View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by LSE Research Online

LSE Research Online

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Alex Bowen, Karlygash Kuralbayeva and Eileen L. Tipoe

Characterising green employment: the impacts of 'greening' on workforce composition

Article (Published version) (Refereed)

Original citation:
Bowen, Alex and Kuralbayeva, Karlygash and Tipoe, Eileen L. (2018) *Characterising green employment: the impacts of 'greening' on workforce composition*. Energy Economics, 72. pp. 263-275. ISSN 0140-9883
DOI: 10.1016/j.eneco.2018.03.015

© 2018 the Authors

This version available at: http://eprints.lse.ac.uk/87472/
Available in LSE Research Online: August 2018

LSE has developed LSE Research Online so that users may access research output of the School. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LSE Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain. You may freely distribute the URL (http://eprints.lse.ac.uk) of the LSE Research Online website.

http://eprints.lse.ac.uk

Energy Economics 72 (2018) 263–275

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Characterising green employment: The impacts of 'greening' on workforce composition☆

Alex Bowen[a], Karlygash Kuralbayeva[b,*], Eileen L. Tipoe[c]

[a] Grantham Research Institute, London School of Economics, United Kingdom
[b] Department of Geography and Environment, London School of Economics, United Kingdom
[c] Department of Economics, University of Oxford, United Kingdom

ARTICLE INFO

Article history:
Received 30 March 2017
Received in revised form 28 February 2018
Accepted 5 March 2018
Available online 3 April 2018

JEL classification:
J24
J21
O33
J62
O51

Keywords:
Skills
Occupational choice
Green employment
Green economy

ABSTRACT

This paper estimates the share of jobs in the US that would benefit from a transition to the green economy, and presents different measures for the ease with which workers are likely to be able to move from non-green to green jobs. Using the US O*NET database and its definition of green jobs, 19.4% of US workers could currently be part of the green economy in a broad sense, although a large proportion of green employment would be 'indirectly' green, comprising existing jobs that are expected to be in high demand due to greening, but do not require significant changes in tasks, skills, or knowledge. Analysis of task content also shows that green jobs vary in 'greenness', with very few jobs only consisting of green tasks, suggesting that the term 'green' should be considered a continuum rather than a binary characteristic. While it is easier to transition to indirectly green rather than directly green jobs, greening is likely to involve transitions on a similar scale and scope of existing job transitions. Non-green jobs generally appear to differ from their green counterparts in only a few skill-specific aspects, suggesting that most re-training can happen on-the-job. Network analysis shows that the green economy offers a large potential for short-run growth if job transitions are strategically managed.

© 2018 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

1. Introduction

The green growth transition ('greening') has been called a modern-day industrial revolution due to its expected large structural impact on labour markets worldwide (Bowen et al., 2016). According to the United Nations Environment Programme (UNEP, ILO, IOE, ITUC, 2008), a 'green economy' is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.[1] Policy-makers have two main goals for the green economy: managing the transition to green jobs and promoting green economic growth (Martinez-Fernandez et al., 2010). The impact on employment is one important way for policy-makers to assess the effects of environmental policies pursuing these goals. However, the definition of a 'green job' is not universal.[2] For example, a secretary might be considered a 'green' worker if employed in a firm in the renewable energy sector, but 'non-green' if the firm is in the non-renewable energy sector, even if the tasks carried out and skills required are essentially the same. Since policy analysis depends heavily on how green jobs are defined, standardised criteria to classify jobs as 'green' need to be adopted.

To do so would require identification of the fundamental differences between green and non-green jobs. Are there skills specific to green jobs, or does the label 'green' merely reflect the type of job to which the same skills are applied? The similarity of skills used in green and non-green jobs can help determine the content of re-training programmes. If the skill sets required for green

☆ The authors would like to acknowledge the support of the UK's Economic and Social Research Council (ESRC), and the Grantham Foundation for the Protection of the Environment. We are grateful to Victoria Druce, Stefania Lovo, Francesco Vona, and Bob Ward for helpful comments and suggestions.

* Corresponding author.
E-mail address: k.z.kuralbayeva@lse.ac.uk (K. Kuralbayeva).

[1] See http://www.unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx.

[2] See, for example, Pociovalisteanu et al. (2015) and Connolly et al. (2016). Winter and Moore (2013) and Furchtgott-Roth (2012) list several different definitions of 'green job', as stated in reports by government organisations, NGOs, and academics researching green jobs. Bowen and Kuralbayeva (2015) discuss differences in the criteria used by various organisations to define 'green job' and compare estimates of green employment based on these definitions.

https://doi.org/10.1016/j.eneco.2018.03.015
0140-9883/ © 2018 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

jobs are largely different from their non-green counterparts, then non-green workers may need extensive off-the-job training to supplement on-the-job training, in order to enable the transition to the green economy.

Literature findings suggest that job-specific skills can reduce labour market flexibility and hamper economic transitions. Wasmer (2006) finds that economies with job-specific skills do well in the absence of shocks but face high transition costs. Lamo et al. (2011) also find that more specialised workers experience more difficulties in responding to economic changes such as sectoral demand shifts, resulting in longer unemployment duration spells. Structural change may be accompanied by higher and persistent unemployment if there is a shortage of workers with suitable skills, since the more specialised workers may require costly and lengthy re-training to integrate with the new economic environment. Identifying the similarities in skill content of green and non-green jobs can help determine the re-training needed to enable the transition to the green economy.

Although the literature on green jobs is expanding[3], the research on skill needs for green growth is still patchy. Fankhauser et al. (2008) note that there is relatively little information on the productivity, pay and other attributes of jobs created and destroyed by climate-change policies. Cedefop (2010) complains that 'We have not paid enough attention to the social dimension of sustainable development: its implications for employment, training and skills.' Even in countries with relatively good labour market data, it is difficult to identify which job skills are most likely to be affected by green growth policies. For example, Hatfield-Dodds et al. (2008) note that in Australia 'current information on green skills and workforce capabilities is very poor.'

Recently, academic studies have used the O*NET database for insights on the nature of green jobs. O*NET, developed by the US Department of Labour, is a cross-sectional database that contains detailed occupation-level information on the tasks and skills involved, and a list of green tasks that are unique to green jobs.[4] Vona, Marin, Consoli, & Popp[5] (VMCP) use O*NET's task information to construct a measure of 'greenness', and identify four general categories of green skills (engineering and technical, science, operation management, and monitoring). They find that green occupations are less routine-intensive and higher-skill than non-green occupations, and require high-level analytical and technical skills related to technology. Similarly, Consoli, Marin, Marzucchi, & Vona[6] (CMMV) find that green jobs involve more high-level abstract skills, and require more education, work experience, and on-the-job training.

CMMV also construct a measure of 'skill distance', based on the conceptual framework of Autor et al. (2003), which indicates the extent of re-training required to transition from one job to another. For example, the skill distance (and hence required re-training) would be smaller between a marketing manager and a sales manager than between a marketing manager and a software developer. CMMV find considerable variation both within and among major occupational groups (as defined by the Standard Occupation Classification (SOC) system). There is some evidence that engineers, scientists, and operation managers have the smallest skill distance across jobs, whereas the largest skill differences are concentrated in a few low- and medium-skill occupations.

We aim to build on existing literature by examining the differences in task and skill composition both *between* and *within* job categories, using O*NET's green job subcategories and self-defined non-green subcategories. We also use these subcategories to estimate the proportion employed in the US green economy and explore some issues with defining green jobs. Using O*NET's new supplementary data files, we construct alternative measures for the ease of transition from non-green jobs to similar green occupations, and investigate the potential long-term effects of greening on career paths.

Our findings support those of VMCP and CMMV, and provide new insights for policymakers on the nature of green jobs as well as the ease of transition to green jobs:

- Using O*NET's broad definition of green jobs, 19.4% of the US workforce could currently be part of the green economy, although a large proportion of green employment would be 'indirectly' green.
- Green jobs vary in 'greenness' (the use and importance of green tasks), with very few jobs only consistent of green tasks, suggesting that the term 'green' should be considered as a continuum rather than a binary characteristic.
- Greening is likely to involve transitions on a similar scale and scope of existing job transitions. Although it is easier to transition to indirectly green rather than directly green jobs, non-green jobs generally appear to differ from their green counterparts in only a few skill-specific aspects, suggesting that most re-training can happen on-the-job. The green economy therefore has large potential for short-run growth, if job transitions are strategically managed.

