Empowering people with green skills for climate-compatible growth: Key Recommendations for LMICs

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Key Recommendations

To effectively prepare workers for a low-carbon transition and ensure the transition is just and equitable, especially those in fossil fuel sectors, the following measures are needed:

For government

1. **Establish a national green skills taxonomy** that defines and assesses green skills as part of national workforce planning to foster a well-prepared workforce.
2. **Promote policies that improve job quality and inclusivity**, ensuring wage parity, gender diversity, and equitable standards across all green jobs.
3. **Reform energy education** by expanding renewable energy programmes and realigning educational curricula with current and future labour market demands.

For researchers

4. **Develop methodologies and use existing datasets** to accurately map green skills needs in LMICs, addressing data gaps and aiding targeted policy and programme development.

Grade 6 students in Tanzania using bottle caps to learn multiplication.

5. **Advance green job modelling** by designing models that project the employment impacts of decarbonisation, specifically in LMICs.
6. **Create region-specific training modules and pursue global certifications** in renewable energy to standardise qualifications and enhance job mobility.

Definitions

Institutional definitions of green skills and green jobs often vary. Here, we adopt the most comprehensive definitions to provide readers with a general overview of green jobs and green skills:

> *Green skills are the knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society.* UNIDO, 2022 [1]

> *Green Jobs are decent jobs that contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency.* ILO, 2016 [2]

Summary

This policy brief addresses the important role that the formation of green skills plays for low- and middle-income countries (LMICs) as they transition to a low-carbon economy. Key challenges in this regard include ambiguous definitions for "green" skills and jobs, and a lack of reliable data to tally them. As a result, transition pathways for fossil fuel workers remain largely uncertain and education systems planning does not yet widely consider the skill demands of a net-zero carbon future. Here, we draw from case studies to gain insights about best practices when it comes to:

1. re- and up-skilling fossil fuel workers,
2. endowing new and future entrants to the workforce with skillsets suitable for the green transition, and
3. leveraging novel data to broaden the evidence base for just and inclusive, pro-poor green growth.

Introduction

Transitioning to climate-compatible growth necessitates a skilled workforce capable of innovation, implementing sustainable solutions, and managing the complexities of green development across all economic sectors. However, there are challenges in equipping the workforce with the types of skills that best meet the changing demands of economies as they phase out the combustion of fossil fuels and transition to a low-carbon mode of production. While evidence of this has been scarce to date, a recent study estimates that, in 2023–2024, global demand for green-skilled workers grew twice as fast as supply. At this rate, half of green economy jobs would be at risk of remaining unfilled by 2050 [3].

This apparent deficit of skilled employees has prolonged recruitment timelines, delaying renewable energy deployment and significantly increasing operational and maintenance costs in the US, the UK, and Japan [4]. Hiring difficulties are intensifying: in the UK, 71% of employers reported recruitment challenges in 2024, up from 53% in 2021[5]. The deficit is more prevalent in developing economies [6], raising concerns that the transition to a green economy could widen the longstanding gaps between high-income countries (HICs) and low- and middle-income countries (LMICs).

While policies such as the 'UK Green Jobs Taskforce' [7] and the 'European Skills Agenda' [8] have outlined clear pathways for building the skill base required for a sustainable future in an HIC context, many LMICs have yet to develop similarly comprehensive strategies that fit their specific needs. Existing policies, like Kenya's 'Green Economy Strategy and Implementation Plan [9]' and Zambia's 'National Green Growth Strategy [10]', acknowledge the importance of education, training, and skills development for fostering inclusive green jobs. However, they fall short of outlining concrete mechanisms for implementation. There is no clear policy framework detailing how green skills training will be integrated into national education and workforce development systems, nor is there an indication of the level of public funding allocated to support such initiatives. Similarly, Ghana's 'National Climate Change Policy' [11] recognises inadequate human resource and managerial skills as major challenges. However, it primarily focuses on community resilience and agricultural development and lacks emphasis on equipping workers with the necessary technical skills for the green transition. Reskilling coal workers and ensuring their inclusion in the labour force throughout and following the transition to a low-

carbon economy have emerged as critical policy priorities, especially in coal dependent LMICs such as Vietnam, South Africa, or India.

