CENTER FOR GLOBAL DEVELOPMENT

Meeting Skill Needs for the Global Green Transition

A Role for Labour Migration?

SAM HUCKSTEP · HELEN DEMPSTER

Abstract

The green transition will generate an enormous demand for workers. This paper reviews demand for, and supply of, skills relevant to the green transition in five countries in the Global South and five in the Global North. It focuses on the installation and maintenance workforce needed in two sectors: solar photovoltaic panels and heat pumps. It finds that in almost all of the ten countries studied, supply of the necessary skilled workers is unlikely to meet demand. In particular, Global North countries, which must cut more emissions sooner, face challenges in obtaining sufficient workers against a backdrop of ageing populations. If green transition targets are to be met, migration is likely to be needed as a complement to domestic training and reskilling. Given that the shortage of green-skilled workers is global, however, migration must be accompanied by support for training and retaining workers at home.

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Abbreviations

AC: Air Conditioning

ACAIRE: (Colombia's) Air Conditioning and Refrigeration Association

APEC: Asia-Pacific Economic Cooperation

APTC: Australia Pacific Training Coalition

AREP: (South Africa's) Association for Renewable Energy Practitioners

ASEAN: Association of Southeast Asian Nations

BEIS: (UK) Department for Business, Energy and Industrial Strategy

BIBB: (German) Federal Institute for Vocational Education and Training

BLS: (US) Bureau of Labor Statistics

CCCUK: UK Climate Change Committee

CEC: (Australian) Clean Energy Council

CEST: (FNU) College of Engineering, Science, and Technology

DfE: (UK) Department for Education

DHA: (South Africa's) Department of Home Affairs

DoE: (US) Department of Energy

DoL: (US) Department of Labor

EBRD: European Bank for Reconstruction and Development

ECSA: Engineering Council of South Africa

EFL: Energy Fiji Limited

ETP: Southeast Asia Energy Transition Partnership

ETU: (Australian) Electrical Trades Union

EU: European Union

FNU: Fiji National University

GSES: Global Sustainable Energy Solutions

GFANZ: Glasgow Financial Alliance for Net Zero

GGGI: Global Green Growth Institute

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit

GW: gigawatt

GWh: gigawatt-hour

HUST: Hanoi University of Science and Technology

HVAC: Heating, Ventilation, and Air Conditioning

ICAP: India Cooling Action Plan

ICMPD: International Centre for Migration Policy Development

IEA: International Energy Agency

IFC: International Finance Corporation

ILO: International Labour Organization

IOM: International Organization for Migration

IRA: (US) Inflation Reduction Act

IREC: (US) Inter-State Renewable Energy Council

IRENA: International Renewable Energy Agency

ISHRAE: Indian Society for Heating, Refrigerating, and Air Conditioning Engineers

JNNSM: Jawaharlal Nehru Solar Mission

JETP: Just Energy Transition Partnership

JETP-IP: (South Africa's) Just Energy Transition Investment Plan

KOFA: (German) Competence Centre for Securing Skilled Labour

LMIC: Lower and middle-income country

MAC: (UK) Migration Advisory Committee

MCS: (UK) Microgeneration Certification Scheme

MOLISA: (Vietnamese) Ministry of Labor, Invalids, and Social Affairs

MoU: Memorandum of Understanding

MRA: Mutual Recognition Agreement

NABCEP: North American Board of Certified Energy Practitioners

NCVT: (India's) National Council for Vocational Training

NSQF: National Skills Qualification Framework

OECD: Organisation for Economic Co-operation and Development

ONS: Office of National Statistics

PALM: Pacific Australia Labour Mobility programme

PV: Solar photovoltaic

RAC: Refrigeration and air-conditioning

REIPPP: (South Africa's) Renewable Energy Independent Power Producer Programme

RET: USP Renewable Energy Training laboratory

SADC: Southern African Development Community

SAPVIA: South African Photovoltaic Industry Association

SCGJ: (India's) Skill Council for Green Jobs

SENA: (Colombia's) Servicio Nacional de Aprendizaje (National Training Service)

SOC: Standard Occupation Classification

SOL: Shortage Occupation List

SSDP: (India's) Suryamitra Skill Development Programme

STEM: Science, technology, engineering, and mathematics

(T)VET: (Technical and) Vocational Education and Training

TW: terawatt

UAE: United Arab Emirates

UCAP: (Vietnam's) Urban Cooling Action Plan

UK: United Kingdom

UNEP: United Nations Environment Programme

US: United States

USAID: United States Agency for International Development

USP: University of the South Pacific

VOCTEC: (USAID) Vocational Training and Education for Clean Energy programme

ZVSHK: German Central Association for Plumbing, Heating, and Air Conditioning

Executive summary

Over the coming decades, countries must reduce their emissions at an unprecedented pace. This requires the rapid development of low-carbon—'green'—technologies, and the workers to operate them. This paper focuses specifically on the skill needs and availability to install and maintain solar photovoltaic (PV) panels and heat pumps.

This 'green transition' must occur everywhere, simultaneously. Net zero carbon-equivalent emissions must be achieved globally between 2050 and 2060, with stringent benchmarks in the intervening decades. This transformative shift is already underway, but it will require many more workers if it is to occur at the scale and pace needed.

The green transition's job creation potential is both an opportunity and a major challenge. On the one hand, the job creation promised by the green transition makes it more politically acceptable; on the other, implementation depends on an adequate workforce which may not be present. This paper finds that in all five Global North countries of destination reviewed, workforce shortages are already a constraint on the deployment of key technologies.

The jobs needed for the green transition are often not high skill, but low attractiveness and other factors could make them hard to fill with domestic workers. In the United States, for example, nearly 60 percent of the green transition's jobs will not need tertiary qualifications, and many require only a short period of vocational education. These jobs are often manual; they are often not highly paid, and may be less well-paid than comparable jobs; and they are often not in the same locations as the high carbon jobs that will be displaced during the same period. Moreover, in many countries, a high proportion of workers in sectors relevant or adjacent to the green transition are approaching the end of their careers. While it is important to provide workers in high carbon sectors with the opportunity to transition to green jobs, neither the transitioning workforce nor other domestic channels appear sufficient to meet workforce needs in the timeframes required.

It is likely that high-emitting countries in the Global North will need to use migration policy to supplement their domestic workforce supply. This could be undertaken through long-term temporary migration of workers already holding skills needed for the green transition. Given, however, that the shortage of skills needed for the green transition is global, conventional loosening of visa policy will do little to increase the total number of green-skilled workers. This is relevant given that international competition for workers is likely to significantly increase.

Countries in need of workers for their green transition will need to support workers' training as well as facilitate their migration. In doing so, they could follow the Global Skill Partnership model, which has been successfully tested in multiple sectors and countries. In this approach, a cohort would be trained in the country of origin to the skill level needed in the country of destination. Part of the cohort would then move to work in the country of destination, while part stays in the country

of origin. This prevents the mere reallocation of skilled workers, which would have a limited effect on emissions reductions and could restrict the green transition in the country of origin.

Because of the constrained timeframes necessary for the green transition, new Global Skill Partnerships in green transition-related sectors would need to be scaled at unusual pace. Not all of the countries of origin selected in this paper would make appropriate partners for all countries of destination. Fiji, for example, could have a mutually beneficial partnership with Pacific peers, but would be unlikely to be a suitable partner for Germany. India stands out among countries of origin due to its very large youth population; the enormous scale of its existing green-skilled training apparatus; and its determination to facilitate international migration.

Countries of origin can benefit significantly from green-skilled training and migration programmes. So long as training is integrated so that migration programmes do not merely relocate migrants to the Global North, the skill stock in countries of origin can be increased. An approach like that of the Global Skill Partnership can support human capital development for green transitions in countries of origin. Moreover, migration can provide migrants with significantly higher earnings—facilitating high-impact remittances—and the opportunity to gain experience in important growing sectors, such as solar PV or heat pump installation. It is possible that due to limited access to necessary finance, countries of origin may undertake their green transitions after Global North countries of destination. This allows for a medium-term circular migration model in which migrants are trained; gain experience; and return to support growing green transition-related sectors in the future.

Policy recommendations

For countries of origin and destination

- **Survey skill needs**. Many countries lack adequate labour market information, especially with regard to new and developing sectors.
- **Prioritise domestic training and reskilling.** All countries will need to support educational institutions, in close partnership with the private sector, to ensure that the necessary workers are trained. This will often include making more funding available.
- **Harmonise training requirements with partner countries.** Where the relevant occupational requirements have not yet been formalised (most commonly in possible countries of origin), governments should prioritise this. Governments should also seek to harmonise or align curricula with partner countries, making efficient mobility more feasible.
- **Engage more closely with the private sector.** Companies are frequently insufficiently consulted by the public sector, leading to educational systems and subsidy structures that do not meet needs. Greater alignment would increase the supply of qualified workers.
- **Stabilise public and private procurement.** In many countries, state policy and procurement have followed boom-and-bust cycles or have been waveringly supported. This makes

investment, by companies in projects and possible workers in skills, more challenging. Policy and investment should be stabilised as a priority.

- **Support the training of existing immigrant and refugee populations.** Many countries already have relatively large populations of migrants and refugees. These potential workers are often underemployed. Assistance with training, job matching, and (if needed) internal relocation to areas with large labour market needs could be efficient and equitable. Governments could also consider providing pathways to regularisation via training into shortage occupation roles.

For countries of destination

- **Develop skill partnerships.** The global shortage of workers means that conventional migration pathways will not provide the green-skilled workers needed globally, and risks stripping countries of destination of the workers they need for their own green transitions. Countries of destination should therefore support training in countries of origin, increasing the total global stock of green-skilled workers rather than merely reallocating them.
- **Integrate the development impacts of migration partnerships.** To maximise the impacts of these programmes, countries of destination should also consider supply-side factors such as the number of unemployed persons; the effects of demographic transitions; and the size of fossil fuel workforces.
- **Expand mid-skill visas (long-term temporary and permanent).** While skill partnerships are necessary over the mid-term, increased immigration is likely to be needed by countries of destination in the short term. In some countries, a dedicated 'green transition' visa may be feasible; in others, alterations to shortage occupation lists and existing visa pathways will be more practical.
- **Ensure that international recruitment respects migrants' rights.** Governments in countries of destination should cooperate with employers; regulatory agencies; migrant organisations; and unions, to ensure that migration policy fulfils migrants' rights.
- **Consult with unions and employers.** The green transition is 'sold' to electorates on the basis of job creation. For political and practical reasons, governments should ensure that both employers and unions are consulted in policy formation, so that migration meets employers' needs without allowing them to undercut domestic workers or drive down working conditions.

For countries of origin

- **Focus on the whole spectrum of skill needs.** Countries of origin often appear to prioritise *installation* over *maintenance*. In the training space, this translates to higher numbers of workers trained for installation, while maintenance may be left to informal workers.
- **Invest in low-cost apprenticeship schemes.** Several countries of origin have developed high-volume apprenticeship schemes providing school leavers with vocational skills

relevant to the green transition. These often provide valuable skills to marginalised groups; they could be expanded to also target refugees and internally displaced persons. These schemes should also be connected to international labour markets, training to the levels needed by countries of destination and supported by these partner countries.

- **Actively harness emigration.** Very few of our countries of origin actively facilitate labour emigration, despite the many benefits of doing so. Countries of origin should position themselves to benefit from increasing international demand for green-skilled workers, partnering with countries of destination in exchange for substantial investment in training infrastructure.

Country summaries

Countries of destination

The United Kingdom (UK)

- The UK has set a highly ambitious decarbonisation agenda, with tight targets. It aims to install 600,000 heat pumps annually by 2028, and to reach 70 GW of installed solar capacity by 2035. These targets are not currently on track to be achieved.
- Workforce availability is a significant challenge for the UK. The UK Climate Change Committee, a key independent advisory body, estimates that the green transition will create 135,000 to 725,000 net new jobs by 2030. Shortages are especially apparent in several sectors, but there is a particular lack of electricians: a shortage of over 100,000 is expected by 2032.
- Heat pump installations are rising, especially thanks to large new subsidies, but are far from the 600,000-per-year target. By 2028, 27,000–33,700 additional heating engineers will be required, and 62,000–69,500 by 2035. 40 percent of current heating engineers are anticipated to leave the industry in the next ten years; 33 percent are over 55 years old.
- In 2022 the UK had roughly 14 GW of deployed solar PV capacity. To meet the target of quintupling capacity, 35,000 new solar sector jobs will be needed by 2030, versus 6,500 employed in 2022.
- In both the heat pump and solar sectors, there is low confidence that the apprenticeship system will deliver the workers needed for the green transition's goals.
- Solar sector bodies have already warned that immigration may be needed. Several advisory studies have recommended opening green transition-relevant sectors' access to immigration, including through the creation of skill partnerships.
- The British immigration system may currently be unsuited to providing the workers needed for the green transition, with an excessively complex, bureaucratic, and expensive visa system. This is aggravated by the fact that many companies in green transition-relevant sectors are unaccustomed to active international recruitment.

The United States (US)

- The 2022 Inflation Reduction Act will hugely stimulate the implementation of the US' green transition. This will have enormous effects for labour market demand in relevant sectors. Between 1.5 and 2.9 million clean energy jobs are estimated to be created by 2030. This coincides with a 'silver tsunami' of retirements.
- Green transition-relevant sectors already face shortages of workers. This is driving up prices; leading to market consolidation; and inhibiting projects. A shortage of one million electricians is anticipated by 2030.
- The heat pump installation workforce must grow dramatically. A higher average age in the existing workforce, and an inadequate supply of new entrants, will pose a serious challenge to installation targets. Some lessons could be learned from the state of Maine, which has been unusually successful in building its workforce (while still facing bottlenecks).
- Demand for solar PV installers will rise rapidly. The solar PV workforce will need to double from 255,000 in 2022 to 538,000 in 2032. In 2023, 97 percent of companies reported that it was difficult to source qualified solar workers. Labour costs across solar sectors rose by between 5 and 25 percent in 2023.
- The US' solar training pipeline is inadequately developed and fragmented across states. No solar installation apprenticeship programme has yet been recognised by the Department of Labor, and there are not enough apprenticeship programmes to meet demand. Despite this, the variety of paths into the industry available, and the low qualifications needed, suggests that it should not in principle be hard to introduce more workers to the industry.
- Migration to support the green transition has so far been little discussed in the US. Any changes would be likely to come through an update to Schedule A; the H-2B visa; or the J-1 visa, but could face considerable political blowback.

Australia

- Australia aims to increase its share of low-carbon power generation from 32 percent of its energy production in 2023 to 82 percent in 2030, and to reduce its emissions versus 2005 levels by 43 percent.
- Workforce constraints are recognised to be a major challenge to Australia's green transition. Up to 42,000 additional electricians may be needed by 2030, in one of the OECD's tightest labour markets. Across sectors, a major shortage of skilled workers is expected.
- Australia's solar PV sector is in good health but unlikely to hit federal targets. This is in part due to a shortage of installers, despite the fact that only 17 percent of the PV installation workforce holds tertiary qualifications, and only 58 percent vocational qualifications. Australia's apprenticeship sector is considered to be unable to provide the necessary workers.
- Australia's heat pump sector is small and growing, but faces a shortage of qualified workers. Heat pump installations must be undertaken by teams of plumbers and electricians; few

plumbers are qualified to work with electrical fittings, and the path to qualification is prohibitively difficult.

- Australia is becoming more proactive in seeking skilled migrant workers for its green transition. The Australian Government has recognised that alongside domestic skill approaches, Australia will "be heavily reliant on effective migration settings."
- Two flagship federal reports have argued that the migration system must be reformed to meet green transition workforce needs. Reforms will need to facilitate easier recognition of migrants' qualifications (historically migrants are often underemployed). This is already being undertaken with India, along with deeper migration partnerships.
- Australia will need to seek skill partnership agreements with countries of origin. This approach is understood to be being discussed with India, and is also likely to meet wider goals in the Pacific.

Germany

- Germany aims to achieve net zero greenhouse gas emissions by 2045, and to reduce emissions by 65 percent by 2030 (versus 1990 levels). These goals are highly challenging, and Germany has already missed intermediate targets.
- Germany targets 500,000 heat pump installations in 2024, and 22 GW of installed solar PV capacity each year to 2030. High heat pump subsidies have boosted residential purchases, but may need to increase further. A current shortfall of up to 30,000 electricians makes installations harder.
- Germany's solar PV workforce is insufficient to meet full targets. Across the solar industry, Germany is estimated to need up to 204,000 further workers. Filling these gaps is made harder by competition from other sectors. In February 2023, around 60 percent of German solar contractors had vacancies.
- There is not currently any state-recognised solar PV installation accreditation. Many solar PV installation companies use a mix of unqualified support staff, trained in a few weeks, and fully qualified electricians.
- In the heat pump sector, a workforce shortage is "the current biggest bottleneck" in expanding installations. Across the heating sector, a shortage of over 14,000 workers was reported in 2022. Difficulties in the apprenticeship system, which has seen falling numbers of applicants, make recruitment harder. The heating sector's impending retirements will exacerbate challenges.
- Germany has proactively sought to attract international workers. This is undertaken through 2023 reforms to general immigration policy, and through deliberate partnerships facilitating training and active recruitment. These partnerships will be scaled up in the coming years; several build on longstanding engagements in relevant sectors.
- Germany has agreed a field-leading partnership with India's Skill Council for Green Jobs, allowing around 2,000 Indian solar PV installers to work in Germany's solar PV sector.

The European Union (EU)

- The EU aims to reduce emissions by 55 percent by 2030 versus 1990 levels, and to reach net zero emissions by 2050. It targets a 42.5 percent share of renewable energy by 2030, versus 32 percent in 2021. A US$1.07 trillion investment plan is intended to support implementation.
- As a bloc, the EU intends to install 30 million additional heat pumps by 2030, and 320 GW of solar PV by 2025 (more than doubling 2020 capacity), rising to nearly 600 GW by 2030.
- The heat pump installation rate will have to increase by over 50 percent to meet targets. The ability to do this is challenged by shortages of installers. The heat pump installation workforce must rise from around 40,000 in 2022 to up to 750,000 in 2030.
- Solar PV capacity installations are rising sharply. In 2023 58 GW of solar PV was installed (a 41 percent increase versus 2022), versus an EU target of 48 GW. The solar industry has been bolstered by EU energy supply challenges after Russia's invasion of Ukraine.
- The solar PV sector will need a significantly larger workforce to achieve encouraging forecasts. 281,000 workers were employed in the EU solar sector in 2022; more than 700,000 further workers across the value chain may be needed by 2030, of which around 80 percent will be needed in deployment, and 63 percent in rooftop solar.
- In 2022 18 EU countries faced shortages of electricians; 18 also faced shortages of plumbers and pipefitters. The European Commission has recognised that a shortage of workers is a key bottleneck.
- Multiple EU-level training initiatives have been established, including the creation of a new network of Net-Zero Industry Academies; the Pact for Skills, targeting public-private partnerships; and the Just Transition Fund, supporting retraining of displaced workers. Training and accreditation requirements are not homogeneous across the EU, making the intra-EU labour market less fluid.
- The role of migration for the EU's green transition has been increasingly recognised. The Commission's *Green Deal Industrial Plan* noted that skilled workers will need to be attracted from third countries.
- The Talent Pool, announced in 2023, may make international recruitment more practicable, but faces challenges. Talent Partnerships (integrated into the Talent Pool framework) may be necessary to guarantee a supply of workers, but will need to be rapidly piloted and scaled.

Countries of origin

India

- India targets net zero emissions by 2070, and 50 percent of electricity generation from renewable energy sources by 2030. It is also a major emitter, with a heavy reliance on coal, and its emissions are expected to continue rising.
- India aims to install 280 GW of solar PV capacity by 2030. Targets have so far been undershot: in 2022 only 63 percent of the targeted capacity was installed. This is in part due

to the high cost of imported solar panels; with falling costs and onshoring of production, this problem will pass.

- Both solar PV and increased air conditioning will be necessary for adaptation to a rising number of high-heat days. At least 90 percent of households do not have an air conditioning unit; demand is expected to rise considerably, with around 1 billion units installed in the three decades to 2050.
- Between 24 and 35 million new jobs could be created by 2050 if India meets its targets. This skill transition is overseen by the Skill Council for Green Jobs (SCGJ), which manages India's green transition-relevant vocational system.
- The solar industry employed around 280,000 workers in 2023; it is estimated to need 3.26 million by 2050. The *Suryamitra* training programme is a large-scale, field-leading training and apprenticeship programme. Since 2015 it has trained around 80,000 workers in solar PV installation.
- The air-cooling and refrigeration industry will need to see a 10-fold increase in jobs, rising to two million in 2027. The PMKVY programme aims to train 100,000 technicians. Currently only 36 percent of air-cooling technicians have training, and most work in the informal sector.
- India has a very young population, and employment will be an increasingly important state goal. It also currently has around 21 million people working in high-emitting sectors, who will need support in retraining.
- India is proactively seeking to support emigration, including by establishing training centres providing skills to international standards. India has actively sought agreements with 30 countries in need of labour, including Australia, Japan, the US, and Canada.
- Due to the Covid-19 pandemic and high import costs for solar PV panels, a lower-than-expected PV installation rate has left many *Suryamitra* graduates without employment. Recognising India's rare surplus of workers, the German Solar Association (BSW) has agreed with the SCGJ a programme supporting around 2,000 solar PV installers in coming to work in Germany from 2024 to 2026.

Vietnam

- Vietnam targets net zero emissions by 2050, and a 43.5 percent emissions reduction by 2030. Vietnam's high reliance on coal, and challenges attracting finance, may make these goals difficult to achieve.
- The cooling sector in Vietnam is relatively large, and growing. Around 100 million air cooling units could be installed by 2050 (a 50-fold increase versus 2016). Vietnam has pledged for 75 percent of urban, and 55 percent of rural, air-cooling units to be high efficiency by 2030.
- Vietnam targets 30 percent of energy generation from renewable sources by 2030. Following the announcement of a Just Energy Transition Partnership in 2023, new financing availability and policy assurance may increase demand for workers.

- The decade 2010 to 2020 saw a solar PV boom, followed by a relative sector bust after the grid became overloaded. Vietnam now only targets 4 GW of solar PV capacity additions by 2030. Vietnam's solar PV workforce fell from 126,000 in 2020 to 32,000 in 2021.
- It is doubtful that Vietnam has an adequate supply of the workers needed for its green transition. The vocational system may not be equipping trainees with the skills required. Modular or full training options are provided in both solar PV and cooling by the Hanoi University of Science and Technology; sector-specific companies, such as Daikin; and international donor agencies.
- Vietnam's coal sector employs over 80,000 workers, who will need support in transitioning to new employment.
- Vietnam actively facilitates skilled labour emigration as part of its national development strategy, but has not yet made any agreements relevant to the green transition. Vietnam aims to facilitate 90,000 workers in emigrating each year; in 2022 142,000 left.
- It is possible that Vietnam's underemployed solar PV workforce could be amenable to international employment.
- Several countries of destination are already active in supporting the TVET system in Vietnam, including the UK and Germany (which trains Vietnamese workers to Germany standards in some sectors).

South Africa

- South Africa targets net zero emissions by 2050, and a decrease in emissions of up to 21 percent by 2030 versus 2020 levels. A failure to decommission coal-fired power plants now means that the 2030 target cannot be achieved. 70 percent of energy generation is derived from coal.
- South Africa needs clean and reliable energy for climate adaptation. In recent years, its energy supply has been regularly disrupted. Its green transition will be supported by a Just Energy Transition Partnership (JETP).
- South Africa's air conditioning market is very small: only four percent of households are estimated to own air conditioning. The state energy firm Eskom provides subsidies for heat pump installations, which appear to be predominantly used in industrial settings.
- South Africa aims to add 6.5 GW of solar PV by 2030, with 10 percent directed to coal-reliant areas. From 2020 to 2023 over 4.5 GW were added to the grid.
- The solar sector significantly lacks skilled workers. Some 29,000 jobs could be created by 2030 in solar PV, and 65,000 by 2050. It is unclear how many workers are employed in South Africa's nascent heat pump installation sector.
- Inadequate supply of skills is deeply challenging for South Africa's green transition. A government review of South Africa's JETP found that "all stakeholders are agreed that the focus on skills development… is insufficient", with no indication of how crucial bottlenecks will be addressed.

- South Africa hosts the largest number of migrants in Africa. It also faces a high rate of emigration, leaving challenging skill gaps in key sectors, including engineering. Yet South Africa does not currently attempt to facilitate or proactively benefit from emigration, despite past government policy papers suggesting that this should be done.
- In the absence of sufficient domestic training options, international companies have brought in foreign workers for renewable projects needing particular skills, such as welders. Conversely, some domestic (solar manufacturing) firms have resorted to sending workers to China for training when unable to source trained workers locally.

Fiji

- Fiji aims to achieve net zero emissions by 2050. Over 50 percent of Fiji's energy supply is currently derived from renewable sources, but the remaining 45 percent of oil-derived energy could be hard to abate.
- The solar PV sector is underdeveloped. As of 2020 only 4 MW of solar PV has been installed; Fiji instead relies heavily on hydropower.
- Little attention has been paid to the green transition's skill needs. A lack of labour market data makes estimates difficult; in 2019, approximately 9,000 'green' jobs were assessed to be held in Fiji (versus 196,800 employed), with around 740 in the electricity sector.
- Fiji is projected to need 2,100–4,200 'green' workers by 2030, and 5,000–12,000 by 2050.
- The Fiji National University's College of Engineering, Science, and Technology is the dominant training provider for green transition-relevant skills. International donors provide further support.
- Fiji has a longstanding history of emigration. Fiji participates in Australia's Pacific Australia Labour Mobility scheme, providing nine-month visas for seasonal work in multiple sectors, and in New Zealand's Pacific Access Category visa.
- Fiji could plausibly be a partner for green-transition related skilling and migration programmes with Australia and Fiji, meeting Pacific development objectives through circular migration programmes. This could be delivered through a retooled version of the Australia Pacific Training Coalition, which has already trained hundreds of Fijians to Australian standards in green transition-relevant sectors. Fiji could actively seek a mutually beneficial programme in this area.
- Because of Fiji's small population, it is likely only to be a viable country of origin for local partners. Its small population also makes it vulnerable to emigration-related workforce gaps, and any partnership will have to be carefully equitable.

Colombia

- Colombia targets net zero emissions by 2050 and a 51 percent reduction in greenhouse gas emissions by 2030.
- Colombia is currently highly dependent on oil and gas, which accounts for 60 percent of its exports. It has committed not to award new gas and oil exploration contracts.