2. The share of jobs affected by greening

2.1. Data

To estimate the proportion of jobs in the US that would benefit from a transition to the green economy, we use O*NET v19.0 (released July 2014), and employment data from the Bureau of Labor Statistics (BLS). O*NET counts any occupation that will be affected by greening as a green job[7], and defines 3 subcategories of green jobs according to the effect that greening will have on the tasks, skills, and knowledge required for the job:

1) **Green Increased Demand** (Green ID) are existing jobs that are expected to be in high demand due to greening, but do not require significant changes in tasks, skills, or knowledge. These jobs are considered as indirectly green because they support green economic activity, but do not involve any green tasks.
2) **Green Enhanced Skills** (Green ES) are existing jobs that require significant changes in tasks, skills, and knowledge as a result of greening.
3) **Green New and Emerging** (Green NE) are unique jobs (as defined by worker requirements) created to meet the new needs of the green economy.

In the short term, the greening of the US economy will affect Green ID occupations more heavily, whereas Green ES and Green NE jobs will probably play a larger role in the medium and long term, as

[3] For example, some US studies estimate the effects of clean energy policy on green employment and green business development (Yi, 2013, 2014). Other studies focus on the differences between jobs in the non-renewable and renewable energy sector, analysing determinants of the wage differential across sectors (Antoni et al., 2015) or estimating the cost (in USD) of the job transition to the renewable energy sector (Louie and Pearce, 2016). Studies on other labour markets in both developed and developing countries find that green job creation is projected to increase over the next few decades, driven by policy initiatives such as energy efficiency requirements and investment in sustainable tourism (Aceleanu, 2015; Lehr et al., 2012).

[4] Data are updated regularly (around once every 1–2 years).

[5] Vona et al. (2017).

[6] Consoli et al. (2015).

[7] See Appendices A.1 and A.2 for a comparison of O*NET's approach with other standard definitions, and further details on O*NET's procedure for classifying green jobs.

workers acquire the knowledge and training needed to transition to these jobs.

We use O*NET's supplementary data to further classify non-green jobs as 'Green Rival' or 'Other'. In 2012, O*NET added information about which jobs are considered 'similar', according to job-specific aspects (similar jobs labelled as 'Career Changers') or worker-specific aspects ('Career Starters'), for a subset of listed occupations (858 out of 974). The differences between Career Changers and Career Starters are more relevant to our discussion in Section 4, so we leave formal definition and further explanation of these terms until then.

Occupations classified as Other are non-green, with all similar occupations also listed as non-green. These occupations are less likely to be affected (at least in the short term) by the greening of the economy, because of their lack of similarity to green occupations.[8] All other non-green occupations (with at least one similar occupation that is green) were classified as Green Rival. These occupations are likely to be affected by the greening of the economy because of their similarity to existing green occupations. A glossary box of terms used throughout this paper is in Appendix A.4.

Fig. 1 shows how O*NET jobs were categorised, along with an example of the data available for each occupation in the supplementary data files (for all other occupations, only tasks and skills information are available). Each occupation belongs to one of the five job subcategories (Green Rival, Other, Green ID, Green ES, Green NE) and has ten Career Changers and ten Career Starters[9], along with qualitative and quantitative information on tasks and skills. The supplemental data files had information on 538 Green Rival jobs, 149 Green jobs[10], and 171 other jobs.

O*NET data was matched with BLS employment data via the Standard Occupational Classification (SOC) code, an eight-digit number that uniquely identifies occupations. The first two digits of the SOC code give the major occupational group, the middle four digits give the broad occupation, and the last two digits give the specific occupation in that group.[11] Data were only available for broad occupations (the first six digits of the eight-digit SOC code).[12] As in previous literature (such as VMCP (2017)), this limitation was addressed by assuming an equal distribution of workers across all specific occupations within each broad occupation.[13] This is not a major limitation for most of our analysis, which focuses on tasks and skills, because information on these are available at the occupation level.

Another limitation with the BLS data is that at the state level, some employment information is missing for some 6-digit SOC codes but is available at the 2-digit level, so the sum of employment across all 6-digit occupations in each state may not add up to the reported total state employment.[14] This missing data issue affects 1.6–8.4% of all 6-digit SOC codes per state (accounting for 2% of state employment on average), and usually more than one observation per 2-digit group is affected, so it is impossible to impute the missing data from the information given. Since we cannot resolve this issue, we chose to classify any missing data in the Other jobs subcategory, so our estimate of green employment is conservative in that sense.[15] However, this limitation is only present at the state level, so it only affects the estimates of state-level employment shown in Table 15 in the Supplementary material. Also, VMCP (2017) note that employment data from other sources are at a more aggregated level than the BLS data.[16] Therefore, the BLS data is currently the best source to use for our employment estimates, despite the limitations described.

2.2. Green employment estimates

BLS employment data for each broad occupation in 2014 was aggregated by job subcategory (Green Rival, Other, Green ID, Green ES, Green NE) to calculate the potential proportion employed in each job category for each US state in 2014 (Supplementary material, Table 15). While the workforce size varies across states, the share of employment that could be involved in green economic activity (either directly or indirectly) is quite similar across most states, ranging from 13 to 25%.

One interesting point to note is that even states with a large natural resource industry (such as Wyoming) have a substantial potential for greening, with a similar proportion of employment in Green Rival jobs (40.8%) compared to other states. This potential is because natural resource workers have similar skills to those required for green jobs. These findings are consistent with those of Louie and Pearce (2016), who estimate that a relatively minor investment in retraining of coal workers (0.0052–0.0543% of the US federal budget) would enable the vast majority of them to transition to jobs in the solar photovoltaic industry. Also, the relatively high proportion of employment in Green ID jobs is due to a large proportion of workers having occupations that could be part of a low-carbon economy in some shape or form, including labourers (such as carpenters and electricians), first line supervisors, and customer service representatives. It is important to bear O*NET's broad definition of green employment in mind when interpreting these results.

At the national level, 19.4% of workers could currently have green jobs (both directly and indirectly green), 44.3% are in Green Rival jobs, and 36.3% have Other jobs. The estimates of Green ID and Green ES employment indicate that the proportion of jobs affecting by greening becomes much larger when including jobs that support the green economy or are not specific to green economic activity. The substantial percentage of workers in Green Rival jobs suggests that there is some potential for greening employment further in the short term. The large proportion of employment in 'Other' jobs suggests that many workers will be unaffected by the greening of the economy, at least in the short term.

This O*NET-based estimate of the proportion of jobs that could currently be involved in the green economy in 2014 is much larger than the 2011 BLS estimate of 2.6%, but this difference is largely due to the way that green jobs are defined. The O*NET definition is broader and includes all jobs that will be affected by or can support green economic activity (which do not necessarily involve green tasks), whereas the BLS definition is restricted to jobs directly involved in green economic activity (which must involve green

[8] Examples include police patrol officers, bartenders, and surgeons.

[9] Some occupations in this subset had fewer than 10 Career Changers, but all occupations in this subset had 10 Career Starters.

[10] Information about similar occupations was not available for most Green NE jobs (54 out of 78 Green NE jobs).

[11] For example, in the eight-digit SOC 11-3051.02, 11 refers to the occupational group 'Management', 3051 is the broad occupation 'production managers', and 02 is the specific occupation 'Geothermal production managers'. For more information about the SOC system and classification, see http://www.bls.gov/soc/socguide.htm.

[12] 681 broad (6-digit) occupations had only one specific (8-digit) occupation, so these could be matched perfectly to the BLS data. These occupations constituted 72.2% of all O*NET listed occupations. For the remaining 6-digit occupations, the average number of 8-digit occupations is 3, with a median of 2, standard deviation of 1.8, and maximum of 12.

[13] For example, the broad occupation 'Carpenters' (SOC code 47-2031) consists of three specific occupations: Construction Carpenters (47-2031.01), Rough Carpenters (47-2031.02), and Carpenters (all other types) (47-2031.00). Since Construction Carpenters and Rough Carpenters are both green jobs but the other category of carpenters is a non-green job, our estimate of green employment in this broad occupation is two-thirds of the total employment in Carpenters (47-2031).

[14] The BLS data documentation states that there are some 6-digit occupations where the employment estimate is not released, but there is no further explanation for this omission.

[15] A minor issue with the BLS data is that employment figures are rounded to the nearest 10 workers. While rounding could lead to overestimates, in practice this led to discrepancies of at most 50 workers when comparing 2-digit totals and their 6-digit subtotals. Therefore, the missing data issue is a larger limitation.