Addressing these challenges requires examining the workforce requirements of the low-carbon transition across countries' unique contexts. To this end, this policy brief addresses the question: ***What skillsets are essential for a low-carbon transition?*** We further divide the research question into two sub-questions:

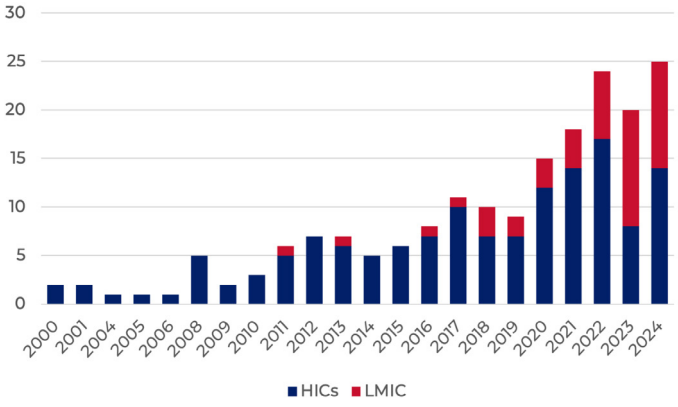
1. How can workers currently employed in the fossil fuel industry be effectively re- and upskilled to transition them into low-carbon jobs?
2. How can new entrants to the labour market acquire the skills needed to meet the increasing demands of jobs in a low-carbon economy?

To obtain a better understanding of the latest research regarding these questions, we systematically review the academic (n=188) and the grey literature (n=34) on the labour market's transition toward a low-carbon economy. This review enables the identification of six critical challenges in enabling the workforce with the necessary skills for the green transition. Building on these insights, we formulate several recommendations for policymakers who wish to address these challenges, aiming to facilitate the transition of skillsets to a low-carbon economy and promote equitable, inclusive growth.

Method

We conducted a comprehensive literature review to identify academic publications focusing on labour market transitions in the context of low-carbon energy. Using the Web of Science Core Collection, we applied targeted search terms related to employment and renewable energy, filtering for English-language articles published since January 1, 2000. This initial search yielded 660 publications. Upon screening titles and abstracts, we excluded studies not directly addressing skill development, such as those focusing solely on labour impacts from extreme climate events. This resulted in a selection of 188 academic papers. As shown in **Figure 1**, the majority of papers in our academic sample focus on labour market transitions in HICs, while papers engaging with this topic in LMIC contexts are only recently emerging. To gain a more well-rounded image of the policy-shaping conversation regarding labour market transitions, we supplemented our academic literature sample with selected institutional reports from highly salient, policy-shaping entities in this topic area. They include the International Energy Agency (IEA, n=3), the International Renewable Energy Agency (IRENA, n=3), the World Economic Forum (n=1), the World Bank (n=2), and LinkedIn (n=3).

***Figure 1:** Academic publication by year (grouped by LMICs and HICs, n=188).*



We conducted a detailed review of the texts in this final corpus to identify key themes. For each theme, we examined the findings in relation to global trends and investigated to what extent papers about LMICs differ from those focused on HICs. To begin with, we reviewed papers addressing skillsets to understand the types of skills required for the

low-carbon transition, as well as any barriers that may hinder their development. The research on green jobs was analysed to explore how they are currently being defined, estimated, and modelled. To capture their broader implications for labour market dynamics, we also looked for assessments of their quality in terms of job satisfaction, wage levels, and gender inclusion. Finally, we examined studies on energy education systems, which ultimately reflect the (future) supply of green skills.

Challenges

The following six challenges for the transitioning labour market emerged from our systematic literature review. While the texts we analysed address them in some detail, they also point to several remaining research gaps. We outline them in turn, discuss their significance, and draw potential ways forward.

CHALLENGE 1. Lack of Common Definitions for Green Skills and Green Jobs

The absence of standardised definitions for both “green skills” and “green jobs” makes measuring, comparing, and addressing skills gaps very difficult. This issue underlies many of the other challenges ***(Challenge 2, Challenge 3, Challenge 6)*** mentioned below as well.

The core meaning of “green skills” entails "the knowledge, abilities, values, and attitudes needed to live in, develop, and support a sustainable and resource-efficient society" [2]. However, interpretations as to what this does and does not include in practice differ widely. As a result, some definitions focus narrowly on skills related to specific low-carbon technologies, such as installing solar panels or managing energy-efficient systems [12], while others take a broader approach by including enabling skills like problem-solving and leadership for sustainability transitions [13]. Rather than prescribing a definition, a third group of studies aims to empirically characterise green skills based on job postings [12] [13], technology types, job and skill taxonomies [16], [17], and economic modelling [18].

Similarly, there is no consensus on the definition of green jobs. Existing definitions generally fall into one of four categories: output-based, process-based, task-content-based, and skill-requirement-based [17] [18]. The output-based approach defines green jobs based on the production of goods or services that directly benefit the environment or conserve natural resources (eg renewable energy generation, pollution control technologies, ecosystem restoration). For instance, the United Nations Environment Programme (UNEP) and the International Labour Organization (ILO) define green jobs as those employments in the production of environmental goods and services sector [21].

On the other hand, the process-based approach defines green jobs by the environmental sustainability of the work practices and processes involved, regardless of the final product. Under this framework, jobs are considered green if they incorporate sustainable practices such as energy-efficient operations, waste reduction, or the use of low-carbon technologies [12], [22]. This broadens the scope of green jobs to include roles in traditionally non-green sectors, provided they adopt environmentally friendly practices.

