to be mapped to more than one UK occupation and vice versa. We rely on a detailed crosswalk provided by 'LMI for All', an online data portal funded by the UK's Department for Education;[14] Appendix A1 sets out our approach in detail.

[13] We begin this analysis in 2011 because that is the first year that applies the UK SOC2010 occupational classification, which we use for the O*NET mapping. We finish in 2019 rather than 2020 so that the data and analysis do not capture impacts of COVID-19 on the labour market.

[14] https://www.lmiforall.org.uk/

Occupation-based estimates of green jobs in the UK

We present estimates of green employment using two main approaches.

- **The first classifies occupations as being either green or non-green.** A UK occupation is considered as a green occupation if at least one of its matched occupations from O*NET is green. Under this definition, of the 369 UK occupations, 144 occupations (39%) are identified as green occupations. Within this, 52 are 'green new and emerging' (GNE), 84 are 'green enhanced skills' (GES) and 81 are 'green increased demand' (GID). Some occupations can be classified as being more than one type of green given this mapping structure. **We call this classification 'green max':** it is likely to be a generous classification of greenness given the fact that the UK occupation codes are more aggregated than the detailed O*NET occupations that are being mapped to them, which means that entire occupational categories are considered green even if only one sub-category is considered green in O*NET.
- **To provide a more conservative estimate of green jobs, we calculate our main measure, the 'green mean'.** This is a simple average of 'greenness' across all the O*NET occupations mapped to a UK occupation[15] (again, we do this separately for green new and emerging, enhanced skills and increased demand). This measure of greenness therefore takes values between (and including) 0 and 1 for each occupation; and when we average this across jobs, we obtain estimates of the average share of jobs that are green.

In **Table 4.1** we set out what these different measures imply for the share of green employment in the UK in 2019.

Table 4.1. UK-wide estimates of the share of green employment (2019)

	Max	Mean
Green (any)	39%	17%
Directly green:		
Green **new and emerging**	16%	5%
Green **enhanced skills**	24%	7%
Indirectly green:		
Green **increased demand**	18%	5%

Notes: Sample includes employed and self-employed workers aged 16-65. LFS person weights applied to calculate averages of the green max and green mean occupational classifications across individuals.

Table 4.1 shows that **the share of existing jobs we can consider green overall ranges between 17% and 39%**. The mean approach gives us estimates that are in line with previous work from the US that estimated an overall share of green employment at 19.4% (Bowen et al., 2018). Our more generous estimates are in line with previous work that mapped O*NET occupations into EU classifications (taking a similar 'generous' approach), which estimated that 40% of EU employment can be considered green (Bowen and Hancké, 2019). In terms of trends, we find that

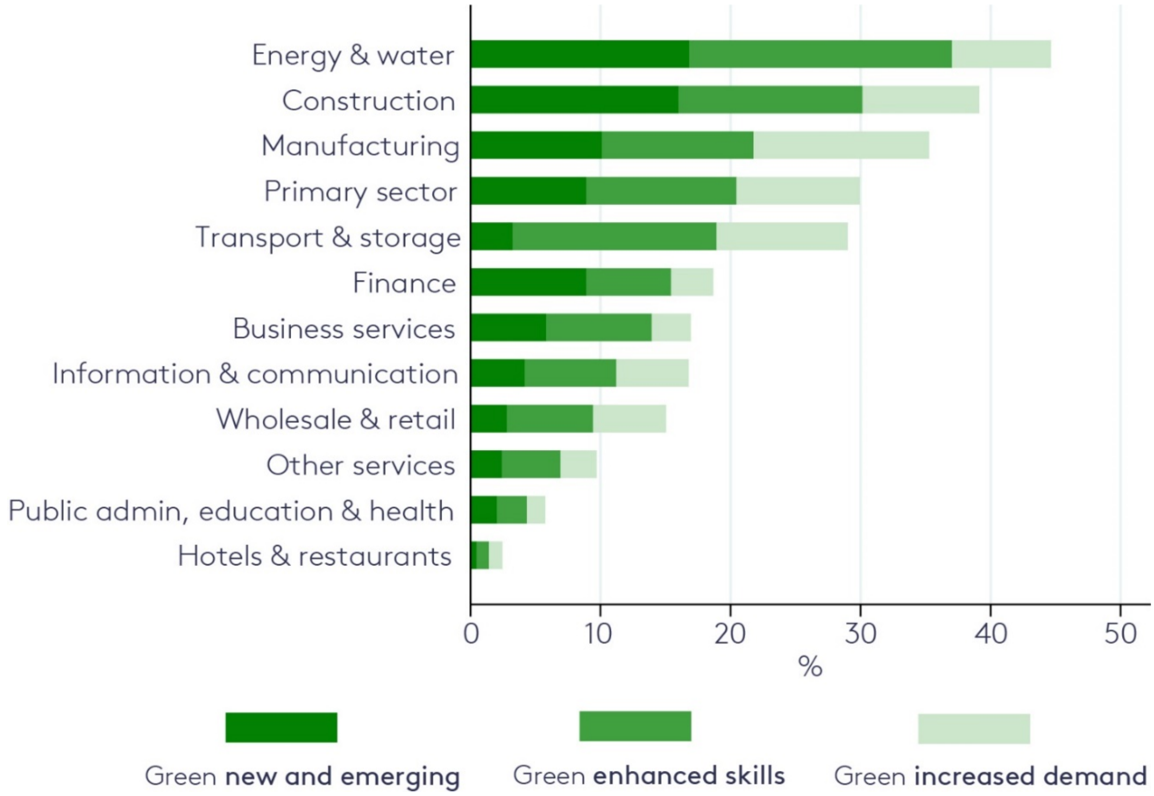
[15] This approach implicitly assumes that there is an equal distribution of employment across all sub-occupations (Bowen et al., 2018). As a robustness check, we also take a further step, calculating a greenness measure that weights O*NET occupations mapped to UK occupations using employment. These estimates of green employment are slightly higher than the green mean approach, with 20.5% of jobs being considered green in 2019 under that approach. In another robustness exercise, for GNE and GES occupations where a share of tasks are 'green' (see Appendix for discussion), we calculate the mean greenness. This approach results in 3% for GNE and 2% for GES. Since there are no 'green' tasks for increased demand jobs, we prefer to treat all green jobs in the same way and the simple 'mean' approach is our core estimate.

there has been a slight increase in the share of green jobs since 2011, and this has occurred across all types of green job (see Appendix, Figure B1).

Next, we focus on the green mean estimates to summarise greenness of employment by sector. **The sectors with the highest shares of green jobs are utilities, construction, manufacturing**, the **primary sector and transport – see Figure 4.1**. Overall, these findings are qualitatively consistent with both Bowen et al. (2018) and Bowen and Hancké (2019), who find these sectors to account for the highest shares of green jobs.

To get an idea of the types of jobs that are considered 'green' across these sectors, we provide a summary of the three most common occupations within each sector (based on individuals in 2019) and their measured 'greenness' in Appendix A2.3.[16]

Figure 4.1. UK green employment shares across sectors (2019)



Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals by broad sector groupings. 20 SIC [standard industrial classification] sections are grouped into 11 categories as labelled; 'primary' sector contains agriculture and mining.

At a broad level, it is interesting to note that **sectors with a high share of green employment, as we have defined it, also tend to be higher emissions sectors**. This is shown in **Figure 4.2**, which plots the green job shares and emissions for 20 sectors (more disaggregated than in Figure 4.1). For example, electricity and gas, and water supply (energy and water in Figure 4.1) – both currently have a high share of green jobs, and relatively high emissions. To some extent this is a mechanical relationship, given the sectors of focus in the O*NET green jobs classifications include

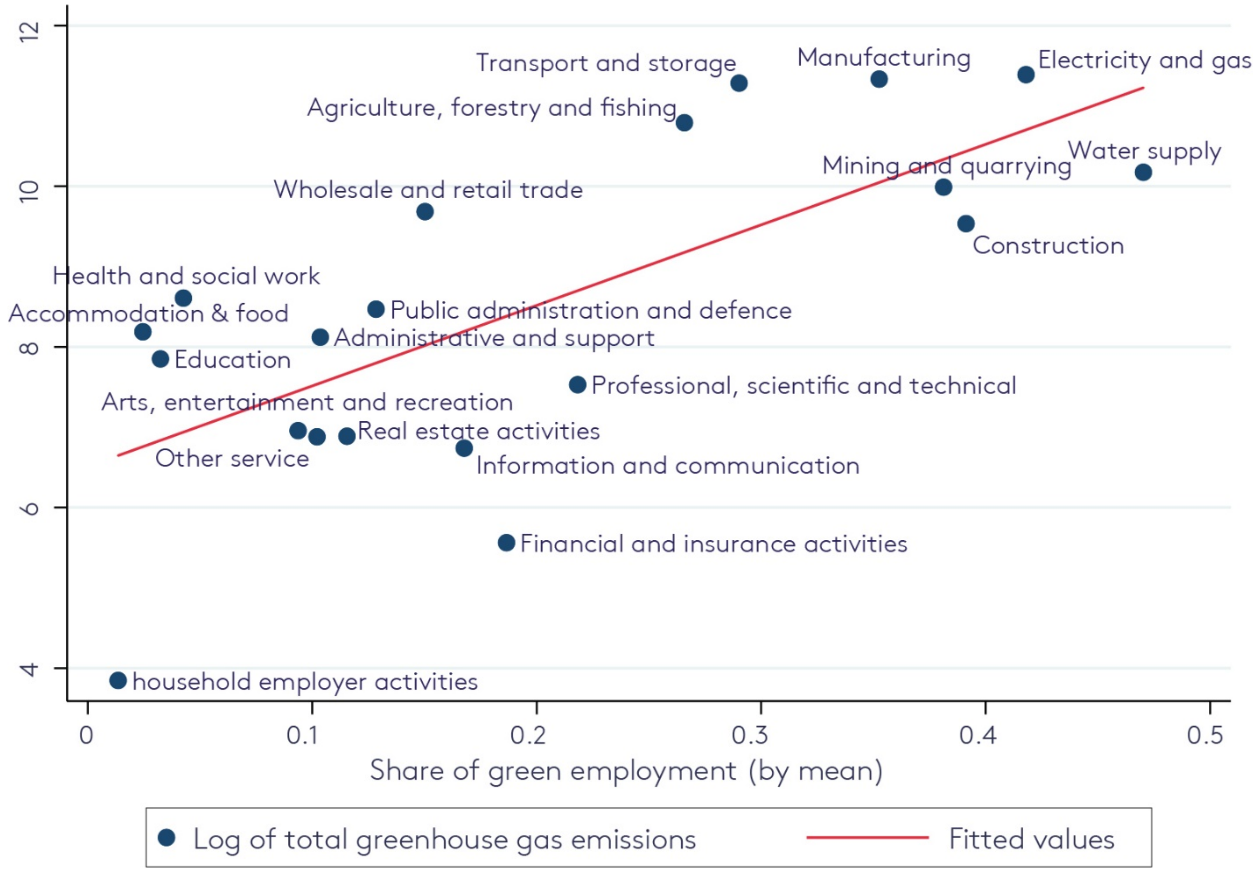
[16] This shows, for example, that in manufacturing, the most common green occupation is 'production managers and directors in manufacturing', for which all detailed O*NET occupations that map to it are green (across GID, GES and GNE). In the finance sector, 'Finance and investment analysts and advisers' are scored as 0.18 green, which comes from GES occupations that are mapped to this UK occupation.

renewable energy generation, transportation, green construction, manufacturing and service sectors (such as research, design and consulting services) – for a full list, see Appendix A1.

However, some sectors stand out – financial and insurance activities; professional, scientific and technical; and information and communication sectors have relatively high shares of green employment and low emissions. **Transport and storage, and agriculture have similar overall sectoral emissions to energy and manufacturing but to date much lower shares of green employment.** Overall, there is a similar positive correlation between the broad sector shares of green new and emerging, enhanced skills and increased demand and emissions.

However, there is no clear relationship at a more disaggregated sectoral level (see Appendix, Figure B5), reflecting the heterogeneity of activities within broad sectoral groupings and the fact that at the sub-sectoral level it is easier to delineate low- versus high-carbon activities. But this analysis highlights the complexity of sectoral approaches that consider all employment in overall more polluting sectors as being 'non-green'.