[16] For example, the American Community Survey has employment figures but at the 5-digit or even 3-digit SOC level only, making the estimates of green employment even more imprecise.

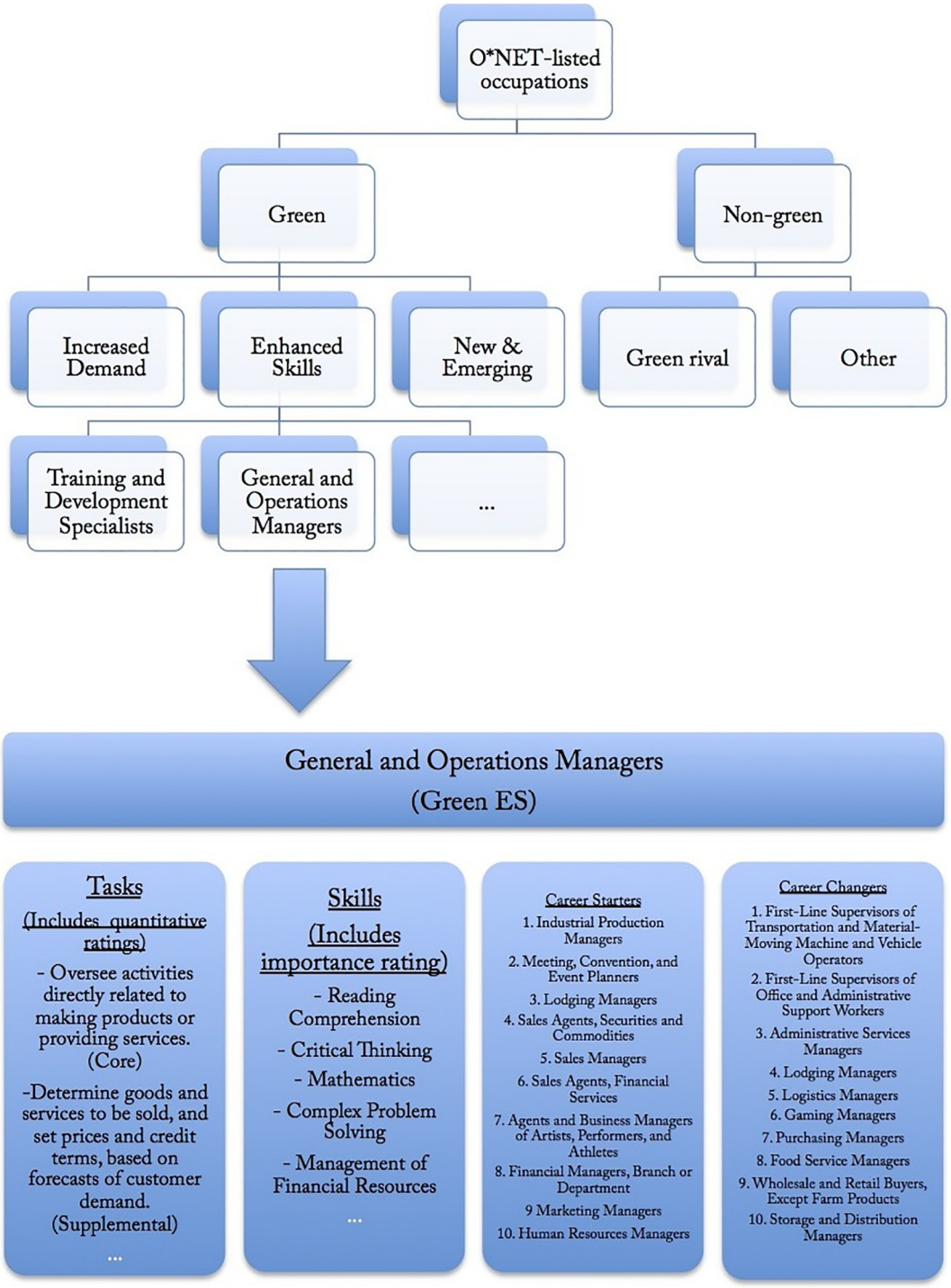

Fig. 1. Visual representation of job types and O*NET data available for each occupation.

tasks). The employment share of 1.2% in Green NE jobs (the O*NET job subcategory that most closely fits the BLS definition) is more in line with the BLS estimate, and suggests that our assumption used to match the O*NET and BLS data for employment estimates is reasonable at an aggregate level. This analysis emphasises the importance of having a standardised definition for green jobs, in order to compare green employment estimates over time and across studies.

Heterogeneity in green employment shares is sectoral, not regional. Table 1 shows employment shares by job subcategory for each of the 20 sectors used by the BLS. Employment shares vary considerably by sector, with some sectors such as healthcare and accommodation/food services being mostly non-green whereas other sectors such as utilities and construction could have a considerable proportion of workers in green jobs (albeit indirectly green). However, in most sectors there is again a large proportion of employment in 'Other' jobs. For all sectors, the proportion of workers in directly green jobs is very small (employment in Green NE jobs is around 1% for most sectors), with Green ID (indirectly green) jobs potentially making up most of the total green employment. Thus, even though a small proportion of workers in the US are currently

Table 1
Employment shares by sector, ranked by total green employment.

Sector	Green Rival	Green ID	Green ES	Green NE	Other	Directly green	Total green
Construction	29.8	29.6	29.6	0.5	10.5	30.1	59.7
Utilities	32.2	30.1	23.6	2.6	11.5	26.3	56.3
Manufacturing	42.2	31.7	17.1	1.1	7.8	18.3	50.0
Transportation/warehousing	45.2	18.9	26.4	0.8	8.7	27.2	46.1
Mining	49.2	15.0	26.4	1.5	8.0	27.9	42.8
Wholesale trade	50.9	15.4	17.7	0.8	15.1	18.6	34.0
Management (companies and enterprises)	53.8	7.1	14.2	4.8	20.1	19.0	26.1
Real estate, rental, leasing	42.8	5.9	19.0	0.6	31.7	19.6	25.5
Professional, scientific, and technical services	55.8	7.1	13.6	3.4	20.1	16.9	24.1
Administrative and support	52.4	15.2	8.0	0.7	23.6	8.7	24.0
Federal, state, and local government	48.9	6.1	8.0	4.7	32.3	12.8	18.8
Information	60.6	7.6	8.0	1.7	22.1	9.8	17.3
Other services	41.2	5.8	9.8	0.9	42.2	10.8	16.6
Finance and insurance	66.3	5.1	8.5	1.7	18.5	10.1	15.2
Agriculture/forestry	81.2	4.9	5.7	0.1	8.0	5.8	10.8
Retail trade	57.9	4.3	4.6	0.1	33.1	4.7	9.0
Arts, entertainment, and recreation	31.4	3.0	4.8	0.6	60.3	5.3	8.3
Educational services	52.9	0.9	2.1	0.9	43.3	2.9	3.8
Healthcare	28.2	0.8	1.7	0.3	69.0	2.0	2.9
Accommodation and food services	23.2	0.3	1.6	0.0	74.9	1.6	1.9

Table 2
National annual wage quartiles (USD), by skill-level and job subcategory.

Skill-level	Job type	25th %ile	50th %ile	75th %ile
Low	Green Rival	25,983	32,022	39,834
	Green ID	29,494	36,904	46,407
	Green ES	29,777	37,576	47,243
	Green NE	36,607	46,799	59,518
	Other	22,680	27,327	33,684
Medium	Green Rival	38,780	49,543	63,150
	Green ID	43,031	53,641	66,381
	Green ES	43,390	56,914	72,724
	Green NE	48,381	63,404	82,548
	Other	32,064	39,740	49,318
High	Green Rival	56,950	73,954	93,561
	Green ID	54,315	68,936	86,148
	Green ES	62,039	79,931	101,759
	Green NE	63,430	80,402	99,166
	Other	60,033	72,949	84,855

involved in green economic activity, a significant proportion of the workforce will be affected by greening.

3. Green vs. non-green: key differences

Aside from providing a useful framework to evaluate the effects of greening, O*NET's green job subcategories represent distinct types of green jobs, according to standard characteristics such as wages, tasks involved, and skills required. Table 2 shows wage quartiles for each job subcategory and skill level[17], taken as a simple average over the respective quartiles for each broad occupation.[18] There is a clear distinction in the wage distribution of Green NE jobs compared with other green and non-green subcategories, with Green NE jobs generally being higher-wage regardless of skill level. There are also noteworthy differences between non-green subcategories, with Green Rival jobs having a more concentrated distribution with a lower median compared to Other jobs.