The task-content approach dissects the nature of occupations, their task content, and links this to the skills required to perform the job well if that information is available in a given country’s context. For this, green job taxonomies are used. The approach enables an assessment of whether a job has specific tasks assigned to lessen the environment impact of consumers and/or firms [19].

Lastly, the skills requirements-based approach uses green skills required in job postings as a signal of the greening of the economy. LinkedIn, for example, is relying on this approach and defines green skills as those that enable the environmental sustainability of economic activities [3].

CHALLENGE 2. Lack of Statistical Measurement for Green Skills and Green Jobs

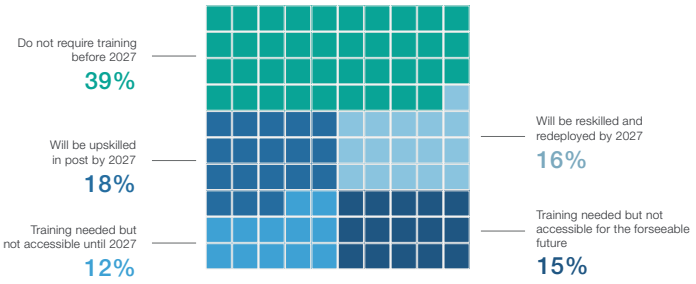
The lack of a common definition complicates efforts to gather and compare data on the number, trends, and needs of green jobs. For instance, the US Occupational Information Network (O*NET) provides detailed descriptions of occupations and associated skills, but the knowledge gathered is not yet extrapolated to countries outside the US [23]. LinkedIn's 2022 Global Green Skills Report, which categorises jobs into "shades of green," has limited coverage in LMICs [24]. The World Bank's Skills Measurement Program (STEP), though a pioneer in assessing skills in LMICs, lacks any measurement of green skills [25]. Novel approaches to measuring greenness based on text analysis may help addressing these caveats [19].

With job postings increasingly posted online, research has adopted natural language processing to identify green jobs in data obtained from online platforms like BuscoJobs (Uruguay, [26]), Ecojob (South Korea, [27]), and Adzuna (Australia, [28]). However, due to the lack of a clear definition of green jobs ***(Challenge 1)***, it is hard to establish comparable frameworks to identify green jobs on online job posting platforms. Lists of "green" key words suffer from the same caveats as skills taxonomies in that they range from highly specific to generic. This makes it difficult to ensure comparability among datasets and raises concerns about data quality. Considering wide range of different statistical text-mining methods applied to these data, the comparability of results also needs to be questioned.

CHALLENGE 3. Green Skills Gap & Uncertain Future Demand

Despite the caveats outlined thus far, the literature has converged on some overarching findings that appear robust. For example, the growing demand for green jobs and skills seems to be outpacing the supply of adequately trained workers. According to LinkedIn's 2024 Global Green Skills Report, global demand for green skills grew twice as fast as supply between 2023 and 2024, with demand increasing by 11.6% and supply by only 5.6% [3]. It is projected that 61% of workers will require training in the next five years to meet this demand **(Figure 2)**. Failure to address this gap risks delaying project delivery and increasing costs. In India, for instance, delays in servicing solar farms due to a lack of trained personnel have resulted in significant energy losses and increased maintenance expenses, undermining the economic viability of such projects [29].

Figure 2: Upskilling and reskilling outlook 2023–2027. Figure adopted from [30]. Blue area shows the percentage of people needing training by 2027.



Lack of investment in training, insufficient policies, and slow responses from the education system are often cited as potential barriers to the supply of green-skilled workers [3], [22].

However, the underlying **lack of a clear definition of green skills *(Challenge 1)*** and the **limited availability of data *(Challenge 2)*** to measure green skills—particularly in LMICs—are the two key factors most frequently highlighted in academic literature [31]. These two challenges also hinder

modelling efforts to predict the growth of green employment and identify the skillsets required under different scenarios. Forecasting future skillsets is key to guiding current training and education systems, ensuring they are aligned with the evolving needs of a sustainable economy.

Two primary types of models are currently used to forecast the future number of green jobs: industry-growth-linked models, or network models. The modelling approach is selected based on the availability of labour market data.

For global estimates, or for countries lacking detailed labour market information, green jobs are often linked to the projected growth of low-carbon industries. These estimates are typically derived using statistical models [12], [22] or input–output models [20]. These approaches provide a broad overview but are limited by their reliance on macroeconomic data, which does not directly support the policymaking on skillset development.