Figure 4.2. UK green employment shares versus greenhouse gas emissions (2019)

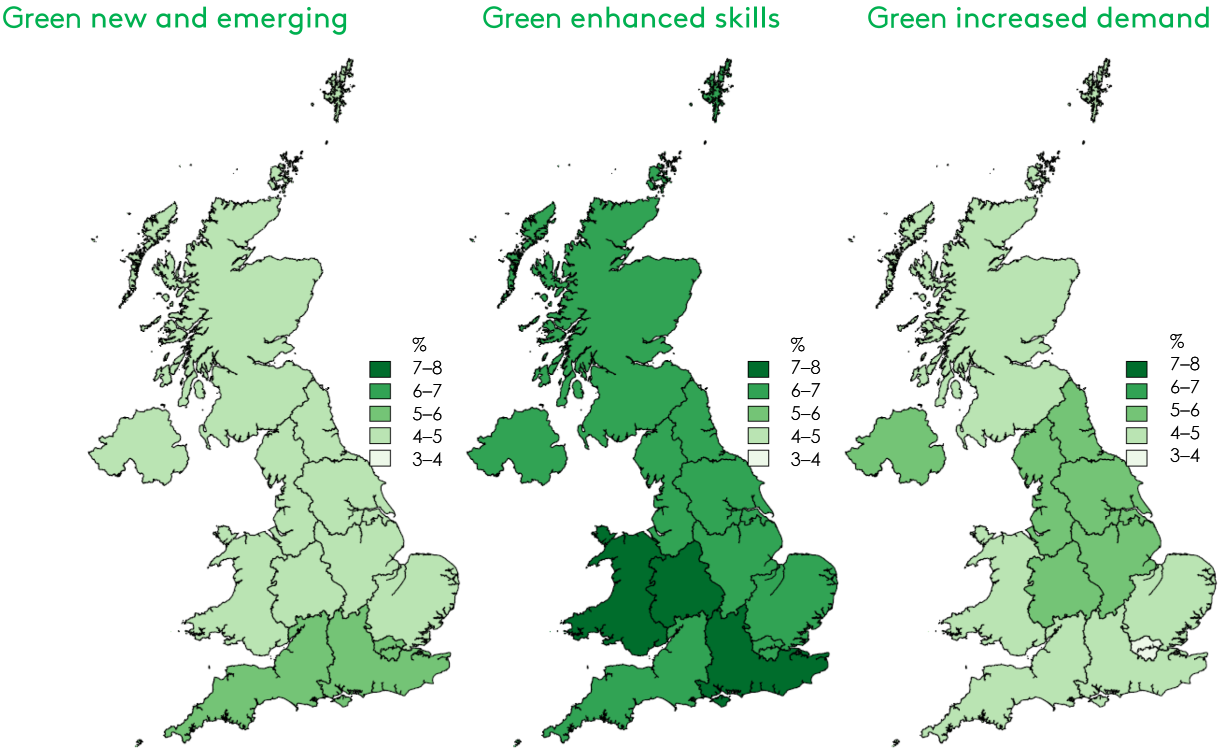


Notes: Sectoral emissions are plotted against averages of the green mean occupational classifications across 20 SIC sections. Source: Sectoral emissions data were sourced from Final UK greenhouse gas emissions national statistics: 1990 to 2019, published 2 February 2021. The natural log of 2019 emissions in thousand tonnes of carbon dioxide equivalent is shown on the y-axis.

We also consider how the shares of green jobs vary across the UK's regions, given their differing occupational and sectoral structures, and find that the pattern differs for the three green job types, though the variation is not great – see **Figure 4.3**. For the directly green jobs, we find that green enhanced skills jobs tend to be slightly more prevalent across Wales, the West Midlands and the South East than in other regions. This could be driven by the energy efficiency products sector, as well as the Midlands' strong position in the manufacturing of low-emission vehicles (BIS, 2015).

Green new and emerging jobs are more concentrated in the South of England, but also have relatively high shares in Scotland and the North West. Contributing factors could be the prevalence of jobs in the low-carbon service-sector, and in waste and biomass, in London and the South East, while the South West shows strengths in low-carbon electricity (ibid.).[17] Green increased demand jobs are more concentrated in Northern Ireland, the North of England and the Midlands than in other regions.

Figure 4.3. Green employment shares across the UK's regions (2019)



Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals at the NUTS1 region level.

What are the characteristics of greener jobs, and the individuals that have them?

Using data at the individual level, we consider how key attributes of individuals and jobs themselves vary with the level of greenness of the job. We analyse correlations between the greenness of jobs and several important dimensions that are available in the data in turn: these are age, gender, whether or not an individual has completed higher education, and whether or not they have received on-the-job training (in the four weeks prior to being surveyed). For employees only, we compare whether or not their employment is permanent and their hourly wages.

The results from linear regressions of these attributes on the green 'mean' index are reported in Table 4.2, where individuals in the LFS over the period 2011 to 2019 are pooled together, and year, industry and regional factors are controlled for. Thus, we are comparing green and non-green occupations within 3-digit industry groups and regions.

[17] A summary of green job shares by region and type of green job is given in Appendix B, Table B1.

Table 4.2. Characteristics of workers in 'green' jobs in the UK

	(1) Age	(2) Female	(3) Degree	(4) Training	(5) Permanent	(6) Log wage
Panel A: Green jobs						
Green job	2.802***	-0.302***	0.115***	0.001	0.024***	0.350***
	(0.854)	(0.051)	(0.041)	(0.007)	(0.008)	(0.071)
Panel B: Green job types						
Green new and emerging	2.040**	-0.230***	0.287***	0.023**	0.033***	0.574***
	(0.856)	(0.051)	(0.049)	(0.009)	(0.008)	(0.083)
Green enhanced skills	5.433***	-0.319***	0.113	-0.004	0.040***	0.419***
	(1.174)	(0.055)	(0.086)	(0.011)	(0.012)	(0.157)
Green increased demand	-1.239	-0.383***	-0.157***	-0.023**	-0.020	-0.120
	(1.217)	(0.106)	(0.058)	(0.010)	(0.017)	(0.095)
N	389,085	389,085	388,195	389,085	332,699	89,158
Clusters	369	369	369	369	369	369

*Notes: Sample includes employed and self-employed workers aged 16-65, apart from columns 5 and 6, which relate to employees only. Labour Force Survey person weights applied (income weights for log wage). All columns control for year, industry (3-digit) and region (NUTS1) fixed effects. Standard errors are clustered at the occupation level. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

We focus on presenting and interpreting the qualitative nature of these relationships. Column 1 in Table 4.2 shows that workers in jobs with a higher green share tend to be older (panel A) (controlling for sector, year and region effects). This seems to be driven by directly green jobs (enhanced skills and new and emerging). All types of green jobs are currently more likely to be held by men. Interestingly, we find evidence that over time the gender balance is improving in greener jobs (relative to their less green counterparts); this is shown in Appendix B, Table B2.

Overall, those in green jobs are more likely to have a university degree than those in non-green jobs, and panel B reveals that this is driven by new and emerging jobs. In fact, increased demand jobs are less likely to be held by university graduates. While there is no relationship overall for training, across the green types, those in new and emerging jobs are more likely to have received training on the job, and those in increased demand jobs appear to be less likely to have done so, compared with the other job categories.

For employees (i.e. excluding self-employed individuals), those in greener jobs are more likely to be on permanent contracts, and again this is particularly the case for enhanced skills and new and emerging jobs. Column 6 shows that the wages in green jobs are significantly higher, a relationship that is driven by new and emerging jobs.[18] This latter result is likely to be driven at least in part by the fact that those in new and emerging jobs are likely to be older (and hence, we can assume more senior in their roles), and educated to a higher level (and so in more skilled professions). We go on to examine the extent to which this is so later in this section. In further analysis not reported here, we find that directly green jobs are more likely to be held by those with

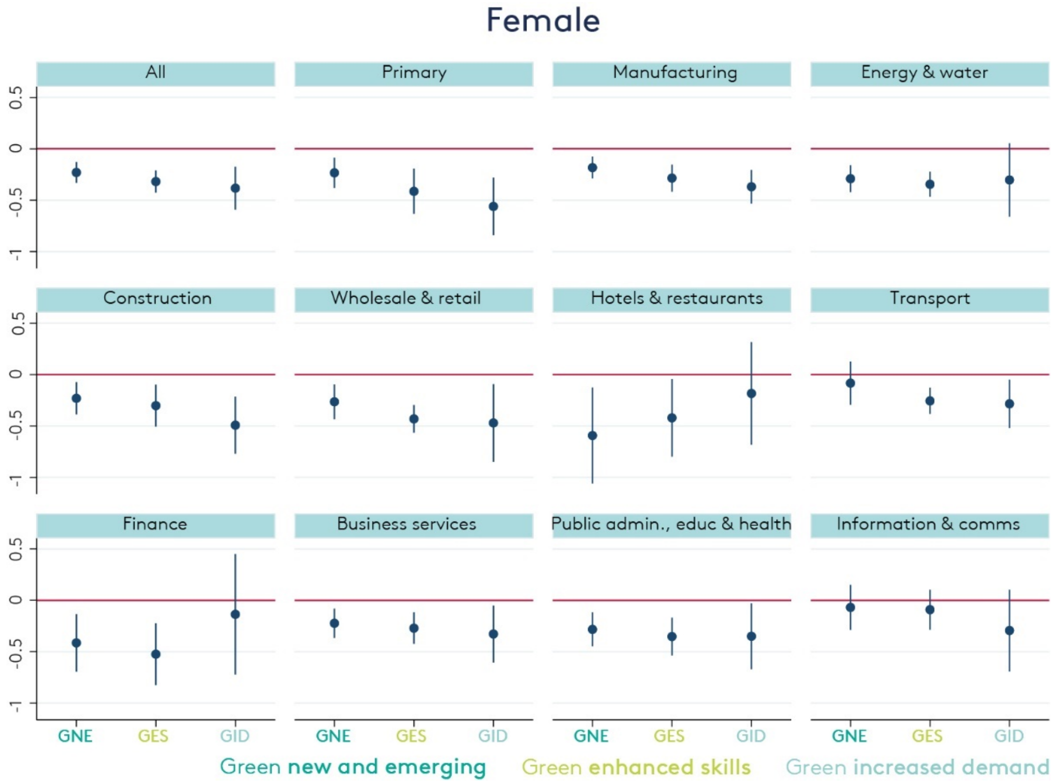
[18] We also find that the patterns we document are not simply driven by managerial occupations within the green jobs classifications (such jobs may be expected to be held by older, male, more educated and permanent individuals); the results excluding individuals in those jobs are reported in Appendix Table B3.

a ‘white’ ethnic background, and that green jobs are more likely to be full-time than part-time, across types of green job.

How do these patterns vary by sector?

The results reported in Table 4.2 control for sector of employment, but the patterns might be quite different across different sectors. We therefore estimate the characteristics by green new and emerging, enhanced skills and increased demand category for each broad industry group in turn, with the key results highlighted below. In fact, the finding that employees in green jobs are less likely to be female appears to apply broadly across industries and across the green job types, although the relationships are not always significantly different from zero – see Figure 4.4.

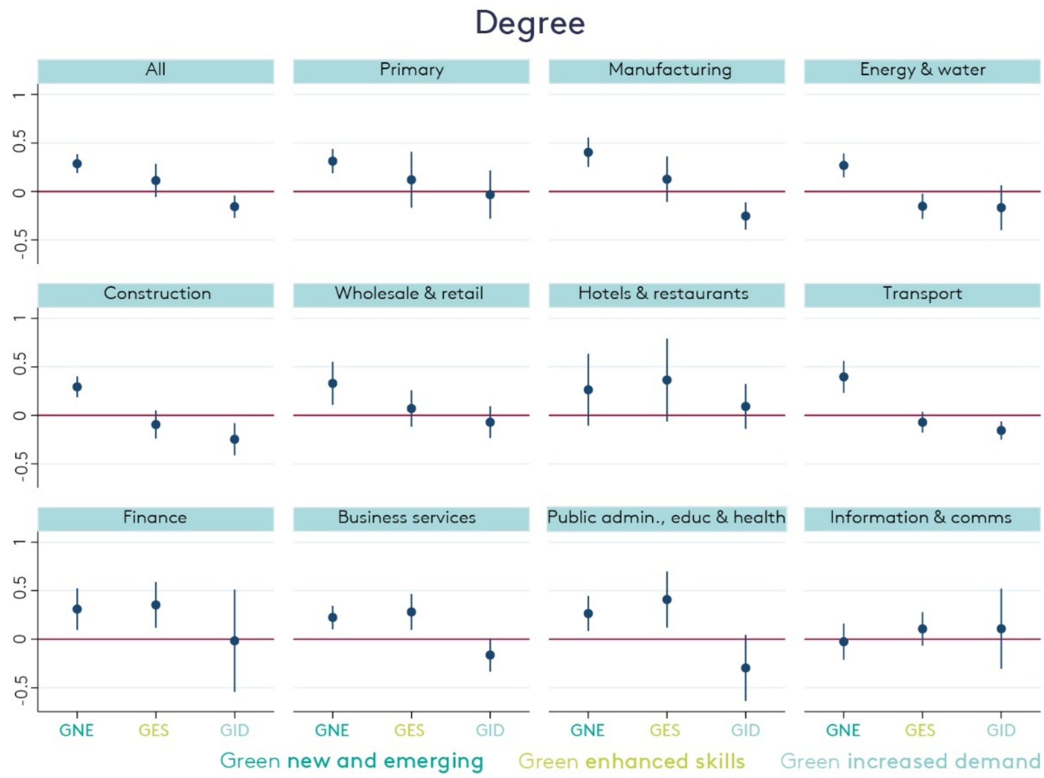
Figure 4.4. Gender and the greenness of jobs in the UK, by sector



Notes: ‘All’ replicates Table 4.2, column 2. Three-digit industry dummies are included in all specifications. The remaining charts restrict the sample to the sector as labelled, and sector fixed effects are therefore not included. The dots show the estimated coefficients on GNE, GES and GID jobs respectively and the bars show the 95% confidence intervals. The sector category ‘other services’ is left out.