The differences in task composition of green subcategories also motivates O*NET's definition of green employment, and suggests that 'green' should be considered as a continuum rather than a binary category. For each occupation, O*NET lists all tasks involved, along with the task frequency (ranging from 1 = yearly or less, to 7 = hourly or more), importance (ranging from 1 = not important, to 5 = extremely important), and relevance (ranging from 0 = not relevant, to 100 = completely relevant). O*NET also indicates whether a task is considered 'green' or not.

For each occupation, the share of green tasks was calculated as the number of green tasks divided by the total number of tasks. The average proportion of green tasks within each green job subcategory is shown in Table 3. Despite these 204 occupations being given the same label 'green', there is considerable variation in the proportion of green tasks used across subcategories. On average, Green NE jobs involve more green tasks than the other two types, with over half the tasks considered as green. When comparing across skill levels, on average, high-skill Green ES jobs involve proportionately more green tasks than do low/medium skill Green ES jobs, though high-skill Green NE jobs involve proportionately fewer green tasks (Table 4). Although some tasks are unique to green jobs, the fact that a significant proportion of tasks are used in both green and non-green jobs

Table 3
Share of green tasks (green jobs only).

% green tasks	Mean	SD	Min	Max	N
Green ID	0	0	0	0	64
Green ES	0.304	0.258	0.037	1	62
Green NE	0.594	0.403	0.083	1	78

Table 4
Share of green tasks, by skill level.

	Skill-level	Mean	SD
Green ES	Low	0.270	0.315
	Medium	0.236	0.125
	High	0.361	0.287
Green NE	Low	0.885	0.305
	Medium	0.555	0.429
	High	0.493	0.389

[17] An occupation's skill level was determined using the O*NET variable entitled 'job-zones', which is a number ranging from 1 to 5 that indicates the level of knowledge, experience, and training required for the job (1 = no preparation required, 5 = extensive preparation required). For our analysis, an occupation with a job-zone of 1 or 2 (some or no preparation needed e.g. waiters, taxi drivers) is considered low-skill, a job-zone of 3 (medium preparation needed e.g. electricians, secretaries) is medium-skill, and job-zone of 4 or 5 (considerable or extensive preparation needed e.g. lawyers, surgeons) is high-skill.

[18] For example, if the median wage for occupation A was 50,000 and the median wage for occupation B was 30,000, then the reported figure is the average of these two figures (40,000).

Table 5
Comparison of task content across green subcategories.

		Frequency		Importance		Relevance	
Green subcategory	Task type	Mean	SD	Mean	SD	Mean	SD
Green ID	Non-green	2.93	1.19	3.86	0.45	3.86	1.09
	Green	N/A	N/A	N/A	N/A	N/A	N/A
Green ES	Non-green	2.66	1.13	3.82	0.47	3.79	1.06
	Green	2.09	1.07	3.58	0.52	3.27	1.32
Green NE	Non-green	2.15	0.85	3.67	0.44	4.34	0.74
	Green	2.26	1.08	3.72	0.49	3.94	1.08

suggests considerable similarities between these categories, which may facilitate the transition to green jobs.

Green NE jobs also differ from the other two green job subcategories in other task-related aspects. Table 5 compares the frequency, importance, and relevance of green and non-green tasks across subcategories (on a scale of 1 to 5, with higher numbers representing higher frequency/importance/relevance). On average, Green New & Emerging jobs use both green and non-green tasks with similar frequency whereas other green job subgroups use non-green tasks more frequently. Interestingly, although Green NE and Green ES jobs are directly green, on average non-green tasks have a higher relevance than green tasks. Green NE jobs have a similar number of green and non-green core (essential) tasks whereas Green ES jobs have a greater number of core tasks that are non-green (Supplementary material, Table 16). Since Green NE jobs are likely to play a more prominent role in the green economy in the long run, these differences suggest that green jobs will become 'greener', by involving more green tasks that are important for the job and using them more frequently.

Aside from differences in task content, there are also clear distinctions in the skill composition and other standard job characteristics of both green and non-green subcategories, suggesting that 'non-green' should also be considered as a spectrum rather than a binary category. Table 6 shows the average skill level (1 = low-skill, 2 = medium-skill, 3 = high-skill) for the five job subcategories. Skill level increases with 'greenness', with most Green NE jobs being high-skill whereas a large proportion of Green ID (indirectly green) jobs are low-skill. On average, Other jobs are slightly higher-skill than Green Rival jobs, and Green Rival jobs are similar in skill level to Green ID jobs.

Table 6
Mean skill level, by job type.

Job type	Mean	SD	N
Green Rival	1.93	0.85	538
Green ID	1.81	0.83	64
Green ES	2.27	0.79	62
Green NE	2.56	0.71	57
Other	2.09	0.83	171

Table 7
Summary statistics of 3 standard skill measures.

Skill measure	Job type	Mean	SD
Education	Green Rival	4.07	2.69
(1–12 scale)	Green ID	3.34	1.95
	Green ES	4.57	2.11
	Green NE	5.34	1.80
	Other	5.42	3.90
Experience	Green Rival	4.95	2.90
(1–11 scale)	Green ID	4.75	2.97
	Green ES	6.13	2.59
	Green NE	6.61	2.09
	Other	4.30	2.91
Training	Green Rival	3.53	1.72
(1–8 scale)	Green ID	4.35	1.64
	Green ES	4.68	1.63
	Green NE	4.01	1.36
	Other	2.36	1.38

Table 7 summarises three standard skill measures (education, experience, and training) for each job subcategory. For each of these skill measures, O*NET provides a number that represents the required qualification or time interval of experience/training before workers can begin that job (the categories and numerical range differs across skill measures). Among the green job types, Green NE jobs require the most education[19], most experience[20], and the least amount of training (though green job types are the most similar in this aspect, requiring on average 3–6 months of training). Compared with non-green jobs, green jobs require more on-the-job training. There are also differences between Green Rival and Other jobs, with the latter category requiring more education and less on-the-job training. Hence, re-training will likely involve a combination of on-the-job training with additional education or qualifications.[21]

Academic literature has proposed other ways to compare the skill content of jobs. CMMV use the framework of Autor et al. (2003), in which tasks are classified according to repetition (routine vs. non-routine), interaction with others (interactive), and degree of physical exertion required (cognitive vs. manual), resulting in 5 general task categories: Non-routine cognitive/analytical, Non-routine interactive, Non-routine manual, Routine cognitive and Routine manual. CMMV identify the basic skills listed in O*NET that are required to carry out each of these types of tasks[22], and take a simple average of their importance ratings.[23] The Routine Task Intensity Index (Autor et al., 2013) is also used as a measure of the importance and frequency of routine tasks in comparison to non-routine tasks. This index is constructed by taking the (log) difference of the routine and non-routine task scores (calculated as a simple average of the basic

[19] 5 = 2-year or bachelor's degree, compared with 3 = post-secondary certificate or 4 = some college.
[20] 6 = 1–2 years, compared with 4 = 3–6 months for non-green or indirectly green jobs.
[21] For example, a Surveyor would require both off-the-job training and on-the-job training to transition to a Soil and Water Conservationist (Green ES), a job which only involves green tasks. Tasks that may require additional education or off-the-job training specific to soil conservation include 'apply principles of specialised fields of science such as agronomy, soil science, forestry, or agriculture, to achieve conservation objectives' and 'develop water conservation or harvest plans, using weather information systems, irrigation information management systems, or other sources of daily evapotranspiration (ET) data', whereas some tasks such as 'visit areas affected by erosion problems to identify causes or determine solutions' can be learnt on-the-job.
[22] For example, non-routine analytical tasks involve 1) 'analysing data or information', 2) 'thinking creatively', and 3) 'interpreting the meaning of information for others'.
[23] Each of the skills is given an importance rating (1 = not important, 5 = very important) for a particular occupation.

skill variables as before), so jobs that rely more on routine tasks would have a higher score than jobs that mainly rely on non-routine tasks.

Tables 17 and 18 (Supplementary material) summarise these measures for each job subcategory. Non-routine tasks (in particular non-routine analytical and interactive) appear to be more important for Green NE jobs compared with other job subcategories. On average, Green NE jobs, which are mostly high-skill, also rely less on manual skills whereas Green ID jobs, which are mostly low-skill, rely the most on manual skills among all job subcategories. These findings correspond with those of CMMV, but there is also considerable variation within green and non-green subcategories that must be taken into account. Although Green Rival and Other jobs are similar in some aspects, manual skills are more important for Green Rival jobs than Other jobs, and Green Rival jobs are also more routine-task-intense. Since Green Rival jobs differ from Green ID and Green ES jobs in a few specific dimensions, these transitions may only require on-the-job training, whereas transitions to Green NE jobs may require additional education to supplement on-the-job training.