In countries with more granular occupation-level data, network models are the most widely used tools. These models offer a more nuanced understanding of how labour markets adapt to green transitions. For example, Lankhuizen et al. (2023) employ an industry and geographic mobility model to identify potential bottlenecks resulting from energy transition in the Netherlands' labour markets [32]. Berryman et al. (2023) utilise an agent-based model integrated with an occupational mobility model to assess how productivity shifts in Brazil in the context of green transitions [33]. Xie et al. (2023) examines the distributional impacts of decarbonising the US power sector, focusing on variations in worker outcomes across states by skill level and gender [34]. Bücker et al. (2025) further quantify the temporal dynamics of US labour market frictions during power sector decarbonisation and identify occupation-specific impacts and skill-mismatch frictions as they evolve through time [35].

While these models offer valuable insights, they are largely focused on HICs, where data are more accessible. For LMICs, where effective labour market policies are crucial for addressing unemployment, informality, and skill gaps, analysis often remains limited.

CHALLENGE 4. Ensuring Quality, Equity, and Inclusion in Green Jobs

While green jobs are often associated with higher job satisfaction due to decent working conditions [36], significant challenges remain in ensuring their quality, equity, and inclusivity.

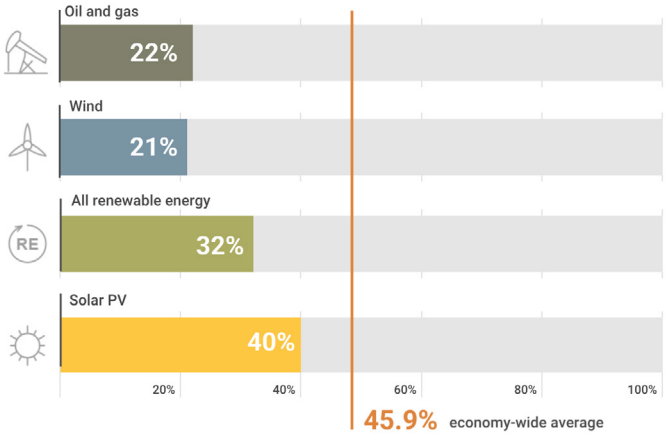
Wage Disparities: Salaries in the oil and natural gas industry continue to outpace those in renewable energy sectors such as wind and solar, raising concerns about the economic attractiveness of green jobs [22]. This wage gap may deter skilled workers from transitioning to green sectors, particularly in regions where fossil fuel industries dominate.

Gender Inequality: Gender representation in green jobs remains uneven. As of 2021, women accounted for only 21% of the wind energy workforce, which is slightly lower than the 22% representation in the oil and gas industry and significantly below the economy-wide representation of 46% **(Figure 3)**[37]. Furthermore, within the wind/solar sector, women are disproportionately concentrated in administrative roles, with significantly lower representation in technical and non-administrative positions[37], [38]. These data indicate a pronounced gender gap across energy sectors, suggesting systemic barriers to female participation.

To combat this, targeted interventions are essential. A notable example of an initiative bridging this gap is the international Solar Programme by Barefoot College, which focuses on training women, particularly from rural areas, to become solar panel installers. This programme

equips women with technical skills, while also offering them economic and social benefits through job opportunities in the renewable energy sector [39].

***Figure 3:** Women in oil and gas, renewables overall, wind, solar PV, and economy-wide average according to IRENA online survey 2021 [37]*



CHALLENGE 5. Missing Pathways on Transitioning Away from High Carbon to Green Jobs

The shift towards a low-carbon economy is generating new opportunities within the green sector; yet, it is also leading to the displacement of workers in high-carbon industries. This is especially pronounced in LMICs, where the fossil fuel sector is labour-intensive, and workers frequently possess skills that are not directly transferable to other industries [40].

Without adequate support, these workers face the risk of unemployment, potentially impeding decarbonisation efforts. Studies from the US (eg Appalachia), Germany, and the UK highlight the social impacts of coal phase-outs, with transitions often managed through early retirement schemes and financial compensation [41], [42], [43]. These tools, often referred to as 'adaptation payments' or 'severance packages', are highlighted as handling a significant portion of the transition. **Box 1** provides a detailed example of successful reskilling in Germany [43], [44].

***Box 1:** Germany Coal Phase Out and Its Social Impact*

Germany's coal phase-out is a remarkable case of managing a transition from a coal-dependent economy to one focused on sustainability and economic diversification. At its peak in the 1950s, the German hard coal industry employed more than 600,000 people supporting regional economies. Over the following decades, employment in the sector dwindled as mining operations became unprofitable compared to cheaper imported coal and other energy sources. By the early 2000s, only a few thousand people were still employed in the industry.

The German government officially decided to phase out this practice when it terminated subsidies in 2007. The phase-out process concluded in 2018 when the last hard coal mines were closed. To address the social impact of this transition, the German government implemented a range of policies aimed at protecting workers. These included early retirement schemes, redundancy payments, and retraining programmes to help workers transition to other sectors, such as the metal industry in the initial phases and later the automotive and technology sectors. Regional policies also promoted education and research to support long-term economic diversification.