Figure 4.5 replicates a similar analysis for the likelihood that individuals have a university degree. The higher likelihood in the case of green new and emerging jobs appears to be driven by the primary, manufacturing, utilities and transport sectors. In many sectors, green increased demand workers appear less likely to have a degree than those in non-green job types.

Figure 4.5. University graduates and the greenness of jobs in the UK, by sector



Notes: 'All' replicates Table 4.2, column 2. Three-digit industry dummies are included in all specifications. The remaining charts restrict the sample to the sector as labelled, and sector fixed effects are therefore not included. The dots show the estimated coefficients on GID, GES and GNE jobs respectively and the bars show the 95% confidence intervals. The sector category 'other services' is left out.

Of the other relationships shown in Table 4.2, we find that workers in green jobs tend to be significantly older, particularly in enhanced skills jobs in the primary sector (which groups mining and agriculture together, manufacturing and some service sectors); new and emerging workers tend to be older in the primary sector, manufacturing and construction. New and emerging workers are particularly more likely to receive training across many sectors (manufacturing, utilities, construction, transport and communications, finance and business services). The finding that new and emerging jobs are more likely to be permanent also appears to apply across many sectors, but in the primary sector, manufacturing and finance this also applies to enhanced skills jobs. Charts displaying these relationships are provided in Appendix B.

Is there a wage premium for green jobs?

Table 4.2 suggests that green jobs, in particular green new and emerging and enhanced skills jobs, tend to have higher wages than non-green jobs. This might be simply because workers in such jobs are more educated or experienced, or it might also be driven by other characteristics of such jobs, or potentially by excess demand (relative to supply) for these jobs in the labour market.

To explore the differences in wages, a good overall proxy for job 'quality', we estimate wage regressions (Mincer, 1974), which have been used in the labour economics literature to estimate the returns to education, controlling for other factors. We add our green jobs indicators to such regressions to ascertain whether green jobs are associated with a wage premium, even after controlling for other standard factors.

The first column in **Table 4.3** replicates column 6, Panel A in Table 4.2 and shows that greener jobs tend to command higher wages. In column 2 we control for gender, whether the individual has a degree or not, and their work experience.[19] We see that green jobs still tend to have higher wages even when comparing individuals with the same level of education and work experience. However, it could just be that green occupations tend to relate to overall higher skill occupations (as suggested by the literature, set out in Section 2) – this is generally true, for example, for people in managerial roles. Column 3 controls for major occupation groups[20] and indeed, the green job wage premium is much weaker and less significant in this specification.[21]

Table 4.3. Wages and the greenness of jobs in the UK

	(1)	(2)	(3)
Green job	0.350***	0.240***	0.070**
	(0.071)	(0.054)	(0.033)
Female		-0.118***	-0.090***
		(0.011)	(0.008)
Degree		0.370***	0.192***
		(0.017)	(0.010)
Experience		0.029***	0.024***
		(0.002)	(0.002)
Experience squared		-0.000***	-0.000***
		(0.000)	(0.000)
N	89,158	89,048	89,048
Clusters	369	369	369
Industry	Yes	Yes	Yes
Occupation	No	No	Yes

*Notes: Sample includes employed workers aged 16-65. Labour Force Survey person income weights applied. All columns control for year, region (NUTS1) and industry (3-digit) fixed effects. Standard errors are clustered at the occupation level. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

While on aggregate there is only weak evidence of a 'green' wage premium, once high-level occupational skill profiles are controlled for, there might be a difference in the relationships across broad occupational groupings. This is explored in **Table 4.4**, where column (1) replicates the final column in **Table 4.3** (including controls for broad occupational groupings) and the remaining columns break the sample into occupations at different skills levels. Within less skilled occupations, green jobs do tend to be paid better, suggesting that at middle and lower skill levels, green jobs could be an attractive proposition. It is important to note that these results are correlational, and any evidence of a premium might still reflect unobserved characteristics of the individuals that move into green jobs within broad occupation and industry groups.

[19] This is the standard 'Mincerian' specification.

[20] There are nine of these: including for example 'Managers, Directors and Senior Officials', 'Skilled Trades Occupations' and 'Elementary Occupations'.

[21] In further analysis, not reported here, we explore whether there is any differential in the green job wage premium for women versus men, and find that there is no evidence of this.

Table 4.4. Wages and the greenness of jobs in the UK, by occupation

	(1) All	(2) High skill	(3) Middle skill	(4) Service-intensive	(5) Labour-intensive
Green job	0.070**	0.055	0.125**	0.417**	0.174***
	(0.033)	(0.045)	(0.055)	(0.167)	(0.041)
Female	-0.090***	-0.119***	-0.059***	-0.055***	-0.072***
	(0.008)	(0.013)	(0.012)	(0.012)	(0.011)
Degree	0.192***	0.292***	0.136***	0.111***	0.076***
	(0.010)	(0.013)	(0.012)	(0.011)	(0.014)
Experience	0.024***	0.039***	0.027***	0.010***	0.009***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)
Experience squared	-0.000***	-0.001***	-0.000***	-0.000*	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	89,048	40,376	17,620	16,321	14,731
Clusters	369	172	82	44	71

*Notes: Sample includes employed workers aged 16-65. Labour Force Survey person weights applied. High skill occupations consist of 1) managers, directors and senior officials, 2) professionals and 3) associate professional and technical occupations. Middle skill occupations are 4) administrative and secretarial and 5) skilled trades occupations. Service-intensive occupations include 6) caring, leisure, and other service and 7) sales and customer service occupations. Labour-intensive occupations are 8) process, plant and machine operatives and 9) elementary operations. All columns control for year, industry (3-digit) and region (NUTS1) fixed effects. Column (1) including occupation controls. Standard errors are clustered at the occupation level. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

How does 'greenness' relate to the risk of job automation?

As we set out in Section 3, previous studies that have examined the task content of green jobs have noted that the work content in green jobs is on average less routinised (and hence at risk of being automated) than that of non-green jobs (Consoli et al., 2016; Vona et al., 2018). This was the case for jobs that are 'directly green', i.e. green enhanced skills and green new and emerging, which are the focus of those studies.

We explore whether this is the case at the level of UK occupations by correlating our measure of the greenness of occupations with estimates of the occupational probability of automation (ONS, 2019)[22] – see Table 4.5. We find that there is a significant negative correlation between the overall greenness of the occupation and its probability of automation (column 1). This survives even when we control for general human capital at the occupation level (measured by the share of degree holders in that occupation in the UK Labour Force Survey in 2019 – which itself is negatively correlated with the risk of automation). This suggests that the relationship is driven by specifics of the occupations rather than the fact that greener jobs tend to require higher level qualifications.

Unsurprisingly, the low risk of green jobs being automated is driven by the employment share of green new and emerging occupations that involve new unique tasks created alongside greening the economy. There is a weaker negative relationship for green enhanced skills jobs, and a weak positive relationship for green increased demand jobs. Again, these patterns survive once general human capital at the occupation level is controlled for. This analysis suggests that greener jobs

[22] We use estimates of the probability of automation based on England and apply these to occupations across the UK.

might also be more resilient to future technological change and risks of automation than their less green counterparts and provides another piece of tentative evidence that green jobs, to date, can be considered to be 'good' jobs.

Table 4.5. Probability of automation and green jobs in the UK

	(1)	(2)	(3)	(4)
Green job	-0.0836*** (0.0269)	-0.0717*** (0.0140)		
Green **new and emerging**			-0.220*** (0.0474)	-0.122*** (0.0252)
Green **enhanced skills**			-0.0918* (0.0500)	-0.0627** (0.0265)
Green **increased demand**			0.0904* (0.0489)	-0.0208 (0.0261)
Share with a degree		-0.423*** (0.0134)		-0.416*** (0.0136)
N	369	369	369	369

*Notes: The dependent variable is the probability of automation for each 4-digit occupation in the UK, estimated by ONS (2019b). The green job variable is continuous, which is the average of green occupation dummies across all the O*NET occupations mapped to a UK 4-digit occupation. The unit of analysis is the 4-digit occupation. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

Analysis of the 'greenness' of job vacancies

Analysis of Labour Force Survey data gives us an idea of the 'stock' of jobs at any point in time. In this section we present a complementary analysis of green jobs, using data from online job vacancies. Analysis of new job advertisements gives us a measure of the 'flow' of new jobs and can help us to better understand the dynamics of labour demand towards a net-zero future.

We employ information about 53.9 million job advertisements over the period 2014 to 2020 across the UK, recorded by Burning Glass Technologies (BGT), a Boston-based job market analytics company.[23] Although this data source is less formally structured and less representative than survey data (for example, it excludes informal and internal recruitment activities that are not posted online), job ads contain detailed textual information on the job and employer over and above information on the occupation and sector which are available in labour force surveys. In addition, the data are higher-frequency and contain detailed geographical information that can be used for fine-grained geographical analysis.

Here we present two pieces of preliminary analysis based on these data as an extension to our main analysis, using Labour Force Survey data. First, using the occupation code provided in the data, we classify job vacancies as being directly and indirectly 'green', using the same O*NET occupational classifications applied previously. Second, we focus on the evolution of a subset of green jobs linked to disruptive technologies.

The occupation code, which is available for 99.7% of vacancies in 2019, allows us to classify jobs as being 'green' in the same way as previously. We find that in 2019, green jobs accounted for

[23] Several studies have employed these data to understand the employment dynamics. Examples include Hershbein and Kahn (2018) and Deming and Noray (2020). In the UK labour market, BGT data has been shown to provide useful information for classifying STEM and creative occupations (Lima and Bakhshi, 2018).

49% and 19% of all vacancies using the green max and green mean approaches, respectively. When compared with the breakdown in Table 4.1, **Table 4.6** suggests that new vacancies are characterised by a slightly higher share of directly green jobs than the overall stock of jobs (the share of indirectly green jobs is similar).

Table 4.6. UK-wide estimates of the share of green vacancies (2019)

	Max	Mean
Green (any)	49%	19%
Directly green:		
Green **new and emerging**	23%	7%
Green **enhanced skills**	28%	7%
Indirectly green:		
Green **increased demand**	19%	5%

Notes: Sample includes all BGT job vacancies with identified 4-digit SIC codes.

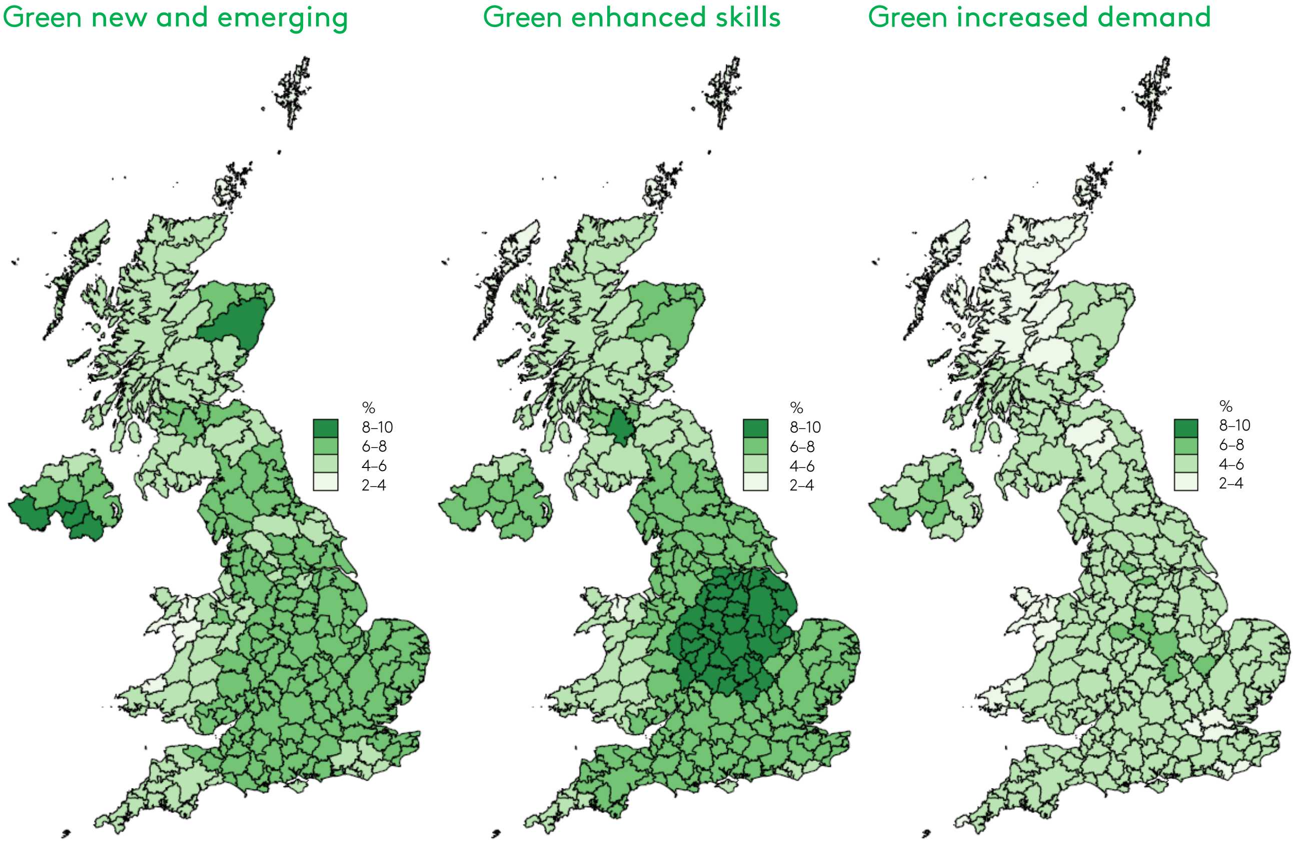
The share of green jobs seems quite stable between 2014 and 2020, with only minor variations. We compare our preferred 'mean' measure to the green share of 'new' jobs in the UK LFS (defined as jobs where the individual has been with their current employer for less than a year) and the trend is consistent (see Appendix, Figure B6).