Overall, our comparison of task and skill content between green and non-green jobs suggests that

- Some tasks are unique to Green jobs, but a significant proportion of tasks are common to Green and non-green jobs.
- 'Directly' green jobs (Green ES and NE) require more on-the-job training, education, and experience compared to non-green jobs, and also rely less on manual skills.
- There are only a few specific skill differences between 'indirectly' green jobs (Green ID) and Green Rival jobs, so transitions may only require on-the-job training.

4. Green job growth

The summary statistics from Section 2 showed the differences in task and skill content between job subcategories. What implications do these differences have for the ease of transition between specific occupations?

We use O*NET's supplementary data on Career Changers and Career Starters to measure the ease of transition between similar occupations.[24] As mentioned in Section 2, O*NET provides two lists that use different criteria to measure occupational similarity: Career Changers use job-specific criteria (knowledge, skills, work activities, work context, and job-zone), whereas Career Starters use worker-specific criteria (abilities, interests, work styles, and work values).[25] Similarity between occupations was determined using a weighted Euclidean distance metric, followed by expert evaluation and refinement of the output.[26] Career Changers and Career Starters represent different types of job transitions, with different implications for the green economy:

- **Career Changers** are occupations that have similar job specifications (skills, experience, work context), so workers can transfer to these occupations with minimal additional preparation. In the short term, the greening of the economy will probably involve transitions from non-green jobs to green jobs that require little re-training, which may be entirely on-the-job. Workers would switch to jobs in the same sector or part of the organisation, for example, switching from being a purchasing manager to a wholesale and retail buyer.
- **Career Starters** are occupations that have similar worker specifications (abilities, occupational interests), so are suited to individuals with similar occupational preferences. In the long term, greening may involve transitions from non-green jobs to green jobs that may be in different sectors or parts of an organisation and possibly require specialised skills, but are suitable for the same people. For example, a worker may still have a managerial job, but in human resources instead of general management. This transition may involve additional education of existing workers, or potential workforce entrants choosing to acquire different educational qualifications that make them more suited to the career starter occupation.

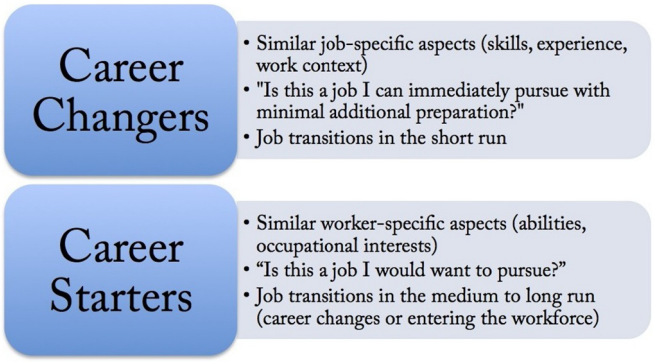

Fig. 2. Career Changers vs. Career Starters.

Fig. 2 summarises the key differences between Career Changers and Career Starters.

Most occupations listed in O*NET each have ten listed Career Changers and ten listed Career Starters. The categories 'Career Changers' and 'Career Starters' are defined in relation to the occupation in question, so a particular job can be a Career Changer for one occupation and a Career Starter for another occupation. In the following analysis, Career Changers represent potential job transitions in the short run, whereas Career Starters represent potential job transitions in the long run.

4.1. Skill distance

We adapt CMMV's measure of skill distance to assess the differences in work requirements between job subcategories. This measure, like the Routine Task Intensity Index, is a summary statistic of the average difference in task importance across all given task categories, and can be used as an estimate of the extent of re-training required to transition from one job to another. Skill distance is the average absolute difference between the task categories of Autor et al. (2003, 2013)[27] for a pair of occupations:

$$\text{Skill Distance}_{i,j} = \frac{1}{6}\sum_{k=1}^{6}\left|\text{task category}_{i,k} - \text{task category}_{j,k}\right| \quad (1)$$

[24] We use these transitions as a proxy for actual transitions that may occur due to greening, since transitions between similar occupations are arguably more likely to occur than transitions between dissimilar occupations.

[25] These terms are defined in Appendix A.2.

[26] Further details on the methods used to determine similarities between occupations are documented in the following O*NET report: http://www.onetcenter.org/dl_files/Related.pdf.

[27] As mentioned in Section 2: Non-routine cognitive/analytical, Non-routine interactive, Non-routine manual, Routine cognitive, Routine manual, and the Routine Task Intensity Index.

Table 8
Mean skill distance, according to type of job transition.

	Transition type	Green ID	Green ES	Green NE
Career Changers	Green Rival to Green	0.076	0.077	0.064
	Green to Green	0.074	0.073	0.073
Career Starters	Green Rival to Green	0.084	0.080	0.073
	Green to Green	0.079	0.077	0.065

Table 9
Number of times green jobs are listed as similar to Green Rival jobs, by job subcategory.

	Frequency	
Job type	Career Changers	Career Starters
Green Increased Demand	523 (9.7%)	528 (9.8%)
Green Enhanced Skills	445 (8.3%)	471 (8.8%)
Green New & Emerging	153 (2.8%)	243 (4.5%)

where $\text{taskcategory}_{i,k}$ is the value of task category k for occupation i.[28] For example, a skill distance of 0.17 means that on average the task categories between the occupations compared differ in importance by 1 (on a scale of 1 = not important, to 5 = extremely important). CMMV compare skill distance between green and non-green jobs within macro-occupational groups to control for differences in skill-level and job complexity (for example, the skill distance between management or construction occupations). Instead, to measure the ease of potential job transitions we calculate the skill distance between the Career Changers or Career Starters of each occupation.

Tables 19 and 20 (Supplementary material) show the mean skill distance between job subcategories, according to skill level. The skill distance measure can range between 0 and 6, so the skill distances of 0.03–0.14 found between similar occupations are relatively small.[29] The mean skill distance is generally larger for Career Starters than for Career Changers (as expected from the way these terms were defined), though not significantly larger in absolute terms. With the exception of low-skill jobs, the skill distance between Green Rival and any green job (first row of each sub-table) is similar to the skill distance between Green Rival jobs, meaning that re-training required for the greening of the economy would probably be similar in scale and scope to existing re-training for Green Rival jobs. Tables 21 and 22 (Supplementary material) suggest that there may be some sectoral variation in skill difference but not across skill levels (for example, skill distances in agriculture and arts/entertainment are larger than those in utilities and mining), so the greening of the economy may require more re-training resources in these sectors compared with the others.

Table 8 summarises the main findings from this distance measure. On average, the skill distance between Green Rival and green jobs is slightly larger than between two green jobs, and the difference is generally larger for Career Starters than Career Changers. However, these differences are not large in absolute terms. Career Changers represent transitions that are more likely to occur in the short run while Career Starters represent long-run transitions. Based on the small skill differences found here, the re-training required in both the short- and long-run need not be major, so additional hours of on-the-job instruction and/or supervision may be more relevant than an academic qualification. These findings suggest that on-the-job training will play an important role in the green growth transition.

4.2. Career paths

The greening of the economy is likely to affect the career paths of both current and future workers. Workers currently employed in Green Rival jobs may need additional qualifications or training to transition to a similar green job. In the long run, future workforce entrants may choose to obtain qualifications or experience more suited to green jobs rather than their Green Rival counterparts. The ease of transition from Green Rival to green jobs determines what training and education are required to facilitate these changes. The content of training and educational programmes may be modified to meet workplace demands. For example, in order to train these students to meet the needs of a green managerial job, business programmes could introduce new courses that develop proficiency in relevant green tasks, such as a module that teaches students how to design implement sustainability programmes.

A likely way for workers to join the green economy is by changing to a Career Changer or Career Starter job. Each link between a Green Rival and green job is a potential option for workers to transition into the green economy.[30] Table 9 shows the total number of links between Green Rival and green jobs, according to green job subcategory. Each Green Rival job may be linked to multiple green jobs from different green job subcategories. As explained earlier, Career Changers can be interpreted as current transitions that will mostly be made by existing workers, while Career Starters can be interpreted as future transitions that will mostly be made by new workforce entrants. As found in Section 3, Green Rival jobs are generally more similar to Green ID jobs than other green subcategories. For both Career Changers and Career Starters, there are more options to transition to indirectly green (Green ID) jobs, but there are also a considerable number of links with Green ES jobs (which do involve green tasks).