The financial responsibility for this transition was substantial. The government provided approximately €289–331 billion in subsidies between 1950 and 2008 to support the phase-out and restructure the affected regions. This funding covered reskilling programmes, infrastructure development, and support for local economies. Structural adjustment policies also focused on enhancing regional attractiveness by improving infrastructure, investing in education and research facilities, and diversifying local industries [41].

CHALLENGE 6. Realigning Energy Education for a Decarbonised Future

The global energy education system remains heavily skewed toward fossil fuels, despite the urgent need for skills aligned with decarbonisation. This misalignment exacerbates the existing skills deficit and threatens to delay the transition to a green economy.

A review of 18,400 universities across 196 countries reveals that 68% of energy-related degree programmes worldwide are dedicated to fossil fuels, while only 32% focus on renewable

energy [45]. This imbalance reflects the inertia of education systems, which have been slow to adapt to the global shift toward decarbonisation **(see Figure 4)**.

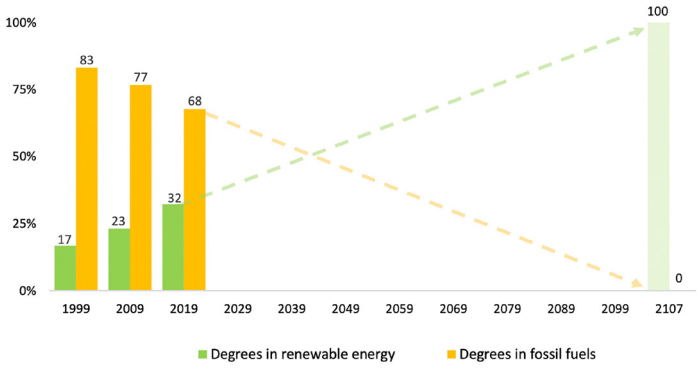


***Figure 4:** Global share of degree programmes in renewable energy and fossil fuels. The dotted green line indicates a simplified projection of when the share of university degrees in renewable energy would reach 100% if the average rate of change from 1999 to 2019 were to continue. Figure adopted from [45].*

Recommendations

To effectively prepare individuals for a low-carbon transition, we propose a set of actions for governments and researchers structured around three themes: (1) the identification and development of essential green skills, (2) the demand and quality of green jobs, and (3) the role of energy education systems in equipping the workforce.

1. Develop standardised green skills frameworks *[Challenges 1 and 2]*

For government: With labour as a key pillar of economic growth, understanding a country's workforce skillset is essential to address skill gaps and support sustainable, climate-compatible transitions. Policymakers can collaborate with international organisations to: (1) define green skills and further establish standardised green skills frameworks, (2) initiate comprehensive data collection on green skills, and (3) develop workforce skillsets aligned with national economic development plans. These frameworks should account for regional and sectoral variations, providing a clear foundation for training programmes and labour market planning.

For research initiatives focused on LMICs: While significant research exists on green skills in industrialised nations, LMICs lack comprehensive data on worker skillsets and transition pathways. This data gap limits the ability to design tailored reskilling programmes for transitioning fossil fuel workers. Researchers can bridge this gap by developing LMIC-specific methodologies and leveraging existing global datasets, such as LinkedIn's green skills taxonomy [46] or O*NET [23], to expand coverage and relevance in LMIC contexts.

2. Advance green job modelling for LMICs *[Challenge 3]*

For research initiatives focused on LMICs: Researchers can collaborate with in-country analysts to enhance job integration in models and support the development of simulations that predict employment outcomes under various decarbonisation pathways. These models should account for sectoral priorities, renewable energy potential, and labour market structures in LMICs. For example, integrating geospatial data with employment projections can highlight regional labour dynamics.

3. Improve green job quality and inclusivity *[Challenge 4]*

For government: While green jobs are increasing in number, disparities in job quality, wages, and gender representation persist. A range of

policies has proven effective in addressing these disparities and enhancing both job quality and inclusivity. Increasing wage transparency helps identify and reduce pay gaps between men and women in similar roles [47]. Monitoring female participation in management encourages greater gender diversity in leadership positions, creating pathways for women's advancement [48]. Policies such as paternity leave and free childcare promote a more balanced sharing of family responsibilities, enabling more women to enter and remain in the workforce [49]. Additionally, vocational training programmes targeting women ensure they have the skills needed for green jobs, while initiatives to align job opportunities specifically for women boost female participation in traditionally male-dominated industries [50].

4. Develop context-specific materials and global certification for renewable energy education for LMICs *[Challenges 5 and 6]*

For Government: Policymakers must mandate and incentivise curriculum reforms that prioritise renewable energy education. These reforms should focus on expanding access to renewable energy programmes, particularly in under-resourced regions, and fostering industry–academia partnerships to align academic training with labour market demands.