We are able to conduct a more fine-grained spatial analysis of job vacancies, and to aggregate the average greenness indices to the 'travel to work areas' (TTWA) level.[24] **Figure 4.6** maps green new and emerging, enhanced skills and increased demand vacancy shares. Across the green job types, there appears to be a relatively high share of vacancies in parts of Northern Ireland. New enhanced skills and increased demand jobs appear to be relatively prominent in the Midlands, which is where the existing 'stock' of these types of green jobs appears to be quite high (as we showed in Figure 4.3). There are pockets of relatively high new and emerging hiring activity in Northeast Scotland and the South of England (Figure 4.3 suggested that existing new and emerging jobs appeared to be most common in the South East).[25] Some areas like Wales, with high stocks of green jobs (specifically enhanced skills), do not, however, display high enhanced skills vacancy rates, which might derive from the sampling bias of job vacancies or could highlight that the demand for green jobs is not as dynamic as in other regions.

[24] We harmonised counties/unitary authorities (UAs) information attached to job adverts with the counties/UAs map 2018 from the Office for National Statistics (ONS). Then job adverts are located to TTWAs map 2011 by ONS. Whenever a county/UA spreads over several TTWAs, we assume even geographical distribution and use the area ratios to partition the (green) job counts. However, we ignore the negligible partitions of areas that are less than 1% county/UA area.

[25] Appendix Figure B7 show a similar spatial pattern of green job rate across the country in 2020, which could be affected by changes in hiring patterns due to COVID-19.

Figure 4.3. Share of 'green' job vacancies (%) across the UK (2019)



*Notes: Analysis based on BGT vacancies data for 2019, using O*NET-based occupational mappings (mean approach). The geographical unit is the travel to work areas (TTWAs) 2011. Exceptions include the merging of TTWA 'London' with 'Slough and Heathrow' and 'Bournemouth' with 'Poole' to accommodate the less disaggregation of original geographical units used in BGT data.*

Green jobs linked to disruptive technologies

We also attempt to exploit the textual data in the BGT dataset and focus on the evolution of a subset of green jobs linked to disruptive technologies. We draw on analysis in Bloom et al. (2021), which identifies 29 technologies that disrupt businesses, and key phrases that help detect the adoption of these technologies.[26] We focus on three 'clean' technologies that are identified in the study: solar power, (hybrid) electric vehicles and lithium-ion batteries, which are critical for energy generation, mobility and energy storage in the transition to net-zero.[27] The exposure rate for each technology is computed as the share of nationwide job vacancies that contain at least one key term that specifies the technology (and this is then aggregated at quarterly steps).

As shown in Figure 4.4, among these three clean technologies, solar power dominated in the earlier period but it was overtaken by electric vehicles (including hybrid electric vehicles) in 2017. There has also been steady growth in vacancies relating to energy storage.

Figure 4.4. Quarterly exposure to disruptive clean technologies in UK job adverts

Notes: Analysis based on BGT vacancies data over the period 2012 to early 2019. The y axis is on a base-10 logarithmic scale and measures number of vacancies exposed to a particular technology per 1,000 job adverts.

[26] The authors do this by identifying key terms in influential patents and the earnings conference calls of listed firms.
[27] See Appendix A4 for more detail on the phrases we use to identify job vacancies relevant for these technologies.

5. Green jobs across European economies

Summary

- Our analysis of EU Labour Force Survey data reveals a picture broadly consistent with the UK analysis.
- The indirect and direct green share of employment is of a similar order of magnitude, and key characteristics of green jobs are quite similar.
- Some interesting country-level differences emerge, specifically the education level of green job workers, perhaps hinting at differences in education and skills systems as well as in demographics.

In this section we conduct an analysis similar to that for the UK but focusing on the (former) 'EU15'[28] countries, therefore including the UK for comparison, for the period 2011–2019.

We use European Union Labour Force Survey (EU LFS) microdata provided by Eurostat. Occupational and industry classifications in the EU LFS are more aggregated than the UK LFS analysis, which means that our occupational mappings are less precise than in the UK analysis, and we are not able to control for detailed sector of work. We set out the steps and assumptions made in the O*NET – EU LFS mapping in Appendix A3.

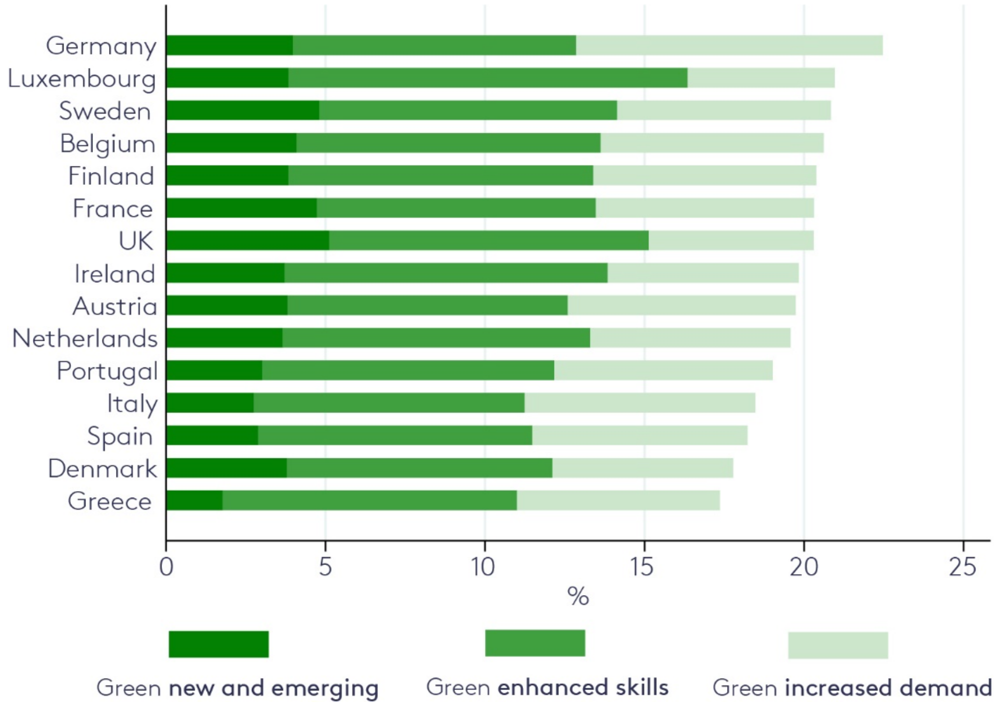
Quantifying green jobs in European economies

We begin by presenting the green jobs shares (according to the more conservative 'mean' approach) for each country in Figure 5.1. Overall, the share of existing jobs we can consider directly and indirectly green is quite similar across EU countries, ranging from 17% (in Greece) to 22% (in Germany). Green enhanced skills jobs account for the largest share of green jobs for most countries, except for Germany, where green increased demand jobs are highest, proportionally.

Applying these green shares to employment numbers by country, the implied overall share of indirect and direct green employment across these 15 countries is 20% (4% new and emerging, 9% enhanced skills and 7% increased demand). Overall, the share of green jobs seems quite stable between 2014 and 2020 across these 15 countries (see Appendix, Figure B8).

[28] The 15 countries in the EU prior to enlargement in 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK.

Figure 5.1. EU15 green job shares by country (2019), mean approach



Notes: Sample includes employed and self-employed workers aged 16-65. EU LFS person weights applied to calculate averages of the green mean occupational classifications across individuals.

Describing green jobs in European economies

Pooling all individuals across the EU15 countries, the green job characteristics are qualitatively similar to the UK findings, despite the difference in occupational and industry aggregation between the two analyses: green job workers tend to be older, fewer are female, more are higher skill and (for employees) more are likely to be on permanent contracts – see Table 5.1. Green new and emerging jobs tend to drive these results, though again the gender result applies across all green job types. There are no discernible differences in training rates on average.[29]

Some characteristics hold across countries: green jobs appear to be less likely to be held by females across all EU15 countries – see Figure 5.2. This gender difference appears to be larger for increased demand jobs and smaller for enhanced skills and new and emerging. The exceptions are Austria, the Netherlands and Germany, where the gap for new and emerging jobs is also quite large.

[29] As with the UK Labour Force Survey, the results look similar if we drop managerial occupations, which are likely to be older, male, more educated and permanent jobs.

Table 5.1. Characteristics of 'green' jobs in EU countries

	(1) Age	(2) Female	(3) Degree	(4) Training	(5) Permanent
Panel A: Green jobs					
Green job	2.117*	-0.414***	0.096*	-0.011	0.063***
	(0.915)	(0.089)	(0.045)	(0.018)	(0.019)
Panel B: Green job types					
Green new and emerging	8.428***	-0.578***	0.255*	0.054	0.244***
	(2.187)	(0.163)	(0.121)	(0.042)	(0.043)
Green enhanced skills	1.687	-0.198	0.166*	-0.015	0.039
	(1.526)	(0.122)	(0.065)	(0.027)	(0.032)
Green increased demand	-1.342	-0.588*	-0.095*	-0.046*	-0.012
	(1.519)	(0.277)	(0.040)	(0.021)	(0.033)
N	4,139,341	4,139,341	4,139,341	4,132,880	3,504,152
Clusters	127	127	127	127	127

*Notes: Sample includes employed and self-employed workers aged 16-65 over the period 2011-2019, apart from column 5, which relates to employees only. EU LFS person weights applied. All columns control for year, industry (1-digit level) and region (NUTS1) fixed effects. Standard errors are clustered at the 3-digit occupation level. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

Those in green new and emerging jobs appear to be more likely to have a university degree in some countries (including Belgium, Greece, Luxembourg, the Netherlands and Spain), as shown in Figure 5.3. In some countries there is a similar relationship for green enhanced skills jobs. In Germany, there is no relationship between having a new and emerging job and holding a degree, perhaps due to the high share (and high quality) of vocational education in the country, which might be relevant for many of these jobs.