The number of green links for each Green Rival job is a more disaggregate way to measure how closely connected green and Green Rival jobs are. For example, for a given Green Rival job, if nine out of ten Career Changer jobs are green, then workers in that Green Rival job have many options to switch to if necessary, and there are many ways for them to join the green economy. Table 10 shows the average breakdown of green (all subcategories) and Green Rival links. On average, Green Rival jobs have two similar green jobs, which indicates that there may be limited ways for Green Rival workers to transition into the green economy.

Throughout their lifetime, workers may change occupations more than once or require a few job transitions to join the green economy. Analysing longer career paths can give further insights into the ease of transition and the long-run potential growth of the green economy. Career paths that start in non-green jobs and end in green jobs are of particular interest for policymakers. Jobs in the 'Other' category are not directly linked to green jobs, but workers in these occupations may eventually transition to a green job by switching to one or more Green Rival jobs. Since each of these transitions may take some time due to on- and/or off-the-job re-training, the number of transitions required to reach a green job from a given non-green job can serve as a rough measure of the length of time needed for

[28] Normalised to be between 0 and 1, for interpretative purposes.
[29] A difference in skill distance of 0.01 means that on average the task categories between the occupations compared differ in importance by 0.06, on a scale of 1–5.
[30] We refer to two jobs as 'linked' if one job is listed as a Career Changer or Career Starter for the other job (for example, in Fig. 1, General & Operations Managers and Sales Managers are linked).

Table 10
Mean number of linked jobs listed in each data file, by job type (SD in brackets).

Job type	Career Changers			Career Starters			
	# Green Rival	# Green	# Other	# Green Rival	# Green	# Other	N
Green Rival	6.82 (1.98)	2.08 (1.94)	1.10 (1.87)	6.68 (1.96)	2.31 (1.81)	1.01 (1.92)	538
Green	5.40 (2.34)	4.57 (2.35)	0.03 (0.21)	6.10 (2.00)	3.76 (2.11)	0.14 (0.63)	149

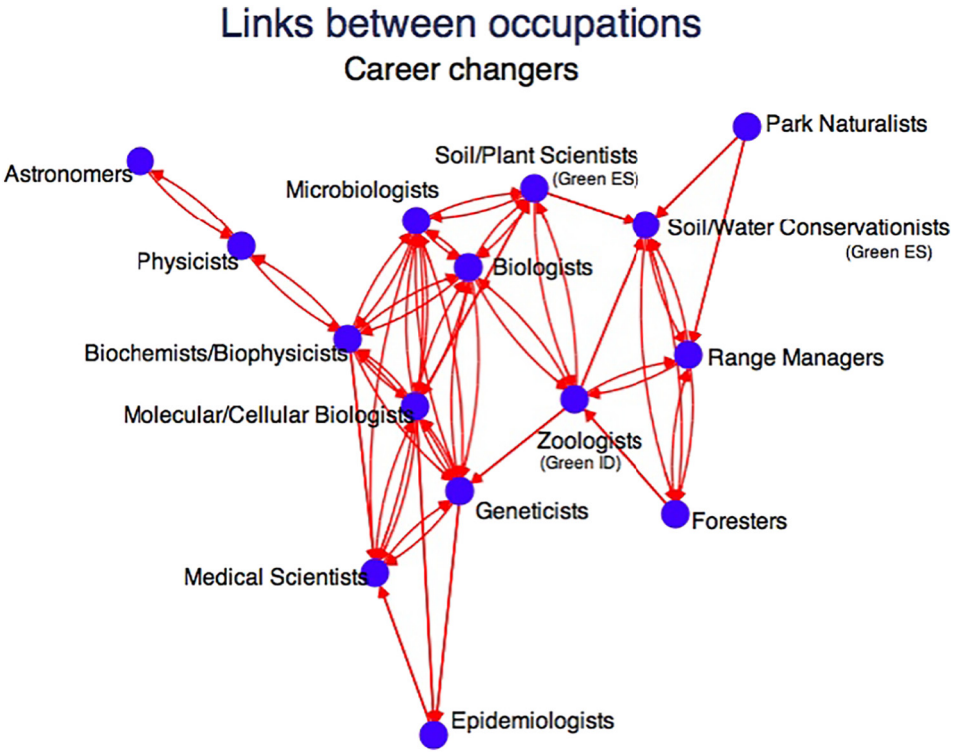

Fig. 3. Visual representation of career paths (Career Changers).

those workers to join the green economy. Looking at the indirect connections between green and non-green jobs can help policymakers understand how the workforce composition could evolve over time.

Fig. 3 shows the connections between a subset of O*NET occupations, based on Career Changers data. Occupations can be thought of as nodes in a network, with arrows indicating a potential transition to a Career Changer occupation.[31] Within this subset, the length of the shortest path between green jobs (labelled) and non-green jobs (unlabelled) varies; it only takes one transition for a Biologist to become a Zoologist, whereas it would take four transitions for an Epidemiologist. The relationships between occupations and their Career Starters can be examined in a similar way, though the time between each transition may be longer than that of Career Changers due to the additional preparation required. Analysis of Career Changers would therefore be applicable to the short and medium run, whereas analysis of Career Starters is more relevant for the long run.

For each entire network of occupations (Career Changers and Career Starters), the length of the shortest path between all possible pairs of occupations was calculated.[32] Table 11 shows the average of all these path lengths, according to the job subcategory of the starting point and ending point. These average lengths can be interpreted as a general measure of closeness between job subcategories. On average, jobs in the same subcategory have shorter paths between them, requiring about one less transition from any starting-point job. The first and last rows of each table section show the closeness between non-green and green jobs. The number of connections between Green Rival and non-green jobs is similar to that

[31] For example, the arrow between Park Naturalists and Soil/Water Conservationists indicates that the latter occupation is a Career Changer for the former.

[32] In the example given in Fig. 3, the shortest path between Biologists and Zoologists is 1, and 4 for Epidemiologists and Zoologists).

Table 11
Average length of shortest path between any 2 given jobs, by job type.

		Ending Point				
	Starting point	Green Rival	Green ID	Green ES	Green NE	Other
Career Changers	Green Rival	4.23	4.30	4.16	3.24	4.18
	Other	4.88	5.11	5.19	4.29	3.95
Career Starters	Green Rival	4.03	4.07	3.95	3.17	3.92
	Other	4.59	4.71	4.77	4.07	3.66

Table 12
Percentage frequency of path length to any green job.

		Path length		
		1	2	3+
Green Rival	Career Changers	79.0	19.1	1.9
	Career Starters	86.4	13.6	0.0
Other	Career Changers		64.3	35.7
	Career Starters		83.6	16.4

of Green Rival and green jobs, whereas Other jobs have longer paths to reach green jobs (especially Green ID and Green ES) compared with non-green jobs. These findings indicate that greening will likely be a long-term process and may require more than one stage of re-training, since on average it takes non-green workers more than one transition to join the green economy.

While average path lengths are a useful summary statistic of the general closeness between jobs in the network, the shortest path length to any green job can give an optimistic estimate of green job growth. The length of the shortest path to any green job was calculated for each Green Rival and Other job (Table 12). This length represents the quickest possible way for a worker to join the green economy. The majority of Green Rival jobs (79% for Career Changers and 86% for Career Starters) can transition directly to a green job, while most Other jobs require an extra transition.[33] These findings suggest that there is large potential for short-run growth in the share of workers involved in green economic activity, if transitions are strategically managed.

5. Conclusion

The green growth transition ('greening') is expected to have a large structural impact on labour markets worldwide. As with previous large-scale labour market shocks such as job outsourcing/offshoring and the IT revolution, greening will change the skills required and tasks involved in existing occupations, and shifts in relative demand for particular occupations will require job transitions and may change workers' career paths.

Using O*NET's definition of green jobs, the proportion employed in the US green economy, using the broadest definition of green jobs, could be as much as 19.4% of the total workforce. However, a large proportion of this estimated employment would be 'indirectly' green, with 10.3% of the total workforce actually using any specifically green tasks in their jobs and 1.2% employed in jobs that are unique to the green economy. While there is a large proportion of employment in jobs that are closely related to green jobs, there is also a substantial proportion of employment in jobs that are not closely related to green jobs, which limits the potential short-term labour market benefits of the green transition.