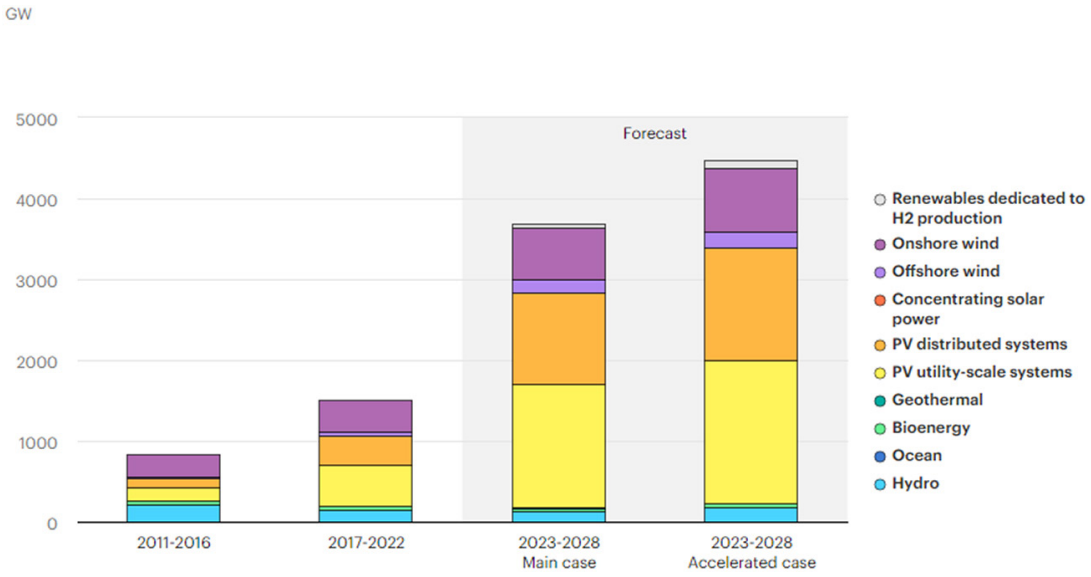
- 70 percent of Colombia's energy generation is provided by hydropower. This is a renewable energy source, but vulnerable to droughts during El Nino periods. Wind and solar currently provide less than one percent of Colombia's energy capacity.
- Colombia will face more frequent high-heat days, and will need increased clean energy generation and air cooling capacity to meet adaptation needs. Because of its topography, however, buildings also need heating capacity; affordable heat pumps would be a high efficiency solution.
- Around 400,000 Colombian households do not have access to electricity; distributed electricity provision and micro-grids may assist adaptation. For many, heat pumps are likely to be out of reach for some time.
- Colombia's green transition faces significant workforce challenges. Pathways into the heating sector are relatively accessible and clear, but are undersubscribed despite good pay for qualified technicians.
- The solar sector employed only around 2,400 workers in 2021, and will need to rapidly scale up. Several international donors are supporting training programmes.
- Over 120,000 workers are employed in the coal sector, and many more in other areas. The Ministry of Labor is currently drafting a national just transition strategy to support retraining.
- Colombia has integrated large numbers of Venezuelan refugees into the labour market. It also has a high emigration rate: in 2022 nearly 550,000 people left Colombia.
- Countries of destination, notably the US and Germany, are attempting to benefit from Colombian immigration. Colombia does not have an active approach to facilitating and benefiting from emigration, but could seek to establish training and migration partnerships for mutual benefit in green transition-relevant sectors.

Introduction

Increasingly, countries recognise that they must transition to an economy which uses and protects resources in a more sustainable way. As countries commit to reducing their emissions and mitigating against the worst impacts of climate change, the concept of the 'green transition' has become prevalent. Globally, more than 80 countries have pledged to substantially reduce their emissions in the coming decades, often to zero by 2050 (Net Zero Tracker, 2021). This requires the rapid development and expansion of low-carbon or 'green' technologies such as solar photovoltaic (PV) energy, wind power, bioenergy, hydropower, building insulation and decarbonisation, and the electrification of transport networks. It also requires the down-scaling of 'high-carbon' or 'brown' technologies such as the extraction of coal, oil, and natural gas.

This transformative shift is already underway (Figure 1). It is widely expected to lead to high levels of net job creation (including the loss of some jobs in current high-emitting sectors). The green transition's job creation potential is both an opportunity and a challenge. In 2022, the clean energy sector was estimated by the International Renewable Energy Agency (IRENA) to employ 13.7 million people, up from 12.7 million in 2021 (IRENA and ILO, 2023; Figure 2). Almost two-thirds of these jobs are in Asia, a region which is seeing huge growth in green technologies, especially solar. Total employment in green sectors is set to increase. The International Energy Agency (IEA) expects that there will be 14 million *new* 'green' jobs by 2030, with a further 16 million people moving over from 'brown' sectors (IEA, 2022c).[1] While the nature of a 'green job' is contested, it is clear that these jobs will be distributed across the skill and pay spectrum: 64 percent of all workers employed in the energy sector require at most vocational training, with 13 percent requiring no post-secondary training whatsoever (IEA, 2023g).

FIGURE 1. Global renewable capacity additions since 2005 and projected to 2028

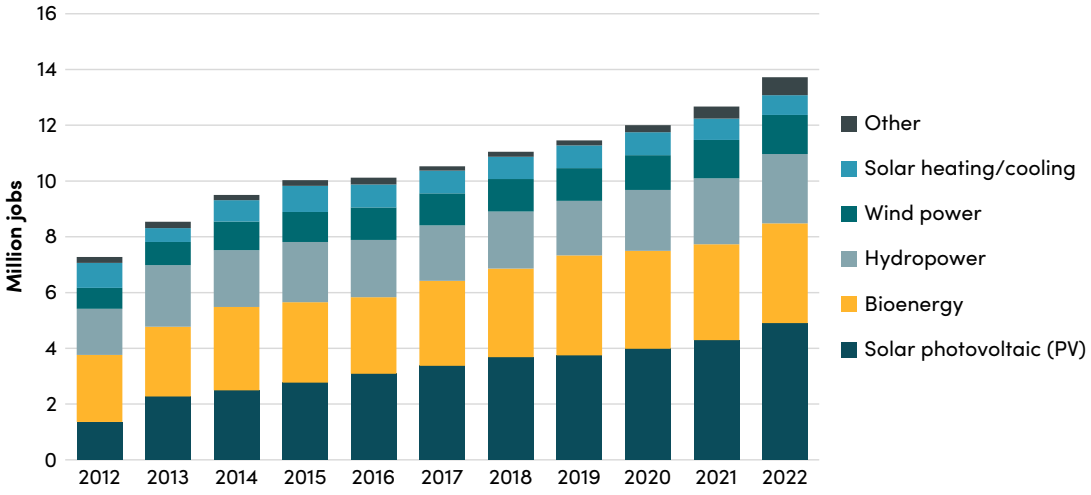


Note: 'Bioenergy' includes liquid biofuels, solid biomass, and biogas. The 'main case' attempts to integrate country-specific challenges that could hinder faster renewable energy expansion. The 'accelerated case' assumes enhanced implementation of existing policies and targets.

Source: IEA (2024).

1 'Brown' jobs are a shorthand term for highly polluting occupations in high-emissions industries, e.g., mining or fossil fuel-based energy production (Vandeplas et al., 2022).

FIGURE 2. The number of 'green' jobs is increasing



Note: 'Bioenergy' includes liquid biofuels, solid biomass, and biogas. 'Hydropower' includes direct jobs only. 'Others' includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy.

Source: IRENA and ILO (2023).

Emissions must be reduced within condensed timeframes set by the state of the atmosphere (IRENA, 2023d). In practice, this requires an energy transition of unprecedented speed, occurring simultaneously across the globe. Limiting warming to below 1.5 degrees Celsius requires reaching net zero emissions globally between 2050 and 2060, with benchmarks in the intervening decades (IPCC, 2022). This will be extremely challenging. In China, India, and South Africa, for example, coal power generation must be reduced at a speed twice as fast as any previous energy transition (Muttitt et al., 2023). Multiple international factors will affect states' ability to achieve this, including access to financing (Espagne et al., 2023; IEA, 2024), access to raw materials (Kowalski and Legendre, 2023), and the stability of key supply chains, especially those in which China is heavily involved (IEA, 2023g; 2024).

Among these crucial factors, the issue of workforce availability is frequently forgotten. The green transition is widely argued, especially by politicians, to have huge job creation potential; but it must not be forgotten that those same jobs will also be necessary to create the green transition. If unfilled, decarbonisation will not happen. At present, all countries are likely to struggle to find enough skilled domestic workers to undertake the jobs needed to make the green transition a reality. The number of jobs demanding qualifications related to the energy transition—such as vocational qualifications in electronics or heating—are expected to rise by eight percent each year through to 2030; around the world, however, the number of workers gaining these qualifications is flatlining or declining (IEA, 2023g). This is a blind spot in many policy documents: many make claims about the number of new solar panels or heat pumps that need to be installed by 2030, without considering whether there are *enough qualified people* to install them. The Boston Consulting Group and the International Organization for Migration (IOM) have estimated that by 2030 there will be a seven million-person

global deficit of 'green-skilled' workers across just five sectors (Harnoss et al., 2023).[2] The IEA has acknowledged that this shortage is already translating into project delays and impacting investment decisions (IEA, 2022c). If countries are to meet their emissions reduction targets, and if 1.5 degrees is to be a reality, they must address their workforce issues.

In this paper, we argue that addressing global green skill needs will require a creative combination of domestic training, re-skilling, and skilled labour migration. Training and reskilling are uncontroversial proposals, and are already included in national transition plans. Firstly, reskilling. There are currently millions of people working in 'brown' jobs who could be retrained to support the implementation of low-emission technologies. This is crucial, but it is likely to be insufficient on its own. Many workers in higher-emission jobs are close to retirement (e.g., Kane, 2022), earn higher wages than those offered in green sectors (Popp et al., 2022), and are often clustered in different locations to the areas benefiting from new green growth (Bergant, Mano, and Shibata, 2022)—all issues which will restrict interest in reskilling. Secondly, training. New entrants to green transition-related areas of work must be attracted from among young populations. In most countries, however, the vocational training and apprenticeship systems are not sufficiently well connected to private sector needs, and are not attracting or producing the numbers of people needed to support the green transition (IEA, 2023g). Political stability concerning planned investments is needed to give these providers the certainty they need to develop new curricula to train the workers of tomorrow, ideally with financial support from government and industry. Even then, however, it appears unlikely that there would be sufficient new entrants to meet all needs.

For many countries in the Global North, where demographic constraints are growing (World Bank, 2023; OECD, 2020a; b), domestic efforts are unlikely to be sufficient to meet the scale of the need in the timeframes required. The EU, for example, is estimated to have 95 million fewer working-age people in 2050 compared to 2015 (Kenny and Yang, 2021). This is where the third option comes in: expanding skilled migration. Many countries of destination already rely on skilled migrants to staff their construction and engineering sectors, and many countries of origin enjoy both remittance and skill transfers from this mobility.

Yet expanding skilled migration *alone,* without complementary policies, would merely move the problem around. Migration does not inherently assist emissions reduction efforts. All things being equal, a solar panel installer in South Africa will have the same impact on emissions reduction as one in the United States: a solar panel has a given energy production capacity, and the place of installation makes little difference. Where workers are underemployed in their place of origin or could (for example, due to technological assistance) be more productive in a country of destination, this could change: a surplus worker installing solar PV at an increased rate in the country of destination will contribute more to the green transition than they would have done remaining underemployed in

2 These sectors are solar PV; wind; bioenergy; electric vehicle charging infrastructure; and hydropower. This estimate does not include, for example, heat pump installation or energy efficiency retrofits.

the country of origin. By contrast, if a) the worker is not surplus or underemployed in the country of origin; b) the worker would be no more productive in their country of destination than they would have been without migrating; and c) energy sources in the country of origin are more emissions-intensive than those in the country of destination (for example, due to a reliance on coal), it is in principle possible that migration might have a net negative effect on total emissions.

It is also possible that the migration of workers with skills relevant to the green transition could leave challenging labour gaps in the country of origin. South Africa, for example, has experienced workforce shortages due to migration in its engineering sector, and faces a known shortage of workers with the skills needed for its green transition. Migration of green-skilled workers could thus allow a form of 'reverse outsourcing' of emissions reduction capacity through the movement of scarce human capital. Instead, what is needed is a rapid expansion of both domestic training and skilled migration if the world is to meet its commitments.

We propose that the approach to migration most likely to succeed is one that deliberately incorporates both proactive training and international mobility. This approach increases the total stock of workers with the skills needed while also facilitating their allocation to the locations where they can have the most impact. This approach, using the Global Skill Partnership model, is not the only one that can be taken: circular migration schemes could also serve a role in facilitating the relocation of workers already possessing the necessary skills. As noted above, however, this does not increase the total stock of workers with scarce skillsets, and thus may merely reallocate emissions reductions without improving the global total. In addition, the global nature of the shortage of the skills needed for the green transition means that this is an approach that is unlikely to be able to wholly fulfil needs: labour migration must be accompanied by training.

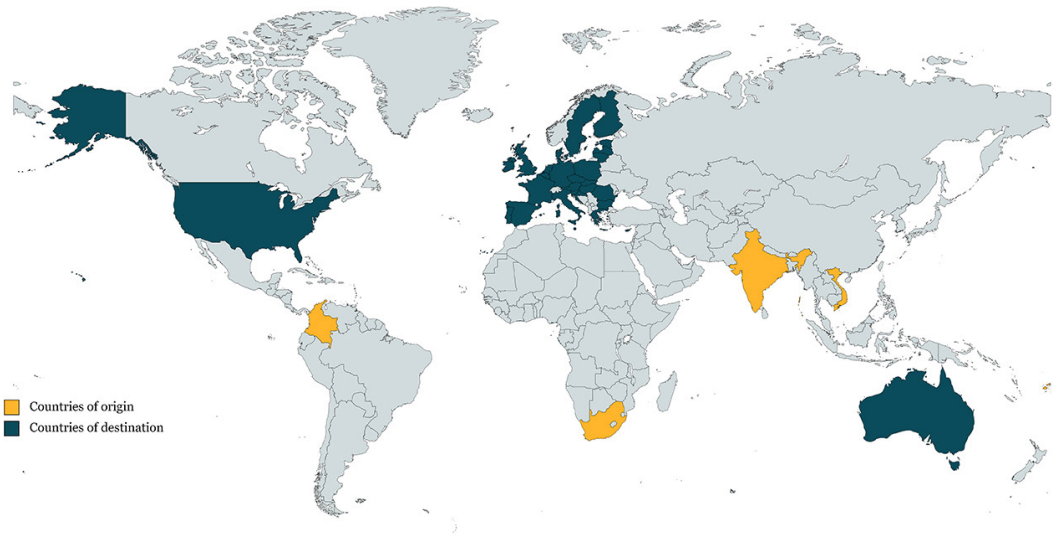
The Global Skill Partnership approach, which has already been successfully trialled in multiple other sectors, supports pre-departure training in necessary skill areas before facilitating whole- or partial-cohort migration of trained individuals. This approach fulfils the needs of both partner countries. For countries of destination, it ensures access to the workers needed in an increasingly competitive international labour market, and allows control over the qualification levels to which workers are trained. For countries of origin, it grows their domestic skill stock while preventing them from suffering skill shortages of their own: while developing economies' green transitions do occur in contexts distinct from transitions occurring in the Global North (IEA, 2023g), the skill needs are often substantially similar. It also provides them with a skilled diaspora who may return with increased experience or send remittances while away. For those trained and migrating, the approach opens up new opportunities and significantly higher wages, some of which is likely to be remitted to support communities at home. These remittances could themselves have beneficial effects for adaptation (Huckstep and Clemens, 2023; Randazzo et al., 2023).

This paper aims to provide a state of play, reviewing current and anticipated demand for green jobs around the world; the domestic supply of skilled workers; and the role that skilled labour migration could (and does) play in meeting this demand. It was based on an extensive review of secondary literature, and key informant interviews with stakeholders in our focus countries and at the global level. Given the broad and contested nature of green jobs, we have chosen to focus our research on just two occupations: solar PV installers, and heat pump installers. These jobs were chosen because they are seeing rapid employment growth in our chosen countries of destination; are at or include jobs in the mid- or low-skill level, and may be amenable to a Global Skill Partnership approach; and are likely to be of even more importance in the decades to come, with attendant labour market demand.

We have also chosen to narrow our focus to five countries of destination (the United States (US), the United Kingdom (UK), Australia, Germany, and the European Union (EU) as a bloc[3]) and five countries of origin (India, Vietnam, Fiji, Colombia, and South Africa) (see Figure 3). These countries were chosen in part to provide broad geographic coverage across continents and possible labour migration corridors, and in part because they represent interesting developments in the fields of the green transition and of migration. India, for example, has been investing in world-leading green training programmes, prominently its enormous *Suryamitra* programme. Vietnam poses a different issue: it previously had a large solar workforce during a residential solar boom, but subsequently has seen its labour pool decline during an installation slump. Fiji, a much smaller state, is committed to decarbonisation but struggling with implementation; it has previously supplied migrant workers to Australia, and collaboration between the states could support both countries' green transition-related skill needs. The US has announced unprecedentedly large clean energy investments, but faces workforce bottlenecks in a political environment reluctant to contemplate immigration reforms. The EU has announced responsive investments, and is actively supporting immigration expansions. Australia and Germany are undertaking immigration reforms to support the green transition workforce; the UK lags behind, but is likely to need to follow. In doing so, these countries will need to turn their attention to our countries of destination or their peers—but these countries often have little experience of training for 'export', and will need support.

3 Including Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The European Union (EU) was chosen, in addition to a specific focus on Germany, given their ability to produce regional estimates of skill predictions and to provide regional-based skilled labour migration visas.

FIGURE 3. This paper focuses on five countries of destination and five countries of origin



The paper will be structured as follows. The first section will describe what a green job is, the qualities of green jobs, and where they are in demand, with a specific focus on solar PV and heat pump installers. The second section will outline the demand for and supply of such installers in our five countries of destination, with a specific focus on the role skilled labour migration plays. The third section will do the same for our five countries of origin. The paper will conclude with some overarching remarks, a short analysis of potential migration models (to be explored in more detail in future papers), and recommendations for policymakers seeking to expand their skilled green workforce.

Understanding the demand for green skills

What is a green job, and what skills do they require?

Varying definitions of 'green skill' and 'green job' are used by different organisations and countries. This can make it hard to assess the current state of the labour market, and to predict the absolute numbers of workers necessary. Given the importance of adequate labour market knowledge for avoiding skill-related bottlenecks, these blind spots pose serious challenges to the green transition at the local and national levels (OECD, 2023b).

While a high-carbon job can be relatively easily defined, the definition of green or low-carbon jobs has been more contested. This is in part because many jobs are expected to become green, or could be construed to contribute indirectly to wider green goals. A bus driver, for example, can conceivably be considered green due to their contribution to reducing total travel emissions. The International

Labour Organization (ILO), in its agenda-setting 2018 report *Greening With Jobs*, defines green jobs as jobs that:

> *"reduce the consumption of energy and raw materials, limit greenhouse gas emissions, minimise waste and pollution, protect and restore ecosystems and enable enterprises and communities to adapt to climate change", and which must, furthermore, be "decent" (ILO, 2018).*

As noted above, however, this is a very broad definition, and may be of limited use for setting policy and assessing labour migration needs.

Agencies and private sector actors meet the challenge in varying ways. The United Kingdom's Office of National Statistics (ONS), for example, argues that "the term 'green job' has no one particular meaning: instead, it uses a variety of definitions depending on circumstance" (Harris, 2021). Some approaches are sector-specific, designating work in certain areas as green and calculating the total number employed by them. This is the approach taken by IRENA in its annual *Renewable Energy and Jobs* reports (IRENA and ILO, 2022).

Other approaches use occupation-specific definitions and calculations. France's National Observatory for Jobs and Occupations of the Green Economy defines green jobs according to activity and occupation, attempting to recognise green jobs and occupations that are 'greening' thanks to changes in activity (Fontaine et al., 2023). The agency recognises nine green, and seventy greening, occupations (Hofman et al., 2022).[4] In the US, estimates of the number of workers in 'clean' jobs are undertaken by the annual US Energy and Employment Report. This definition varies at the national level compared to the state level. The national definition understands a 'clean energy job' to be one that contributes to net zero through a range of activity-based criteria. A job is classified as 'clean' when workers spend more than half their time undertaking that job, recognising that many workers split their time between clean and 'traditional' areas of energy work. The US, like many countries, struggles to capture many green jobs due to the newness of the roles: its Bureau of Labor Statistics, for example, does not have an occupation code for a solar PV installer.

For policymakers considering the possible role of migration in supporting the green transition, broad and nebulous definitions of 'green jobs' are unlikely to be useful. Instead, it is most helpful to examine the technologies and sectors identified as key to national decarbonisation. This would often include, for example, housing insulation; offshore wind development; and upgrades to the national grid. Within these sectors, the workforce development needed to meet decarbonisation goals should

4 According to France's classification system, a 'green' job contributes directly to environmental goals in sectors such as forestry or heat pump installation. A 'greening' job includes occupations that do not have inherently environmental goals but could integrate environmental considerations into their work, in sectors such as architecture or construction (Fontaine et al., 2023).

be compared with plausible domestic pipelines within narrowly defined skill areas. This paper attempts to do this in the areas of solar PV and heat pump installation.

The broad qualities of green jobs

The jobs created by the green transition are far from homogeneous. Despite this, they are often treated as such by politicians eager to emphasise that green jobs will be high-skilled and high-wage. Research largely does not support this claim.

Pay

To date, the jobs created to replace 'brown' jobs—in growing sectors such as offshore wind or utility-level solar planning—have often been better paid. Green jobs are, as a result, often incorrectly argued to be *inherently* higher paid (e.g., Bergant et al., 2022; OECD, 2023a). It is more likely that the green transition-relevant jobs created so far have been at relatively senior and high-skilled levels; the European Bank for Reconstruction and Development (EBRD), for example, suggests that 'green-skilled' workers in the EU may enjoy a 4 percent wage premium, but that this is limited to highly-skilled workers, with mid-skilled workers in fact less well-paid than comparable peers (EBRD, 2023).

It is thus possible that as green sectors develop, moving towards less-skilled implementation from planning or research and development, skill requirements and wages may decrease further. This being the case, jobs in the green transition may ultimately lack a positive wage premium. In some areas, this may already be the case (Sato et al., 2023).[5] France's Conseil d'Analyse Économique, for example, notes that 'green' jobs in France are not currently better paid than comparable work (Fontaine et al., 2023).[6] Even where skill requirements are high, the fossil fuel industry currently still often offers significantly higher wages, requiring a reduction if workers are to be incentivized to transition (Popp et al., 2022). Globally, wind, solar, and hydrogen offer wages some 15–30 percent lower than those offered in conventional energy sectors (IEA, 2023g). In surveys of the energy industry, 71 percent of workers moving from conventional power to green sectors said that they needed further training in order to make the transition effectively: in the absence of a positive effect on wages, this is a hard transition to sell (NES Fircroft, 2023).

Over time, it is likely that wages in some occupations relevant to the green transition (such as electricians or engineers) will rise with demand, stimulating increased interest in the qualifications necessary. This will be expedited with further investments, policy stability, and increased efficiency, all of which will drive demand. Current increases to demand are, indeed, already driving wages higher in some sectors. In the United States, for example, labour costs are estimated to have risen by between 5 and 25 percent across all solar PV sectors during 2023 (Wood Mackenzie and SEIA, 2023).

5 Key informant interviews.
6 See footnote 4 regarding France's definitions of 'green' jobs.

Despite this, the evidence broadly suggests that wages in relevant sectors are unlikely to rise to the extent needed to attract a workforce sufficient to undertake the activities necessary to achieve decarbonisation goals within the necessary timeframes. Indeed, if wages did rise to the extent needed, green technologies would be priced beyond consumer affordability and the state investment likely to be available would be highly inadequate.

Declining demand for fossil fuels is also likely to see wages in high-carbon sectors decline, although uncertainties make it hard to place reliable timeframes on the decline of fossil fuel sectors (Dale and Fattouh, 2018). In the short- to mid-term, however, high-carbon sectors will remain a significant rival to many growing green sectors in the competition for scarce skilled workers (IEA, 2023g).

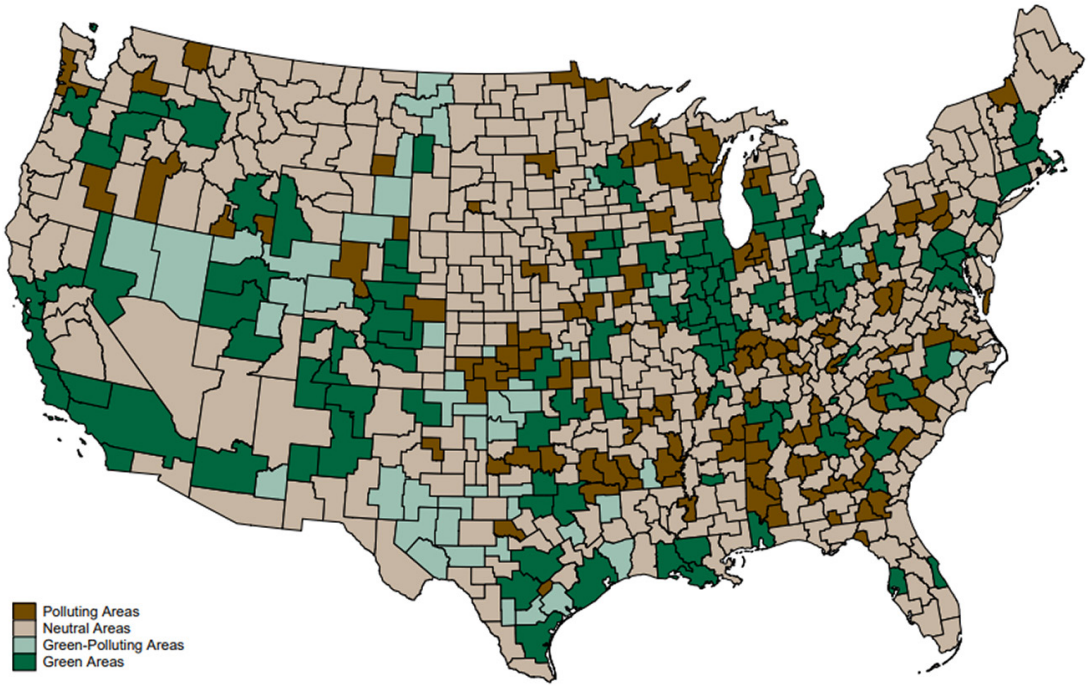
Skill level

Green transition-relevant jobs are also often argued to be more skills-intensive than other jobs, requiring either a higher than average level of technical skills, such as in science, technology, engineering, and mathematics (STEM), or greater levels of 'soft' skills (e.g., Sato et al., 2023; Davidson et al., 2023). This is far from ubiquitous, however: of low-carbon jobs created by the flagship Inflation Reduction Act (IRA) in the US, nearly 60 percent are estimated not to require a college degree, and 11 percent require only an associate degree. Many key jobs require only a short period of on-the-job training (Pollin et al., 2023). In Australia, for example, only 17 percent of the solar PV installer workforce has tertiary education, and 23 percent have no post-secondary qualifications (National Skills Commission, n.d.): in both solar PV and heat pump installation, our two sectors of focus, many low- or mid-skilled workers will be needed. The Boston Consulting Group and IOM estimates that across five large green transition sectors, 40 percent of all workers will need only limited training (Harnoss et al., 2023).

Location

Jobs in the green transition are often not in the same locations as high-carbon jobs. Those transitioning from high-carbon sectors may need to relocate in order to take advantage of new opportunities, in addition to navigating skill gaps and accepting possible wage losses (Bergant et al., 2022). High-carbon jobs are historically extremely socially concentrated, according to the locations of resources for extraction. Low-carbon jobs, by contrast, are more likely to be highly dispersed (Sato et al., 2023). The geographical overlap between low-carbon jobs and existing high-carbon occupations is likely to be limited, and will require reallocation of workers (Saussay et al., 2022; see Figure 4). Targeted public investments are likely to be needed to support reskilling, relocation, and retirement to ensure that the workforce exists to support the green transition and that the transition is equitable. Spatial re-allocation costs are often overlooked.

FIGURE 4. Overlaps between 'brown' and 'green' jobs at the commuter zone level, US



Source: Bergant, Mano, and Shibata, 2022.

Gender distribution

Many sectors relevant to the green transition exhibit gender imbalances. This matches the imbalances in brown sectors (Vandeplas et al., 2022). Globally, women make up only 32 percent of the renewable energy workforce (IRENA, 2019). In the UK, men are estimated to comprise 82 percent of the workforce for 'net zero' industries (Christie-Miller and Luke, 2023), rising to 95 percent in, for example, the heat pump installation sector (DESNZ and DBEIS, 2023a); in the US, women account for only 26 percent of the solar industry workforce (DoE, 2021b). This restricts the pool of the workforce to be drawn into these new and rapidly expanding industries. Attracting new entrants, including greater gender diversity, into these sectors is crucial to the net zero transition, but it is reasonable to expect that this shift will take time and increase hiring difficulties.