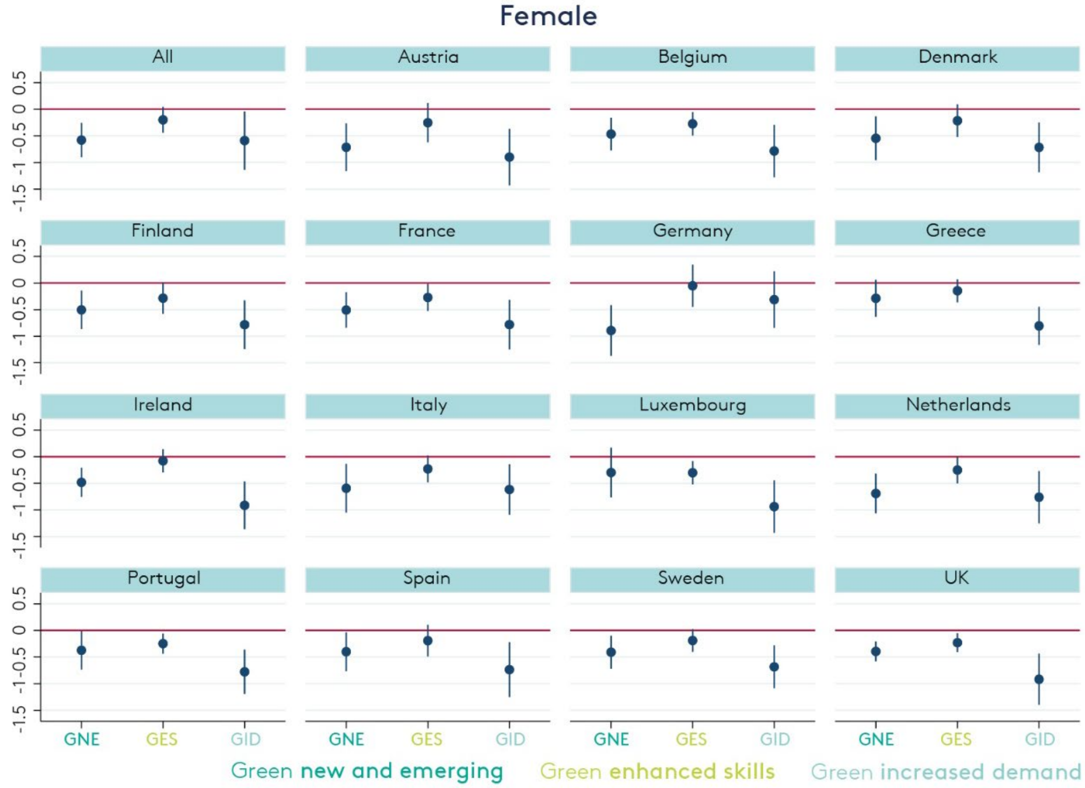
In terms of the other variables in Table 5.1, country by country analysis of the age profile of green jobs shows that in general it is the green new and emerging jobs that are held by older workers.

While on average there appear to be no differences in training (Table 5.1, column 4), there is heterogeneity across countries. In Belgium, Finland, Italy, Greece, Portugal and Spain, those in new and emerging jobs are also more likely to have received recent on-the-job training. But this is not the case in countries that arguably have a stronger apprenticeship or vocational education system, like Germany and the Netherlands. In contrast, those in green increased demand jobs received systematically less training than those in non-green jobs in most countries.

In terms of job security, enhanced skills and new and emerging jobs are more likely to be permanent, and the relationship is larger for new and emerging jobs. This pattern holds across countries. In further analysis not reported here, we find that greener jobs are more likely to be full-time compared with non-green jobs (this applies across all three types of green job).[30]

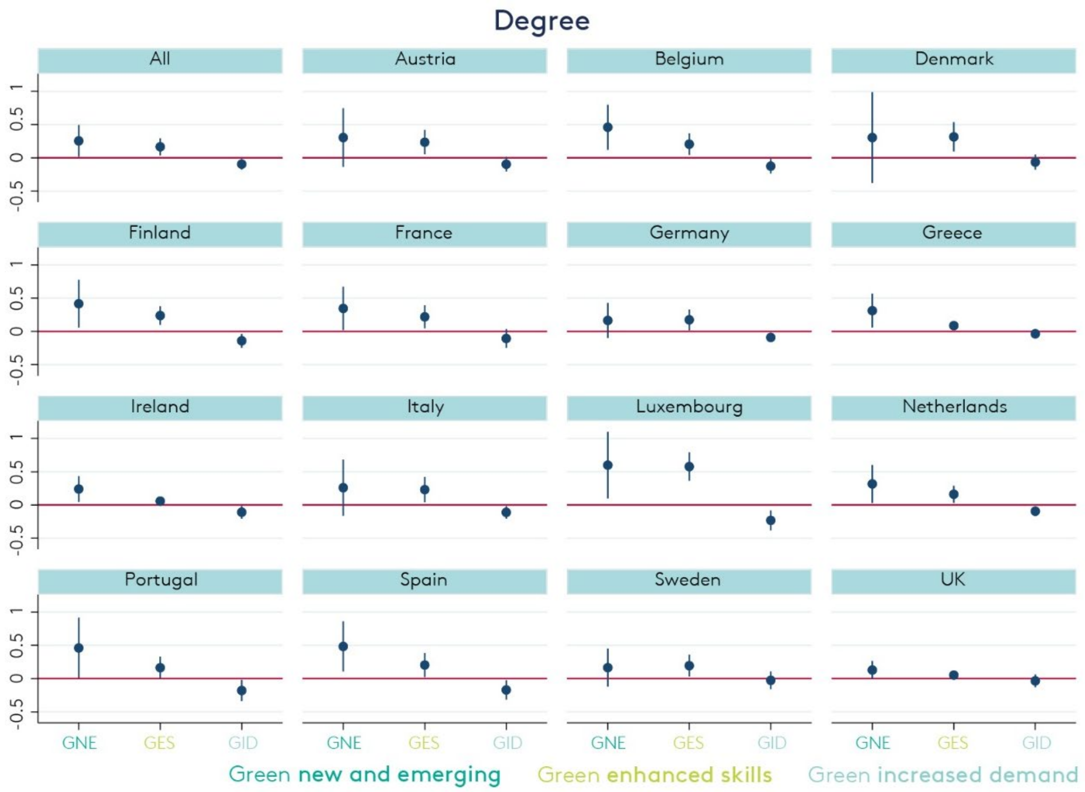
[30] Hourly wages are not available in the EU LFS to enable us to estimate wage regressions, and in addition, there is no ethnicity variable.

Figure 5.2. Gender and the greenness of jobs in EU countries



Notes: 'All' replicates Table 5.1, column 2. The remaining charts restrict the sample to the country, as labelled. The dots show the estimated coefficients on GNE, GES and GID respectively and the bars show the 95% confidence intervals.

Figure 5.3. University graduates and the greenness of jobs in EU countries



Notes: 'All' replicates Table 5.1, column 3. The remaining charts restrict the sample to the country as labelled. The dots show the estimated coefficients on GID, GES and GNE respectively and the bars show the 95% confidence intervals.

7. Conclusions and policy implications

In this report we have quantified and described green jobs in the UK and EU using granular occupational classifications applied to individual-level survey data. Our results suggest that greener jobs tend to be held by older, male workers – across directly and indirectly green jobs. Workers in some types of green job, particularly those that are new occupations related to greening the economy, are likely to be educated to a higher level and be on permanent contracts. However, there are differences in these relationships across EU countries, sectors and regions.

In the UK, we find little evidence of a wage premium in green jobs at higher skill levels, but find that green jobs appear to command higher wages at lower skill levels. In addition, green occupations are associated with a lower risk of automation than non-green jobs. In analysis of hiring activity via data on online job postings in the UK, we find that 18% of new job postings are green, with considerable variation across geographies. We also document a rapid rise in job postings relating to specific clean technologies.

Our results suggest that based on the experience to-date, greener jobs can be considered 'better' than their less green counterparts across some dimensions of job quality that we can observe in our data. Greener jobs appear to command higher wages for lower skill levels, and directly green jobs – in particular those that are new and emerging in the transition – are at less risk of automation than non green jobs.

As commitments to net-zero, and associated investments, are ramped up, policymakers will need to ensure equitable access to the new opportunities this brings in the labour market. Implications for labour market or skills policies will vary according to regional sectoral mix and endowments but particular attention will need to be placed on regions with significant transition needs that currently have a low green job share and on particular demographic groups who are so far underrepresented: that is, women and young people.

Further research is needed to understand the ease of transition for specific groups in particular places, and the role of industrial, skills and labour market policies for enabling a just transition given differing institutional contexts.

Conclusions for policy

Training and skills programmes will be key for a just transition.

The literature to date sets out specific skill requirements, in particular with respect to directly green jobs. This will have implications for education systems in terms of producing the future workforce. But on-the-job training will be an important route for reskilling or upskilling existing workers who need to transition into green occupations. In the presence of externalities that prevent firms from investing in training – particularly in transferable skills – there is a need to consider mechanisms that would incentivise increased firm-level investments in skills. This could be achieved via:

- Conditionality on training provision attached to government support packages; and/or
- Introduction of (enhanced) human capital tax credits (Costa et al., 2018). Such tax credits would allow firms to deduct a credit based on their qualifying training expenditures from their taxable profits. This could be enhanced for training considered relevant and crucial for the net-zero transition.

Given the presence of significant technological and economic uncertainties, education programmes at all levels must create a balance between general and specific skills, building worker resilience and flexibility to change. This will require a deeper understanding of the technical and general skills required in new 'green' jobs over different time horizons, and an assessment of how these can be best acquired for individuals at different stages – i.e. via school, further or higher education, or on the job.

Given current imbalances, targeted transition policies and programmes are likely to be required.

All types of green jobs appear to be less likely to be held by women than men, and many tend to be held by older workers.

- Targeted recruitment policies or information campaigns will be needed for specific sectors, places or demographic groups that have so far been under-represented, given the apparent distributional consequences in the transition to net-zero.
- Improved clarity of career paths at different stages in the transition – as construction activity gives way to maintenance – will be required to ensure that new opportunities are available to underrepresented groups, and transitions are managed effectively.

Conclusions for research

Building new measures to ease the transition for all

Our analysis has described a set of pre-defined green occupations but does not speak to the ease of transition for specific groups in particular places.

- New analyses, building measures of skills or task 'distance' between jobs in decline and those forecast to grow, can inform individual career or reskilling choices, and inform policymakers on the appropriate industrial, skills and labour market policies for enabling a just transition given differing institutional contexts.

New measures of green jobs, in firms carrying out different types of green activity

There are several limitations in analyses that rely on an 'ex-ante' definition of greenness.

- An interesting avenue for future research is to combine data on firms and workers to quantify and describe the jobs within firms that can be classified as green in terms of the products or services they offer, or the processes and operations that they adopt. The rich textual information available in job vacancies will be key to doing this, allowing for more granular analyses of emerging green jobs and specific skill sets required by them.

Further exploration of the policy or institutional drivers of differences in the composition of green jobs

The relationship between higher education and green jobs appears less pronounced for European countries with strong apprenticeship programmes.

- Future research could explore the relationship between national education systems and green job characteristics in Europe to identify the most appropriate ways to train or upskill the net-zero workforce in different institutional contexts.
- More research exploring the causal relationship between differences in environmental regulation or 'green' investments across or within countries, and the impacts on labour markets is required, paying attention to both the quantity and quality of jobs created and lost, and the educational and gender imbalances we have identified here.

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Appendices

Appendix A: The O*NET approach to classifying green occupations

A1.1. Definition of 'green' occupations

We follow the definition of green occupations in O*NET-SOC 2010, produced by the National Center for O*NET Development; see Dierdorff et al. (2009) for details.

The green economy is defined as the "economic activity related to reducing the use of fossil fuels, decreasing pollution and greenhouse gas emissions, increasing the efficiency of energy usage, recycling materials, and developing and adopting renewable sources of energy".

Following detailed research and review of the literature, O*NET chose 12 sectors of activity where the level of occupational greening was assessed. These are: Renewable Energy Generation; Transportation; Energy Efficiency; Green Construction; Energy Trading; Energy/Carbon Capture and Storage; Research, Design, and Consulting Services; Environment Protection; Agriculture and Forestry; Manufacturing; Recycling and Waste Reduction; and Governmental and Regulatory.

Green occupations are classified in three groups, according to the extent to which green economy activities and technologies: generate unique work and worker requirements (Green New and Emerging); shape the work and worker requirements needed for occupational performance (Green Enhanced Skills); or increase the demand for existing occupations (Green Increased Demand).

In total, there are 204 green occupations in O*NET-SOC at 8-digit level:

- 91 are New and Emerging (GNE) Occupations,[31] for which the impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements.
- 62 are Green Enhanced Skills (GES) Occupations,[32] for which the impact of green economy activities and technologies results in a significant change to the work and worker requirements.
- 64 are Green Increased Demand (GID) Occupations,[33] for which the impact of green economy activities and technologies is an increase in the employment demand. These occupations do not experience changes in tasks because of greening the economy.

A1.2. Definition of 'green rival' occupations

Across all occupations (green and non-green), O*NET provides links between O*NET-SOC occupations based on two types of similarities. First, their 'career changers'[34] matrix gives, for each O*NET-SOC code included, 10 related O*NET-SOC codes. The related occupations in this file make use of similar skills and experience; workers from one occupation may transfer to a job in a related occupation with minimal additional preparation.

Second, for each occupation, 10 related O*NET-SOC occupations are listed where the occupations have similar general capabilities and interests. This information is recoded in the 'career starters'[35]

[31] https://www.onetcenter.org/green/emerging.html
[32] https://www.onetcenter.org/green/skills.html
[33] https://www.onetcenter.org/green/demand.html
[34] https://www.onetcenter.org/dictionary/20.3/excel/career_changers_matrix.html
[35] https://www.onetcenter.org/dictionary/20.2/excel/career_starters_matrix.html

matrix, as those interested in the reference occupation may also be interested in the related occupations.