For research initiatives focused on LMICs: Building on collaborative efforts with partner countries, researchers can work alongside local academic institutions, industry stakeholders, and policymakers to develop region-specific training modules. These materials should reflect local energy resources, technologies, and socioeconomic conditions, ensuring that graduates are well-prepared to meet regional challenges. Given the absence of internationally recognised certifications for green skills, researchers can collaborate with global accreditation bodies to design certification programmes that align with international standards. Such certifications would validate technical and practical competencies in renewable energy, providing workers with globally acknowledged credentials.

References

[1] ILO, 'What is a green job?' Accessed: Jan. 28, 2025. [Online]. Available: https://www.ilo.org/resource/article/what-green-job

[2] UNIDO, 'What are green skills?', UNIDO. Accessed: Jan. 27, 2025. [Online]. Available: https://www.unido.org/stories/what-are-green-skills

[3] LinkedIn Economic Growth, 'Global Green Skills Report 2024', 2024. [Online]. Available: https://economicgraph.linkedin.com/content/dam/me/economicgraph/en-us/PDF/Global-Green-Skills-Report-2024.pdf

[4] S. Holder, E. Harrison-Dengate, and D. Fox, 'The Electric Revolution Has a Huge Labor Shortage Problem', *Bloomberg.com*, Jun. 05, 2025. Accessed: Jun. 30, 2025. [Online]. Available: https://www.bloomberg.com/news/articles/2025-06-05/ai-data-centers-green-energy-companies-can-t-fill-engineering-jobs-fast-enough

[5] A. B. Fantini and R. Manager, '2024 Workforce Census', 2024. [Online]. Available: https://www.ecitb.org.uk/research/census/

[6] Sean Kruger, 'Jobs of the future: South Africa has major gaps in skills needed to shape the green economy', The Conversation. Accessed: Jan. 29, 2025. [Online]. Available: https://theconversation.com/jobs-of-the-future-south-africa-has-major-gaps-in-skills-needed-to-shape-the-green-economy-241608

[7] Department for Energy Security and Net Zero, Department for Business and Trade and Department for Business, Energy & Industrial Strategy, 'Green Jobs Taskforce Report', Jul. 2021. [Online]. Available: https://www.gov.uk/government/publications/green-jobs-taskforce-report

[8] European Commission, 'European Skills Agenda'. 2020. Accessed: Jan. 27, 2025. [Online]. Available: https://migrant-integration.ec.europa.eu/sites/default/files/2020-07/SkillsAgenda.pdf

[9] Ministry of Environment and Natural Resources, Kenya, 'Green Economy Strategy and Implementation Plan 2016 – 2030'. 2016. Accessed: Jan. 27, 2025. [Online]. Available: https://repository.kippra.or.ke/items/f4838f8d-71d0-4a1c-9f32-ac42c217bf8f

[10] Ministry of Green Economy and Environment, Zambia, 'National Green Growth Strategy 2024-2030', 2024. Accessed: Jan. 27, 2025. [Online]. Available: https://www.cabinet.gov.zm/newsite/wp-content/uploads/2024/04/2NATIONAL-GREEN-GROWTH-STRATEGY-2024-2030-6.pdf

[11] Ministry of Environment Science, Technology and Innovation, 'Ghana National Climate Change Policy', 2013. Accessed: Jan. 27, 2025. [Online]. Available: https://www.clientearth.org/media/p13faarf/national-climate-change-policy-ext-en.pdf

[12] IRENA and ILO, 'Renewable energy and jobs: Annual review 2024', 2024. [Online]. Available: https://www.irena.org/Publications/2024/Oct/Renewable-energy-and-jobs-Annual-review-2024

[13] Philippa Simmonds and Clare Lally, 'Green skills in education and employment', UK Parliament Post, Jan. 2024. Accessed: Nov. 20, 2024. [Online]. Available: https://researchbriefings.files.parliament.uk/documents/POST-PN-0711/POST-PN-0711.pdf

[14] E. M. Curtis and I. Marinescu, 'Green Energy Jobs in the United States: What Are They, and Where Are They?', *Environ. Energy Policy Econ.*, vol. 4, pp. 202–237, Jan. 2023, doi: 10.1086/722677.

[15] A. Saussay, M. Sato, F. Vona, and L. O'Kane, 'Who's fit for the low-carbon transition? Emerging skills and wage gaps in job ad data', Jun. 09, 2022, *In Review*. doi: 10.21203/rs.3.rs-1649850/v1.

[16] D. Consoli, G. Marin, A. Marzucchi, and F. Vona, 'Do green jobs differ from non-green jobs in terms of skills and human capital?', *Res. Policy*, vol. 45, no. 5, pp. 1046–1060, Jun. 2016, doi: 10.1016/j.respol.2016.02.007.