What is the global demand for green skills?

The IEA expects the creation of 14 million new green jobs by 2030 globally, with a further 16 million workers currently employed in 'brown' sectors to shift into green roles (IEA, 2022c). The IEA estimates that 60 percent of these roles will require post-secondary credentials. Given the difficulties raised above regarding transitions from high-carbon sectors to new green sectors, it is doubtful whether it will be possible to facilitate the transfer of so many workers from brown sectors to low-carbon areas of work. Shortages of skilled labour are already found to be hindering investment

in clean energy projects and the transition to clean energy, even though clean energy has now surpassed conventional energy production in total employment. In 2022, the clean energy sector was estimated by IRENA to employ 13.7 million people globally, up from 12.7 million in 2021 (IRENA and ILO, 2023).

This report focuses on two main skill areas: the installation of heat pumps, and the installation of solar PV technology. Both are vital to decarbonisation, and both will require large increases in workforce availability across both low- and mid-skilled levels.

Heat pump installation

Heat pumps act similarly to a refrigerator or air conditioning (AC) unit. A heat pump extracts heat from a source (such as the surrounding air, the ground, or a nearby source of water); amplifies the heat; and then transfers the heat to where it is needed—including expelling heat to allow cooling. Heat pumps transfer heat rather than generating it, and are therefore considerably more efficient than conventional heating and cooling technologies (Eyre, 2021). This translates to cheaper energy prices and reduced emissions. Heat pumps are currently between three and five times more energy efficient than the best natural gas boilers (IEA, 2022c). They also reduce exposure to fossil fuel spikes: over one-sixth of global natural gas demand is for heating buildings, and in the EU, over one-third.

In the context of the green transition, heat pumps are recognised by the IEA to be "the central technology in the global transition to secure and sustainable heating." In low temperature settings, heat pumps are superior to 'conventional' heating methods; in warmer conditions, they can be used to cool homes (Eyre, 2021; Sissons, 2023). This will be especially important for countries expected to experience significant rises in temperature.

At present heat pumps can, depending on context, save households a significant amount of money—up to US$300 in the US, and US$900 in the EU on annual heating bills—but require a high upfront purchase and installation cost, which deters many consumers (IEA, 2022b). In most low- and middle-income countries, many citizens will struggle or be unable to afford increasingly necessary AC units, let alone a heat pump (Pavanello et al., 2021): in India and Africa only 5 percent of households have access to air conditioning, and across Southeast Asia, only 15 percent have AC (Howarth et al., 2023). In developing countries, increased use of low-efficiency cooling systems is likely to place a severe strain on electricity grids (Sherman et al., 2022). Heat pumps could, if they become more affordable, contribute to reducing the electricity demand of adaptive cooling: in Egypt, for example, ground-source heat pumps are found to reduce energy needs by nearly 20 percent versus conventional air conditioning (Fouad, 2023).

Subsidies or new financing packages are likely to be necessary to scaling heat pump markets: the pace and scope with which these models are introduced will contribute to determining the size and timeframes of workforce shortfalls. In some countries, such as Denmark and Japan, the least

expensive air-based heat pumps are already cheaper than gas boilers for new installations in small houses. The cost of heat pumps is expected to fall further, but prices are currently not falling fast. In the UK, the total cost of an installed heat pump has fallen very little in the past decade. Some forecasts, however, predict a reduction in total installed costs of around 20–25 percent by 2030 (Heptonstall and Winskel, 2023). This is predicated on a fall in non-equipment costs, including labour, rather than a fall in the price of heat pump units. If labour costs rise due to workforce shortages, total installation costs will rise significantly, harming market sentiment and emissions reduction efforts (Murray, 2023). It is possible that several new lower-cost products, notably offered in the UK by the energy company Octopus, could trigger increased domestic uptake (Octopus Energy, 2023).

Workforce needs

Heat pump installation is a skilled profession (Cretu et al., 2022). Quality must be maintained: poor work risks both damaging consumer sentiment, and having serious impacts on buyers' energy bills. The IEA notes that "shortages of qualified installers" are "already a bottleneck in many key heating markets" (IEA, 2022d: 14), and forecasts a quadrupling of demand for full-time heat pump installers by 2030. By 2030, 800,000 new heat pump jobs are expected globally, with the majority in installation and maintenance: an additional 650,000 installers, and 170,000 workers for maintenance and service. Across the value chain, global employment in heat pump supply will nearly triple to 1.3 million workers. Even more workers will be needed to install and maintain conventional AC units in low- and middle-income countries, ideally replacing them with heat pumps in the decades to come.

Heat pump installation has several stages, each requiring particular skills (CITB, 2021).[7] Some of these skills can be taught through on-the-job training; others (such as sizing, drilling, electrical work, and refrigerant handling) require dedicated training and certification for safety and efficiency (IEA, 2022c). Ground-source heat pumps, which require skills in drilling, thermal fusion of pipes, and geological analysis, require another set of skills again.

Estimates of the time-intensiveness of heat pumps vary. The UK Heat Pump Association's *Roadmap for the Role of Heat Pumps* assumes that it takes six working days to install a heat pump in a new-build house; eight working days to retrofit a home; and three working days to replace a heat pump with a new heat pump (HPA, 2019a). The European Heat Pump Association estimates that a heat pump installation takes two days for a team of two, compared to just half a day for a boiler (EHPA, 2023c). The German Central Association of Plumbing, Heating and Air workers (ZVSHK) estimates that installing a heat pump in place of a boiler takes between 11 and 16 working days (AFPAC, 2023).

7 An on-site survey is undertaken to identify the best heating option for the property, taking into account space, heating demands, and the heat distribution system (e.g., water-based radiators vs. underfloor heating). Heat pumps must be sized according to these factors: this is a step that is not typically undertaken by installers of conventional heating systems (HPA, 2019a). The lower flow temperatures provided by heat pumps may require the heat distribution system to be upgraded, and hydraulic balancing systems may need to be installed. Ideally, heat pumps will be integrated into other systems synergistically, such as thermal storage systems and smart tariff systems.

Given that an installer may work for around 200 days per year, and that vast numbers of heat pumps must be installed, these lengthy installation requirements translate to a need for a vastly increased qualified workforce.

Efforts are being made to reduce the labour intensiveness of heat pump installation. Industry actors suggest that heat pump installations will always take significantly longer than a gas boiler installation (Bürger et al., 2022), however, and at present the installation of a heat pump takes more than twice as long as the replacement of a gas heating system with a new gas heating system (Sabel, 2023).

Many skills needed by heat pump installers are similar to those needed for workers currently in the fossil fuel heating industry, such as installers of conventional AC units and gas boilers (IEA, 2022c). Retraining will therefore supply a significant portion of the expanding workforce. Installation requires the ability to calculate heat losses; scale the size of a heat pump; and carry out tasks in both plumbing and electrical areas of work. Training is vital to expand the workforce, but is currently expensive, and can discourage new entrants. Heat pumps have a lifetime of roughly fifteen years (Rewiring America, 2023b). While the large wave of installations will come to an end, there will still be a continued need for a large workforce of heat pump installers and maintenance experts, just as there is currently for boilers. In low- and middle-income countries, the usefulness of heat pumps will depend on their price point. Low- and middle-income countries will increasingly need more energy efficient cooling systems, but often cannot afford them (Mastrucci et al., 2019). While heat pumps can very adequately fulfil cooling needs, their expanded presence in low- and middle-income countries will rely on significant reductions in cost. This may occur as the heat pump supply chain scales up in the coming decades, creating a delayed demand for skilled installers in those countries.

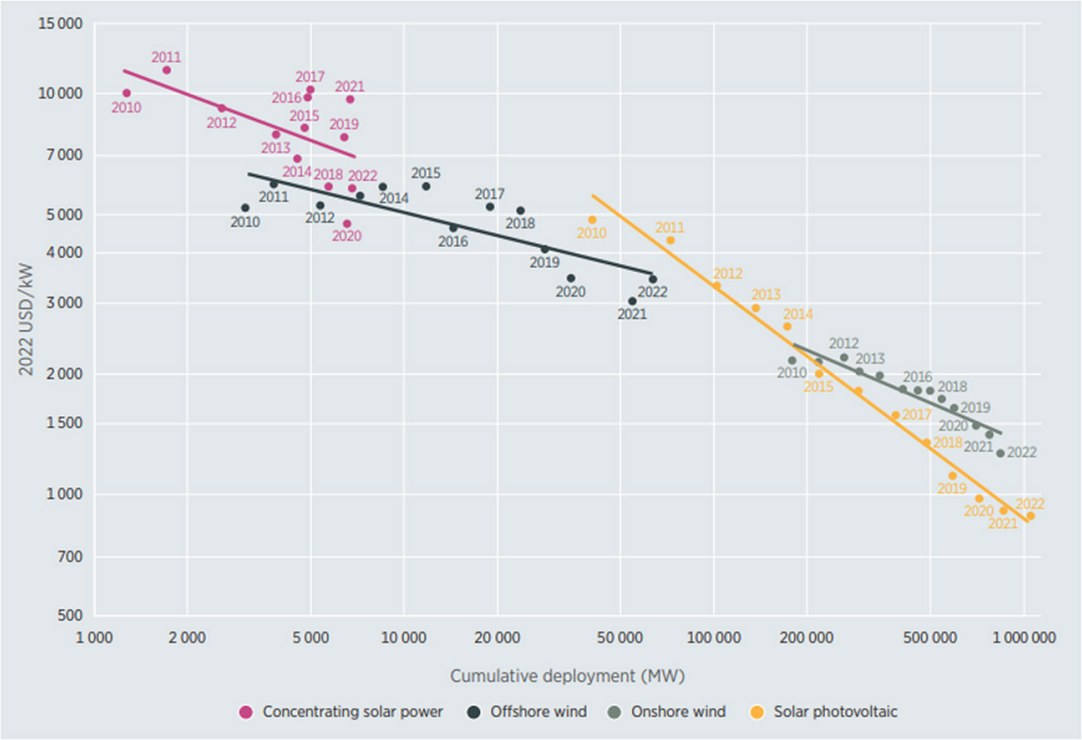
Solar panel installation

Solar power holds a crucial role in the green transition. In 2022, energy generated by solar PV installations accounted for 4.5 percent of total global electricity generation, making solar the third largest renewable electricity provider behind hydropower and wind; and 191.4 GW were estimated to have been installed, bringing the global installed total to approximately 1.3TW (IRENA and ILO, 2023; IEA, 2023b). Building solar PV capacity is a strong priority of our countries of destination and origin. 4.9 million people were estimated to be employed globally across the solar PV value chain (IRENA and ILO, 2023). To meet international energy and climate goals, solar PV installations must increase at an unprecedented scale. By 2030 6TW of solar power capacity must be installed to meet net zero goals, requiring installation rates to more than triple to 630 GW annually (IEA, 2022a).

This is made significantly more feasible by the rapidly declining cost of solar PV, which is now the cheapest option for new electricity generation in most countries (IEA, 2023f); in 2023, 96 percent of newly installed utility-scale solar PV or onshore wind was cheaper than new coal or natural gas plants (IEA, 2024). The cost of solar PV has fallen continuously over the past decade (at a decline of

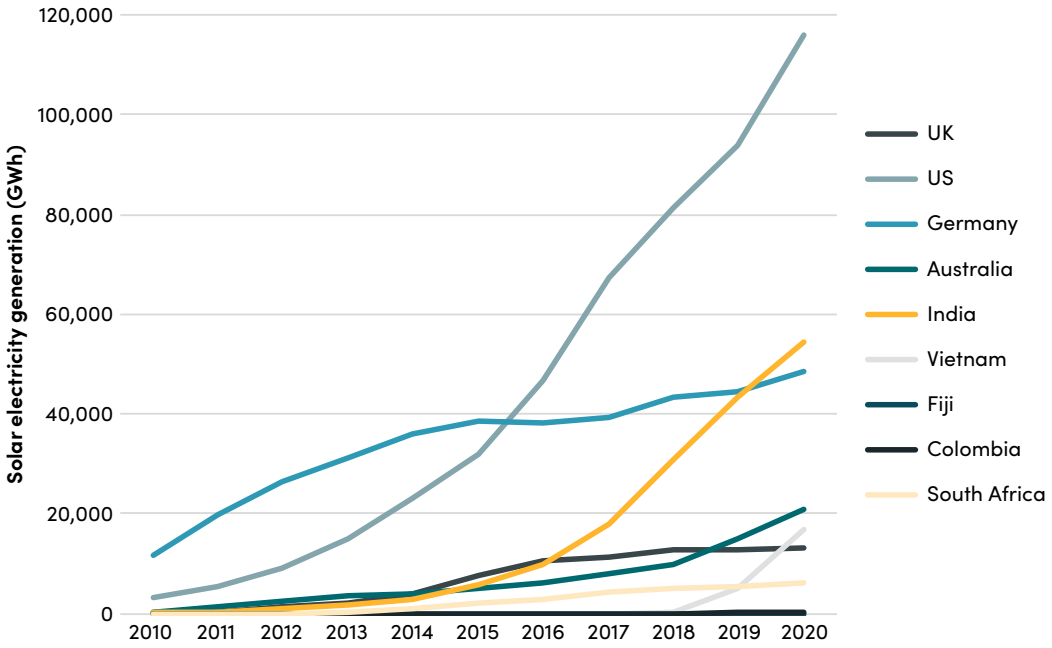
15 percent year on year from 2010 to 2020), driven by and driving further installations (Nijsse et al., 2023; see Figure 5). Over 2023 alone, spot prices for solar PV modules declined by almost 50 percent, and global manufacturing capacity tripled 2021 levels (IEA, 2024). Solar PV is expected to overtake hydropower in 2024 as the renewable energy source with the greatest installed capacity, and all forms of power generation by 2027; it could overtake nuclear electricity generation in 2025, and wind electricity generation in 2028 (McCormick, 2023; IEA, 2024). Compared with other renewable energy sources, solar PV capacity has been installed at a significantly faster rate, and has fallen significantly further in price (Figures 1 and 5). Increasingly, financing will go further, with attendant effects for job creation in the installation and maintenance sectors.

FIGURE 5. Global weighted average total installed cost learning curve trends for solar PV, concentrated solar power, and onshore and offshore wind, 2010–2022



Source: IRENA (2023b).

FIGURE 6. Solar generation (GWh) is growing in our countries of origin and destination, 2000–2020



Note: We have excluded the EU as it would skew the scale.
Source: IRENA (2023a).

Workforce needs

The installation of solar PV is highly labour-intensive. The labour-intensiveness of installations varies according to the type of project for which capacity is being installed. Rooftop solar installation is estimated to be around three times more labour-intensive than utility-scale solar, and will therefore create more jobs (SolarPower Europe, 2022). Because the solar PV sector is well-established, its greatest need is for installers and technicians (IEA, 2023g). Installations can often be undertaken by relatively unskilled workers, such as retrained roofers or entry-level construction workers. Electricians are needed at some stages of the installation process—notably, at the crucial stages of connection, and to verify that installations have been undertaken correctly—but a relatively small percentage of the total PV installation workforce needs full electrician qualifications. Australia's Clean Energy Council, for example, estimates that only 20 percent of Australia's solar PV workforce comprises qualified electricians (Clean Energy Council, n.d.).

The global solar PV installation workforce will need to expand several times over in order to meet targets. Fortunately, the skills needed can be acquired with little pre-requisite knowledge. Solar workforce mapping undertaken by the Inter-State Renewable Energy Council (IREC) in the US suggests that skills required for solar PV installation may include a considerable knowledge of electrical wiring; understanding of solar and energy storage techniques; some mathematical ability; physical dexterity and strength; and the ability to work at heights (DoE, n.d.). Many of these skills can

be learnt to an adequate degree through on-the-job training. This is already evident in the fact that a number of companies are already establishing solar training 'bootcamps' providing prospective employees with very short, but sufficient, training before employment. In Germany, the US, and elsewhere, companies are already starting to provide workers with short training opportunities: workers only need a minimum amount of previous employment experience, and the rest can be learnt on the job (Martinez et al., 2023).

Countries of destination

This section provides a top-level overview of the demand for, and supply of, green-skilled workers in five key countries of origin—the UK, US, Australia, Germany, and the EU (as a bloc)—with greater detail provided in the cases below.

All of the countries of destination analysed have set ambitious and necessary decarbonisation targets, aiming to achieve net zero carbon emissions by 2050 or before, with all also specifying intermediate goals with large emissions reductions before that date. Installations of both heat pumps and solar PV will be crucial in achieving these goals. For all of these countries, a number of barriers must be surmounted for installations to reach the necessary levels. Skilled workforce shortages are notable. Many countries studied have broadly ageing workforces and face economy-wide labour shortages. The sector-specific workforce is also often relatively old, with large proportions retiring within the next decade. This is the case, for example, in the UK and the US.

In all countries, domestic upskilling and retraining will be necessary and will require support. This is practical: it ensures that those who already have relevant skill sets can be assisted in efficiently reallocating themselves to the roles where they are most needed. If done correctly, it is equitable: it ensures that a just transition occurs, with fossil fuel workers, in particular, being supported in moving from a dwindling industry into growing sectors with new opportunities. It is also politically sensible: support for the green transition has been increased through a strong emphasis on its job creation potential, and it is crucial that domestic populations are aware that job opportunities are being created.

Domestic training and reskilling is, however, unlikely to deliver the numbers of skilled workers needed in the timeframes demanded by the green transition. In the US, over one million electricians will be needed in the coming decades, at a time when the current pipeline does not fully replace those leaving the workforce. In the EU, up to three quarters of a million additional heat pump installers are anticipated to be needed by 2030. The demand, in other words, is enormous, and the domestic supply must be vastly expanded but will be highly unlikely to be adequate.

Increasing the domestic supply of workers faces a number of obstacles. Workers in the relevant sectors are often relatively old, and may have low interest in retraining. New workforce entrants

appear insufficiently convinced by the opportunities available in the green sectors studied, due to a combination of the manual intensity of the work; relatively low starting wages in some sectors; lack of knowledge; and uncertainty regarding the reliability of the areas of work (State of Maine, 2022; Hofman et al., 2022; Public First, 2021). Beyond perceptions, there is simply a straightforward absolute shortage of potential entrants where the workforce as a whole is shrinking. This is notably the case in Germany. Training may also be unattractively expensive for those already in the workforce, especially where single traders or very small enterprises predominate. Several countries, especially Australia and the US, are also reported to face severe shortages of trainers. This problem is likely to increase if trainers feel they can earn more returning to a tight labour market than remaining as educators. Apprenticeship systems are reported to be near-universally broken, with inadequate support provided to employers, insufficient interest among new entrants in apprenticeship opportunities, and a lack of formalisation of apprenticeships in new areas of work, such as solar PV installation.

In these circumstances, migration is likely to be necessary in order to complement the domestic workforce in countries of destination. Some countries, such as Germany, have already recognised this and have been making significant preparations for some time. Others, such as Australia, have recently recognised this and are undertaking the reforms needed to allow a greater intake of green-skilled workers. All countries recognise that the global green-skilled labour market will be increasingly competitive. In a context of a global shortage of the necessary workers, countries of destination will need to facilitate active international recruitment, either by opening visa systems to greater free movement or by creating bespoke pathways, and support training in countries of origin. Again, this is already being undertaken by some actors, but must be attempted by those not yet doing this if they are to meet the workforce needs associated with their necessary reductions in emissions. Successful lessons should be shared to allow rapid scaling of training and mobility pathways.

United Kingdom

The United Kingdom (UK) has set an ambitious decarbonisation agenda. It aims to achieve net zero carbon emissions by 2050, and a reduction of emissions of 68 percent by 2030 relative to 1990 levels (DESNZ and DBEIS, 2021b; DESNZ and DBEIS, 2022b). To achieve this, the UK aims to install 600,000 heat pumps annually by 2028, and to reach 70 GW of installed solar capacity by 2035 (DESNZ and DBEIS, 2023b; DESNZ and Stuart, 2023). Thus far, these targets are not on track to be met. The UK's Climate Change Committee (CCCUK), a key non-governmental advisory group, suggests that it has 'low confidence' in the UK's ability to meet its goals, noting that only 28 percent of requIred emissions reductions by 2030 are covered by 'credible' plans (CCCUK, 2023c).

Workforce remains a significant challenge to the UK's decarbonisation efforts. The CCCUK estimates that the green transition will create from 135,000 to 725,000 net new jobs by 2030. Several key sectors face severe shortages of qualified workers (CCCUK, 2023a).

Demand

The UK's heat pump installation targets are highly ambitious, and make heating decarbonisation a key part of the net zero transition. At present, the heating of buildings contributes 17 percent of annual national carbon emissions (DESNZ and DBEIS, 2018). In 2020, only five percent of total heating demand in the UK was met by low-carbon heating options, and almost all homes will need upgrading to a decarbonised heat option (Rosenow and Lowes, 2020). The CCC expects heat pumps to supply the majority of low-carbon heat, contributing around 75 percent of heating installations in 2030 (CCCUK, 2020). The government's target of 600,000 installations per year will be a major challenge: meeting them will require a "radical change in less than a decade, from international laggard to leader" (Heptonstall and Winskel, 2023: 20). In 2019, only 27,000 heat pumps were installed (HPA, 2020). In 2021, only 54,000 residential heat pumps were installed (Heptonstall and Winskel, 2023); in 2022, 72,000 were installed (Harris and Walker, 2023). Installation rates are thus rising, but remain far from the desired 600,000 per year.

The policy environment in which this is targeted, however, has been fluid, in part due to growing political polarisation over the green agenda. The Department for Business, Energy and Industrial Strategy (BEIS) set out the ambition to end the sale of gas boilers by 2035 in its Net Zero and its Heat and Building Strategies (DESNZ and DBEIS, 2021a; DESNZ and DBEIS, 2021b). To facilitate this, a Boiler Upgrade Scheme was offered, providing households with grants of up to £5,000 (US$6,200) for air-source heat pumps and £6,000 (US$7,400) for ground-source heat pumps and further funds for company research and development (DESNZ and DBEIS, 2021b). In October 2023, a previous gas boiler phase-out was moved to 2035 and the distribution of the £150 million (US$186 million) Boiler Upgrade Scheme pot was altered, bringing household support up to £7,500 (US$9,300). This means that new, cheaper, and more efficient heat pump designs (such as the heat pumps sold by energy company Octopus) are fully covered by the grant for most households (Octopus Energy, 2023). In December 2023 a further £1.5 billion was committed to support up to 200,000 households in installing heat pumps (DESNZ, 2023a). Following the announcement of the £7,500 subsidy, applications for the grant increased by 57 percent, and Octopus announced that it would seek to hire a further 2,000 heating engineers in 2024 to meet demand (DESNZ, 2023a). Eligibility for the grant requires that the installation is undertaken by an MCS-qualified installer, however; in 2023, fewer than 40,000 such installations were undertaken (Galvin and Osborn, 2024).

Policy uncertainty, labour market inertia, an ageing workforce, and low availability and high cost of training have contributed to a skill pool currently inadequate to meet the significant installation challenge. In 2019, the UK's Heat Pump Association found that 5,300 heat pump installers would be needed by 2023 to keep the UK on track to meet decarbonisation targets (HPA, 2019a). In 2022, however, there were only 3,000 qualified installers (Sarsentis, 2022). By 2028 at least 27,000 qualified heating engineers will be needed, rising to 62,000 by 2035. This means training around 5,000–7,000 installers every year from 2025–2035: expanding the worker stock by more, each year, than the

size of the current pool. Modelling by the Heat Pump Association, and used by BEIS, predicts higher needs: 33,700 by 2028, and 69,500 by 2035 (HPA, n.d.; DESNZ and DBEIS, 2023a).

The demand for solar PV installers is also considerable. As of 2022, the UK had roughly 14 GW of deployed solar PV, of which a third was installed on rooftops (DESNZ, 2023b; SolarPower Europe, 2023b). The government targets 70 GW of installed solar capacity by 2035, a quintupling of capacity versus 2023 (DESNZ, 2023b). To assist in meeting these goals, the UK established a Solar Taskforce in 2023, bringing together the heads and senior officers of a variety of industry actors, certification providers, and financiers (UK Government, 2023). Among other areas, it is mandated to consider the development of an adequate skills pipeline. Solar Energy UK, the trade body whose head chairs the UK Solar Taskforce, estimates that achieving the 70 GW target could support 60,000 jobs, with 35,000 jobs created by 2030 (Solar Energy UK, 2022). If the government followed its 2035 goal with a target of 100 GW by 2050, more than 100,000 jobs could be created. There are currently around 6,500 people employed across the UK solar industry. Nearly 190,000 MCS-accredited solar PV installations were carried out in 2023 (Galvin and Osborn, 2024), despite the absence of any state subsidies (Lempriere, 2024).

The extent to which the solar industry is challenged by workforce shortages is disputed. The thinktank Green Alliance suggests that solar is "well established", with "no perceived skills gaps" (Alvis et al., 2022) The Construction Industry Training Board argues that greater deployment of solar PV "will not present a significant skills challenge", in part due to the fact that on-site energy systems such as solar PV "are often straightforward to install", requiring only conventional electrical skills (CITB, 2021: 43). Solar Energy UK, however, notes that solar companies are already finding recruitment more challenging, and warns that increased immigration for the sector will be necessary if significant investment in domestic retraining is not provided (Solar Energy UK, 2022). According to data from the online hiring platform Indeed, demand for solar PV installers has risen by 315 percent in the past three years, and pay has risen to an average of £33,613 (US$41,600) per year (Lempriere, 2023).

Supply

The supply of heat pump installers is complicated by a range of factors. Firstly, the broader energy and utilities workforce is ageing: one in five are expected to retire before 2030 (DESNZ and DBEIS, 2022a). In a 2019 survey, the Heat Pump Association found that 22 percent of heating system installers are at least 60 years old, and that over half are older than 51 (HPA, 2019b). A 2023 study by BEIS found that 66 percent are over 45 years old, and 33 percent over 55 years old, with 40 percent of the workforce planning to leave the industry in the next ten years (DESNZ and DBEIS, 2023a). Upskilling the existing workforce will be important: a qualified heating engineer could be trained for heat pump installation in only one 40-hour week of training (followed by manufacturer training for work on specific models) (CITB, 2021). BEIS' study suggests, however, only around half of heating

engineers could be induced to upskill: a significant proportion are either planning to imminently retire, or have no interest in retraining (DESNZ and DBEIS, 2023a). This is made more probable by the fact that many heating engineers are sole traders, with limited time or money for retraining: Nesta estimates that the cost of a course for a self-employed sole trader ranges from £1,200 to £2,500 (US$1,500 to $3,100) (Cretu et al., 2022).

Existing training pathways for heat pump engineers in the UK are complex and fragmented, with "no single, clear route for someone new to the industry to train as a heat pump engineer" (Cretu et al., 2022: 4) Retraining of a gas boiler engineer or plumber can be fast, taking as little time as three to five days; only six percent of this labour force are under 35 years old, however, and 58 percent are 51 and over (ibid.). Moreover, some heat pumps require specific certifications. Air-to-air heat pumps, especially, are likely to require qualification for work with environmentally harmful F-gases; in 2023, only 17 percent of businesses were certified to work with them (Sissons, 2023; CITB, 2021; DESNZ and DBEIS, 2023a).[8] 50,000 individual engineers are F-gas qualified, however, and new subsidies for (cheaper) air-to-air heat pumps could prompt a retraining drive within this cohort (DEFRA, 2022). Certification for key green skill areas, including heat pump and solar PV installation, is provided by the Microgeneration Certification Scheme (MCS). By August of 2023, more than 850 contractors had become MCS-certified heat pump installers, more than the number who signed up during the whole of 2022 (Ambrose, 2023). While this suggests growing interest, it remains far below the necessary recruitment level.