Bowen et al. (2018) classify non-green occupations as 'Green Rival' or 'Other' occupations. A green rival occupation is defined as those non-green occupations with at least one similar occupation that is green in *either* the Career Changers Matrix *or* the Career Starters Matrix. In summary, based on these classifications, among all 1,100 O*NET-SOC 8-digit occupations, 204 are green occupations, 368 are green rival occupations and 538 are other occupations.

A1.3. Green tasks

As set out previously, GID occupations have no 'green' tasks – they are existing jobs that are likely to see increased demand due to greening. But for GES and GNE occupations, O*NET provides a green task statement.[36] This information allows for the calculation of the share of green tasks for each occupation in the case of GES and GNE occupations (e.g. Vona et al., 2018).

A2. Mapping O*NET classifications to UK occupations

A2.1. Crosswalks

The occupational category in the UK Labour Force Survey is the UK Standard Occupational Classification (UK SOC) 2010, and there are 369 such occupations given at the four-digit level.[37] We use a direct crosswalk from O*NET-SOC (8-digit) to UK SOC developed by the 'LMI for All', an online data portal funded by the UK's Department for Education.[38]

A2.2. A binary definition of green occupation

Under this definition, a UK occupation is considered a green occupation if at least one of its matched occupations from O*NET is green. Therefore, it is a binary variable which takes the value 0 or 1. Under this definition, the 369 UK SOC2010 occupations are allocated as follows: 137 occupations are identified as green occupations (75 GID, 80 GES and 51 GNE). We call this 'green max' as it is likely to be a generous classification of greenness.

A2.3. Continuous definitions of green occupations

For each green occupation, several continuous measures of greenness are also calculated. For example, if a UK SOC2010 occupation has three O*NET occupations mapped to it, and one of them is 'green', then the UK SOC2010 is classified as green under the 'green max' approach.

A simple average or 'green mean' approach, takes the average greenness of the three O*NET occupations, so that this occupation would be given a greenness score of 1/3. This approach gives each occupation in the mapping an equal weight. This is our core measure of greenness used in this paper. To provide a sense of the types of UK occupations being labelled as 'green' according to this measure, the following table sets out the top three most common occupations in the 2019 UK Labour Force Survey data, by sector, among occupations that have any positive level of greenness ascribed to them.

[36] https://www.onetcenter.org/reports/GreenTask.html
[37] https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010/soc2010volume1structureanddescriptionsofunitgroups
[38] https://www.lmiforall.org.uk/

UK SOC 2010 Occupation	Green	GNE	GES	GID
Primary sector				
5111 Farmers	0.40	0.10	0.20	0.10
5119 Agricultural and fishing trades nec	0.33	-	0.08	0.25
1211 Managers and proprietors in agriculture and horticulture	0.40	-	0.20	0.20
Manufacturing				
1121 Production managers and directors in manufacturing	1.00	0.25	0.50	0.25
3545 Sales accounts and business development managers	0.40	-	0.40	-
5223 Metal working production and maintenance fitters	0.36	0.07	0.07	0.21
Energy & Water				
8211 Large goods vehicle drivers	1.00	-	1.00	-
9235 Refuse and salvage occupations	1.00	0.33	0.67	-
7219 Customer service occupations nec	0.33	-	-	0.33
Construction				
5319 Construction and building trades nec	0.40	0.20	0.20	-
5315 Carpenters and joiners	0.40	-	-	0.40
1122 Production managers and directors in construction	1.00	0.67	0.33	-
Wholesale & Retail				
9260 Elementary storage occupations	0.33	-	-	0.33
5231 Vehicle technicians, mechanics and electricians	0.27	-	0.18	0.09
7219 Customer service occupations nec	0.33	-	-	0.33
Hotels & Restaurants				
7219 Customer service occupations nec	0.33	-	-	0.33
7220 Customer service managers and supervisors	0.50	-	-	0.50
1132 Marketing and sales directors	0.50	-	0.50	-
Transport & storage				
8211 Large goods vehicle drivers	1.00	-	1.00	-
9260 Elementary storage occupations	0.33	-	-	0.33
8213 Bus and coach drivers	0.50	-	-	0.50
Finance				
3534 Finance and investment analysts and advisers	0.18	-	0.18	-
1150 Financial institution managers and directors	0.33	-	0.33	-
3538 Financial accounts managers	0.33	0.33	-	-
Business services				
3545 Sales accounts and business development managers	0.40	-	0.40	-
1132 Marketing and sales directors	0.50	-	0.50	-
2423 Management consultants and business analysts	0.25	0.25	-	-
Public admin, Education & Health				
3239 Welfare and housing associate professionals nec	0.20	-	0.20	-
3561 Public services associate professionals	0.50	0.25	-	0.25
3563 Vocational and industrial trainers and instructors	0.13	-	0.13	-
Information & communication				
2136 Programmers and software development professionals	0.25	-	-	0.25
3545 Sales accounts and business development managers	0.40	-	0.40	-
2135 IT business analysts, architects and systems designers	0.18	0.18	-	-
Other services				
5241 Electricians and electrical fitters	0.50	0.13	0.13	0.25
1259 Managers and proprietors in other services nec	0.17	-	0.17	-
3413 Actors, entertainers and presenters	0.10	-	0.10	-

To give two specific examples, take UK occupation 1150, Financial institution managers and directors (prominent in the finance sector). This occupation has three O*NET occupations mapped to it: one is green (GES) 11-1021.00 General and Operations Managers, and two are not: 11-3031.00 Financial Managers; 11-3031.02 Financial Managers, Branch or Department. Our classification therefore gives 1150 a green mean score of 0.33, which is based on GES.

UK occupation 8211 Large goods vehicle drivers (prominent in the transport and storage sector), has two O*NET occupations mapped to it, both of which are classified as GES. These are 53-3032.00 Heavy and Tractor-Trailer Truck Drivers and 53-7081.00 Refuse and Recyclable Material Collectors. This UK occupation is therefore given a green mean score of 1.

A more sophisticated approach follows Dingel and Neiman (2019) and Dickerson and Morris (2019). This weights the different O*NET occupations by their employment shares in the US (available at the more aggregated 6-digit level[39] and then split equally among the O*NET sub-occupations within each category). However, an additional step is required. Some of those O*NET occupations may have been mapped to other UK SOC2010 occupations. To avoid double counting, we use UK employment shares of those occupations to adjust the US employment used in the weighting of greenness. We call this classification the 'green mean weighted' approach.

We use these different approaches for sizing the extent of green employment in countries, regions or sectors. Where a share of greenness is allocated to the occupations of individuals in Labour Force Survey data, means of these shares can then be calculated for individuals in particular countries, regions or sectors to give a range of estimates of the greenness of employment.

A3. Mapping to occupations in the EU LFS

To map O*NET SOC 2010 codes to ISCO 2008, we use official crosswalk provided by BLS from SOC 2010 to ISCO08.[40] Several challenges arise here to do with levels of aggregation in the crosswalks and in the data. First, the crosswalk is available at the 6-digit US occupation level (this is more aggregated than the green job classifications that are at the 8-digit level). We first compute the share of greenness of each 6-digit US occupation based on the share of 8-digit occupations that are green and are mapped to it.

For example, the occupation "11-3051: industrial production managers" has five green sub-occupations out of seven that are GNE, such as "11-3051.02: geothermal production managers"; one sub-occupation which is GID, and one sub-occupation that is not green. We thus consider that occupation 11-3051 is 0.85 green as it is 14% GID and 71% GNE. This is then mapped to the 4-digit ISCO08 code "1321: Manufacturing managers".

Second, while the crosswalk is to ISCO08 occupations at the 4-digit level, many countries in the EU LFS provide occupation data at the 3-digit level only. While our mappings allocate 'greenness' to the more detailed 4-digit ISCO08 codes, we again have to aggregate this. In the 'green max' approach we consider a 3-digit occupation to be green if it contains any green detailed sub-occupations. In the example above, "132: Manufacturing, Mining, Construction and Distribution Mangers" would all be considered green. The 'green mean' approach takes an average greenness of occupations mapped to a single ISCO08 occupation.

A4. Disruptive green technologies and identifiers used in BGT data

In our analysis of job vacancies, we draw on analysis in Bloom et al. (2021) which identifies 29 technologies that disrupt businesses and key phrases that help detect the adoption of these technologies.[41] We focus on three 'clean' technologies that are identified in the study: solar power,

[39] https://www.bls.gov/oes/tables.htm
[40] https://www.bls.gov/soc/soccrosswalks.htm
[41] The authors do this by identifying key terms in influential patents and the earnings conference calls of listed firms.

(hybrid) electric vehicles and lithium-ion batteries, which are critical for energy generation, mobility and energy storage in transition to net-zero. The relevant identifiers we use in the Burning Glass data are as follows:

(Hybrid) electric vehicles	Hybrid vehicle; electric vehicle; electric motorcycle; vehicle charging; hybrid electric; plugin hybrids; electric buses; electrical vehicles; electric car; electric vehicles
Solar power	Solar wafer; rooftop solar; solar modules; solar cells; crystalline silicon; silicon solar; solar panel; solar power; solar wafers; solar energy; solar applications; solar module; solar cell; solar PV; solar grade; solar panels; photovoltaic; solar thermal
Lithium battery	Ion battery; lithium ion battery; lithium ion batteries; lithium batteries; ion batteries; lithium polymer; lithium ion; lithium battery

Notes: Sourced from Bloom et. al. (2021)

Appendix B: Extra results

Appendix tables

Table B1. Regional green job estimates

Region	Green job	GNE	GES	GID
North East	16%	4%	6%	6%
Yorkshire and the Humber	16%	5%	7%	5%
East Midlands	18%	5%	7%	6%
East of England	16%	5%	6%	5%
Greater London	15%	5%	7%	3%
South East	17%	6%	7%	4%
South West	16%	5%	6%	5%
West Midlands	17%	5%	7%	5%
North West	16%	5%	6%	5%
Wales	17%	5%	8%	5%
Scotland	16%	5%	6%	5%
Northern Ireland	16%	4%	6%	5%

Notes: Sample includes employed and self-employed workers aged 16-65. Labour Force Survey person weights applied to calculate averages of the green mean occupational classifications across individuals by region.

Table B2. Gender composition of green jobs, over time

	(1) Female	(2) Female
Green job	-0.302***	-0.330***
	(0.051)	(0.053)
2012 x Green job		0.008
		(0.009)
2013 x Green job		0.007
		(0.010)
2014 x Green job		0.024**
		(0.010)
2015 x Green job		0.032***
		(0.010)
2016 x Green job		0.031***
		(0.012)
2017 x Green job		0.050***
		(0.013)
2018 x Green job		0.040***
		(0.015)
2019 x Green job		0.054***
		(0.014)
N	389,085	389,085
Clusters	369	369

Notes: Column 1 replicates Table 4.2, column 2. Column 1 interacts year dummies with the overall green mean variable.

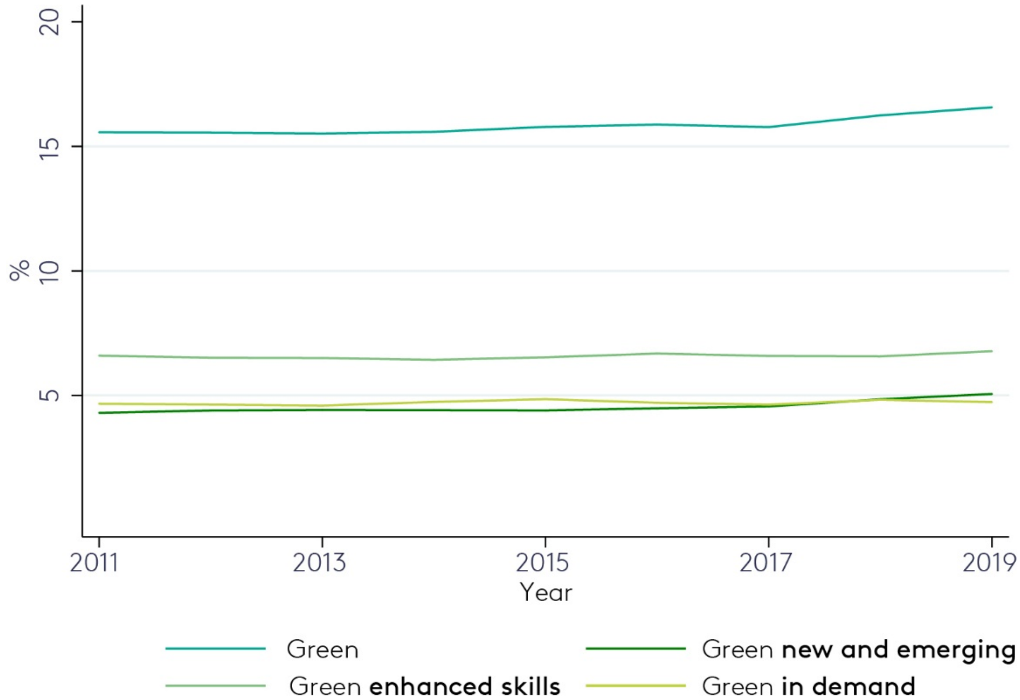
Table B3. Robustness: characteristics of workers in 'green' jobs in the UK, excluding managers, directors and senior officials