[17] F. Vona, G. Marin, and D. Consoli, 'Measures, drivers and effects of green employment: evidence from US local labor markets, 2006–2014', *J. Econ. Geogr.*, vol. 19, no. 5, pp. 1021–1048, Sep. 2019, doi: 10.1093/jeg/lby038.

[18] J. Greenspon and D. Raimi, 'Matching geographies and job skills in the energy transition', *Extr. Ind. Soc.*, vol. 17, Mar. 2024, doi: 10.1016/j.exis.2023.101397.

[19] J. Granata and J. Posadas, 'Why Look at Tasks when Designing Skills Policy for the Green Transition? A Methodological Note on how to Identify Green Occupations and the Skills they Require', The World Bank, Apr. 2024. doi: 10.1596/1813-9450-10753.

[20] P. Urban, V. Rizos, A. Ounnas, A. Kassab, and H. Kalantaryan, 'Jobs for the green transition', 2023. Accessed: Jan. 28, 2025. [Online]. Available: https://cdn.ceps.eu/wp-content/uploads/2023/09/CEPS-In-depth-analysis-2023-12_Jobs-for-the-green-transition-1.pdf

[21] UNEP/ILO/IOE/ITUC, Ed., *Green jobs: towards decent work in a sustainable, low-carbon world*. Nairobi, 2008. [Online]. Available: https://www.ilo.org/publications/green-jobs-towards-decent-work-sustainable-low-carbon-world-full-report

[22] IEA, 'World Energy Employment 2024', 2024. [Online]. Available: https://www.iea.org/reports/world-energy-employment-2024

[23] A. C. Crouter, S. T. Lanza, A. Pirretti, W. B. Goodman, and E. Neebe, 'The O*Net Jobs Classification System: A Primer for Family Researchers', *Fam. Relat.*, vol. 55, no. 4, pp. 461–472, Oct. 2006, doi: 10.1111/j.1741-3729.2006.00415.x.

[24] LinkedIn Economic Growth, 'Global Green Skills Report 2022', 2022. [Online]. Available: https://economicgraph.linkedin.com/content/dam/me/economicgraph/en-us/global-green-skills-report/global-green-skills-report-pdf/li-green-economy-report-2022.pdf

[25] World Bank, 'Skills Measurement Program (STEP)'. Accessed: Jul. 01, 2025. [Online]. Available: https://microdata.worldbank.org/index.php/collections/step

[26] Fidel Bennett, Verónica Escudero, Hannah Liepmann, and Ana Podjanin, 'Using Online Vacancy and Job Applicants' Data to Study Skills Dynamics', ILO, Aug. 2022. Accessed: Jul. 01, 2025. [Online]. Available: https://www.ilo.org/publications/using-online-vacancy-and-job-applicants%E2%80%99-data-study-skills-dynamics

[27] K. Song, H. Kim, J. Cha, and T. Lee, 'Matching and Mismatching of Green Jobs: A Big Data Analysis of Job Recruiting and Searching', *Sustainability*, vol. 13, no. 7, Art. no. 7, Jan. 2021, doi: 10.3390/su13074074.

[28] H. Chen and C. Mason, 'Explainable AI (XAI) for Constructing a Lexicon for Classifying Green Energy Jobs: A Comparative Analysis of Occupation, Industry, and Location Composition With Traditional Energy Jobs', *IEEE ACCESS*, vol. 12, pp. 142709–142720, 2024, doi: 10.1109/ACCESS.2024.3430317.

[29] B. Standard, 'Skills shortage hampers India's clean energy goals and manufacturing plans'. Accessed: Jan. 29, 2025. [Online]. Available: https://www.business-standard.com/industry/news/skills-shortage-hampers-india-s-clean-energy-goals-and-manufacturing-plans-124112000146_1.html

[30] World Economic Forum, 'Future of Jobs Report', May 2023. [Online]. Available: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf

[31] M. Fuchs, 'Green Skills for Sustainability Transitions', *Geogr. Compass*, vol. 18, no. 10, p. e70003, 2024, doi: 10.1111/gec3.70003.

[32] M. Lankhuizen, D. Diodato, A. Weterings, O. Ivanova, and M. Thissen, 'Identifying labour market bottlenecks in the energy transition: a combined IO-matching analysis', *Econ. Syst. Res.*, vol. 35, no. 2, pp. 157–182, Apr. 2023, doi: 10.1080/09535314.2022.2048294.

[33] A. Berryman *et al.*, 'Modelling labour market transitions: the case of productivity shifts in Brazil', Working Paper, Oct. 2023. Accessed: Nov. 18, 2024. [Online]. Available: https://oms-inet.files.svdcdn.com/production/files/EEIST-D4-Labour-ABM-case-study.pdf?dm=1697722443

[34] J. J. Xie, M. Martin, J. Rogelj, and I. Staffell, 'Distributional labour challenges and opportunities for decarbonizing the US power system', *Nat. Clim. Change*, vol. 13, no. 11, pp. 1203–1212, Nov. 2023, doi: 10.1038/s41558-023-01802-5.