Entry options for new learners into the heat pump profession are limited. In August 2023, a new low-carbon heating apprenticeship was approved for delivery by the Institute for Apprenticeships and Technical Education (Institute for Apprenticeships and Technical Education, 2023). Delivery has not yet started. The apprenticeship takes 36 months, and includes (but is not limited to) ground and air source heat pumps. Despite being an occupational apprenticeship, it does not result in recognition by a professional body. Finding firms willing to take on apprentices may be challenging, however. BEIS' 2023 study found that only 21 percent of Heating, Ventilation, and Air Conditioning (HVAC) employers had apprentices, and that only a further 10 percent were interested in taking one on (DESNZ and DBEIS, 2023a). Beyond apprenticeships, short and intensive Skills Bootcamps are intended to support rapid modular training to patch gaps and support up/reskilling (DESNZ, 2023b). The focuses of Skills Bootcamps are determined by the Department for Education (DfE) in response to industry demand. DfE currently allocates £550 million in funding for Skills Bootcamps for 2022–2025; by the end of 2023, at least 35 Bootcamp courses in green areas are anticipated. According to the government's list of Skill Bootcamp providers, however, only nine courses currently provide heat pump installation skills (DfE, 2023).[9] Because the demand for net-zero work has until very recently been either limited

8 Fluorinated gases (F-gases) are man-made gases used in a range of industrial applications, including some HVAC technologies. They are often used as a substitute for ozone-depleting chlorofluorocarbons (CFCs), banned from 2010 under the Montreal Protocol; however, F-gases are extremely potent greenhouse gases, and must be handled very carefully.

9 When contacted, moreover, several of the providers listed said that their inclusion was erroneous.

or non-existent, the demand for training to provide these skills has also been limited. These courses have therefore been under-developed (CITB, 2021).

Supply of solar PV installers is also currently limited. A 2020 survey undertaken by the Electrical Contractors' Association found that 49 percent of solar installation firms suffered from lack of access to skilled workers (ECA, 2020). There is currently no 'solar apprenticeship' scheme; instead, ten relevant Apprenticeship Standards are described as relevant by the MCS accreditation body, ranging from 'material cutter' to 'fenestration fabricator' and 'utilities engineering technician' (MCS, 2020). Of the available Skill Bootcamps supported by the government, only three currently offer solar PV installation skills, despite the fact that the flagship Powering Up Britain plan emphasises bootcamps' importance (DfE, 2023; DESNZ, 2023b).

Solar installation can be undertaken by highly skilled electricians, or by a combination of less-skilled professionals (such as roofers) and electricians.[10] The system currently used in the UK, however, prioritises the training of electricians for all positions within solar installation. The entry requirements for this route are minimal: access to a Level 3 Diploma in Electrical Installation at a vocational college requires only four GCSEs above a C grade (Howell, 2022). An electrical apprenticeship, however, takes around four years to complete (TESP, 2023). Up to £20,000 (US$24,800) of government funding is available, and most apprentices will work 30 hours a week while receiving training (UK Government, n.d.). After electrical training is complete, electricians can undertake one of a range of short courses to become qualified to install solar PV systems. These courses plus MCS certification typically take around five days and cost up to £1,000 (US$1,200) (Howell, 2022). This means that for new entries to the field, the path to becoming a fully qualified solar panel installer, able to manage every stage of installation, typically takes three to four years. The UK currently faces a major electrician shortage, with more than 100,000 additional electricians needed by 2032 (About Apprenticeships, 2023). This is driven in part by an ageing workforce, and in part by increased demand from other sectors, such as the need to install hundreds of thousands of electric vehicle charging points (CCCUK, 2023a). If solar PV installation continues to be dominated by electricians, rather than by teams comprising more narrowly qualified workers cooperating across the installation process, solar PV installation goals may be difficult to hit.

Migration

Willingness to consider migration as a complement to the domestic labour force has been growing as the extent of the skilled labour shortages facing the green transition has become more evident. The influential 2022 Independent Review of Net Zero argued that alongside expansions to apprenticeships, the government should expand "options for retaining talent within businesses and access to international labour" (DESNZ and DBEIS, 2022a). The CCCUK's 'Skills and Net Zero

10 Notably, however, the UK also faces a significant shortage of roofers (Roofing Today, 2023), demonstrating the widespread nature of labour gaps.

Expert Advisory Group' recommended that the government consider implementing a Global Skill Partnership for green transition-relevant roles, supporting training in and migration from partner third countries (CCCUK, 2023b). Notably, such a scheme has previously been undertaken in the UK. In the 1990s, the UK's power grid partnered with the training provider Apex Training and City and Guilds, an accreditation provider, to support the training and migration of Zimbabwean nationals. Zimbabwean electrical engineers were trained in Harare, and then successfully came to the UK, where some still live and work.[11]

Importantly, the EU workforce, which was previously easily available to UK employers, is no longer practically accessible. The increased regulatory burden on employers and migrants following the UK's departure from the EU makes Britain an uncompetitive destination. Moreover, many firms which could seek to use the immigration system to support their workforce have limited experience of it, and are especially unused to direct recruitment (Kumar et al., 2023). On the state's side, the UK's points-based migration system, and its reliance on visa- and work-sponsorship systems, are seen as excessively complex, bureaucratic, and expensive (Kumar et al., 2023). Responsive visa policy has also been made more challenging by the insufficient granularity of the codes used under the Standard Occupational Classification (SOC) system, which hinders the gathering of labour market data. The most recent SOC codes may not adequately describe jobs in developing green transition-related sectors, making it harder to assess demand for these jobs and whether the domestic labour supply in these areas is sufficient (Dempster et al., 2022). The Home Office currently uses SOC codes from 2010, and has not updated to the newer 2020 codes (Kumar et al., 2023).

In facilitating migration for the purposes of the green transition, UK policymakers will also need to be careful to ensure that migrants are not at risk of exploitation. Multiple sectors have previously had reports of poor or dangerous working conditions, withheld or inadequate pay, and threatening relationships, especially in the healthcare, construction and agricultural sectors (e.g., Prescott, 2019; UNISON, 2023; Breese, 2023). Irregular migrants engaged in the offshore wind sector, for example, were previously reported to have been paid less than the legal minimum wage (Lawrence and McSweeney, 2018). The UK government should ensure that it engages closely with regulatory and oversight bodies, notably the Gangmasters' and Labour Abuse Authority, and with employers, unions, and migrants' rights organisations to ensure that employment is equitable and respects rights.

11 Information obtained through interview and email with key informant.

BOX 1. Changes to the Shortage Occupation List

The Shortage Occupation List (SOL) allows international holders of the Skilled Worker visa to be recruited on lower salaries of up to 20 percent below the 'general threshold' of £26,200 or the 'going rate' specific to occupations. Several roles relevant to the green transition, including electrical engineers and welders, have been on the SOL for some time (UK Visas and Immigration, 2022).

In late 2023 the UK's Migration Advisory Committee (MAC) recommended that the SOL should be abolished or significantly cut down, on the basis that the reduced 'going rate' undercut resident workers and make the exploitation of migrants more widespread (MAC, 2023). Among the professions still recommended for inclusion are roofers (relevant for solar PV installation) and housing retrofitters (relevant for heat efficiency). The UK Government announced in late 2023 that the Shortage Occupation List would be renamed the Immigration Salary List, with the MAC advising on the occupations to be retained. The 20 percent salary discount for shortage occupations will be abolished, and the base earnings threshold will be raised to £29,000 (US$37,000) per year and then progressively to £38,700 per year (Home Office, 2023).

Industry analysis suggests that the changes to the SOL are unlikely to have major impacts on UK international recruitment capacity, due to a combination of very high visa costs imposed on workers or recruiting businesses; the relatively low 'general threshold' of the Skilled Worker visa; and continued MAC analysis of individual sectors for future targeted migration options (Muguit, 2023). Indeed, if the MAC's request for future sector-specific engagement is heeded, bespoke visas to complement domestic green skills may be more feasible. As Kumar et al. (2023) note, however, the UK's existing immigration policies and systems are not well set up to achieve this, and the firms that could benefit from new loosening in the visa system have little experience of active migration. While migration policy is a sensible tool in response to the key challenge of workforce shortages, targeted complementary policies are also likely to be needed.

United States

The 2022 Inflation Reduction Act (IRA), which provides US$370 billion in direct clean energy investments and potentially much more in tax credits, is expected to vastly stimulate the implementation of the green transition in the United States (US) (The White House, 2023; Anderson, 2023). It will also turbocharge US labour market demand. More than 1.5 million clean energy jobs are estimated to be created by 2030 (and possibly as many as 2.9 million) (REPEAT, 2023; Pollin et al., 2023). Filling many of these jobs will be challenging: the US is expected to need a further one million electricians by 2030, and must contend with an exit rate higher than intake and a long training period (Rewiring America, 2022; Border States, 2022; Mize, 2023). This comes at the same time as a wider 'silver tsunami' of retirements approaching the US labour market. From 2021 to 2031, 1.7 million workers (12.2 percent) are expected to leave the infrastructure sector each year, due to retirement or dissatisfaction with manual work and low pay (Kane, 2022).

To receive the full 30 percent Investment Tax Credit made available by the IRA for clean energy projects (rather than the six percent base rate), 12.5 percent of a project's labour hours must be undertaken by qualified apprentices participating in an apprenticeship programme registered with the Department of Labor (DoL) or a state equivalent (Rewiring America, 2023a; Kennedy, 2023). In 2022, the DoL reported almost 600,000 apprentices active across nearly 27,000 registered programmes (Farrell and Lawhorn, 2022). This is intended to stimulate durable training. The Department of Energy (DoE) is planning on spending US$260 million on workforce development for energy efficiency (Jenkins, 2022).

Many of the jobs created will not be high-skilled. Analysis conducted by the Political Economy Research Institute (PERI) at the University of Massachusetts suggests that of jobs created by IRA-related investments, nearly 60 percent do not require a college degree, and 11 percent require only an associate degree (an occupational or vocational certification) (Pollin et al., 2023). As noted above, these jobs will not always be high-paid, and filling them may be challenging. In these roles, especially, the US' large labour deficit may be a problem highly amenable to migration policy.

Demand

Heat pump use is currently relatively low in the US: roughly 16 percent of households have a heat pump as their primary heating equipment. This is changing, however; in 2022, even before the IRA kicked in, sales of heat pumps overtook sales of gas furnaces (Olano, 2023). To meet decarbonisation targets, heat pump sales must grow still faster, increasing by more than three times by 2032 (Rewiring America, 2023b). There is no national heat pump installation target, but subnational actors have set installation goals. In September 2023, 25 US states and territories committed to undertaking 20 million residential heat pump installations by 2030 (Gartman et al., 2023). The IRA is expected to incentivise the installation of 7.2 million heat pumps through tax credit 25C (Smedick et al., 2022). This provides up to US$2,000 in tax credits to lower the cost of a heat pump installation, representing up to 30 percent in savings, with up to US$8000 for heat pumps and US$6,500 for panel upgrades further available, especially for those in disadvantaged households (Brutkoski, 2023; Root, 2023; Gartman et al., 2023). The federal government also plans to invest US$250 million in heat pump manufacturing (Jenkins, 2022).

The heat pump workforce must grow dramatically, but the number of entrants into the market remains inadequate. The average age of an HVAC technician is somewhere from 54 to 62, indicating that the coming wave of retirements will be a serious challenge (Murray, 2023). IRENA estimates that in 2021, the US had only around 99,000 workers in renewable heating and cooling, and the DoE estimated in 2022 that only 26,000 workers were employed in heat pump installation (IRENA and ILO, 2022; DoE, 2023). While the incentives of state commitments and IRA tax credits have yet to fully take effect, the shortage of workers is already driving up installation prices; restricting access to installations; and even contributing to market restructuring, with clean energy companies in several

sectors reported to be considering buying smaller firms simply to obtain their workers (Groom and Volvovici, 2023). Consolidation of firms and workforce supply risks creating regional monopolies that reduce competition and drive up installation prices, especially where buyouts are conducted by private equity actors demanding large premiums. Rising costs for undersupplied installation expertise is estimated to have contributed to increases in the cost of a heat pump: labour costs now account for over half the total cost of an installed heat pump, potentially negating IRA incentives (Murray, 2023).

Demand for solar PV installers will also need to increase rapidly. In 2023, five percent of homes in the US were estimated to have rooftop solar (Rewiring America, 2023b). To achieve net zero targets, 100 percent coverage should be targeted by 2050, increasing capacity in the short term from 129 GW in 2022 to 336 GW in 2027 (Kennedy, 2023). Installations must thus increase by more than seven times if the necessary emissions reductions are to be achieved (Rewiring America, 2023b). Workforce shortages represent a bottleneck. In 2022, the DoE estimates, the workforce grew by only 3.7 percent (DoE, 2023). The total workforce is estimated to need to double from roughly 255,000 in 2022 to 538,000 in 2032 (SEIA, 2023). Knowledge of the workforce is made more challenging by poor data collection practices. The Bureau of Labor Statistics (BLS) does not collect employment data by energy technology, meaning that solar installation workers, for example, are labelled in workforce data as 'electrical contractors' (DoE, 2023).

Supply

At present solar jobs are relatively heavily geographically concentrated. As of late 2020, 35.7 percent of all solar energy jobs were located in California (E2, 2021). As support for installations rolls out more widely, especially for geographically dispersed residential installations, this will have to shift.

The supply of solar PV installers is currently highly inadequate. In 2023, 97 percent of companies in the construction industry reported that it was 'very' or 'somewhat' difficult to find qualified solar workers (DoE, 2023). 75 percent of utilities companies reported the same. As a result, labour costs are estimated to have risen by between 5 and 25 percent across all solar PV sectors during 2023 (Wood Mackenzie and SEIA, 2023), versus broader energy sector pay increases of 7.5 percent during 2022 and inflation of 6.5 percent (IEA, 2023g). In 2021, the median solar PV installer earned nearly US$47,000, and the median electrician earned US$60,000 (Kane, 2023).

The solar training pipeline is not highly developed. The US has no national requirement or standard for certification of solar PV installers (Gadzanku, 2023). At the state level, some qualifications are required, varying across states. The North American Board of Certified Energy Practitioners (NABCEP) PV Installation Professional Certification is a common PV installation certification requirement, but this is not ubiquitous. As of 2023, 11 states had formal education or apprenticeship requirements; 16 states had no formal licensing requirements; and other states may have strict local licensing requirements, but have no state-level requirements.

The Solar Energy Technologies Office has argued for a need for improved national coordination of training and certification programmes, allowing skills and certifications to be transferable across jobs and states (DoE, 2021a). In the short term, there are not enough solar apprenticeship programmes available to meet demand, and no solar installation apprenticeship programme is yet recognised by the DoL (Misra, 2022; Gadzanku et al., 2023). This may make it harder for companies to access IRA tax credits, slowing wider solar installations. The IRA allows a 'good faith' exemption from the apprenticeship requirement if a company is unable to recruit from a registered apprenticeship programme, but it is uncertain how reliable or durable this exemption is (Nautilus Solar, 2023).

Despite this, it should not in principle be hard to find solar PV installers. The Interstate Renewable Energy Council's (IREC) 2022 Solar Workforce Census report shows that most solar hires require only some previous workforce experience: less than half of all solar jobs demand a bachelor's degree, only a third an associate's degree, and almost none required a vocational or post-secondary certificate (IREC, n.d.). Workforce mapping by IREC indicates that there are several paths into the solar PV profession[12]:

1. An entry-level installer is expected to have a high-school degree and possibly some post-secondary credentials, in addition to 1–3 years of previous work experience, normally in the construction or electric installation sectors. They are normally paid around US$28,600 per year, or $13.77 per hour. Progression to professional solar installation status requires a two-year degree or electrical apprenticeship and solar certification.
2. A professional solar PV installer is normally required to have 3–5 years of work experience and either a bachelor's degree, an associate's degree, or to have reached journey-level qualifications through apprenticeship. PV installers are "highly skilled solar installers with backgrounds in site assessment, system design, installation and operations." Most have engineering, skilled trades, and/or electrical training. They are however only paid around US$40,000 a year, or $19.24 an hour.
3. There are also options for retraining into solar PV installation. A roofer with retraining in solar PV installation is normally trained on the job in roofing and then trained on the job in solar PV installation, although a three-year apprenticeship is also possible. Roofers trained to install solar PV have a median pay of US$35,760 a year. An electrician with solar PV expertise can demand significantly more, at around US$47,180 a year. They will normally have over five years of experience, and will have undertaken further training in solar panel installation.

Opportunities for solar PV training are not evenly accessible across the US. Research by IREC shows that in several states NABCEP-certified training, required for access to apprenticeship-related tax credits, is provided by either very few registered training bodies or even none at all (NABCEP, 2023).

12 All information below is from the IREC Solar Career Map (2023).

In Maine, for example, there are only ten programmes providing solar PV installation training (State of Maine, 2022).

In the absence of apprenticeship programmes recognised by the DoL, apprenticeships are primarily offered by unions, contractors, and other third parties such as community organisations or non-profits (Gadzanku et al., 2023). These may take from three to five years, and are often broader electrician training programmes with solar components rather than solar-focused. GRID Alternatives, a nonprofit solar installer primarily working in the residential and commercial markets, offers a five-week hands-on installer training programme with certifications contributing to further industry-level qualifications such as the NABCEP PV Associate degree (GRID Alternatives, n.d.). This requires no funding by participants, and has minimal prerequisites.

Heat pump installations face an even greater workforce shortfall. Several states are attempting to foster heat pump skill development. Massachusetts has set up a US$1.2 million Equity Workforce Training programme, intended to provide "job training and support services to underserved individuals seeking employment in the clean energy sector" (MassCEC, 2023). Heat pumps and solar PV installation are both included as a 'climate critical priority occupation' in the call for proposals. State efforts have not always been successful. New York City committed US$54 million to a programme run by BlocPower, a clean energy company, intended to train up to 3,000 disadvantaged New Yorkers for jobs in the green economy (Ma, 2022). The company has not delivered results, however, and sources have suggested that recruitment of "troubled youth" may not be scalable given the length of training needed (Harris, 2023).

Maine has been more successful than most states in increasing its stock of heat pump installers. This is part of a broader successful effort to increase heat pump installation rates: between 2019 and 2023 it installed over 100,000, and it now aims to install 175,000 more between 2024 and 2027 (Takemura, 2023). In January 2023 Maine had 700 qualified installers, more per capita than any other state (Fitzgerald, 2023). Despite this, workforce recruitment remains a challenge. Employers report being largely concerned with the sheer volume of demand against a tight labour market (State of Maine, 2022). 62 percent of Maine's clean energy employers agreed that "there are not enough applicants for the firm's open positions", and 53 percent agreed that "it was a small applicant pool."

Recruitment is made harder by what is widely perceived to be a widespread cultural disinclination among US youth against entering manual green jobs, with a preference against challenging labour with long hours (Harris, 2023; Osaka, 2022; State of Maine, 2022). The DoE's 2023 energy workforce report found that in the energy efficiency subsector (which includes heat pumps), 'competition/ small applicant pool' was the most common reason for hiring difficulties in the construction; manufacturing; wholesale trade; and professional and business services areas. Lack of skills, experience, and certification followed (DoE, 2023).

According to workforce mapping undertaken by the IREC, there are two primary pathways into the heat pump installation sector: an apprenticeship, or learning on the job. Both options often follow some training offered by a community college.

1. Some employers offer an HVAC apprenticeship (IREC, n.d.). This allows workers to learn HVAC skills on-the-job, working in a full-time paid position while being taught and gradually advancing. The apprenticeship typically lasts four to five years. Apprenticeships normally receive wage increases every six months, according to their firm's progression pathway. Upon completion of the programme, apprentices graduate as a journey-level technician. Many workers pass through vocational schools or post-secondary HVAC education before entering an apprenticeship; this allows the apprenticeship to be shortened. Apprenticeships start at a salary of around US$35,000, but this rises to around US$75,000 with progression. A high school diploma or equivalent is normally required; during the apprenticeship, apprentices work during business hours and attend classes on the evening or weekend.
2. A residential trainee typically has a high-school degree (IREC, n.d.). Firms often offer on-the-job training, but post-secondary HVAC training is preferred, and can be obtained at some community colleges. Recognised certifications include the EPA; HVAC Excellence; NATE; and OSHA 10. Residential trainees require basic skills: some mechanical aptitude, the ability to work with heights, some mathematical ability, and the ability to work in closed spaces. A residential trainee is normally paid US$36,000–$44,000 a year, or around $18–$22 an hour. After one or two years, and after completing HVAC/R Certifications, trainees can qualify as full installers.

The US' community college system has struggled to scale up its provision of relevant training options. This is in part because training providers are reactive to demand, and may have inadequate contact with industry, leading to lag times between training needs and provision (State of Maine, 2022). Training from scratch does not necessarily take long, however: some community college courses can qualify workers for residential installations from within sixteen weeks of training to a year of apprenticeship and on-the-job learning, although this may still be long enough to put off potential workers (MCC, n.d.; Moe, 2022; State of Maine, 2022). Retraining of HVAC workers for heat pump installation is also possible. One Department of Energy training programme suggests that this may take up to six weeks of classroom learning, simulated learning, and on-the-job experience (Moe, 2022). Some HVAC companies have started bringing teaching in-house, recognising the shortage of training options (Van Oot, 2023). Conversely, the workforce shortage has also made it harder to recruit trainers, who can earn more as installers than they can teaching (Pontecorvo, 2023).

Migration

Migration for the purposes of the green transition has thus far received relatively little attention. One 2021 study finds that 23 percent of all 'green job workers' are foreign-born, an overrepresentation

given that immigrants make up only 16 percent of the workforce (Nooraddini and Nazar, 2021). Slightly more than a third were naturalised US citizens, suggesting that many are immigrants who came for other purposes and have subsequently entered green sectors. Analysis of the American Community Survey census data supports this idea, suggesting that the median year of arrival for a foreign-born solar PV installer, for example, is 1998 (Census Bureau, 2019).[13]

Given the shortage of qualified workers, calls for increased immigration have started to grow. In August 2023, 120 business leaders signed a letter from American Business Immigration Coalition Action calling for immigration reform to support IRA implementation (Sievers, 2023). Construction bosses, an adjacent and competing industry, are also reported to be pushing for immigration reform, as are some lawmakers (Chu, 2023; Colman et al., 2023). Immigration to complement the domestic green workforce would be most likely to come through an updating of Schedule A; the H-2B visa; or the J-1 visa, but all would require some measure of creative thinking, and would be likely to face severe political blowback. It is notable that even in the semiconductor industry, a sector noted to be of national security importance and with strong bipartisan support for the 2022 CHIPS and Science Act, the immigration reform necessary to secure an adequate workforce has not been forthcoming (Neufeld, 2022; Chu and Irwin-Hunt, 2023).

There is, however, encouragement in the fact that the Department of Labor announced at the end of 2023 that they would be seeking public input into the possible expansion of Schedule A, the list of occupations eligible for streamlined green card processing. Schedule A currently only provides streamlined access for some healthcare professions and individuals of exceptional skills, and the list has not been updated for decades (Fragomen, 2023b; Dempster and Milliken, 2023). A new approach to Schedule A, if implemented, could see the US learn from the approach taken by the UK's Migration Advisory Committee, regularly updating a shortage list of undersupplied occupations. At present, a list informed by labour market gaps would be likely to include electrical engineers and environmental engineers (Milliken et al., 2023); as the IRA takes effect, it could come to include lower-level jobs in increasingly high demand.

In designing any migration programme intended to bring international workers to support the US green transition, care would need to be taken to protect migrant workers from exploitation. Only 11 percent of solar workers are unionised, and there have been multiple reports of worker exploitation in the solar industry especially (DoE, 2023; Gurley, 2022; Harris, 2022). Investigative journalism by the New York Times has suggested that solar PV installers from out-of-state are especially likely to work without adequate safety or certification procedures (Scheiber, 2021). While developers denied these assertions, the difficulties posed to cross-state enterprises by divergent workforce requirements suggests that migrant workers risk facing dangerous working conditions unless preparations were made for monitoring and enforcement of employer treatment.

13 Analysis by key informant (unpublished).

Australia

Australia aims to increase its share of low-carbon power generation from 32 percent of its energy production in 2023 to 82 percent in 2030, and to reduce its emissions versus 2005 levels by 43 percent (DCCEEW, 2023; DCCEEW, 2022a).

In 2023, estimates by the Australian Industry Energy Transitions Initiative suggested that Australia had 26,000 workers directly employed across the renewable energy sector, and that a further 59,000 workers would be needed by 2030. An estimated 168,000 workers, in addition to those expected to be able to transition from fossil fuel sectors, are needed by 2050 (Australian Industry ETI, 2023). Other estimates suggest that Australia's workforce needs may be greater still, and that there will be growing competition for the same skills between green transition-relevant and other sectors. The Australian Government's flagship *Clean Energy Generation* report, published at the end of 2023, found that Australia will need between 26,000 and 42,000 additional electricians by 2030 and as many as two million workers across the building and engineering trades by 2050, representing a 40 percent increase (Jobs and Skills Australia, 2023b). To achieve its 'Renewable Superpower' ambitions, Australia is estimated to require around 750,000 workers by 2060 (Jobs and Skills Australia, 2023b); in the hydrogen sector alone, delivering the optimal scenario is anticipated to need 240,000 workers in transmission, construction, electricity generation and storage (Rutovitz et al., 2023).

This occurs in a challenging context: Australia has one of the tightest labour markets in the OECD (OECD, 2022a). In late 2022, the Australian Government estimated that public infrastructure projects faced a shortage of 214,000 skilled workers and noted a worsening shortage of workforce in "every state and territory jurisdiction" (Infrastructure Australia, 2023). Australia's green transition must navigate significant skill constraints; migration will need to play a major role.

Demand

Australia's decarbonisation goals rely heavily on solar power. The Australian Energy Market Operator (AEMO)'s Integrated System Plan has set a target of roughly 3.5 GW of rooftop solar installation per year through to 2030 in order to meet the federal government's goal of 82 percent renewable energy by 2030; the IEA recommends adding 30 GW by 2030 (Clean Energy Council, 2023; AEMO, 2022; IEA, 2023a).

This requires a significant increase in the current rate of rooftop solar PV and will be challenging to achieve. As of June 2023, there were over 3.52 million PV installations across Australia, with a total capacity of 32 GW; rooftop solar accounted for around 20 GW (APVI, 2023; Peacock, 2023a). The federal government estimated in 2022 that to meet targets, 22,000 0.5kW solar panels must be installed every day for the next eight years, for a total of 60 million by 2030 (Bowen, 2022). Industry leaders have warned that a combination of factors, including a shortage of skilled labour, may make it "impossible" to achieve this target (ibid.).

More broadly, the Australian solar market is in good health. Despite the difficulties in achieving high targets, Australia still has the highest share of rooftop solar per capita in the world (IEA, 2023a). From 2020–2023, total solar capacity rose by around 50 percent (APVI, 2023). At the local level, this increase is driven in large part by rooftop solar installations responding to increased energy costs and decreased solar PV prices; at the state level, increased installations are supported by subsidies and high targets (Hannam, 2023a; Hannam, 2023b; IEA, 2023a). Utility-scale solar farms have also been installed at a considerable scale, but a combination of issues including grid capacity, supply chain difficulties, and planning delays has led to a decline in their construction and a worrying reduction in financial commitments (AEMO, 2023; Peacock, 2023b).

Installation of rooftop solar PV in Australia must be performed by a licensed electrician. Much of the solar workforce comprises less-skilled support for electricians, however: electricians are estimated by the Clean Energy Council (CEC) to comprise only a fifth of the solar PV workforce, and are typically assisted by trade assistants, roofers, or apprentices (Clean Energy Council, n.d.). These roles require minimal formal training. Nearly half of the residential solar workforce is estimated to comprise electricians, apprentices, trade assistants, and roofers. Despite the dominance of the PV workforce by non-electricians, Australia's broader critical shortage of electricians still poses a risk to the sector (Jobs and Skills Australia, 2023a).