	(1) Age	(2) Female	(3) Degree	(4) Training	(5) Permanent	(6) Log wage
Panel A: Green jobs						
Green job	1.754**	-0.332***	0.103**	0.009	0.017*	0.310***
	(0.798)	(0.062)	(0.051)	(0.008)	(0.009)	(0.071)
Panel B: Green job types						
GNE	1.941**	-0.264***	0.351***	0.032***	0.033***	0.658***
	(0.795)	(0.065)	(0.054)	(0.010)	(0.008)	(0.094)
GES	3.409***	-0.338***	0.067	0.012	0.027**	0.280*
	(1.247)	(0.067)	(0.102)	(0.012)	(0.013)	(0.153)
GID	-0.767	-0.405***	-0.141**	-0.023**	-0.016	-0.063
	(1.070)	(0.112)	(0.059)	(0.011)	(0.017)	(0.089)
N	348,172	348,172	347,368	348,172	300,924	80,762
Clusters	369	369	369	369	369	369

*Notes: This table replicates Table 4.2, excluding managerial occupations. Labour Force Survey person weights applied (income weights for log wage). All columns control for year, industry (3-digit) and region (NUTS1) fixed effects. Standard errors are clustered at the occupation level. *** denotes significance at the 1% level, ** 5% level and * 10% level.*

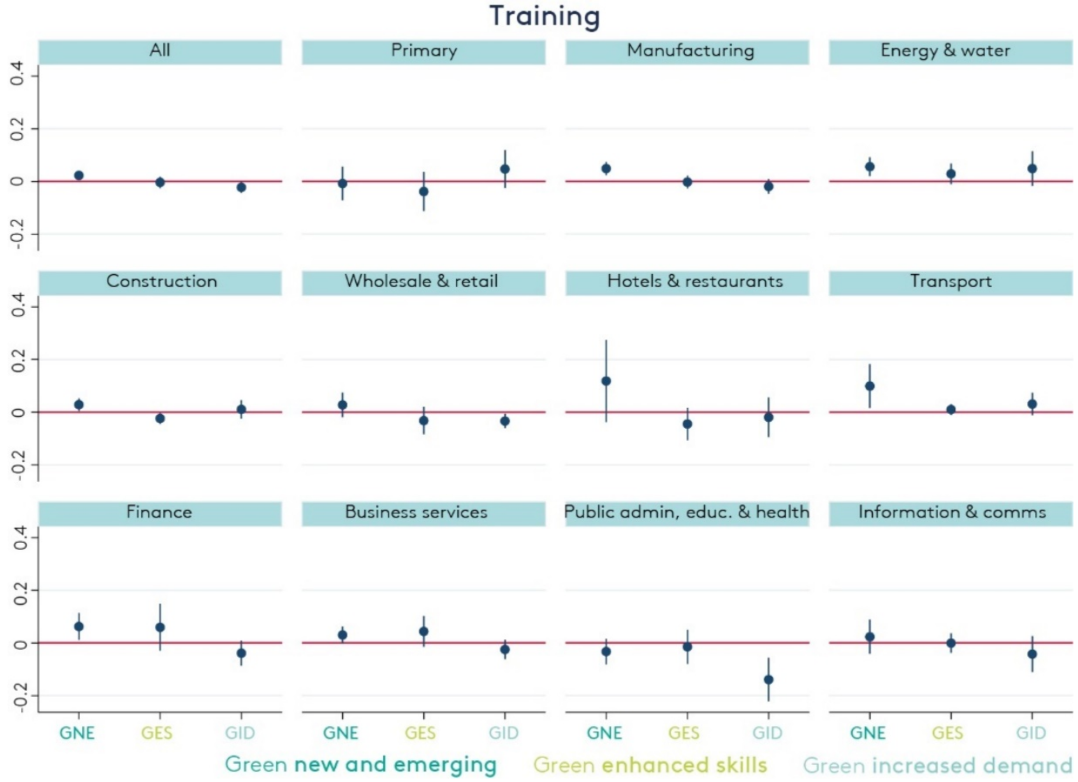
Appendix figures

Figure B1. Time trends of green job shares in the UK



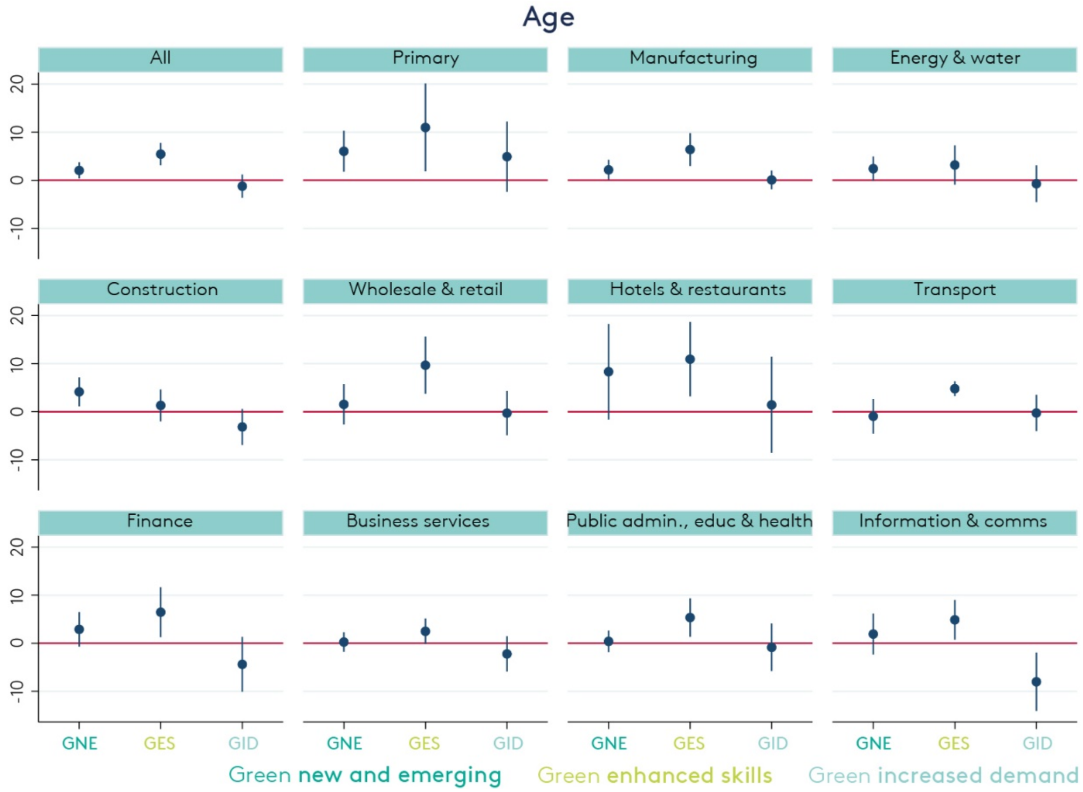
Notes: This figure illustrates the evolution of the share of GNE, GES and GID jobs (%) over time using the 'mean' approach.

Figure B2. Age of employees and the greenness of jobs in the UK, by sector



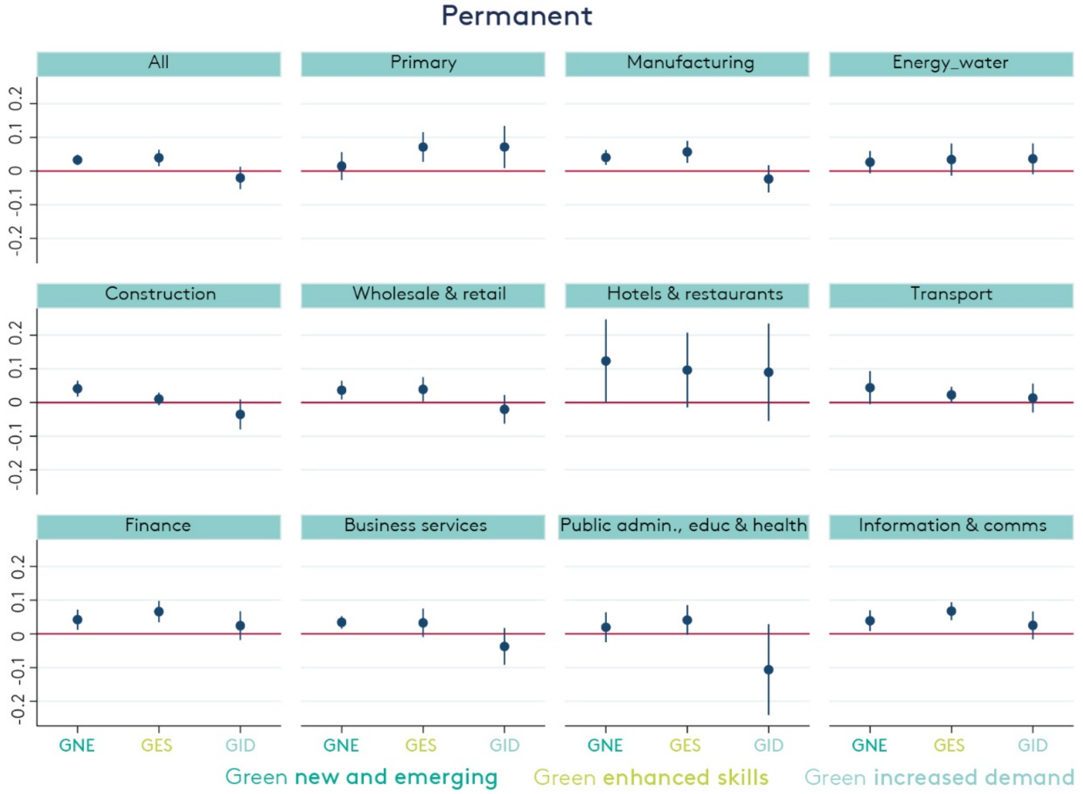
Notes: 'All' replicates Table 4.2, column 1. 3-digit industry dummies are included in all specifications. The remaining charts restrict the sample to the sector as labelled, and sector fixed effects are therefore not included. The dots show the estimated coefficients on GNE, GES and GID respectively and the bars show the 95% confidence intervals. The sector category 'other services' is left out.

Figure B3. Training received and the greenness of jobs in the UK, by sector



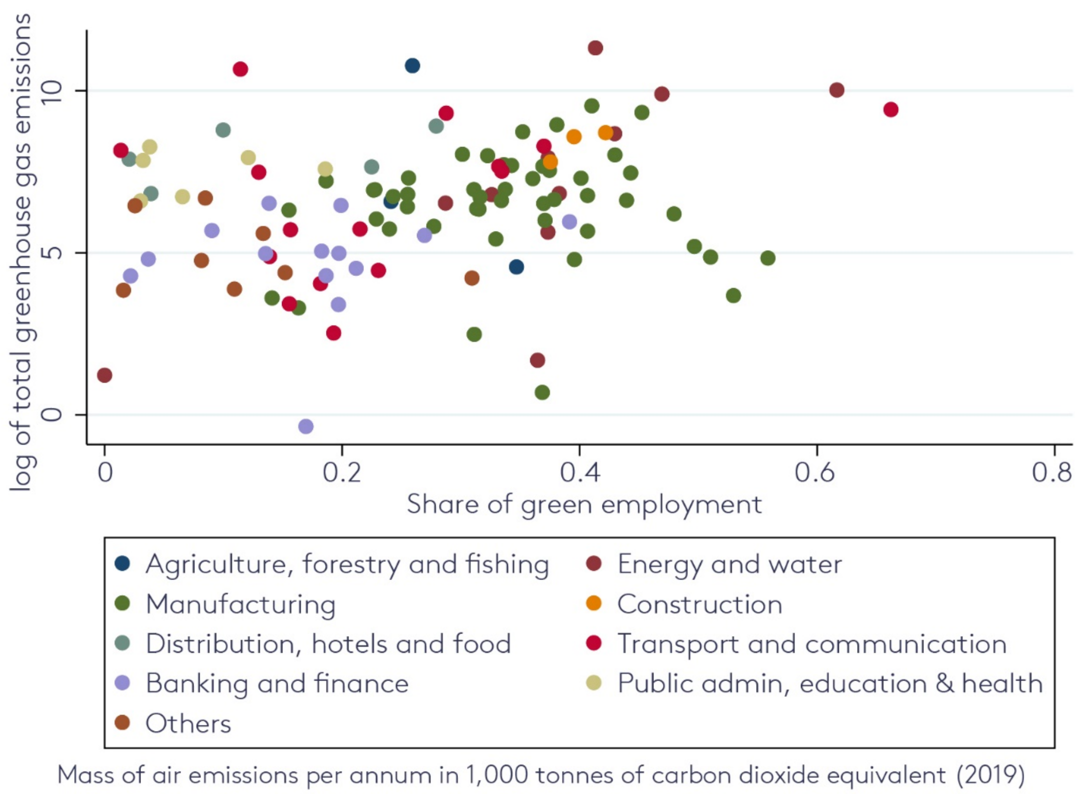
Notes: 'All' replicates Table 4.2, column 4. 3-digit industry dummies are included in all specifications. The remaining charts restrict the sample to the sector as labelled, and sector fixed effects are therefore not included. The dots show the estimated coefficients on GNE, GES and GID respectively and the bars show the 95% confidence intervals. The sector category 'other services' is left out.