[35] J. Bücker, R. M. del Rio-Chanona, A. Pichler, M. C. Ives, and J. D. Farmer, 'Employment dynamics in a rapid decarbonization of the US power sector', *Joule*, vol. 9, no. 2, p. 101803, Feb. 2025, doi: 10.1016/j.joule.2024.12.004.

[36] O. Başol, 'Classic or Modern? Enhancement of Job Satisfaction Scale for Green Job Workers. | EBSCOhost'. Accessed: Mar. 10, 2025. [Online]. Available: https://openurl.ebsco.com/contentitem/gcd:116993906?sid=ebsco:plink:crawler&id=ebsco:gcd:116993906

[37] IRENA, 'Solar PV: A gender perspective', 2022. [Online]. Available: https://www.irena.org/Publications/2022/Sep/Solar-PV-Gender-Perspective

[38] IRENA, 'Wind energy: A gender perspective', 2020. [Online]. Available: https://www.irena.org/Publications/2020/Jan/Wind-energy-A-gender-perspective

[39] 'Barefoot College InternationalSolar | Barefoot College International'. Accessed: Feb. 10, 2025. [Online]. Available: https://www.barefootcollege.org/solution/solar/

[40] ILO, 'Skills and jobs mismatches in low- and middle-income countries', 2019. Accessed: Jan. 29, 2025. [Online]. Available: https://www.ilo.org/publications/major-publications/skills-and-jobs-mismatches-low-and-middle-income-countries

[41] Grace E. Chesmore, Rachel L. Starr, Rebecca Van Hoeck, and Meredith L. Ward, 'The Crisis of US Coal Communities: Strategies for a Just Transition to Renewable Energy', *J. Sci. Policy Gov.*, vol. 18, no. 2, Jun. 2021, Accessed: Jul. 01, 2025. [Online]. Available: https://www.sciencepolicyjournal.org/article_1038126_jspg180202.html

[42] H. Brauers, P.-Y. Oei, and P. Walk, 'Comparing coal phase-out pathways: The United Kingdom's and Germany's diverging transitions', *Environ. Innov. Soc. Transit.*, vol. 37, pp. 238–253, Dec. 2020, doi: 10.1016/j.eist.2020.09.001.

[43] L. Haywood, M. Janser, and N. Koch, 'The Welfare Costs of Job Loss and Decarbonization: Evidence from Germany's Coal Phaseout', *J. Assoc. Environ. Resour. Econ.*, vol. 11, no. 3, pp. 577–611, May 2024, doi: 10.1086/726425.

[44] P.-Y. Oei, H. Brauers, and P. Herpich, 'Lessons from Germany's hard coal mining phase-out: policies and transition from 1950 to 2018', *Clim. Policy*, vol. 20, no. 8, pp. 963–979, Sep. 2020, doi: 10.1080/14693062.2019.1688636.

[45] R. Vakulchuk and I. Overland, 'The failure to decarbonize the global energy education system: Carbon lock-in and stranded skill sets', *Energy Res.*

Soc. Sci., vol. 110, p. 103446, Apr. 2024, doi: 10.1016/j.erss.2024.103446.

[46] Zhichun Jenny Ying, 'How we mapped the "skills genome" of emerging jobs', LinkedIn Engineering Blog. Accessed: Jul. 01, 2025. [Online]. Available: https://www.linkedin.com/blog/engineering/skills-graph/how-we-mapped-the-skills-genome-of-emerging-jobs

[47] M. Bennedsen, B. Larsen, and J. Wei, 'Gender wage transparency and the gender pay gap: A survey', *J. Econ. Surv.*, vol. 37, no. 5, pp. 1743–1777, 2023, doi: 10.1111/joes.12545.

[48] L. Farré, 'Parental Leave Policies and Gender Equality: A Survey of the Literature', *Stud. Appl. Econ.*, vol. 34, no. 1, Art. no. 1, 2016, doi: 10.25115/eae.v34i1.3005.

[49] Barros, Ricardo Paes de, Olinto, Pedro, Lunde, Trine, and Caralho, Mirela, 'The impact of access to free childcare on women's labor market outcomes : evidence from a randomized trial in low-income neighborhoods of Rio de Janeiro (Inglês)', World Bank, Oct. 2013. Accessed: Jan. 27, 2025. [Online]. Available: https://documents1.worldbank.org/curated/en/672391468231860498/pdf/814980BRI0Impa00Box379810B00PUBLIC0.pdf

[50] S. Krishnapillai, 'Impact of Vocational Education and Training on Employment: An Empirical Study In The Northern Province of Sri Lanka', *Soc. Sci. Educ.* Res. Rev., Dec. 2021, doi: 10.5281/ZENODO.5789971.

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