Given that most of the solar PV workforce are electricians or ancillary staff, the skills in demand are not especially high. Only 17 percent of the solar installer workforce has tertiary education; 23 percent have no post-secondary qualifications whatsoever, while 58 percent have some form of further qualification, from certificate level to an advanced diploma (National Skills Commission, n.d.). Despite this, a combination of a relatively low wage (an electrical apprentice earns 72 percent of the average Australian worker's wage); an absolute shortage of skilled workers; and inconvenient locations, makes hiring challenging (Jobs and Skills Australia, 2023b). While rooftop solar and heat pumps are geographically concentrated in denser urban areas, and are therefore relatively easier to recruit for, wind and large-scale solar projects are more likely to be concentratedly located in rural areas. Vocational Education and Training (VET) providers and employers have reported difficulties in attracting suitable candidates to these rural and remote locations (Australian Industry ETI, 2023). It is possible that migrant workers, with less place attachment and reliance on geographically constrained networks, may be less hesitant to work in rural areas.

Air-to-air heat pumps also have the potential to be very useful for Australia. Around 17.2 million air conditioning units are installed across the country (DCCEEW, 2022b). Climate change is predicted to make high-heat days hotter and more frequent in Australia, and cooling for living and working spaces will become increasingly necessary (NSW Government, 2023). Air-source heat pumps, which can both heat and cool spaces, can serve a dual purpose at high levels of efficiency.

Several state-level subsidies for heat pump installation are available. The Australian Capital Territory offers an AU$2,500 rebate for heat pump installation (US$1,590), subject to strict

eligibility requirements (ACT Government, 2022); Victoria offers an AU$1,000 rebate and also has an AU$112 million scheme upgrading heating in social housing to heat pumps; and Tasmania has an AU$15 million scheme upgrading public housing for heat pump use (MCCCRH, 2023). A number of state government grants, covering up to 100 percent of heat pump installation costs, are also available for small and medium enterprises (Brodribb et al., 2023). This seeks to reverse a decline in heat pump installations due to a reduction in rebates in 2017 (DCCEEW, 2022b). Installations of heat pumps are also supported by eligibility for the tradeable small-scale technology certificates delivered through the Small-Scale Renewable Energy Scheme (Clean Energy Regulator, 2017). The certificates are tradeable as carbon credits, giving individuals and small businesses an incentive to install more efficient technologies.

These interventions are so far not fully adequate; the Australian home heating market demonstrates considerable inertia (Australian Energy Council, 2022). Heat pumps account for only a sliver of the market. In 2023, roughly 2.7 million households (of approximately 9.3 million) relied on gas for home heating and 45 percent of water heating was undertaken using gas (Wood et al., 2023; Rewiring Australia, 2021). As of late 2022, only around 420,000 air-source heat pumps were installed across Australia (IEA, 2023a). In the first half of 2023, installations of heat pumps rose considerably, with the total number growing to an estimated 60,000 versus 36,000 in the same period of 2022 (Clean Energy Regulator, 2023). This followed a previous year-on-year rise in imports of 90 percent between 2020 and 2021 (DCCEEW, 2022b). These increases are encouraging, but must accelerate. For full electrification of the residential sector alone, 13.2 million gas appliances must be replaced (MCCCRH, 2023).

The workforce qualified for heat pump installation will be in high demand. Research conducted by Monash University finds that over ten years, the substitution of residential gas for electricity would by itself create nearly 20,000 full-time jobs in Australia, with the majority located in Victoria and New South Wales (ibid.). These jobs would normally be held by plumbers (required for safely disconnecting old gas boilers) and electricians (needed for the installation of heat pumps). Research commissioned by the Australian Government indicates that a shortage of qualified workers is expected to pose a challenge to the heat pump transition (Energy Efficiency Council and Australian Alliance for Energy Productivity, 2023).

Supply

Australia's clean energy workforce faces significant supply challenges. This is especially evident for electricians, but is also the case across multiple occupations. Analysis undertaken by Deloitte for the Australian Government's *Clean Energy Generation* report suggests that there will be inadequate supplies of, among other roles, electricians; HVAC mechanics; machinists; and welders, in the short-, medium-, and long-term. For electricians, the report finds that "there is insufficient capacity in the training and migration pipelines" to meet the need to increase the electrician workforce by 26,000 to 42,000 by 2030 (Jobs and Skills Australia, 2023b).

The 2023 Clean Energy Generation found that organisational links between industry, higher education, and VET providers were still lacking, with insufficient opportunities for apprenticeships and work-based learning. In particular, a shortage of VET trainers with clean energy experience limits training capacity and throughput, an experience shared by other countries and sectors within Australia (Jobs and Skills Australia, 2023b). Energy Skills Australia, in a submission to the Australian Government, noted "chronic shortages of electrical teachers across the country", resulting in delays to electrical apprentice training of up to eighteen months (Energy Skills Australia, 2023: 4). The Electrical Trades Union (ETU) of Australia, in another submission, noted that the Australian VET sector faces "major workforce shortages that may place a handbrake on our ability to train the skilled workers needed for the transition" (Electrical Trades Union of Australia, 2023: 1). The ETU suggests that due to inadequate funding for the vocational sector and to a shortage of trainers, "almost no" training providers are currently able or willing to provide elective modules related to renewable energy to electrical apprentices. The Australian Government, in its *Clean Energy Generation* report, suggests that at least 70 training organisations may be qualified to train electricians in connecting solar PV systems to the grid, and that as many as 1,700 students were enrolled in these courses in 2022 (Jobs and Skills Australia, 2023b).

An electrician seeking to install rooftop solar PV must de facto hold accreditations provided by the CEC. Only then are they eligible for small-scale technology certificates (STCs), a form of tradable carbon credit providing a rebate (Clean Energy Council, n.d.; Clean Energy Regulator, 2022). Until 2023, an engineering or electrical licence was a prerequisite for the relevant CEC accreditations, which must be renewed on an annual basis (Clean Energy Council, n.d.). From December 2023, non-electricians have become eligible for CEC accreditations in renewable energy design, including for qualifications in solar PV installation, grid connection, and battery storage (GSES, 2023). This path requires that learners complete a course on electrical principles, allowing the recognition of prior learning. This may open skilled areas of the renewable sector up to a wider pool of workers, including to migrant workers with previous qualifications not easily recognised by Australian qualification systems. CEC accreditation costs a total of around AU$715 before tax (Clean Energy Council, n.d.). In 2023, there were only around 8,000 CEC accredited solar PV installers in Australia.

Individuals can become a qualified electrician through a combination of VET training and an apprenticeship (or through dual-qualification tertiary training). Trainees must complete the Certificate III in Electrotechnology (Electrician) (Australian Government, 2022), a course that takes one or two years, followed by an apprenticeship and modular top-up training in solar PV installation. A bachelor's degree in electrical engineering takes four years to complete (The University of Sydney, n.d.). In 2018, only 703 electrical engineers were trained across Australia, a fall from 1,317 in 2003. Historically, between fifty and sixty percent of all engineering courses are completed (Engineers Australia, 2020). In 2021, around 1,600 bachelor's degrees in electrical and electronic engineering were commenced. 1,766 students across Australia had chosen elective courses in solar PV installation, and 1,239 had chosen an elective focused on heat pump installation (Jobs and Skills Australia, 2023b).

An apprenticeship takes four years to complete, and is provided through a combination of school and on-the-job training undertaken through a contract with an employer (NECA, 2023; Jobs and Skills WA, n.d.). In South Australia, the four-year training period for a Certificate III course and apprenticeship cost students a maximum of AU$4,395 in 2023 (TafeSA, n.d.). In 2022, 5,327 individuals nationally commenced training for the new Certificate III in Electrotechnology (Electrician) apprenticeship (AATIS, 2022). This compares to a total of over 415,000 apprentices in training across all courses (NCVER, 2022). Surveys suggest that only 52 percent of electrical apprentices complete their training, however, due to a combination of low wages, poor work culture, and a lack of mentorship (O'Sullivan, 2022). For this reason, the apprenticeship system has been described as "broken" by the ETU (ibid.).

BOX 2. Labour market responsiveness in Australia's electrical sector

The responsiveness of the Australian solar installation workforce to market demand is hindered by a constrained labour pool, and also by limited labour market flexibility. The total pool for recruitment is narrowed by a historical exclusion of women from electrical trades. While this certainly can and should be addressed, there is likely to be residual friction in recruiting women for some time. According to data analysed by Australia's National Skills Commission, only six percent of solar installers in Australia are female (National Skills Commission, n.d.). The wider electrician workforce is still less gender diverse, with only 2.1 percent of electricians female (Jobs and Skills Australia, 2023a).

Geographical flexibility for electricians within Australia has also historically been constrained by state-limited licenses, making it harder for labour to be allocated to areas of high demand. In 2021, Automatic Mutual Recognition of qualifications across state boundaries was introduced, meaning that licensed electrical workers in one state would no longer need to obtain a licence in another state to undertake the same activities (Parliament of Australia, 2019).

Electricians moving permanently across state boundaries must still obtain a new licence, however, reflecting the fact that while one state's qualifications may be recognised in another, the safety standards and obligations present in one state may not be identical to those of another (Energy Safe Victoria, n.d.; ETU, n.d.). In part because of this, only five percent of Australian electricians move interstate when changing jobs (Richards, 2021).

In Australia and elsewhere—notably the US and EU—policymakers will need to be aware of constraints on internal mobility due to variations in qualifications between sub-units. When surges in green transition-relevant work occur in a given area—such as the construction of a utility-scale plant, or suddenly increased demand due to a new state incentive—the inability of firms in that area to recruit workers from other parts of the same country poses a challenge to decarbonisation. Internal mutual recognition agreements are likely to be necessary. For international migrants, these licensing limitations may mean that they are de facto bound to certain administrative units; care will have to be taken to ensure that this does not facilitate rights abuses by unscrupulous employers.

The heat pump sector will also need to compete for the scarce supply of electricians. Due to the shortage of electricians and their relatively limited experience in installing heat pumps, it is expected that Australia's heat pump workforce will be stretched, creating bottlenecks in the transition to efficient heating and cooling (Wood et al., 2023). Heat pump installations are undertaken by qualified electricians. In 2022, 86 organisations were registered to train electricians in installing air conditioning and water-based heat pump systems and 1,239 electricians were registered taking these courses (Jobs and Skills Australia, 2023b). Skill gaps may also be met through the use of short unaccredited courses; the Queensland Technical and Further Education network, for example, offers an unaccredited three-day course providing heat pump experience.

Australia currently has 96,000 plumbers qualified to work on gas installations, but this workforce is seldom qualified to work with electrical fittings (Wood et al., 2023). At present the only way for a plumber to become qualified to work on heat pumps would be through an electrical apprenticeship; this would last four years and typically entail an AU$45,000 pay cut in the first year alone.[14] Training opportunities for reskilling into heat pump installation are currently lacking (Energy Efficiency Council and Australian Alliance for Energy Productivity, 2023). This is in part due to a 'chicken and egg' situation in which relatively low demand for installations is contributed to by a workforce shortage; workers are therefore less interested in obtaining training; and training providers are therefore not incentivized to offer training. It is likely that the heat pump transition will need to be supported by both state subsidies and state intervention to support training programmes ahead of demand. In New South Wales, the Certificate III in Air Conditioning and Refrigeration, which includes the option of modules on heat pump installation, is currently covered within the 'Smart and Skilled' programme, making it fee-free (Training Services NSW, 2023).

Migration

In 2023, Clare O'Neil, Australia's Minister for Home Affairs, described Australia's migration system as "broken… unstrategic… complex, expensive, it's slow… It's not delivering for migrants and it's not delivering for the nation", citing the fact that it could not deliver the international workforce needed for the green transition (O'Neil, 2023). This is a problem for both the broader Australian economy and for its renewables development. If Australia's economy continues growing at historical rates through to 2050, it will need an additional two million migrant VET-qualified workers (Chand and Clemens, 2021). In 2023, 26 percent of Australia's clean energy workforce was filled by migrant workers, rising to over 30 percent in some sectors (Jobs and Skills Australia, 2023b). Senior figures in Australia's green transition have been calling for increased access to the international labour market for some time. In June 2023, the chief executive of Engineers Australia warned that a lack of skilled engineers "poses significant challenges to achieving the country's clean energy and sustainability goals", arguing that only labour migration could solve this problem (Madew, 2023).

14 In this regard Australia differs sharply from peer countries, where it is recognised that plumbers can and should be rapidly upskilled for heat pump installation.

The Australian Government has recently agreed with this view in its *Clean Energy Generation* report, acknowledging that "whilst efforts to skill, upskill and reskill the domestic population will drive the net zero transformation, it will also be heavily reliant on effective migration settings to assist in addressing existing and anticipated skills gaps and support the growth of the clean energy workforce" (Jobs and Skills Australia, 2023b). Both the 2023 Review of the Migration System and Australia's *Clean Energy Generation* report noted that global competition for skilled migrants is likely to increase (Department of Home Affairs, 2023).

To maximise the contribution of migration to the green transition in Australia, reforms will have to be undertaken. Migration to Australia has historically often been challenging. Recognition of qualifications, in particular, is known to pose problems to migrants' integration into the workforce. Nearly 25 percent of permanent skilled migrants are in jobs below their skill level (Jobs and Skills Australia, 2023c). For an electrician, the process of electrical trade recognition can take more than 18 months and cost over AU$9,000 (CEDA, 2023). In 2023, a senior migration review panel commissioned by the Federal Government concluded that Australia's skills recognition system was inefficient, giving the specific example of the difficulties faced by electricians in immigrating, and that the level of inefficiency could prevent migrants from seeking to come to Australia at all (Department of Home Affairs, 2023). This is due in part to the fact that while qualifications may be adequate to gain access to Australia through the Skilled Migration Program, they may not be considered adequate for work in the Australian sectors to which they are relevant.

A pilot project running from 2022–2024 could provide some lessons for improving skill recognition of migrants in Australia. The Skills Assessment Opportunities for Migrants Pilot aims to provide onshore migrants with free, fast-tracked skills assessments, allowing workers with skills in priority occupations to more quickly enter shortage sectors. Multiple professions relevant to the green transition, including electricians, welders, technical cable jointers, and VET teachers, are eligible for fast-tracked assessments, job-finding support, and AU$3,000 of employability training (Trades Recognition Australia, 2023; Australian Government, n.d.).

The 2023 Review of the Migration System recommended that Australia pursue international mutual recognition of licences from a broader range of countries, allowing easier access to the international worker pool, and that it improve alignment between the credentials necessary for visa access and those necessary for sector-specific work, reducing the likelihood of a migrant entering a 'limbo' period (Department of Home Affairs, 2023). Australia has already agreed a Framework Mechanism for Mutual Recognition of Qualifications with India, and it is understood that Australia has also been in discussions with India's Skill Council for Green Jobs regarding the training of Indian workers for Australia's domestic market (Press Information Bureau, 2023).[15] Australia has also been undertaking active labour recruitment at the state level. In 2023 a delegation from the Western Australia Government visited several towns in the UK, attempting to recruit (among other roles) electricians.

15 Key informant interview.

Government recruiters argued that the salary of an electrician in Western Australia is 172 percent higher than that of an electrician in the UK, a wage of £63,000 in Australia (US$77,500) compared to £36,000 in the UK (US$44,300) (Shadwell, 2023).

In managing labour migration, efforts will need to be made to ensure that migrants have decent jobs and are not exploited. The Australian solar industry has previously used migration to fill installation labour needs, especially for large solar farms. These practices have not always been good for migrants: investigations of large projects have, on some occasions, found migrants performing work for which they were not qualified; dangerous working conditions; and labour exploitation (ACTU, 2020). Future migration approaches would need to ensure that workers were qualified or provided with training, and that employers were monitored to protect migrants from exploitation.

As the *Clean Energy Generation* report recognises, there is also the possibility for migration to Australia to be deliberately beneficial for the wider Pacific (Jobs and Skills Australia, 2023b). Seasonal migration to Australia already provides Pacific islands with a valuable source of remittances; deliberate investment in training in the Pacific and job market matching in Australia could provide Pacific islanders with skills for adaptation and mitigation, and access to higher-paying renewable jobs in Australia (World Bank, 2017). This could be delivered through the Pacific Australia Labour Mobility (PALM) programme, or through a redesigned approach to the Australia-Pacific Training Coalition.

Germany

Germany aims to achieve net zero greenhouse gas emissions by 2045, and has set intermediate milestones of 65 percent emissions reductions by 2030 versus 1990 levels, and 88 percent by 2040 (OECD, 2022b). These emissions targets are highly challenging: logistically, politically, and economically—especially after a November 2023 court ruling blocked €60 billion of federal funding, forcing spending cuts (Packroff, 2023b). Germany missed its climate targets in 2021 and 2022, and stands at risk of failing to meet its 2030 and 2045 goals (Kurmayer, 2022a; Wettengel, 2023a; Alkousaa et al., 2023). If this happens, Germany will also face severe financial sanctions at the EU level. According to EU rules set in 2023 under the Effort Sharing Regulation system of permits, the five richest countries—including Germany—must cut their emissions by 50 percent by 2030 (European Commission, 2021a). Germany is currently anticipated to miss these emissions reduction targets by around 150 million tonnes of CO2-equivalent gases, forcing it to buy carbon certificates from other EU nations. These may cost up to €30 billion (US$32 billion; Kurmayer, 2023b).

Germany's energy supply has experienced significant challenges in recent years. In 2022, 27 percent of Germany's energy mix was provided by natural gas, of which 55 percent was imported from Russia, and around six percent was provided by nuclear power (Umwelt Bundesamt, 2023; Oltermann, 2022; Appunn, 2021). Following the invasion of Ukraine by Russia, Germany reduced gas consumption

by around 20 percent; and following a longstanding post-Fukushima plan, Germany's last nuclear power plants were shut down in early 2023 (Moll et al., 2023; Federal Office for the Safety of Nuclear Waste Management, 2023).

In the coming years, Germany will rely on newly installed renewable energy sources and increased energy efficiency to transition its economy. It aims to generate 80 percent of its electricity through renewable sources by 2030. In an extremely tight labour market, Germany will have to rely on access to international labour pools for economic growth and its green transition (Wettengel, 2023b; Angenendt et al., 2023).

Demand

Germany aims to install 500,000 heat pumps per year by 2024, reaching a total stock of six million by 2030. It also aims to install 22 GW of solar capacity each year to 2030, reaching a total solar energy stock of 215 GW (Wettengel, 2022; Gesetzentwurf der Bundesregierung, 2023).

Interest in heat pumps rose sharply in Germany due to energy price hikes following the invasion of Ukraine. In a January 2023 study, 13 percent of households plan energy-saving renovations in the next five years (Sirius Campus, 2022). In the first half of 2022, heat pump installations rose by 25 percent versus the same period in 2021; across 2022, the German heat pump market grew by 53 percent (Naylor, 2022; EHPA, 2023a). There were as many applications of federal subsidies for heat pump installations in August of 2022 alone as during the whole of 2021 (Mathiasen et al., 2022). This was, however, a peak in interest, and applications tumbled by around half in the first half of 2023 following a subsidy cut (Wehrmann, 2023). Subsidies were still available, with up to 25 percent of installation costs funded by the federal government through to 2030, and rebates of up to 40 percent of the cost of purchase and installation available through further subsidy systems (EHPA, 2023b; King, 2023). During this period even the cheapest heat pumps remained considerably pricier than gas boilers, even if they are cheaper to run after installation (IEA, 2022c). Funding reforms announced at the end of 2023 will provide households with up to €21,000, or 70 percent of costs, to support heat pump installations (Von der Burchard, 2023; Energie-Fachberater, 2023); this could see installation rates leap again.

BOX 3. Political commitment and workforce ramifications

Germany's decarbonisation goals will have major workforce ramifications, for which the key sectors are not prepared. Political u-turns, however, have reduced market confidence, and have altered the timeframes within which workers will be needed.

In 2023, 30 million homes were heated with fossil-fuel boilers, and only four percent of households had heat pumps. New fossil boilers were expected to be banned in Germany from January 2024, when all new heating systems would be required to run on at least 65 percent renewable energy (Kurmayer, 2023a; Connolly, 2023). In autumn 2023, a watered-down ban on fossil fuel heaters was adopted instead, pushing the phase-out date back to 2028 (Kurmayer, 2023a; Kurmayer, 2023c). Prior to this delay, sales of fossil fuel-based heaters had surged by 44 percent in the first half of 2023 (Kurmayer, 2023d).

Given that the 2030 target of six million installations has not changed, heat pump installations must be significantly scaled up in the late 2020s—meaning that the heat pump installation workforce will also need to expand to accommodate the larger workload. In May 2023, ZVSHK (the German Central Association for Plumbing, Heating, and Air Conditioning) reported at least 40,000 vacancies (Missing and Lobo, 2023). The ZVSHK expected that 60,000 additional heat pump installers would be needed over the nine years 2022–2030 to meet targets.[16] Given the anticipated backloading of installations, a greater number may be needed in a shorter time frame (Hilpert, 2022).

Further assistance with heat pump installation costs, and reductions in Germany's high electricity taxes to keep prices within a range manageable for households, are likely to be necessary to support accelerated uptake (Meza, 2023). In autumn 2023, representatives of the coalition government suggested that electricity taxes could be reduced by 95 percent (Kurmayer, 2023d). Grid upgrades will also be necessary to allow increased electricity demand during winter: six million heat pumps will require an extra 44TWh to be drawn from the grid in 2030, some 10 percent of total capacity in 2023 (Bateman, 2023a; BWP, 2023; Fraunhofer ISE, 2023).

Germany's solar sector is growing fast, but to grow at the necessary speeds will need a significantly increased workforce. In 2021, Germany produced nearly 50 GWh through solar PV installations, accounting for nearly 8.7 percent of total electricity generation (Bateman, 2023b). For 2023, the national solar association predicted an annual growth of total capacity of 9–11 GW, versus 7.4 GW in 2022 (BSW Solar, 2023). Across wind and solar energy, Germany had an estimated shortage of over 216,000 workers in 2021/2022 (KOFA, 2022). This deficit is exacerbated by the fact that the same skill stocks are being competed for by related industries, such as e-mobility and energy efficiency renovation.

16 Note: this number is for the residential sector alone, without accounting for commercial and industrial installations.

In 2022, Germany had an estimated 65,000 workers in the solar sector. 68 percent of this employment was generated by rooftop PV installations (Umwelt Bundesamt, 2022). According to BSW Solar, Germany's solar PV industry association, Germany is expected to need 165,000 solar workers by 2026 to meet the annual installation target (Bateman, 2023b). SolarPower Europe, the European solar association, goes further, estimating that Germany will need a total of around 204,000 solar workers to meet targets (SolarPower Europe, 2022). By 2027, Germany is anticipated to have the EU's largest solar workforce (SolarPower Europe, 2023a). Yet in February 2023, around 60 percent of German electrical contractors working in solar had vacancies (Ford, 2023).

Supply

Germany's labour market is ageing and overstretched. In 2020, the median age in Germany was 45.7 years; by 2045, it is expected to be 49.2 (OECD, 2020b). The European Commission has forecast a decline in the working-age population of nearly six million by 2050 versus 2019 (European Commission, 2021b). In 2022, vacancies for skilled workers across the German economy rose by 30 percent to 1.3 million (Martinez et al., 2023).

The heat pump market faces major skilled labour challenges. From 2021–2022, there was a shortage of 14,013 plumbing, heating, and air conditioning specialists (KOFA, 2022). Vocational training is mostly provided through the formal education system, and is managed by the Federal Institute for Vocational Education and Training (BIBB). Colleges (Berufschulen) and vocational schools (Oberstufenzentren) are the main providers of vocational training, and can be attended either part-time or full-time (Hofman et al., 2022). Heat pump certifications are organised at the federal level by the ZVSHK (EHI, 2022). Certification is given after a three-and-a-half-year apprenticeship, regulated by national authorities, at a craft enterprise. After two years of employment, installers can apply for a master craftsman's diploma administered by the chambers of crafts, after which they can open their own business. To handle F-Gases, an installer must pass a federally organised exam.[17] Installers only working with small heat pumps are not required to pass this. Training on heat pumps' installation is available from several institutes and from heat pump manufacturers. For most trainees, however, heat pumps do not feature heavily in their training: most buildings in Germany are still heated by fossil fuels (Sabel, 2023). This is changing in anticipation of market shifts, but according to the German Heat Pump Association remains insufficient.

German apprenticeships comprise a classroom component with a practical component at a certified company, in which theoretical knowledge can be put into practice and consolidated. Completion of an apprenticeship normally provides a qualification. Because of the important role of 'dual apprenticeships', the private sector is a large contributor to skills training (Cedefop, 2018).

17 Fluorinated gases (F-gases) are man-made gases used in a range of industrial applications, including some HVAC technologies. They are often used as a substitute for ozone-depleting chlorofluorocarbons (CFCs), banned from 2010 under the Montreal Protocol; however, F-gases are extremely potent greenhouse gases, and must be handled very carefully.

The 'dual apprenticeship' system has its difficulties, however, which are also felt in the heat pump sector. In 2021, 63,000 dual-training contracts were not taken up: only 496,000 were signed, a fall from 561,000 in 2011 (Gordon, 2023). Within the skilled crafts and trade sector, around 20,000 apprenticeship places are unfilled each year (Packroff, 2023a). This reflects a fall in both the total number of young people in Germany, and a reduced interest in vocational training. Interviews by RAND found that young people prefer 'bite-size' training programmes rather than longer-term training lasting for three years (Hofman et al., 2022). Vocational schools in Germany are also experiencing a significant shortage of teachers. The ZVSHK estimates that the present pipeline of trainees is only sufficient to compensate for half the age-related decline in the HVAC sector, let alone meeting the need for expansion (Hilpert-Präsident et al., 2022).

The German energy think-tank Agora Energiewende recommends that further government investment will be necessary, supporting the development of further training infrastructure in anticipation of significantly increased demand (Bürger et al., 2022). Agora Energiewende describes the shortage of skilled heating installers as "the current biggest bottleneck" in expanding heat pump take up (p. 40). Production of heat pumps is not a major hindrance: investments by major manufacturers such as Daikin and Viessmann should ensure a reliable supply of units (Daikin Global, 2022; Martinez, 2023). Instead, a shortage of heat pump specialists; competition from other areas of work, such as bathroom installations; and a labour pool constrained by gender imbalances, restricts the speed at which the heat pump workforce can grow. Agora Energiewende recommends shortening the training period where possible to attract more young people into the sector.

In 2023, homeowners seeking to have a heat pump installed typically had to wait between a month and a year for a skilled installer to be available (Sabel, 2023). In the January 2023 survey regarding energy efficiency upgrades, 23 percent of households said that they were put off by long waiting times for craftsmen (versus 15 percent in 2022) (Sirius Campus, 2022). A legal installation of a heat pump requires at least two professionals, and sometimes three, across HVAC and electricity (Sabel, 2023). At present, however, vocational courses for becoming an HVAC systems mechanic contain training superfluous to heat pumps while not including necessary skills, such as in electrical work (Bürger et al., 2022). Updates to training may therefore be necessary to meet changing needs. State subsidies for a heat pump installation can only be claimed when the installation is undertaken by a craft company, or pair of craft companies working together, registered in both plumbing and electricity and able to take on liability (Sabel, 2023). In 2023, only 15–20 percent of HVAC companies were estimated to be able to undertake heat pump installations. Training curricula will need to be redesigned to include the necessary combinations of skills.

In the face of these shortages, some companies are increasing training of their own workers. Viessman, a major German-American heat pump manufacturer and installer, has announced that it scaled up its training activities by 75 percent in 2022 compared to 2019 (Missing and Lobo, 2023). It is also experimenting with new heat pump designs intended to cut down installation times by as much as half. It is rare for companies to provide in-house training; in Berlin, for example, only 11 percent of

companies provide any vocational training (Packroff, 2023a). The federal government has recognised the extent of these shortages, and have increased subsidies for domestic retraining. From April 2023, the German government has provided 90 percent subsidies for people training as heat pump specialists (Martinez et al., 2023).