The use of green tasks and types of skills required varies greatly across the green job subcategories defined by O*NET, which suggests that 'green' should be considered as a continuum rather than a binary characteristic. Between the two 'directly' green job categories, Green New and Emerging jobs are 'greener' than Green Enhanced Skills jobs, i.e. involve a higher proportion of green tasks to non-green tasks and use green tasks more frequently, and also rely more heavily on non-routine skills. It is also important to recognise that non-green jobs fall into two distinct subcategories: aside from their connection to green jobs, Green Rival and Other jobs also differ in standard skill measures and skill content. It is important to account for this heterogeneity within green and non-green job categories when defining green employment and designing re-training programmes.

Analysis of skill content indicates that it is easier to transition to indirectly green rather than directly green jobs. Among the three categories of green jobs, Green Rival jobs are more similar to Green Increased Demand jobs in terms of educational requirements and the types of skills utilised more heavily. Compared to 'directly' green jobs, Green Rival jobs are typically lower-wage, lower-skill, require less on-the-job training, and involve more routine and manual skills. However, all the distance measures used in this paper indicate that these differences are not large in absolute terms. Green Rival and green jobs differ in only a few specific aspects, so the scale and scope of transitions due to greening is likely to be similar to that of existing job transitions and much smaller than transitions which resulted from the IT revolution and outsourcing, so re-training can mostly happen on-the-job.[34] Network analysis shows that the green economy has large potential for short-run growth, if job transitions are strategically managed.

[33] Other jobs, by definition, have no direct links with green jobs, though a large percentage of Other jobs (64% for Career Changers and 84% for Career Starters) can transition to any green job via Green Rival jobs.

[34] To put these anticipated effects on the US economy into perspective, the IT revolution had a large negative effect on routine task-intensive employment that varied with exposure to technology and skill level, with an interquartile range of −1.8 percentage points per decade (Autor et al., 2015). In a cross-country study, Michaels et al. (2014) find that on average, IT adoption accounts for up to 25% of the growth in demand for highly educated workers, but a 1 percentage point increase in ICT intensity is associated with a 0.8 percentage point fall in the share of middle-skilled workers. Similarly, outsourcing also had a large effect on labour market outcomes, though its impacts were more geographically concentrated and sector-specific compared to the nationwide impacts of technology adoption (Autor et al., 2013). Wright (2014) estimates that outsourcing caused a net loss of 69,000 production jobs (6% of all low-skilled workers), but a 1% increase in high-skill non-production jobs. Increased outsourcing is associated with a 0.8% decline in labour force participation and a 0.8% larger decline in wages in import-competing sectors (Autor et al., 2013).

Appendix A

A.1. Defining green jobs

Table 13 summarises the 3 main approaches taken for defining green jobs. O*NET's approach is unique in that green occupations may require a mixture of green and non-green tasks, so 'green' is more of a continuum than a binary distinction.

Since some definitions of 'green jobs' are broader than others, estimates of green employment will differ (and may differ greatly) according to the approach chosen. Further discussion of the distinctions between these and other definitions of green jobs or the green economy, along with a comprehensive list of definitions, can be found in Bowen and Kuralbayeva (2015), Winter and Moore (2013), and Furchtgott-Roth (2012).

Table 13
Main approaches to defining green jobs.

Approach	Criteria	Examples
Output and process (US Bureau of Labor Statistics)	'Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources', and 'workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources' (Bureau of Labor Statistics, 2013).	Workers in a factory that produces solar panels, workers in a retail shop that uses solar panels.
Industry (Eurostat)	Products and services that are directly related to natural resource protection and conservation (Eurostat, 2009).	Workers in a factory that produces solar panels, but not workers in the retail shop that uses solar panels.
Effect of greening (O*NET)	Any occupation affected by greening, whether via increased demand, changes in work or worker requirements, or the creation of unique worker requirements (National Center for O*NET Development, 2015).	Workers in a factory that produces solar panels, workers in a retail shop that uses solar panels.

A.1.1. O*NET's procedure for identifying green jobs

Identifying and classifying green jobs required an extensive research and screening process (see Rivkin et al., 2009 for more details). The first step involved collecting and reviewing over 60 publications related to the green economy from reputable sources such as academic journals and governmental technical reports. O*NET then compiled a list of job titles that were referenced in these sources, along with the sectors commonly used to categorise these green jobs.[35] To facilitate matching with O*NET SOC occupations, similar job titles that referred to the same occupational content were grouped together, and all job titles were sorted into easily interpretable broad groups.

Job titles were then compared to existing O*NET occupations to determine whether they were 1) a direct match (Green Increased Demand), 2) a close but not exact match (Green Enhanced Skills), or 3) possibly new and unique (Green New and Emerging). Two occupational analysts conducted this assignment process independently and then resolved any disagreements among themselves. Job titles initially categorised as Green New and Emerging were then evaluated according to specific criteria used in previous new and emerging occupations research[36] in order to confirm that they were correctly classified. This multi-step process identified 204 'green' O*NET-SOC occupations from 467 initial green job titles (64 as Green Increased Demand, 60 as Green Enhanced Skills, and 78 as Green New and Emerging).

A.2. Definitions of criteria used by O*NET

These definitions are paraphrased from O*NET documentation (see http://www.onetcenter.org/reports/Related.html).

Job-specific criteria

- **Knowledge**: facts, information, and principles obtained via training, education, or experience.
- **Skills**: capabilities of individuals gained through experience and practice, which help individuals to acquire knowledge.
- **Work activities**: activities involved in carrying out major work functions e.g. information input, interacting with others.
- **Work context**: aspects of the work environment or working conditions e.g. health and safety.
- **Job-zone**: a weighted measure of the level of education and experience required for the occupation.

Worker-specific criteria

- **Abilities**: stable characteristics of an individual.
- **Interests**: six elements that describe an individual's preferred job characteristics (realistic, investigative, artistic, social, enterprising, conventional), based on Holland's taxonomy of occupational preferences.
- **Work styles**: descriptors of an individual's personality and cognitive styles.
- **Work values**: six elements that describe an individual's preferred working environment (achievement, independence, recognition, relationships, support, working conditions), based on the Minnesota Theory of Work Adjustment.

[35] The 12 broad sectors identified are as follows: 1) Renewable Energy Generation, 2) Transportation, 3) Energy Efficiency, 4) Green Construction, 5) Energy Trading, 6) Energy/Carbon Capture and Storage, 7) Research, Design, and Consulting Services, 8) Environment Protection, 9) Agriculture and Forestry, 10) Manufacturing, 11) Recycling and Waste Reduction, and 12) Governmental and Regulatory Administration.

[36] The six specific criteria used were the following: 1. Reputable evidence of significant (>5000 workers) employment, 2. Forecasted positive employment growth in the occupation over the next five years, 3. Training programmes/institutions offer credentials tailored to the occupation, 4. States require a license/registration/some certification in order to practice the occupation, 5. At least one national association exists for workers in that occupation, and 6. At least one trade or professional journal dedicated to workers in that occupation.

A.3. Defining green jobs: an example

The following example of employees in a transport company provides further intuition about how the job categories are defined. The job that most closely fits the BLS and Eurostat definition of 'green' is the transportation planner (Green NE). As the economy switches to environmentally-friendly transportation methods, there will be a specific need for workers who can develop and implement new models of sustainable transportation systems, and transportation planners may need to acquire a new knowledge or skill set in order to do their job. Greening will also require a significant change in the tasks conducted by truck drivers (Green ES), but consist more of changes in the way that their skills and knowledge are applied. For example, driving a hybrid truck and using GPS systems to plan a low-carbon route might require some on-the-job training, but drivers already know how to handle a truck and work the GPS system.

Workers such as customer service representatives are likely to be in high demand due to greening (Green ID), because they can use their existing skills to support the green economy, even though their jobs do not involve any green tasks. For example, customers may have questions about the environmentally-friendly delivery process that the transport company is adopting, which the representative can answer. However, they are considered 'indirectly' green because they do not directly contribute to making the economy low-carbon. Workers in similar occupations, such as retail salespersons, currently are not supporting the green economy but already possess skills that could enable them to transition to a green job (Green ID in this case).

Table 14
Differences between job categories: A transport company example.