Figure B4. Permanent contracts and the greenness of jobs in the UK, by sector



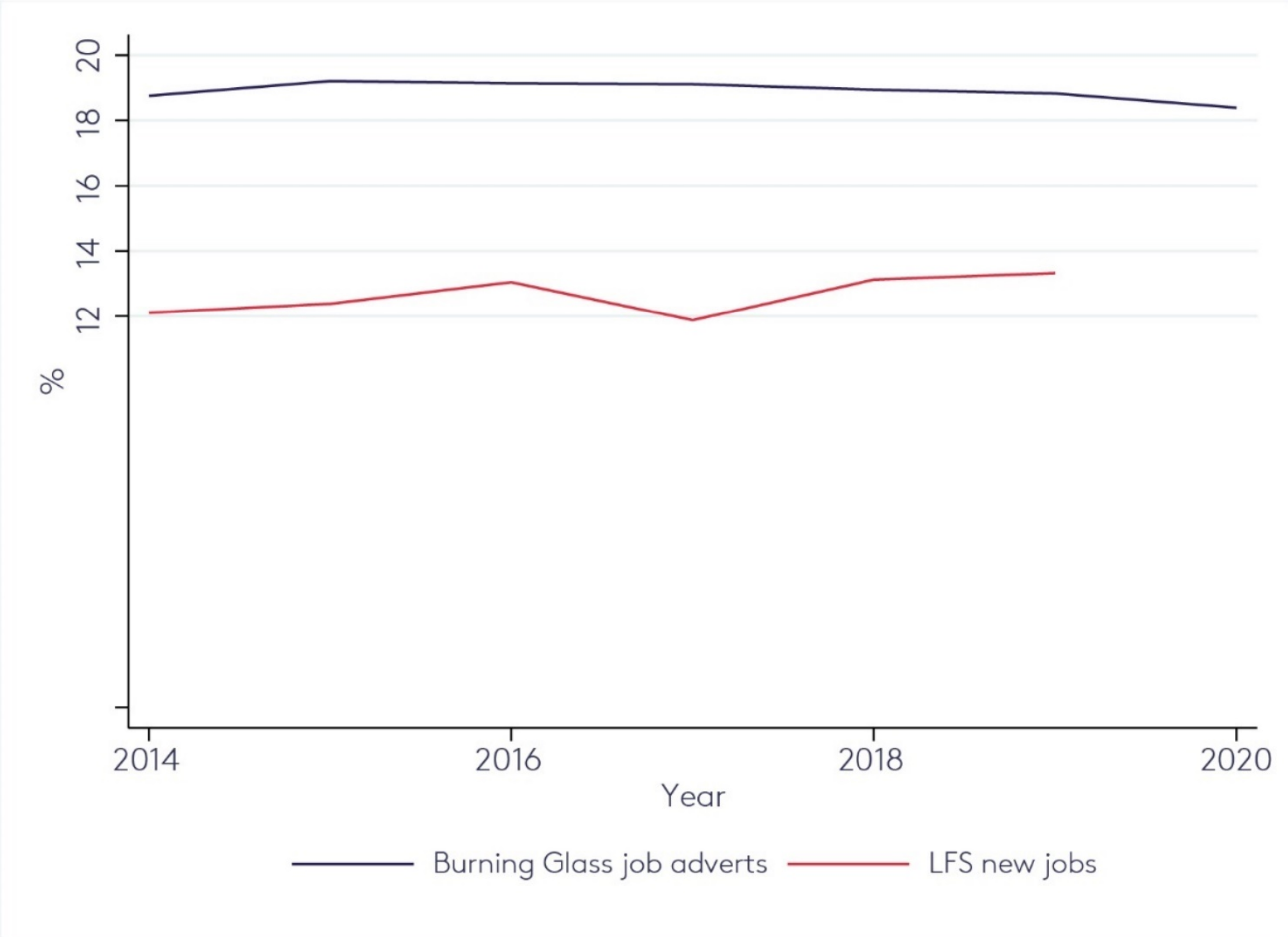
Notes: 'All' replicates Table 4.2, column 5. 3-digit industry dummies are included in all specifications. The remaining charts restrict the sample to the sector as labelled, and sector fixed effects are therefore not included. The dots show the estimated coefficients on GNE, GES and GID respectively and the bars show the 95% confidence intervals. The sector category 'other services' is left out.

Figure B5. Sectoral emissions and share of green jobs in the UK (2019)



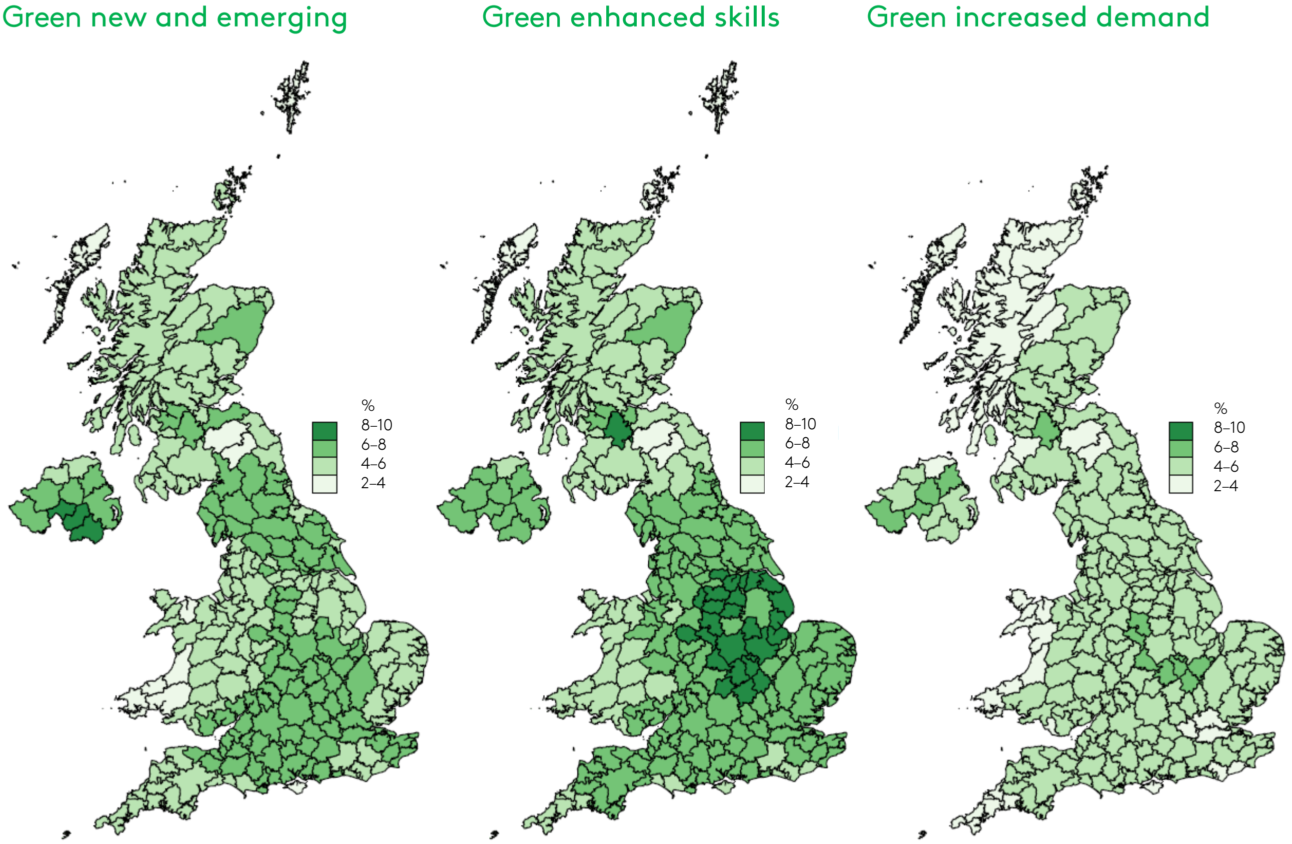
Notes: Sectoral emissions are plotted against averages of the green mean occupational classifications across 125 2-3 digit SIC codes at which level greenhouse gas emissions are available from ONS, which are broadly grouped and colour coded into the sectors in the legend.

Figure B6. Trends in the share of new 'green' jobs



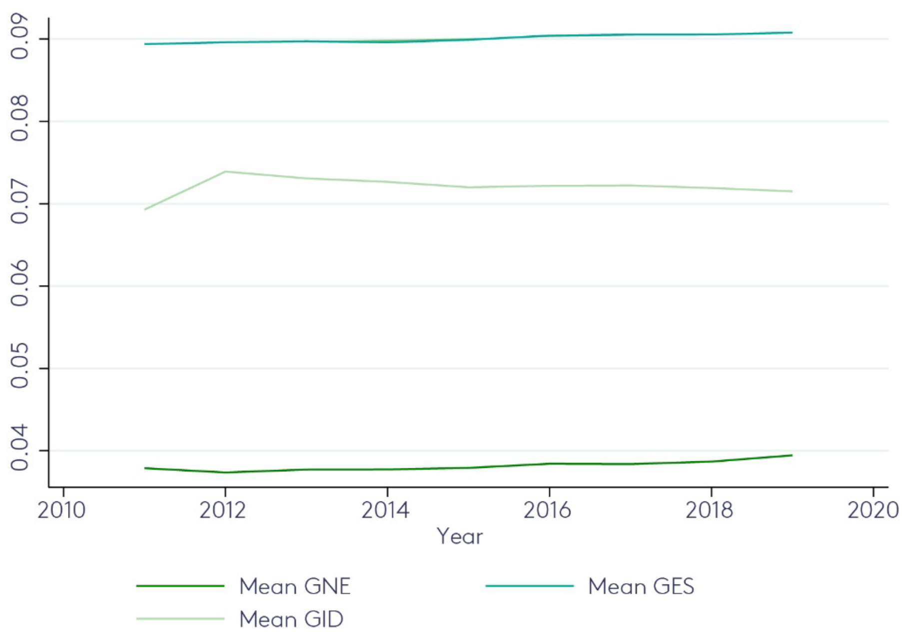
Notes: This figure illustrates the evolution of the share of green jobs (%) in Burning Glass job adverts (blue line) and Labour Force Survey (LFS) new jobs (red line) over time using the 'mean' approach. LFS new jobs were defined by a sample of people who had been with their current employer for less than one year.

Figure B7. Share of 'green' job vacancies (%) across the UK (2020)



*Notes: Analysis based on BGT vacancies data for 2020 using O*NET based occupational mappings (mean approach). The geographical unit is the travel to work areas (TTWAs) 2011. Exceptions include the merging of TTWA 'London' with 'Slough and Heathrow' and 'Bournemouth' with 'Poole' to accommodate the less disaggregation of original geographical units used in BGT data.*

Figure B8. Time trends in green job shares in the EU15



Notes: This figure illustrates the evolution of the share of GNE, GES and GID jobs (%) over time using the 'mean' approach.

Appendix C. Estimating green jobs in emerging markets – overview of the literature

Approach	Report title	Authors (year)	Country/ region	Green employment share and year
Top-down				
Subset of industries	People's Republic of China: Strategies for Green Jobs Creation and Promotion	Dongliang, Z. (2014)	China	19% in 2011 (direct + indirect)*
	Study on Green Employment in China	Institute for Labor Studies and Ministry of Human Resources and Social Security (2010)	China	3% in 2007/2008 (direct)*
	Assessment and Model of Green Jobs Potential in India	Sinha et al. (2018)	India	1% in 2009/2010 (direct)
	Green jobs mapping study in Malaysia	International Labour Organization (2014)	Malaysia	2% in 2009/2010/2011 (direct)*
	Evaluation of the Potential of Green Jobs in Mexico	International Labour Organization (2013)	Mexico	4.5% in 2011 (direct)
	Green Jobs in Tunisia: Measuring Methods and Model Results	Lehr et al. (2018)	Tunisia	3% in 2010 (direct)*
Combination				
Based on industry- and firm-level data	Green jobs assessment: Mauritius	Sultan and Harsdorff (2014)	Mauritius	6.3% in 2010/2011 (direct)

** Calculation of employment share based on total employment data from the World Bank.*