There is currently no state-recognised solar PV installation accreditation. As a result, different professional qualifications and levels are used. Some trainers suggest that an unskilled person could learn to install a PV system in only a few days of training, allowing them to support PV installation rapidly (KOFA, 2022). This is especially recommended by companies focused on PV installation and is already being trialled by a number of actors in this space. Enpal, a major German solar PV company, has opened up a training centre in Berlin to provide unqualified workers with two weeks of training before they join professional installers to learn further on the job (Martinez et al., 2023). As of August 2023, Enpal had trained over a thousand solar PV installers and had six months of training booked.

While basic PV installation can be undertaken by a low-skilled worker after a short period of training, grid connection can only be undertaken by a fully qualified electrician (with a masters degree) or a journeyman working for a registered master workshop (KOFA, 2022). Germany's shortage of qualified electricians therefore stands as a prominent bottleneck for solar capacity development (EURES, 2023). KOFA (the Competence Centre for Securing Skilled Labour) estimates that Germany had a shortage of nearly 17,000 electricians in 2021/2022 (in addition to over 14,000 workers qualified to work with HVAC technology) (KOFA, 2022). In 2023, KOFA revised this estimate higher, suggesting that there could be a shortfall of as many as 30,000 electricians across all skill levels (KOFA, 2023). The number of training contracts for workers entering the electrical sector is, far from increasing to meet needs, in fact declining. In 2018, around 128,000 new training contracts were concluded across metalwork and electrical sectors; in 2021, only 110,874 were filled (KOFA, 2023). In 2021, 14,763 apprenticeship positions went unfilled across the wind and solar sectors (KOFA, 2022). This is in part, as elsewhere, due to a gender-constrained labour pool. In 2021, only 7.4 percent of electrical engineering graduates in Germany were female (KOFA, 2022).

Because fewer training places are being offered for electrical training, and because there is less interest among young people in multi-year apprenticeships, KOFA recommends that partial qualifications should be considered for solar workers, allowing low-skilled workers to receive quick training for rapid deployment (KOFA, 2022). This could be brought into state-organised training systems, as well as industry-supplied short training approaches.

Migration

Recognising the challenges it faces in sourcing the workforce necessary for the green transition, Germany has proactively sought to attract workers from third countries. This has been achieved through both reforms to general migration policy, reducing barriers to immigration and increasing support for firms recruiting from overseas, and through deliberate partnerships facilitating active

recruitment, including through pilot training and migration programmes. These initiatives are all set to be scaled up in the coming years: as the OECD notes, "facilitating the migration of skilled workers from non-European countries" is, alongside domestic TVET, "essential to ease labour shortages" hindering the green transition (Krill et al., 2023). This call is also made by the German Heat Pump Association and by KOFA (BWP, 2023; KOFA, 2022).

BOX 4. Germany's 2023 immigration system overhaul

In early 2023 Germany reformed its immigration system, coming into force in stages from November 2023 to March 2024 (Fragomen, 2023a). This was undertaken in part to supply workers needed for the green transition (Jordans, 2023). The new system has three pillars (BMI, 2022):

1. The *skilled workers pillar* is directed at non-EU citizens who hold a recognised higher education qualification. These skilled workers will be eligible for an EU Blue Card.
2. The *experience pillar* is directed at workers who have gained a vocational or higher education qualification and professional experience abroad in a profession they intend to carry out in Germany. Workers will need to hold a job offer with a salary above a certain threshold, or have collective bargaining coverage. Skilled non-EU citizens will also be able to submit foreign qualifications for recognition after beginning work in Germany, accelerating the process for starting work.
3. The *prospects pillar* is directed at non-EU citizens who do not have an employment contract in Germany. These workers will be eligible for an 'opportunity card' if they meet the selection criteria of a points-based system, which prioritises qualifications; language skills; professional experience; connection to Germany; and age.

Germany is already starting to prepare for the possibilities offered by its new immigration system by building partnerships with possible countries of origin. Most prominent is the agreement between BSW Solar and the Indian Skill Council for Green Jobs (SCGJ), to allow Indian solar installers trained through the *Suryamitra* programme (see Box 7) to work in the German PV industry (Ernst, 2023). This was agreed in February 2023. In May 2023, BSW prepared a curriculum and pilot programme to allow Indian workers access to member companies (Yuen, 2023b). BSW's India solar recruitment scheme is a business-to-business agreement between the SCGJ and BSW, but is being managed in collaboration with government departments and associations through the Hand in Hand for International Talents project (Yuen, 2023a). This type of programme is currently relatively rare; a poll of German companies in 2022 suggests that only 17 percent have attempted to actively recruit foreign workers (Schultz, 2022). This programme has the potential to increase the annual earnings of these workers by US$30,700 per year, and to reduce carbon emissions by over 800 tonnes per year per worker: a public social good of some US$175,000 annually (Huckstep et al., 2023). It is anticipated that from 2024–2026, around 2,000 *Suryamitra* graduates will travel to Germany, with the possibility of the programme subsequently expanding.[18]

18 Key informant interview.

As Germany seeks to expand its international recruitment of green-skilled workers, it is likely to need to draw on sources further afield than its own neighbourhood. Immigration from EU states is likely to be constrained by those states' own demographic declines (Angenendt et al., 2023). Germany could also seek to recruit more workers from the neighbouring Western Balkans, from which the 2015 Western Balkans Regulation permits low-skilled temporary immigration. This migration route is capped at 25,000 beneficiaries a year, and has historically been dominated by construction workers (Bither and Ziebarth, 2018). In 2021, the Western Balkans accounted for 17 percent of total labour migration, of whom only 3,000 migrants entered via the Regulation (Angenendt et al., 2023).

In turning to a broader range of countries of origin, Germany can draw on its longstanding experience supporting training and migration programmes across the world. In Vietnam, for example, Germany has supported solar training programmes since 2009 (VNEEP, 2021). As of 2021, 49 intensive training courses had been conducted for nearly 2,400 Vietnamese trainees. The global 'Skills Experts' programme, launched by the BMWK in 2017, has also supported German companies operating abroad in training local workers through the dual vocational training system (BMWi, 2019). This is implemented in conjunction with the German Chambers of Industry and Commerce, and aims to "guarantee globally comparable and quality-assured standards of in-company training and its certification according to the German model" (AHK Nigeria, n.d.) The Skills Expert Programme (so far) takes place in eleven countries.[19] The programme was originally envisaged to run until 2021/22; it has been extended from 2023, with a new focus on incorporating training courses relevant to climate action, especially in Argentina, Chile, Nigeria, and South Africa (BMWi, 2019). Within this scope, TVET structures are also being created on a pilot basis for the preparation of skilled worker migration from Turkey and Brazil to Germany (BMWK, 2023).

The BMZ is also directly collaborating with the International Centre for Migration Policy Development (ICMPD) on a two-year pilot initiative focused on green skill areas, 'INSPIRE'. Intended to be implemented in the Western Balkans, Eastern Partnership region, and Africa, the project is now focusing on supporting migration from Kenya and Ghana to Germany (Angenedt et al., 2023). The project has struggled to collaborate with German companies in providing training in countries of origin, and instead is now focusing on supporting youth in moving to Germany to subsequently be trained there.[20] The key difficulty is likely to be engagement with German companies in Germany, and the placement of migrants in jobs. The online portal 'Make it in Germany', which currently is directed towards skilled workers, could conceivably be altered to support job market matching for lower-skilled workers (ibid.). This would be especially relevant for the solar sector, which as noted has very few prerequisites for labour market participation.

19 These countries are: Indonesia; Malaysia; Vietnam; Croatia; Bosnia and Herzegovina; North Macedonia; Kenya; Ghana; South Africa; Chile; and Nigeria.

20 Key informant interview.

Germany has also engaged in deliberate circular migration for education purposes, supporting the development of renewable sectors in partner countries. BMZ has financed the VET4Africa project, which brings trainers of trainers from 17 African countries to Germany for 10-day training in solar skills (Green People's Energy for Africa, 2023). Trainers then return to their home country to pass knowledge on. From 2018–2023, 300 trainers were trained in Bavaria. Participants have subsequently trained around 4,000 PV technicians.

BOX 5. Bringing refugees into green sectors

Several projects in Germany have demonstrated the potential for bringing refugees and underemployed migrants into green transition sectors facing skill shortages. There is room for Germany to do more: Agora Energiewende and other sector analysts recommend increased integration of skilled refugees into the labour market to increase the size of the heat pump worker pool (Bürger et al., 2022; Mason et al., 2022). Other countries can also learn from efforts in Germany and elsewhere. The Berlin branch of the HVAC company SHK, for example, has provided refugees with short- and longer-term assessments, training, and apprenticeship placements, including in heat pump manufacturing (SBZ Das SHK, 2022). Several other small-scale projects support the development of green skills for migrants and refugees in other parts of Germany (Hofman et al., 2022).

Two new initiatives are promising in the heat pump and solar PV installation sectors. In November 2023, the Berlin-based start-up Smalt obtained €4.1 million (US$4.4 million) in international investment to train immigrants and refugees already in Germany in rooftop solar PV installation, and support them in finding work (De Marzo, 2023). Montamo, another Berlin-based start-up, obtained €2.1 million in December 2023 for a similar in the heat pump installation sector (De Marzo, 2023), demonstrating that demand for labour has now reached a sufficient height that venture capital actors recognise that specialist labour procurement is a high-potential growth sector. Both Smalt and Montamo provide refugees and migrants with six- to eight-week training courses in highly tech-supported training centres before providing installation companies with access to workers from the company's pool, uniting entry-level trainees with experienced installers. Smalt intends to provide PV-trained refugees with options for progression toward full qualification as an electrician. The company expects to grow at a rapid rate over 2024–25, recognising that labour demand is extremely high; that Germany's 2.5 million refugees (UNHCR, 2023b) often struggle to find work; and that German nationals find the manual work of installation unattractive.[21]

21 Key informant interview with a representative of Smalt.

The European Union

The European Union (EU) is a major actor in the green transition. This section considers the EU's policies and labour market needs as a bloc. Both EU- and member state-level policies will be important to both the green transition and to the bloc's labour migration approaches.

The EU has set ambitious decarbonisation targets and has also introduced measures intended to both stimulate renewable sector development and sanction member states that do not achieve the necessary pace. By 2030, the EU aims to have reduced greenhouse gas emissions by 55 percent versus 1990 levels, and to have increased the share of renewable energy from 32 percent to 42.5 percent (European Commission, 2021a). It aims to achieve net zero carbon emissions by 2050 (European Commission, 2022a), a goal supported by the European Green Deal, a package of major policy initiatives (European Council, 2023). The Green Deal Investment Plan, the investment pillar of the European Green Deal, will mobilise at least €1 trillion (US$1.07 trillion), including over €500 billion of direct EU funding, for renewable investments (European Commission, 2020a). These measures will have significant impacts on job creation. The European Green Deal is anticipated to create 2.5 million new jobs across the EU by 2030 (Cedefop, 2021). This occurs in a context of an ageing population, which is already making recruitment hard and will make it still harder. By 2050, there will be 95 million fewer working-age people in Europe compared to 2015 (Kenny and Yang, 2021).

Demand

As a bloc, the EU intends to install 30 million additional heat pumps (versus 2022 stock) by 2030 (European Commission, 2022c), and 320 GW of solar PV by 2025—an increase in solar PV capacity of over 100 percent versus 2020—, rising to nearly 600 GW by 2030 (European Commission, 2022d).

Meeting these targets will require an increase in annual heat pump installations to seven million in 2030, up from two million in 2021, and to have installed 10 million by 2027 (European Commission, 2023c). As of 2022, four percent of the EU's old heating systems were replaced each year (European Heating Industry, 2022). At this rate, it would take over 20 years to meet EU targets. For targets to be met, the replacement rate will have to increase by 50 percent. Meeting the goals will also require a diversification of clean heating technologies (ibid.). These include electric hydronic heat pumps, hybrid heat pumps, and thermally driven heat pumps. The rollout of heat pumps across the EU has been patchy. Some member states are significantly ahead of others (IEA, 2022d). In Norway, 60 percent of buildings are equipped with heat pumps; in Sweden and Finland, more than 40 percent have heat pumps (See Figure 7). In late arrivals to the heat pump market, installations are scaling up noticeably, potentially assisted by rises in gas prices following Russia's invasion of Ukraine. In Spain, heat pump sales grew by over 20 percent in 2022 compared to 2021; in Poland, sales grew by 130 percent; and in France, sales grew by 20 percent. At the same time, the EU still has over 90 million gas and oil boilers, and a new boiler is installed every eight seconds (European Climate Foundation, 2023).

Multiple EU member states have moved to ban the installation of fossil heating systems, across varying timeframes. Subsidy packages are being created to support the use of heat pumps instead of gas and oil boilers. The Netherlands will ban the installation of new fossil heating systems from 2026, making heat pumps mandatory, and will provide €150 million (US$161 million) per year to support homeowners in purchasing heat pumps (Kurmayer, 2022b). Denmark banned oil and gas boilers in new builds in 2013. Ireland is banning fossil fuel boilers in new build houses from 2023, and will ban all new installations from 2025; an €6,500 (US$7,000) grant will be provided to support heat pump installations. France has a ban on oil boilers in all buildings and gas boilers in new builds from 2023; up to €9,000 (US$9,700) is available to subsidise the installation of an air-source heat pump, and €15,000 (US$16,000) for a ground-source heat pump. Austria provides households installing a heat pump with an €7,500 (US$8,000) grant, extending to 100 percent of costs for low-income households (Woollard, 2023). From 2026, in addition, member states will be able to provide further subsidies supported by the new €86.7 billion (US$93.1 billion) Social Climate Fund (European Commission, 2023g).

To meet the REPowerEU heat pump installation targets, the IEA estimates that the number of heat pump installers must rise from around 40,000 in 2019 to around 110,000 in 2030 (IEA, 2022d).[22] Other actors' estimates suggest still greater workforce increases will be necessary. The European Heat Pump Association estimates that the workforce of the entire European heat pump value chain must grow from around 117,000 in 2023 to between 450,000 and 500,000 by 2030. The Association of the European Heating Industry (EHI) estimates that the number of heat pump manufacturing, installation and maintenance workers must increase by 50 percent by 2030, and that in addition at least 50 percent of existing heating installers must be reskilled for heat pump technologies, for an increase in the number of heat pump installers of 750,000 (EHI, 2022; European Commission, 2023b). The European Electrical Contractors' Association (EuropeOn) estimates that there are 161,000 workers in the EU heat pump industry in 2023, with a need of at least 500,000 by 2030 (EuropeOn, 2023).

Installed solar PV capacity is also expected to rise sharply. Already, the EU's solar PV installation rates have been improving steeply. In 2022, 41 GW of new solar PV capacity was installed, a 60 percent increase on the capacity installed in 2021 (European Commission, 2023f). In 2023, an estimated 58 GW of solar was estimated to have been installed, a further 41 percent increase versus 2022 (Maisch, 2023). REPowerEU solar targets require annual additions of 48 GW for solar PV, for a total installed capacity of 750 GW by 2030 (IEA, 2022a). In 2023, the EU had 221 GW of installed solar capacity. At the member state level, targets lag behind the EU goals. As of August 2023, the aggregate of national targets was only 425 GW of installed solar PV. Despite this, SolarPower Europe anticipates a total installed capacity of 900 GW by 2030; in other words, that the EU will exceed its goals by a considerable margin (SolarPower Europe, 2023c). EU solar rollout has so far been faster

22 The REPowerEU plan was created in 2022, and aims to support the EU in both reducing its dependence on Russian gas and in undertaking its green transition.

than expected, incentivised by the effects on EU energy supply costs of Russia's invasion of Ukraine (Jack, 2023).

According to SolarPower Europe, the EU solar industry directly employed 281,000 full-time equivalent workers in 2022, with a further 367,000 workers indirectly employed as a result of the solar industry (SolarPower Europe, 2023a). The solar industry was estimated to have experienced a 39 percent rise in employment versus 2021. Of these jobs, 84 percent were in the deployment of solar systems. This proportion is not expected to decline significantly in the coming years (SolarPower Europe, 2022). SolarPower Europe estimates that for the EU to meet the 750 GW REPowerEU target by 2030, a total of one million solar PV workers will be needed, with a further 500,000 required if the EU wanted to increase its ambition to 1 TW of solar PV capacity (Touriño Jacobo, 2022). As elsewhere, the majority of jobs are in the more labour-intensive rooftop PV, although the disparity is expected to be reduced (SolarPower Europe, 2023a). In 2022, 73 percent of solar jobs were in rooftop solar; by 2027, this is expected to be reduced to 63 percent thanks to an increase in the prevalence of utility-scale installations. Swedish companies are expected to need to hire 28,000 solar installers from 2023–2028, per SolarPower Europe (Ford, 2023). Sourcing these workers domestically, or in the EU, will require some competitiveness. Germany expects competition for skilled workers with other EU member States to be a challenge in obtaining the necessary number of green-skilled workers (Martinez et al., 2023).

If solar PV manufacturing chains are also scaled up within the EU, additional skilled workers would be needed, totalling 64,000 to 106,000 from 2026 (SolarPower Europe, 2022). The EU imported 84 percent of the solar PV modules it installed between 2017 and 2021 (IRENA and ILO, 2023).[23]

Supply

The EU's supply of workers with the skills necessary for the green transition currently appears insufficient. In 2022, 18 EU countries faced shortages of electricians, of which 40 percent were "high magnitude"; the same number faced shortages of plumbers and pipefitters (IEA, 2023g: 27). The European Commission has recognised that Europe already faces a shortage of skilled workers, and that "the bottleneck could grow quickly if unaddressed" (European Commission, 2022f). The 2023 *Green Deal Industrial Plan for the Net-Zero Age* recognises that skills are a key impediment to the EU's green transition, and that "there will be fierce competition for talents" (European Commission, 2023a: 14). The European Investment Bank has identified a lack of relevant skills as reducing capacity to invest in the EU's green transition, especially for municipalities (European Investment Bank, 2023). As in other areas, gender imbalances in key green sectors constrict the pool of available workers: in 2020, women accounted for less than 5 percent of the EU's electricians, for example (McGrath, 2021).

23 For comparison, the US imported 77 percent, and India 75 percent, almost entirely from China.

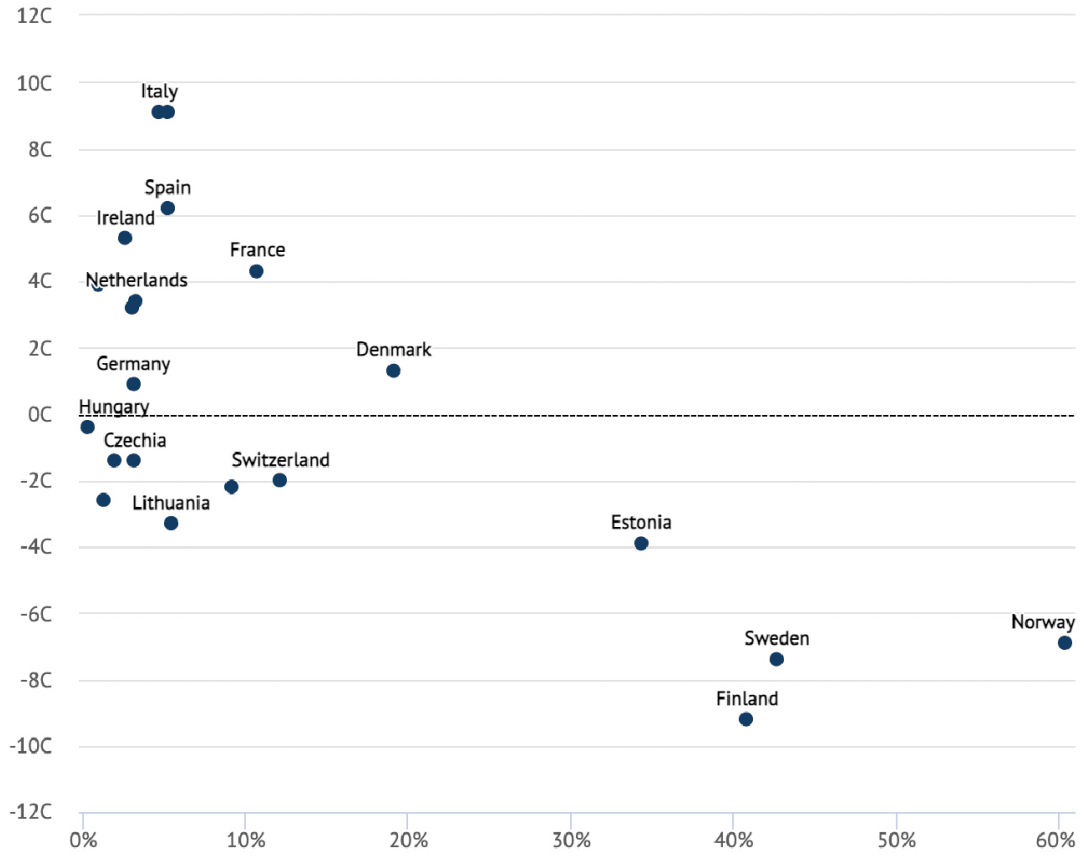
In the heat pump sector, the IEA warned in 2022 that the EU's REPowerEU strategy is already challenged by a combination of supply chain constraints and labour shortages (IEA, 2022a). The IEA calls for "more aggressive policies" to navigate this bottleneck. Member state institutions are also sounding the alarm. France's High Council for Climate, for example, notes that while building decarbonisation technologies are financially supported, "needs related to the development of skills present major challenges", and are "the principal challenge" in building decarbonisation (Haut Conseil pour le Climat, 2023). In surveys conducted in multiple EU member states for the research project HP4All, a lack of a qualified and experienced installation workforce was identified as a, or the, main barrier to the growth of the heat pump market in Ireland, Austria, and Spain. In a survey of 101 members of the European Heat Pump Association, 61 percent said that a lack of installers was the largest barrier to heat pump market growth (Southernwood, 2021). In the Netherlands, heat pump deliveries increased by 36 percent in 2023; limited installer capacity is cited as a standout limiting factor (Vereniging Warmtepompen, 2024).

This perception is borne out by surveys of consumers. As noted, 23 percent of German households are put off energy efficiency renovations by the long waiting time for skilled craftsmen (Sirius Campus, 2022), and there are consumer concerns regarding installers' quality (Hilpert, 2022). In Sweden, by contrast, the high standard of training for heat pump installers, and the high technical standards for installations and equipment, are reported to have contributed to higher consumer confidence in heat pumps as a method of heating (Gross and Hanna, 2019).

Training for heat pump installation is not homogenous across the EU. All EU countries require certification for installers of heat pumps using refrigerants, which is the case for most heat pumps. Requirements for training and certification of heat pump installers vary between countries (International Energy Agency, 2022d), however, making the Renewable Energy Directive's requirement for mutually recognised certification harder to implement (European Commission, 2022e). This risks making the intra-EU labour market less fluid.

Many EU member states have subsidies supporting heat pump installation, often contingent on installers holding the necessary certifications. This is the case, for example, for Austria, Belgium, and Finland (Heat Pump Association, 2020). These subsidies can have notable impacts on demand for heat pumps and, consequently, on retraining into heat pump installation. In France, the 'Coup de Pouce' subsidy, which provides a grant for heat pumps when replacing an oil boiler, incentivised a rapid expansion in the number of qualified heat pump installers. The programme was launched at the start of 2019; in the first half of 2019, 264 percent more heat pump installers were trained than in the same period of 2018 (Combe, 2019). The programme aims to see 3.5 million oil boilers replaced by 2030.

FIGURE 7. Share of homes with heat pumps vs. average January temperatures, 2022



Source: Rosenow and Gibb (2022).

In 2022, the European heat pump sector was estimated to employ a total of approximately 40,000 workers across installation and maintenance (HP4All, 2022). Retraining to expand this pool is made more possible by the fact that the EU has a large pool of workers who could potentially be retrained as heat pump installers: in 2020, it had around 2.7 million plumbers, electricians, electrical fitters, and refrigeration mechanics. While these workers can be retrained, these sectors also currently face hiring gaps. The IEA suggests that this indicates that retraining must be undertaken by introducing heat pump-related requirements to existing qualifications if it is to succeed, creating generalist tradespeople able to perform multiple tasks (International Energy Agency, 2022d). This is likely to be challenging, but may be wise. As elsewhere, the heat pump installation industry appears unattractive to young labour market entrants, despite its reliable future. Research by the European Heating Industry Association indicates that in the Czech Republic, the number of qualified heat pump installers fell by three percent across 2020–2021; in Spain and Poland, there were no increases in workforce across 2020–2021; and in Germany and Italy, the number of installers grew by only one percent and 0.9 percent respectively. The distribution of qualifications for heat pump installation within the existing HVAC workforce also vary across countries: in Italy, for example, 30 percent of

heating installers are qualified to install heat pumps; in France, 25 percent; in the Czech Republic, 20 percent; and in Poland, only 10 percent (European Heating Industry, 2022).

The structure of training and accreditation systems vary across member states. Research by the European Heating Industry Association suggests a diversity of approaches (European Heating Industry, 2022):

- In *France*, nearly 15 different training schemes are in operation, provided by over 350 institutions and training centres. Several certification schemes are in practice, including one provided by the renewables certification association Qualit'ENR, which delivers training in heat pumps and other areas.
- In *Spain*, training courses are normally organised by national or regional installers' associations; manufacturers; and heat pump vendors, rather than by national authorities. A variety of vocational training and certification bodies exist.
- In the *Czech Republic*, there is no specific curriculum for installers of heating systems. A heat pump installer must follow a training course organised by the Union of Cooling and Air-Conditioning Technology. Service engineers, who can install heat pumps and also maintain, service and commission them, must undertake a longer training to obtain F-Gas accreditation. This can take five years of practice to complete.

While the EU market outlook for solar PV is considerably rosier than the outlook for heat pumps, achieving the encouraging forecasts is contingent on the development of an adequately skilled workforce. The IEA notes that "the shortage of skilled workers has slowed the installation pace for distributed PV systems", and that expanded training programmes are necessary to improve installation capacity (IEA, 2022a). SolarPower Europe recognises that shortages of skilled labour "risk becoming a real bottleneck to the deployment of solar PV", and notes that in some countries—such as Austria and the Czech Republic—a lack of workforce is the single greatest factor inhibiting more rapid rollout of solar PV capacity (Schmela, 2022). Reports are already emerging from a number of countries highlighting the constraints being imposed by a lack of ready workforce. In some parts of Europe, the wait time for residential and commercial PV installations is reported to now last several years (Scully, 2023a). By the end of 2023, around 40 GW of solar panels will be held in European warehouses—not far off a year's installations (Gordon, 2023). The panels' installation is delayed by a combination of labour shortages, critical material delays and long interconnection queues. In total, these panels could displace seven billion cubic metres of fossil gas per year.

Severe shortages of workers are reported in markets such as Spain, Germany, and Italy (Scully, 2023c). In Spain, so many installation requests have been put in that companies are now turning contracts down (Scully, 2023d). Industry leaders have suggested that the EU faces "an unprecedented skills shortage" in solar PV (Scully, 2023b). This is in part because companies seeking solar installers are competing against energy, automotive, and other industries for workers, making recruitment harder (Ford, 2023). Because the job areas in question are also often relatively new, policymakers

also face shortages of data. The European Solar Alliance notes that with regard to solar PV manufacturing, there is a lack of knowledge of the current state of the workforce and the skills needed, which makes it harder to prepare plans (ESIA, 2023a). This is aggravated by unstandardised job profiles and curricula across the EU; varying forms of accreditation and certification; and inadequate opportunities for upskilling and training, with insufficient funding available.