Job type	Job title	Job description	Example of tasks involved
Green Rival	Retail salespersons	Sell merchandise, such as furniture, motor vehicles, appliances, or apparel to consumers.	Recommend, select, and help locate or obtain merchandise based on customer needs and desires. Demonstrate use or operation of merchandise. Consult with company officials, sales departments, and advertising agencies to develop promotional plans.
Green ID	Customer service representative	Interact with customers to provide information in response to inquiries about products and services and to handle and resolve complaints.	Confer with customers by telephone or in person to provide information about products or services, take or enter orders, cancel accounts, or obtain details of complaints. Solicit sales of new or additional services or products. Recommend improvements in products, packaging, shipping, service, or billing methods and procedures to prevent future problems.
Green ES	Heavy and tractor-trailer truck driver	Drive a tractor-trailer combination or a truck with a capacity of at least 26,000 pounds Gross Vehicle Weight (GVW). May be required to unload truck. Requires commercial driver's license.	Plan or adjust routes based on changing conditions, using computer equipment, global positioning systems (GPS) equipment, or other navigation devices to minimize fuel consumption and carbon emissions. Operate idle reduction systems or auxiliary power systems to generate power from alternative sources, such as fuel cells, to reduce idling time, to heat or cool truck cabins, or to provide power for other equipment. Drive electric or hybrid-electric powered trucks or alternative fuel-powered trucks to transport and deliver products, livestock, or other materials.
Green NE	Transportation planners	Prepare studies for proposed transportation projects. Gather, compile, and analyse data. Study the use and operation of transportation systems. Develop transportation models or simulations.	Produce environmental documents, such as environmental assessments or environmental impact statements. Analyse information related to transportation, such as land use policies, environmental impact of projects, or long-range planning needs. Collaborate with other professionals to develop sustainable transportation strategies at the local, regional, or national levels.

A.4. Glossary of terms used in this paper

Green economy economic activity related to reducing fossil fuel usage, decreasing pollution and greenhouse gas emissions, recycling materials, increasing energy efficiency, and developing/adopting renewable energy sources.

Greening the effect of the green economy on occupations, which includes increased demand, changes in worker requirements, and the creation of new occupations/worker requirements.

Green Increased Demand (ID) Existing jobs that are expected to be in high demand due to 'greening', without requiring significant changes in tasks, skills, or knowledge (hence considered 'indirectly green').

Green Enhanced Skills (ES) Existing jobs that require significant changes in tasks, skills, and knowledge due to 'greening'.

Green New & Emerging (NE) New jobs with unique worker requirements that meet the specific needs of the green economy.

Green job/occupation Any job classified by O*NET to be affected by 'greening', which could involve increased demand, changes in worker requirements, and the use of new worker requirements. All other jobs are considered Non-green.

Career changer Jobs with similar skills and experience as the initial job, requiring minimal additional preparation to transfer from the initial job.

Career starter Jobs that appeal to individuals with similar general abilities and preferences over job characteristics/work environment, which may require more extensive preparation to transfer from the initial job.

Linked jobs Two jobs, one of which is either a career changer or career starter for the other. Hyphens signify 'to' i.e. Green Rival-Green is short for 'Green Rival to Green'

Green Rival job/occupation Non-green jobs with at least one Green career changer or career starter.

Other job/occupation Non-green jobs with all Career Changers and Career Starters also being non-green.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2018.03.015.

References

Aceleanu, M.I., 2015. Green jobs in a green economy: support for a sustainable development. Prog. Ind. Ecol. 9 (4), 341–355.

Antoni, M., Janser, M., Lehmer, F., 2015. The hidden winners of renewable energy promotion: insights into sector-specific wage differentials. Energy Policy 86, 595–613.

Autor, D.H., Dorn, D., Hanson, G.H., 2013. The China syndrome: local labor market effects of import competition in the United States. Am. Econ. Rev. 103 (6), 2121–2168.

Autor, D.H., Dorn, D., Hanson, G.H., 2015. Untangling trade and technology: evidence from local labour markets. Econ. J. 125 (584), 621–646.

Autor, D.H., Levy, F., Murnane, R.J., 2003. The skill content of recent technological change: an empirical exploration. Q. J. Econ. 118 (4), 1279–1333.

Bureau of Labor Statistics, 2013. The BLS Green Jobs Definition. January, 2013: Available at http://www.bls.gov/green/green_definition.htm (accessed 20 September 2015).

Bowen, A., Duffy, C., Fankhauser, S., 2016. 'Green growth' and the new industrial revolution. LSE Working Paper,

Bowen, A., Kuralbayeva, K., 2015. Looking for Green Jobs: The Impact of Green Growth on Employment. Global Green Growth Institute.

Cedefop, S., 2010. Skills Supply and Demand in Europe: Medium-term Forecast up to 2020. Luxembourg: Publications Office of the European Union.

Connolly, K., Allan, G.J., McIntyre, S.G., 2016. The evolution of green jobs in Scotland: a hybrid approach. Energy Policy 88, 355–360.

Consoli, D., Marin, G., Marzucchi, A., Vona, F., 2015. Do Green Jobs Differ From Non–Green Jobs in Terms of Skills and Human Capital? (No. 2015-16). SPRU-Science and Technology Policy Research. University of Sussex.

Eurostat, 2009. The Environmental Goods and Services Sector: A Data Collection Handbook. Available at: http://ec.europa.eu/eurostat/documents/3859598/5910217/KS-RA-09-012-EN.PDF (accessed 25 September 2015).

Fankhauser, S., Sehlleier, F., Stern, N., 2008. Climate change, innovation and jobs. Clim. Pol. 8 (4), 421–429.

Furchtgott-Roth, D., 2012. The elusive and expensive green job. Energy Econ. 34, S43–S52.

Hatfield-Dodds, S., Turner, G., Schandl, H., Doss, T., 2008. Growing the green collar economy. In Report to the Dusseldorp Skills Forum, CSIRO, Canberra, Available at: www.csiro.au/resources/GreenCollarReport.html (accessed 20 September 2015). June.

Lamo, A., Messina, J., Wasmer, E., 2011. Are specific skills an obstacle to labor market adjustment? Labour Econ. 18 (2), 240–256.

Lehr, U., Lutz, C., Edler, D., 2012. Green jobs? Economic impacts of renewable energy in Germany. Energy Policy 47, 358–364.

Louie, E.P., Pearce, J.M., 2016. Retraining investment for US transition from coal to solar photovoltaic employment. Energy Econ. 57, 295–302.

Martinez-Fernandez, C., Hinojosa, C., Miranda, G., 2010. Greening jobs and skills: labour market implications of addressing climate change. OECD Local Economic and Employment Development (LEED) Working Papers, No 2010/02, OECD Publishing, Paris.

Michaels, G., Natraj, A., Van Reenen, J., 2014. Has ICT polarized skill demand? Evidence from eleven countries over twenty-five years. Rev. Econ. Stat. 96 (1), 60–77.

National Center for O*NET Development, The development and evaluation of a new O*NET related occupations matrix. O*NET resource center. Available at http://www.onetcenter.org/reports/Related.html (accessed 11 November 2015).

Pociovalisteanu, D.M., Novo-Corti, I., Aceleanu, M.I., Servan, A.C., Grecu, E., 2015. Employment policies for a green economy and the European Union level. Sustainability 7 (7), 9231–9250.

Rivkin, D., Lewis, P., Dierdorff, E.C., Norton, J.J., Drewes, D.W., Kroustalis, C.M., 2009. Greening the World of Work: Implications for ONET SOC and New and Emerging Occupations. Labor Report Raleigh. The National Center for O* NET Development, NC.

UNEP, ILO, IOE, ITUC, 2008. Green Jobs: Towards Decent Work in a Sustainable, Low–Carbon World. Report Produced by Worldwatch Institute and Commissioned by UNEP, ILO IOE. ITUC, Nairobi.

Vona, F., Marin, G., Consoli, D., Popp, D., 2017. Environmental regulation and green skills: an empirical exploration. J. Assoc. Environ. Resour. Econ.

Wasmer, E., 2006. General vs. specific skills in labor markets with search frictions and firing costs. Am. Econ. Rev. 96 (3), 811–831.

Winter, J., Moore, M., 2013. The 'green jobs' fantasy: why the economic and environmental reality can never live up to the political promise. SPP Research Paper 6 (31).

Wright, G.C., 2014. Revisiting the employment impact of offshoring. Eur. Econ. Rev. 66, 63–83.

Yi, H., 2013. Clean energy policies and green jobs: an evaluation of green jobs in US metropolitan areas. Energy Policy 56, 644–652.

Yi, H., 2014. Green businesses in a clean energy economy: analyzing drivers of green business growth in US states. Energy 68, 922–929.