Several EU-level initiatives are expected to support workforce development, across solar and other green transition skill areas. Under the REPowerEU plan, the European Commission is attempting to support member states in convening solar industry stakeholders to support reskilling and training initiatives (European Commission, 2022f). The *EU Net Zero Industry Act*, published in March 2023, set out several measures for the expansion of the green-skilled workforce (European Commission, 2023b). This includes the simplification of equivalence and mutual certification recognition schemes and accreditation processes across the EU (Art. 24), and the creation of a Net Zero Europe Platform (Art. 25), which would guide the process of revising job profiles. It also includes the creation of a new network of Net-Zero Industry Academies (Art. 23), which would each aim to train 100,000 learners within three years of being established, working with the private sector and training organisations to provide portable accreditations. The curricula used, and qualifications delivered, by the Academies are expected to be updated every two years to meet member state needs. In September 2023, the Renewable Energy Skills Partnership (a coalition of sector actors) proposed that these should target known skill shortages following a comprehensive EU-wide skill mapping, including in the solar sector (SolarPower Europe, 2023d). The European Solar Alliance similarly suggests the development of an EU-wide skills roadmap incorporating curricula, certification schemes, and accreditation recognition processes; the creation of an EU-level Solar Academy; and new and enhanced pan-EU initiatives, including through the Pact for Skills (ESIA, 2023b).

The Pact for Skills, a pan-EU initiative supporting upskilling and reskilling for the green and digital transitions, is intended to advance skills development through public-private partnerships (European Commission, 2023f). In 2022, the Pact for Skills assisted around two million people in accessing skill-enhancing activities, across 15,500 training programmes (European Commission, 2023e); over 1,000 stakeholders have collectively pledged to upskill and reskill six million people (European Commission, 2023b). In March 2023, a new Large-Scale Partnership for onshore renewable energy was launched (European Commission, 2023d); it is expected to include training in areas including solar PV and heat pump installation. A smaller skill partnership for heat pump installation has also been announced (Santos, 2023). Under the European Green Deal, furthermore, sits the €19.2 billion Just Transition Fund, running from 2021–2027.[24] This is intended to support economic diversification in regions affected by the Green Transition; training and reskilling; job-seeking for those whose jobs are displaced; and active labour market policies. The InvestEU Just Transition Scheme is also expected to mobilise a further €10–15 billion in predominantly

24 It is hoped that the Fund will additionally mobilise a further €25.4 billion (European Commission, 2019).

private sector investments, some of which will be used for social investment and skill development (OECD, 2023a).

Migration

The role of migration for the green transition has been increasingly recognised, by both the European Commission and by some member states. Migration is a shared competence within the EU (European Parliament, 2019). This means that the EU may set the conditions for entrance into and legal residence within a member state, while the member states may cap the number of people allowed to enter to seek work.

In April 2022, the European Commission published its statement *Attracting Skills and Talent to the EU*, arguing that migration is "an investment in the economy and the society as a whole, supporting the EU's green and digital transition, while contributing to making European societies more cohesive and resilient." It suggested that "legal migration has to accompany the EU's [green] transition", and that the transition would "require additional labour and new skills" (European Commission, 2022b).

Several concrete migration proposals were made in the *2023 Green Deal Industrial Plan* (European Commission, 2023a). The Plan recognised that skilled workers would need to be attracted from outside the EU, and announced plans to support the recognition of third-country qualifications; support relevant labour mobility policies; and help to match skills to employers' needs. Qualification recognition would be facilitated under the EU's Skills Agenda, possibly allowing expedited authentication. The Commission will also seek to combine a 'skills-first' approach with a qualifications-based approach, where recognition is more challenging. Finally, it tied the issue of green skills to the idea of a Talent Pool, previously announced by the Commission in the 2020 New Pact on Migration and Asylum (European Commission, 2020b).

BOX 6. The new EU Talent Pool

The new EU Talent Pool was announced in November 2023, following the Commission's recognition that "the transition towards a more sustainable and green economy necessitates expertise and skills that may not be readily available in the EU" (European Commission, 2023l: 145), and that "skill shortages pose a significant challenge to the Union's aspirations… the demand for skilled workers cannot be met by the Union's workforce alone" (European Commission 2023k: 1–2).

In the Talent Pool's 2023 consultation, many responses demonstrated considerable eagerness in some quarters for increased access to international workers for the green transition (European Commission, 2023l). Two submissions by regions in northern Sweden, for example, emphasise that the development of green infrastructure (such as new battery plants) will require municipalities with tight labour markets to expand their workforce "at unprecedented speed", and that without access to migration the more than 100,000 people needed will not be obtainable (Region Västerbotten, 2023; Region Jämtland Härjedalen, 2023).

The Talent Pool is expected to be managed through a system of national contact points appointed by member states (European Commission, 2023k). These contact points will assist employers in sharing on an online portal positions on a new list of EU-wide shortage occupations (Dempster and Knoll, 2023). Among the occupations named on the shortage list for the Talent Pool are electrical engineers; electrical engineers professionals; roofers; air conditioning and refrigeration mechanics; mechanical engineering technicians; and plumbers and pipe fitters—all of which are urgently required for the EU's green transition (European Commission, 2023j).

The Commission (2023k) recommends that the Talent Pool follow a 'skills first' approach, allowing the identification and full use of skills which may not have been acquired in formal settings, rather than limiting mobility access to those holding formal qualifications. It notes, however, that EU-based employers and recruiters often struggle to recruit internationally, due to a lack of knowledge of third-country qualifications; administrative hurdles and lengthy processing times; and translation requirements. Verifying skills and qualifications held by candidates can also be challenging (European Commission, 2023m). The Commission therefore recommends (2023k) that a 'whole-of-government' approach to attracting talent, allowing skills and qualifications to be more easily recognised and thereby increase member states' attractiveness to international workers. This could include cooperating with third countries to offer migrant workers pre-arrival access to recognition procedures, and developing with partner countries the capacity to efficiently verify qualifications. It is also expected to be integrated into existing approaches to Talent Partnerships and complementary pathways (European Commission, 2023m).

While promising, the new Talent Pool faces several constraints (Dempster and Knoll, 2023). Firstly, EU member states may not choose to use it. Despite early suggestions that the instrument could be mandatory (European Commission, 2023i), its use is entirely voluntary. Secondly, employers may choose not to use it. Despite frequent lobbying by employers for greater access to international labour pools (e.g., Kyllmann, 2022), it is frequently hard to obtain employer buy-in for migration programmes. Thirdly, candidates may not choose to use it. The EU is relatively attractive in principle to migrants, but despite this is relatively ineffective in converting attractiveness to actual immigration (European Commission, 2023l). As the Commission notes, migrant workers face multiple hurdles in immigrating; it is quite possible that the Talent Pool—assuming that knowledge of its existence does filter to migrants—will make little difference (Dempster and Knoll, 2023).

The 2022 statement *Attracting Skills and Talent to the EU* had previously suggested that Talent Partnerships should "in particular take into account the green and digital transition" (European Commission, 2022b: 3.1). Talent Partnerships are intended to be bespoke programmes addressing the labour market and skill needs of both member states and partner countries. They aim to achieve a triple win, benefiting migrants, communities of origin, and host communities, while also avoiding brain drain. They are not skill-limited, and can be temporary, long-term, or circular. To optimise their effects, they should be targeted towards skill areas needed in both partner countries (Dempster and

Clemens, 2022). In practice, the Talent Partnership framework is operationalised largely through the Migration Partnerships Facility, an initiative managed by the ICMPD. So far, the projects funded have been pilots, and await further scaling (Stefanescu, 2020).

Given that there is a global shortage of green skills (IRENA and ILO, 2023), Talent Partnerships based on the Global Skill Partnership model—combining migration and training—are most likely to meet the goals set out in the European Commission's 2022 document (Huckstep and Kenny, 2023; European Commission, 2022b). This is, in fact, also the model endorsed by the European Commission in its 2020 *Communication on a New Pact on Migration and Asylum* (European Commission, 2020b). These programmes take time to be implemented, and pilot programmes have previously sometimes found that the skills in demand when training is commissioned are no longer needed several years later. Given the relative certainty of the green transition's skill needs, however, the model may suit the EU's needs unusually well in this context (Di Salvio, 2022). Organising mutually beneficial partnerships may require better labour market data, especially in partner countries (Fakhry, 2022).

Beyond bespoke arrangements, the most important pan-EU migration instrument is the Blue Card. This is an EU-wide work permit, used in 25 of the EU's 27 countries (European Commission, 2023h), allowing highly skilled third-country nationals to work in the EU for up to four years (European Commission, 2021d). Eligibility for a Blue Card requires that a migrant has a work contract with an EU-based employer. It also requires that the migrant's gross salary is at least one and a half times the average national salary, except where a lower salary threshold of 80 percent (set for recent graduates and according to member state skill shortages) applies (European Commission, 2021d). The salary threshold required by the Blue Card is currently often likely to be too high to allow many workers with skills relevant to the green transition to come to the EU. In Germany, for example, a Blue Card holder must be paid at least €58,400 (US$63,000), and €45,552 (US$49,000) if working in a lower threshold field (Government of Germany, n.d.); in the Netherlands, eligibility requires a monthly salary of at least €5,867 (US$6,300) (Ministry of Justice of the Netherlands, 2023). These thresholds are likely to be significantly higher than many offered by vocationally skilled jobs necessary to the green transition.

Several countries are also experimenting with green-focused migration pathways. Germany, as noted, is explicitly seeking to recruit international workers, including through its partnership with India. Denmark has also entered negotiations with India over a labour mobility partnership in the context of the green transition, alongside discussions over an existing strategic green energy partnership (Udlændinge- og Integrationsministeriet, 2023). Spain, under the Migration Partnerships Facility, has undertaken a pilot circular mobility project with Morocco, providing young entrepreneurs in green sectors with access to training and employment in Spain before return. The project, named MOVE_GREEN, runs from 2021–24, with a budget of over €2.2 million (US$2.36 million) (MPF, n.d.).

Countries of origin

This section provides a top-level overview of the demand for, and supply of, green-skilled workers in five key countries of origin: India, Vietnam, South Africa, Fiji, and Colombia.

While a shortage of workers poses a challenge to urgent mitigation measures necessary in the Global North, skill gaps in Global South countries of origin also threaten adaptation measures. Across all five countries studied, and especially in the case of India, adaptation to warming temperatures will necessitate enormously increased access to cooling devices. These tend to be stand-alone air-conditioning units (given they are cheaper and more readily available). These, and other, devices are already straining electricity grids, and will place still more strain on them in coming years; with these increases, more sustainable forms of power will need to be scaled up (Colelli et al., 2023). One of these forms is solar. All five focus countries have sunny climates which could support a large expansion in solar power capacity, something which is becoming more readily available as the cost of inputs decrease (IEA, 2024; see Figures 5 and 6). However, all are reliant on Chinese imports, and a lack of domestic manufacturing may constrain growth.

Within several countries studied (notably Vietnam and South Africa), there is an indication that a lack of a skilled workforce is another constraint to the expansion of sustainable cooling devices and solar energy supply. This lack of skills results in (1) lower performance of the technologies; (2) safety issues; and (3) grid-connection issues (APEC, 2015a). Utility-scale solar tends to employ fewer people at the higher end of the skill spectrum, often bringing workers in from overseas. By contrast, rooftop solar relies on a vast network of low- and mid-skilled trainees who are skilled in both installation and maintenance. This is especially important in rural and informal areas, where grid penetration is poor. Similarly, RAC engineers are needed to service domestic and commercial buildings across the country. In both professions, installation appears to be prioritised with maintenance an afterthought, leading to the decline of technologies.

Most countries haven't yet fully thought through the skilling and reskilling needed to meet this growing energy demand. A vast array of training—private, public, and industry-led—is provided, at vastly different costs, timelines, and relying on different curricula. The lack of focus on maintenance as well as the presence of a large informal supply of workers means the lack of *formal* skills harmonisation may not (as yet) be a binding constraint to the expansion of such technologies. Yet the trajectory of these technologies suggests that it will be an increasingly pressing issue in the mid-term, when scarce finance can go further thanks to falling technology costs. More efforts to survey the skills needed and standardise training (as India and Vietnam have done) are needed.

Doing so would allow governments to support the training of workers needed for domestic goals, while also supporting these countries in expanding skilled migration to countries of destination. Facilitated emigration could harness remittances and other diaspora investments, ideally in return for investments in training provided by countries of destination. Notably, access to international

migration through specific training pathways could incentivise a greater number of young people to seek to enter eligible professions, driving an increase in the number of qualified people (Abarcar and Theoharides, 2021).

All five countries already have large diaspora populations, which have grown in the last ten years. India and Vietnam see the value of this emigration and are taking steps to expand it, while South Africa, Fiji, and Colombia do not have an official view on such mobility. Given the vast green skill needs in countries of destination, green-skilled trainees *will* move in the coming decades. Policies to harness such movement, ensuring that it benefits countries of origin as well as countries of destination, are therefore a necessity. It is likely that countries in the Global North will reform visa options to expand routes in the coming years; migrant-sending countries in the Global South should expect this when making their own skill plans, and should leverage their ability to provide workers for development goals.

India

India targets net zero emissions by 2070, and 50 percent of electricity generation from renewable energy sources by 2030 (Birol and Kant, 2022). It has not, however, committed to any deadlines for phasing out its use of coal or other fossil fuels (Singh, 2023). India is the third-largest emitter of fossil fuels globally; its emissions are expected to rise with increased energy demand due to a rapidly growing population and continued economic development (Gupta et al., 2022).

India is rapidly expanding both its utility-scale and rooftop solar, but is hindered by grid challenges and the cost of imported solar PV panels. This is important given rising energy demand, including due to a rising demand for cooling in response to rising heat. This has led the government to develop plans to create a sustainable cooling industry. Meeting renewable energy targets could create somewhere from 24 to 35 million new jobs by 2050 (Gupta et al., 2022; PAGE, 2023). The government has created a Skill Council for Green Jobs (SCGJ) to ensure its vocational system is ready to meet this demand and training programmes such as *Suryamitra*. They are also seeking to export those skills abroad, signing agreements with the UAE and Germany to harmonise green skills and expand employment opportunities.

Demand

India could become one of the first places in the world to experience heat waves that break the human survivability limit (World Bank, 2022a). Yet 9 in every 10 households don't have an air-conditioning unit (Parkin, 2021), largely because they are expensive (the average cost is US$260–500) (World Bank, 2022a). Despite this limitation, there is increasing demand for units, both among an increasingly affluent middle class and from industry (particularly among pharmaceuticals, chemical, food, and beverage, in India's southern region) (6Wresearch, 2023). By 2037, India's demand for cooling is estimated to be eight times more than now, with a new air-conditioner purchased every

15 seconds (The Economic Times, 2023b). The IEA estimates that India will account for a third of all sales of air-conditioners in the coming decades (IEA, 2018), rising from an inventory of 48 million in 2020 to 1.1 billion in 2050 (Sherman et al., 2022).

Recognising the potential impact of this growth, in 2019, the Government adopted the India Cooling Action Plan (ICAP). It is one of the first ever comprehensive country-wide cooling plans, aiming to create a sustainable cooling industry over the next 20 years. One element is around skilling, particularly around the servicing of air-conditioning units. Servicing will see a 10-fold increase in jobs over the next two decades (0.2 million in 2017 to 2 million in 2027) (Bhasin et al., 2020). In 2018, set aside US$5.25 million to train 100,000 RAC technicians under the Pradhan Mantri Kaushal Vikas Yojna (PMKVY), to be implemented by the Electronic Sector Skill Council of India and Ozone Cell, MOEFCCC (World Bank, 2022a). Skilling is also recognised to be important by private sector players: Daikin Industries aims to make India the biggest manufacturing hub for air-conditioning units (FT, 2023).

Turning to solar power, India aims to have 500 GW of renewable energy installed capacity by 2030, including the installation of 280 GW of solar power (Hussain, 2023). New solar farms have been added, mostly in Rajasthan and Gujarat, and most being PPP's run with utility companies (WRI, 2017). Indeed, Ernst & Young has named them the world's most attractive solar market (Santos, 2022). Yet by the end of 2022, only 63 GW had been installed, far short of the 100 GW target (which aimed for 40 GW in rooftop and 60 GW in utility-scale solar) (The Economist, 2023). Despite a federal rooftop solar subsidy plan (Ministry of New and Renewable Energy, n.d.), rooftop installation in particular is lagging.

This is largely due to the high cost of solar panels. In 2021–2022, India imported US$3 billion of solar panels, 92 percent from China. In a bid to boost domestic manufacturing, India imposed import duties of 40 percent on all modules and 25 percent on all cells (IRENA and ILO, 2022), which raised the cost. They are currently in talks to reduce the tax to 20 percent, due to a (among other things), a "lack of skilled tradespeople to install and operate the high-tech machinery, especially for cells and other upstream components" (Singh, 2023; Waterworth, 2023).

Through an increase in domestic manufacturing and stimulating demand, the Government (through the Jawaharlal Nehru Solar Mission (JNNSM)), aims to make India a global leader in solar technology. In 2023 there were approximately 201,400 jobs in grid-connected solar PV (up 47 percent from 2021) with 80,000 in off-grid solar (IRENA and ILO, 2023). Onshoring solar panel production alone is anticipated to create 30,000 direct jobs, and 120,000 indirect jobs (IRENA and ILO, 2022). In 2017, the World Resources Institute estimated that meeting solar power targets would require ~300,000 jobs in construction, project commissioning and design, business development, and operations and maintenance. The SCGJ expects much higher employment in the solar sector, with up to 3.26 million jobs by 2050 (Reddy et al., 2023). It has been suggested that focusing on decentralised rural energy (such as rooftop solar, mini-grids, and floating solar) would have the potential to create even more jobs, given its labour-intensive nature (Tyagi et al., 2022a).

Supply

By 2030, it is expected that a third of the world's working age population (aged 15 to 59) will be from India (British Council, 2016). It also currently has around 21 million people working in high-emitting sectors who will need support in retraining (Aklin, 2023). This presents a major skilling challenge, at a massive scale (Modak et al., 2023). India aims to become the "human capital" centre of the world (CSE, 2016), the Government has developed a strong focus on skilling; in 2015 they launched the National Skills Development Mission (aiming to provide training in market-relevant skills to youth) and established a number of sector skill councils (including on green jobs: see Box 7). Much of this training is to be delivered through over ~12,000 public and private industrial training institutes (ITIs), which deliver the National Skills Qualification Framework (NSQF) and are certified by the National Council for Vocational Training (NCVT) (PRS, n.d.). There are also a number of international donors who deliver training programmes in India, such as GIZ's HPMP project (described above).

The ICAP outlines the extremely varied training landscape for RAC engineers. Most formal trainees are aiming to obtain a two-year NSQF Level 4 certification in 'Refrigeration and Air Conditioning' (Jha, 2023). The cost of the programme varies depending on whether the ITI is public (Rs2,000–20,000; US$24–240) or private (Rs5,000–50,000; US$60–600) (MSDE, 2022). Upon graduating, RAC engineers can earn between Rs10,000 and 18,000 per month (US$120–216) (ibid.). Existing engineers can undertake top-up training; for example, the Indian Society for Heating, Refrigerating, and Air Conditioning Engineers (ISHRAE) provides a four-month course (three months of theory and one month of training) at a cost of Rs65,000 (US$782) (ISHRAE, n.d.).[25] Private sector players also deliver on the job training; for example, Daikin has a 'Centre of Excellence' which does skill upgrading (The Hindu Business Line, 2017). However, Sridhar and Chaturvedi (2017) argue that of the 200,000 RAC technicians in India,[26] only 36 percent have training (mostly through ITIs), and most work in the informal sector. This is because very few people prioritise official servicing of their units, instead relying on informal technicians, 90 percent of whom earned less than Rs600 (US$7) per air-conditioner serviced in 2017 (Sridhar and Chaturvedi, 2017). Some actors, such as the World Bank, have therefore argued for a minimal threshold for training, certifications for technicians, and an overall formalisation of the sector (World Bank, 2022a).

Solar PV technicians largely aim to complete a one-year NSFQ Level 4 certification in 'Solar Technician (Electrical)' (MSDE, 2018), delivered by ITIs throughout the country. Top-up training for engineering students is also available; for example, the solar training company kWatt Solutions runs two- and five-day courses at their skilling centres in five Indian states. The Government has also invested in a shorter and cheaper training programme—the *Suryamitra Skill Development Programme* (SSDP)—which has trained approximately 80,000 people to install solar panels, connect them to grids, and maintain batteries (see Box 7). Some companies have their own training arms, while

25 ISHRAE is one of the two prominent industry associations. The other, the Refrigeration and Air-Conditioning Service Sector Society (RASSS), has 500 members.

26 An informal number. There is no official census of the sector.

others have called for more standardised training programmes (Financial Express, 2023).[27] However, similar issues to those faced in the RAC industry apply to solar. Utility-scale solar plants require a vast number of formally trained staff who are often hired on a permanent basis. Yet most employees in large- and small-scale grid and off-grid projects are unskilled, and there is little investment in on-the-job training (Jairaj et al., 2017). Few people and companies see the value in maintaining their solar panels, leading to a reliance on cheaper and informal technicians (Nagaraj, 2022).

Unlike many other countries (such as Vietnam or South Africa), there are fewer fears concerning the effects of the green transition upon job displacement in India. State-owned companies operating in the energy sector do not have a culture of mass layoffs; instead, state jobs are considered safe until retirement. If this continues, workers in the energy sector are likely to be retrained and reallocated through intra-organisational transfers (Modak et al., 2023).

BOX 7. India's Skill Council for Green Jobs (SCGJ) and the Suryamitra Skill Development Programme

Set up in 2015, the Skill Council for Green Jobs (SCGJ) is a not-for-profit, autonomous, and industry-led organisation. Their role is to undertake skill gap analysis; develop national occupational standards; and train and certify skilled manpower. In FY22, they trained 100,000 people within the renewable energy sector; they want to train 1 million people by 2030 through a network of 20 centres of excellence, 750 affiliated centres, and 7,500 trainers nationwide (SCGJ, 2022).

Their flagship is the *Suryamitra Skill Development Programme*. Its objective is to train high-school leavers and vocational diploma holders as field technicians to operate and manage solar energy projects. Since 2016, it has provided 90 days of free training to 78,000 people, allowing them to obtain a NSQF Level 4 certification (Nagaraj, 2022), and some 500,000 in total (Modak et al., 2023). A 2020 external evaluation by Finnovation surveyed 1,004 trainees and 505 trainers in 11 states, finding positive outcomes: trainees reported improved knowledge (95.7 percent), increased job opportunities (88.5 percent), and increased incomes (80.5 percent) (SCGJ, 2020).

Yet more recent data paints a mixed picture. In 2022, government data found that less than a third of trainees have found a role in the solar industry, and that the placement rate is going down over time (Tyagi et al., 2022b). Many constraints were offered, including the impact of COVID-19 on the industry; the lack of rooftop solar; poor demand for qualified engineers; and a mismatch between the location of qualified engineers (Maharashtra, Uttar Pradesh, Madhya Pradesh) and areas of high solar capacity (Karnataka, Rajasthan, Tamil Nadu) (ibid.). The programme has also been criticised for not adequately focusing on training women and those in rural areas (Nagaraj, 2022). Going forward, it appears that centres will no longer be offering free training and they will be aiming to better match trainees with roles, diversifying training for different needs, including placement abroad, reflecting the presence of a surplus of trained workers (ibid.).

27 See, for example, the Selco Foundation (https://selcofoundation.org/training/).

Migration

India is the world's largest origin country for international migrants; in 2020, there were 18 million Indians living abroad (The Economic Times, 2023a). Slightly more than half live in the Gulf Cooperation Council (GCC) countries, with 3.5 million in the UAE alone. These tend to be semi- and lower-skilled workers from the northern states of Uttar Pradesh and Bihar. Higher-skilled workers, often from the southern states of Tamil Nadu and Kerala, tend to go to countries such as the US, Australia, Canada, and the UK (Singh, 2022). These workers send vast amounts of money home—US$89 billion in 2021, or 15 percent of all global transfers to low- and middle-income countries (The Federal, 2023). Yet high rates of emigration have led to fears of 'brain drain'; for example, 75 percent of Indian students studying abroad don't want to come back (Shah, 2023). India is therefore attempting to walk a middle line: promoting economic migration as a way for diaspora to gain experience and send remittances, while also encouraging skilled diaspora to return home.

One way India is promoting economic migration is through actively partnering with destination countries. The government is currently drawing up a plan to train and supply skilled Indian workers to 30 countries in need of labour, such as the US, UK, Canada, Australia, Germany, Japan, Sweden, and Finland (Sharma, 2023). This process is managed by the National Skill Development Corporation International (NSDCI), with the support of the Ministry of Skill Development and Entrepreneurship (MSDE).[28] New Skill India International Centres (SIICs) aim to be a one-stop shop, providing up-skilling, visa support, and language training. One such SIIC, in Varanasi, has already deployed 278 people abroad in roles such as HVAC Technician, Technical Electrician, Plumber, and Retail Sales Associate (Sharma, 2023). Destination countries are also directly approaching India. The UAE has a skill harmonisation programme with India, creating a network of Trade Test Centers to deliver assessments in benchmarked qualifications (Suri, 2020). India has signed a Mutual Recognition of Qualifications (MRQ) agreement for higher education graduates with the UK (Department for Business and Trade, 2022). Similarly, India has agreed a Mechanism for the Mutual Recognition of Qualifications with Australia, signed earlier in 2023 (Press Information Bureau, 2023). Finally, the SCGJ signed an agreement with Germany's solar industry association BSW-Solar at the start of 2023 to bring around 2,000 rooftop solar installers trained through the *Suryamitra* programme to Germany, starting in 2024 (Kyallmann, 2023).[29]

Vietnam

Vietnam targets net zero carbon-equivalent emissions by 2050 and 43.5 percent emissions reductions by 2030 (Agarwal et al., 2022), with goal power generation to be phased out during the 2040s (Chua et al., 2023). While these goals are laudable, Vietnam's high reliance on coal, and its difficulties in attracting foreign finance, make them difficult to achieve (Wengel et al., 2023).

28 For more information, see https://nsdcinternational.com/about-us/partners/.
29 Key informant interviews.

Vietnam is one of the largest markets for cooling in Southeast Asia. Solar PV capacity is increasingly recognised to be necessary if this increasing demand is met in a sustainable way. Support from government and external partners has seen the amount of (particularly rooftop) solar explode in the last decade, yet this expansion overloaded the grid and led to a boom-and-bust cycle of employment. Most RAC and solar trainees passing through the Hanoi University of Science and Technology (HUST), yet the overall landscape for vocational skills is poor. Efforts to address this are underway, especially by regional bodies such as APEC and ASEAN, and private companies such as Daikin. They are, with India, the only case study country to actively facilitate skilled labour migration, although it remains to be seen whether green skills will feature in their international agreements.

Demand

Between 2000 and 2010, the total energy demand in Vietnam doubled (Scoccimarro et al., 2023). High rates of urbanisation, a growing number of middle-class households, and warming temperatures have led to an increasing demand for cooling devices. In 2016, 1.98 million AC units were sold and only 17 percent of households had one (Tomiyama and Ito, 2018). Yet GIZ estimates that the total stock of unitary AC units could grow to about 100 million units by 2050, with the growth rate peaking in 2030 (GIZ, 2019). Vietnam is expected to grow its air conditioning load more than its regional peers, and has been suggested to be the second largest market in Southeast Asia (Minh, 2018). This growth is taking its toll. In May 2023, the government cut public lighting to avoid crashing the electricity grid, under pressure from high AC use during a heatwave (Nguyen, 2023).

It is also having an impact on greenhouse gas emissions: the RAC sector was responsible for 9 percent of Vietnam's total emissions in 2016, with emissions due to increase by 7.1 percent every year until 2030 (GIZ, 2019). In November 2020, the Southeast Asia Energy Transition Partnership (ETP) was launched, aiming to accelerate the transition to modern energy systems in Indonesia, the Philippines, and Vietnam (ETP, 2022). As part of this process, Vietnam pledged that by 2030, 75 percent of city households and 55 percent of rural households would be using high efficiency AC, which is 30 percent more expensive than normal AC but reduces energy consumption by 30 percent. The National Green Cooling Programme (NGCP), launched in February 2023 under the ETP, aims to provide an in-depth study to the government, assessing the role of cooling in reducing greenhouse gas emissions (VIR, 2023a). One focus area is cities. The 'Sustainable Urban Cooling in Viet Nam Cities' project, a United Nations Environment Programme (UNEP) and Cool Coalition initiative, is supporting Can Tho and Tam Ky to prepare Urban Cooling Action Plans (UCAPs) which aim to provide a sustainable way forward (Cool Coalition, n.d.).

To support this demand, the government has prepared the National Power Development Plan 2021–2030 which aims (among other things) to increase the ratio of renewable energy to 30 percent. There is a strong focus on solar. In 2010, Vietnam was ranked 196th in the world for solar capacity; by 2021, it was 9th (Rapid Transition Alliance, 2023). A good policy environment, external investment (including, more recently, a Just Energy Transition Partnership (JETP)—see Box 10), and a financing

model which supported utility-scale and rooftop solar all stimulated demand. They are now leading ASEAN in solar power development with an estimated 17.6 GW in 2021 (up from only 105 MW in 2018: ITA, 2022b; IRENA and ILO, 2022). Initially, the focus was on rooftop solar: the Rooftop Solar PV Promotion Program aimed to install 100,000 systems by 2025 (Ministry of Industry and Trade, 2019); they reached that figure in 2020 (Rapid Transition Alliance, 2023). Yet this boom overloaded the electricity grid, leading to a new emphasis on off-grid rooftop deployment (Le, 2022; IRENA and ILO, 2022).

The government's National Green Growth Strategy 2021–30 identified the creation of green jobs as a priority.[30] Currently it is only assessed at a small share of employment (3.6 percent, or 1.7 million jobs) and mainly includes people with higher levels of education.[31] However, the share of job postings requiring green skills jumped 22 percent from 2022 to 2023 (VIR, 2023b). There is little data on what the expansion of AC systems will mean for the pipeline of RAC engineer talent. More data is available for the growth of the solar PV industry. Between 2015 and 2030, the COBENEFITS study estimated that solar PV installation and maintenance could create 3.51 jobs per MW, compared with only 1.4 jobs in coal (IASS et al., 2020). 80 percent of the roles would be in construction and installation, with approximately half falling into the semi-skilled sub-group. This growth is closely linked to the policies outlined in the previous paragraph. The solar PV workforce rose to 126,300 jobs in 2020, largely as a result of the rooftop solar boom. In 2021, a reduction in installations "likely led to a sizeable reduction in the workforce", down to 31,700 jobs, 23,000 of which were in operations and maintenance (IRENA and ILO, 2022: 48). The government appears to have become more cautious as a result, and now only aims to add 4 GW by 2030 (IRENA and ILO, 2023).

Supply

Yet there are concerns as to whether people have the skills to take up these new roles, which align with broader concerns about the lack of skills in Vietnam (The Sun Daily, 2023). There are also fears that the phasing down of Vietnam's large coal-related sectors—comprising nearly two dozen operational mines and around 25 coal power stations—may result in large layoffs of coal workers who cannot be easily deployed in other or new sectors (Wengel et al., 2023). In 2017, the coal mining sector employed over 86,000 workers (ILO, 2022). Coal sector jobs are also feared—as in other countries—not to be located in the same areas as populations whose jobs may be displaced (Do and Burke, 2023).

There are also doubts as to whether Vietnam's training system is currently capable of supplying the workers needed: the COBENEFITS study identifies that vocational training schools are not equipping trainees with the skills required by growing green sectors. Instead, people are turning to top-up

30 Vietnam defines 'green jobs' as decent work that reduces the consumption of energy or raw materials; reduces carbon emissions; minimises waste; protects resources; and—unusually—supports adaptation (ASEAN and ILO, 2021).

31 The Green Jobs Survey, which was carried out between February and March 2023, aimed to assess the profiling of tasks performed in green jobs.

training, often delivered through donor-funded pilot projects.[32] In the absence of the qualified workers needed, companies are relying on engineers not trained in renewables, or upon foreign experts. That being said, the private sector companies COBENEFITS surveyed indicated that they were willing to hire local workers if training was aligned with private sector demand (IASS et al., 2019b). Recognising this, the government is partnering with GIZ to develop green vocational training facilities, including the Irrigation Mechanic College.

Most trainees currently seek qualifications at HUST. The University offers two undergraduate degrees—in Mechanical and Mechatronics Engineering—where students are able to take classes offered by the Department of Refrigeration and Air Conditioning. OWC Group, renewable energy consultants, has an MoU with HUST to offer opportunities to students to work in the industry (APEC, 2015a). Similarly, their Renewable Energy Research Centre offers a Bachelor of Electrical Engineering and Renewable Energy, a three-year degree for a cost of VND$50m (US$2,100) for Vietnamese students. The Electricity Power University and Ho Chi Minh City University of Technology (HCMUT) also offer degree programs in electrical and environmental engineering respectively. The latter allows trainees to transfer to partner universities in Australia for the latter two years of their degree. It is unclear whether these institutions have adopted the recommendations issued by the human development group of APEC (Nash, 2023). They have issued a training needs analysis for solar, proposing minimum standards for a solar panel designer (four-year bachelors degree) and installer (two-year degree or trade certificate) (APEC, 2015b). Some private sector companies, such as Daikin Industries, also run their own training schools (see Box 8).

BOX 8. Daikin Industries

Founded in 1924 in Japan, Daikin Industries manufactures and sells air-conditioning equipment, refrigerants, and fluorochemicals. They are now the world's largest air-conditioning company (Stevenson and Furukawa, 2022); their products are manufactured in over 100 bases and sold in over 170 countries. Emerging markets in Asia, such as India and Vietnam, are key targets for expansion. For example, in 2016, Daikin invested 10 billion yen (US$68 million) to build a factory on the outskirts of Hanoi, Vietnam, which can produce 1 million units annually and employs 1,500 staff (Daikin Global, 2018).

They also have a strong focus on skills, preparing trainees for roles in local factories and in Japan, offering a range of courses in both sales and servicing (both in person and online). The Hanoi factory has an attached training centre; another is planned as part of their local headquarters in Ho Chi Minh City (Tomiyama and Ito, 2018). They are also cooperating with local vocational colleges to provide "Daikin standard" training courses in air-conditioning installation and maintenance.

32 For example, GIZ and BMZ have supported training on the 'Mechanics for Sanitary, Heating, and Climate Technology' as part of their 'Programme Reform of TVET in Viet Nam'; the Ninh Thuan Vocational College (NTVC) to deliver two courses on basic installation of solar systems under their 'Development Partnership (DPP) Vocational Training Center for Renewable Energies—Wind and Solar Technology'; and the Lilama 2 International Technology Vocational College.

Migration

Vietnam aims to become a high-income country by 2045, in part through exporting labour (FCDO, 2022). In the early 1990s, Vietnam started to promote Asia and the Middle East as destination countries, with an initial focus on Japan, South Korea, Saudi Arabia, Kuwait, and Lebanon (Miller, 2015). Today, on average, the government aims to send 90,000 people overseas every year, with 142,000 leaving in 2022 (Vietnam Plus, 2023). In the first six months of 2023, 72,000 workers were sent, mostly to Japan, Taiwan (China), the Republic of Korea, and China (Alffram et al., 2023). Their 2022 Law on Vietnamese Guest Workers creates the legal environment for these transactions, detailing minimum labour standards, and providing workers with support for training and travel expenses (Vietnam Law & Legal Forum, 2022; Loi, 2023). Yet the visas of many workers are tied to their employers, and there are concerns about worker protections (Alffram et al., 2023).

The Ministry of Labor, Invalids, and Social Affairs (MOLISA) is responsible for developing bilateral agreements to expand overseas markets while enforcing labour standards. They have signed an MoU with South Korea under their Electronic Permit System, allowing temporary labour migration for low-skilled workers (CGD, 2021). Vietnam has also signed cooperation agreements with Australia, Japan, and Germany. In particular, the government would like to expand the range of trainee occupations abroad and enhance their migration profile in Europe (VOV, 2023). Similarly, New Zealand has opened a special work visa for Vietnamese chefs and engineers (New Zealand Immigration, n.d.).

Many destination countries are also actively involved in improving the TVET system in Vietnam. The UK implements International Skill Partnerships through the British Council (British Council, n.d.), and Germany provides training directly (GIZ, n.d.), trains trainers (GIZ, 2023), and promotes engagement with German companies, especially in the solar industry (GIZ, 2022). As many of these countries are APEC and ASEAN members, it will be interesting to see how these regional bodies aim to facilitate such labour mobility in future (see Box 9).

BOX 9. Mutual Recognition Agreements/Arrangements (MRAs)

Asia-Pacific Economic Cooperation (APEC), an inter-governmental forum with 21 member economies, was established to promote free trade throughout the region. Many of their guiding strategies, including the Connectivity Blueprint 2015–2025 and the Services Competitiveness Roadmap (2016–2025), recognise the importance of enhanced labour mobility to develop skills, promote trade and investment linkages, and foster economic development.

One way in which APEC is fostering labour mobility is through the development of Mutual Recognition Agreements (or Arrangements, MRAs). Parties to MRAs recognize and uphold decisions made by an authority in another participating country. In the field of skills, they allow qualifications to be harmonised: a certificate would be recognized in all participating countries,

facilitating the mobility of trained professionals. As at September 2021, APEC had 194 such agreements. They are concentrated among some member states (Australia; Hong Kong, China; Canada; New Zealand; and the US) and some professions (engineers; accountants; surveyors; actuaries; and architects) (APEC, 2021b). To date, there have been no specific initiatives to harmonise qualifications within green-skilled professions.[33] That being said, they have developed proposed job descriptions in green-skilled professions, such as for solar panel designers and installers (APEC, 2015b).[34]

Similarly, the Association of Southeast Asian Nations' (ASEAN) 1995 Agenda for Greater Economic Integration commits member states to aligning qualifications and standards to facilitate greater intra-regional trade (ASEAN, 2012). This is done through MRAs for higher-skilled occupations and Mutual Recognition of Skills (MRS) for lower-skilled occupations (AQRF level 1–4), particularly those with technical and vocational levels of education.

Member states in both regional bodies face many challenges to getting such agreements signed and implemented, including differences in standards, differences in definitions, and a lack of incentives. Most notably, they find that many trainees do not see the benefit in signing up for a qualification under an MRA, perhaps due to the lack of a clear linkage between the MRA and the immigration policies of host countries (APEC, 2021a).

South Africa

South Africa targets net zero emissions by 2050 (UNDP, 2023), and to limit greenhouse gas emissions to between 350 and 420 million tonnes of CO_2 equivalent by 2030 (Farand, 2021), versus 442 million tonnes in 2020. A combination of energy crises and delays to decommissioning coal-fired power plants means that these targets will not be achieved (Mukherjee, 2023).

South Africa also faces adaptation challenges. The temperature in South Africa is rising sharply, yet the outdated electricity grid is failing to keep pace with this substantial increase in demand. Of our five countries of origin, South Africa is the only case study actively promoting heat pumps. The private sector has stepped in to fill the energy gap, rapidly expanding both utility-scale and rooftop solar, and expanding skilled hiring. While a number of training options are available, they vary wildly in level and price, and don't appear to be targeting fossil fuel producing areas (despite the intention of the newly signed JETP agreement). Emigration from South Africa is increasing, but the government has not yet introduced any policies to facilitate or benefit from this despite recognising the trend.

33 From APEC email (11 September 2023).

34 In 2015, the Pacific Northwest National Laboratory and International Copper Association worked with APEC on a project entitled 'capacity building for installers and system designers for solar PV rooftop installations". They ended up publishing a mapping of solar PV training institutions (APEC, 2015a) and a training curriculum for solar PV installers and designers, that referenced in the text.

Demand

Sub-Saharan Africa is a climate change hotspot. The temperature within Southern Africa is rising at twice the global rate, leading to longer and more extreme heat waves (Bega, 2021). Yet air conditioning penetration is poor, especially in rural areas and informal settlements. The IEA predicts that demand for air conditioners in Africa will increase 10 times by 2040 (IEA, 2019), and that the number of air conditioners in the Southern African Development Community (SADC) will increase from 5.4 million to 17.7 million by 2030 (Green Cooling Initiative, 2023).

Since 2016, South Africa has installed approximately 350,000 air conditioning units each year (DMRE, 2023). The air conditioning market remains very small: only 4 percent of households are estimated to own air conditioning (with significant variation across wealth levels). 90 percent of air conditioning units imported are bought from China. In 2023 residential air conditioning comprised less than 0.02 percent of total electricity demand; this is expected to rise by nearly 2.5 times by 2040 with increased market penetration (ibid.). South Africa is the sole of our country of origin case studies to support heat pump installations: the state energy firm Eskom provides installation subsidies of R5.25 million (US$281,000) per MW anticipated to be saved, and heat pumps are increasingly valued within the mining sector. Rebates are also available for residential consumers, who are increasingly interested in them following energy price hikes (Kukard, 2023). Keiser and van Eldik (2020) estimate that rolling out heat pumps could reduce South Africa's carbon emissions by 12 percent. No data is available regarding heat pumps' current market penetration. Uptake is understood to be limited by high upfront costs and a lack of consumer knowledge about the technology (Hattingh and Bluhm, 2022).

Increased use of air conditioning will place greater strain on South Africa's electricity grid, which is already failing to keep up with current energy demand. Rolling blackouts ('load shedding') are a frequent reminder of the country's reliance on old coal technologies: 70 percent of South Africa's energy is provided by coal (Cassidy, 2023). To address this, the South African Renewable Energy Masterplan aims to add 6,500 MW of solar PV by 2030, ensuring 10 percent of renewable energy manufacturing is in coal reduction areas. They will be supported in these efforts by international financing, channelled through their recently agreed JETP; see Box 10). Yet, to date, the national utility Eskom has largely failed to support this transition.[35] One such reason may be the fact that 80 percent of solar PV materials are imported (largely from China), contributing to their high cost (Jacobs, 2023). In Eskom's difficulties, other companies have increasingly stepped in to meet demand. From 2020–2023 4,550 MW of private capacity was added to the grid, expected to increase to 6,850 MW by

35 As an example, in 2010, Eskom developed Demand Side Management (DSM) programmes to manage the supply and demand of electricity. They included two rebates, on solar water heaters and heat pumps. The programmes were expanded in 2012, aiming to install 65,000 systems by 2013 (World Bank, 2014). As of 2015, only 19,354 heat pumps were installed, and the solar water rebate only met 11 percent of its initial target (World Bank, 2014). Both programmes were suspended in 2015. Kritzinger and Covary (2016) speculate that the programmes failed as they didn't stimulate demand for the more efficient technologies.

the end of 2023, on par with the total capacity of the government's Renewable Energy Independent Power Producer Programme (REIPPP) (Daily Investor, 2023).

BOX 10. Skilling within the Just Energy Transition Partnerships (JETPs)

JETPs are financing mechanisms which allow richer countries to fund poorer countries' efforts to phase-out coal and transition towards clean energy. Funding can include grants, loans, and investments. The two main groups of donors are the International Partners Group (IPG, made up of Japan, the US, Canada, Denmark, France, Germany, Italy, Norway, the EU, and the UK) and the Glasgow Financial Alliance for Net Zero (GFANZ) Working Group (made up of multilateral and national development banks and finance agencies) (Kusuma, 2023). There are currently four JETPs: South Africa (signed November 2021, US$8.5 billion); Indonesia (signed November 2022, US$20 billion); Vietnam (signed December 2022; US$15.5 billion); and Senegal (signed June 2023, €2.5 billion (US$2.7 billion).

To different extents, the JETPs recognize the importance of skilling and reskilling (especially of workers engaged in the coal industry) to realise the goals of the agreements. For example, Vietnam's JETP aims to "develop and implement education, vocational training and re-skilling programmes to develop necessary skills and competencies and support job creation for labour in sectors and regions affected by the transition." To do this, they plan to develop a centre for excellence for renewable energy (FCDO, 2022).

Yet it is the agreement with South Africa that contains the most focus on this challenge. Their Just Energy Transition Investment Plan (JET-IP) 2023–2027 includes ZAR$2.65 billion (US$0.14 billion) for skill development, including the establishment of a national-level strategic skills hub and skills development zones run by technical colleges in Mpumalanga (coal), Eastern Cape (vehicles), and Gauteng / Northern Cape (hydrogen economy).[36] This new focus is also intended to guide how broader education and training funding is spent, to support a just energy transition (The Presidency Republic of South Africa, 2022).

In May 2023, the Presidential Climate Commission released their assessment of the JET-IP. This found that "all stakeholders are agreed that the focus on skills development in the JET-IP is insufficient" (Presidential Climate Commission, 2023: 10). In fact, only 1 percent of the total JETP funds are allocated to skilling (Mehta, 2023). The Commission continues to state that the JET-IP lacks detail of what skills will be prioritised, doesn't critically assess the existing skills base, and doesn't address broader issues with the education system. They conclude: "the current supply of skilled labour and technical expertise is limited, and the JET-IP gives no indication of how it will be addressed in the short-term" (Presidential Climate Commission, 2023: 10). While there are

36 Research by the Council for Scientific and Industrial Research (CSIR) suggests that Mpumalanga in particular could be a significant solar contributor, creating up to 79,000 clean energy jobs, but that existing renewable projects are being developed far from the coal-mining region (Mehta, 2023).

anecdotal reports of some JETP grants supporting training (Vanheukelom, 2023), there is not yet any public documentation or transparency regarding the establishment of any of the promised skills development zones. It remains to be seen how transformative these investments are, and whether additional financing is required (Obuekwe and Matsuo, 2023). More transparency and commitment is urgently needed if political support for the JETP is not to be lost: in October 2023 Eskom's most powerful trade union called for the partnership to be suspended entirely due to fears that 51,000 coal and power industry jobs could be lost (Vanheukelom, 2023).

There is little information available regarding what the increase in the demand for air conditioning (and, indeed, heat pumps) will mean for the number of jobs in the industry, but there is some information for solar. Shifting to renewable energy would add 150,000 net new jobs (including the losses in the coal sector), with the bulk being higher-skilled (70 percent) and in construction (63 percent). The COBENEFITS study estimates that an 86 MW solar plant alone would create 950 jobs, and that across the solar sector 29,000 jobs could be created by 2030 and 65,000 by 2050 under a ambitious decarbonisation agenda (IASS et al., 2019a). Most of these roles are likely to be in the Northern Cape, Free State, and North West (Businesstech, 2023). For this to have a transformative effect, there needs to be a sustained and predictable pace of solar procurement over a long period of time. For example, the REIPPP doubled direct employment between 2016–17 (31,207 job years) and 2021 (63,291) (Freimann and Magnus, 2023). Yet three quarters of the roles were in construction, leaving them vulnerable to a boom / bust demand for skills (IASS et al., 2019a; IRENA and ILO, 2023). Fears remain that the jobs created by the green transition will be low-skill and temporary (Mirzania et al., 2023).

South Africa must tread carefully in its green transition. The country must navigate both a high unemployment rate and a large fossil fuel workforce—sometimes in the same areas. The coal-dependent region of Mpumalanga, for example, has an unemployment rate of 38 percent and relies on coal for more than 100,000 jobs (Molelekwa, 2023). Eskom plans to shut down nine coal power stations, mostly in Mpumalanga, by 2035, potentially destroying up to 55,000 jobs (Pilling, 2022a). 2019 COBENEFITS study found that jobs in coal mining were expected to decline by 35–40 percent between 2020 and 2050, the equivalent of 18,000 full-time jobs (IASS et al., 2019a). For reasons of justice and equity, these workers must be supported in transitioning to new jobs. This is also important for political and practical reasons, however: the ruling African National Congress has close political ties to unions in coal-reliant areas, and influential actors will resist the scaling down of fossil fuel employment without a reliable supply of new employment (Pilling, 2022b).

Supply

In 2010, the ILO found that "across all green occupations [in South Africa] there exists a skills gap in skilled jobs including all engineering and technical roles" (ILO, 2010). Little seems to have changed. The Department of Higher Education and Training (DHET) wants to expand enrolments in TVET

colleges to 2.5 million by 2030 (City & Guilds Group, 2015), yet the TVET sector in South Africa is seen as weak, with few links to the labour market (Freimann and Magnus, 2023). The JETP places a strong priority on skilling and reskilling, including involving technical colleges, but little progress has been made to date (see Box 10).

For someone seeking to qualify as a RAC engineer, there appears to be three 'levels' of education: NQF Level 2, 4, and 6. For example, the Ifihlie Training Academy runs Level 2 courses (45–60 days, at a cost of R22,000 (US$1,165)) and Level 4 courses (roughly one year per course) (Ifihlile Training Academy, 2023). The Air Conditioning and Refrigeration Academy, started in 1990, also provides a Level 4 diploma (85 days, R148,500 (US$7,860)) (ACRA, 2023). Intec offers a Level 6 Diploma in Air Conditioning and Refrigeration (two years). The other option is to pursue a learnership: both R&A Training and Ieti provide a Level 4 learnership (Ieti's is 14 weeks of class time and 6–8 months of on-the-job training).[37]

There are more options available to someone seeking to become a Solar PV installer. PQRS, South Africa's largest solar PV training provider, offers a two-day design and installation course (20 hours, R5,020 face-to-face and R4,365 online). Their focus is residential and small-scale solar. Similarly, the Solar Training Centre SA, started by SUNCybernetics and the Engineering Facility of the North West University (NWU) in 2012, offers a small-scale technology installation course (five days). Also specialising in short courses, the Green Solar Academy administers five training courses in South Africa, including a three-day Solar 101 course (R6,900, US$365) and a five-day SuperSolarSchool (R13,500, US$715) (GREEN Solar Academy, 2019). Installers can become accredited through the South African Photovoltaic Industry Association (SAPVIA) and / or the Association for Renewable Energy Practitioners (AREP). More recently, the University of Pretoria has signed an agreement with Nepoworx (a solar skilling platform) to train 900 people over the next three years, supporting the rollout of REIPPP-funded projects (Tena, 2021).

Migration

South Africa hosts the largest number of immigrants in Africa, three-quarters of whom are from the African continent, and this number is increasing. So too is emigration, with the White population and Black professionals moving to the UK, Australia, and the US in particular (Moyo, 2021). By the end of 2020, at least 900,000 South Africans were living abroad, up from 765,000 in 2015. A 2022 representative survey of 3,204 randomly selected South Africans by the Social Research Foundation found that a quarter were considering emigration, the figure rising with social and economic status (SRF, 2022). Countries of destination are actively working to attract skilled South African professionals. For example, there is an MRA between Engineers Australia and the Engineering

37 A learnership is a government-backed programme whereby a trainee embarks on structured learning and practical work experience, leading to an NQF-recognized qualification. Trainees must be aged 16–35 and a school leaver or unemployed. Quotas are also in place: 85 percent of trainees must be Black and 54 percent must be women. A learner is able to access their training for free, with the employer paying them an allowance.

Council of South Africa (ECSA), and approximately 50 to 70 engineers typically migrate to Australia each year (Department of Home Affairs, 2024). From 2016–2019, nearly 2 percent of all members of the South African Institution of Civil Engineering emigrated from the country (CBN, 2019).

There are reports that in the absence of an adequately skilled local workforce, companies managing renewable energy projects are bringing in international workers. In some cases, this is reported to be leading to a backlash by local workers angered by the lack of opportunities made available to them. It is possible that incentives or requirements could be put in place for international companies to hire or train local workers (Mirzania et al., 2023). Conversely, some firms, unable to hire international workers or find sufficiently skilled workers domestically, have sent South African workers abroad for training. Several solar PV manufacturing firms have been unable to locate adequate domestic training opportunities when scaling up their workforces, and instead were forced to send local staff to China for training every six months (Dietsch et al., 2022).

The country is doing little to facilitate or proactively benefit from this emigration. In 2017, the Department of Home Affairs (DHA) issued a 'White Paper on International Migration' (DHA, 2017). It reviewed the various migration policies in place and aimed to chart a way forward to more strategically manage human mobility. It found that "South Africa has not yet built consensus at policy, legislative and strategic levels on how to manage international migration for development." While emigrants were "a source of development in terms of skills, capital and connections", that potential was not being harnessed. It recommended, among many other things, that South Africa proactively engage with countries of destination to promote emigration and expand diaspora engagement. Yet our interviews noted that there has been little to no action taken since, largely due to the fact that the DHA is "woefully short of resources, has serious governance issues, and is almost entirely preoccupied with immigration issues."[38] As an example, recently the government has launched an approved employers scheme to expand skilled immigration (Business Live, 2023). A new DHA White Paper is due soon, which will hopefully accelerate progress on these issues, however the upcoming election has complicated migration politics in the country.

Fiji

Fiji has ambitious aims to ensure that all power is generated through renewable energy, including the goal of reaching net zero carbon emissions by 2050 (Ministry of Economy, 2019). In doing so, Fiji hopes to drive action by other nation states, and obtain support for its own mitigation and adaptation needs (Averchenkova and Chan, 2023). Over half of Fiji's energy supply is derived from renewable sources, making it the Pacific Island State with the lowest oil dependency (Malik, 2021); despite this, its government has recognised that transitioning from fossil fuels for the remaining 45 percent of its energy supply will be challenging (Ligaiula, 2023).

38 Key informant interview.

Solar (particularly utility-scale solar) has received little attention to date. As of 2020 only 4 MW of solar PV had been installed, although work is ongoing for larger solar energy production (Prasad and Raturi, 2020). Similarly, there appears to be little attention paid to the skills Fijians need to take advantage of this new renewable landscape. Fiji's National University is the largest provider of training in both RAC and solar, while donors such as Australia, the US and South Korea have also invested. It will be a challenge to ensure Fiji can train enough workers to facilitate this transition, without losing more skilled workers to overseas markets such as Australia, Canada, New Zealand, and the US.

Demand

The threatening nature of both temperature and sea-level rise on the sustainability of Fiji as a country has led them to prioritise the shift towards renewable energy.[39] Their National Development Plan 2017–2036 lays out a path to ensure that all power is generated from renewable sources by 2036. Currently, 45 percent of the country's power is generated by fossil fuels, almost all of which are imported via Singapore-based suppliers (ITA, 2022a). This accounted for 20 percent of the country's imports in 2019, costing AU$700 million (US$451 million) (Hall, 2020). Moving away from this dependence will require an increase in both hydropower (currently 50 percent of the country's power), biomass and wind (currently 5 percent), and solar.

Solar has received less attention within Fiji than other renewable energy sources, especially hydropower, which provided 63 percent of all renewable energy in 2022; solar, by contrast, provided only 4 percent (IRENA, 2023b). Yet there is good potential for such generation, especially on the outer islands and coastal regions (IFC, 2021). A number of solar farms are currently in progress, supported by extensive external investment. For example, the International Finance Corporation (IFC) has provided US$15 million for a 15 MW solar plant in Vanua Levu, connected to the national grid run by Energy Fiji Limited (EFL), to supply 14,000 households: the Pacific's largest solar project (Hall, 2020). It appears, however, that implementation has been slow (IRENA, 2023b). Rooftop solar is also being prioritised, predominantly to electrify rural households. Between 2012 and 2014, the Department of Energy's Solar Home System Project (SHS) installed 1,000 solar home systems in 41 villages (SE4ALL, n.d.). In 2021, there were 150 rooftop solar PV installations in Fiji, although most were very small. Energy Fiji Limited (EFL) is developing a new rooftop solar policy, aiming to double such provision (IFC, 2021).

In 2019, a total of up to around 9,000 'green' jobs were estimated to be held in Fiji, versus a total national employment of 196,800 (Johnston, 2019). Of these, approximately 740 were estimated to be held in the electricity sector. A stark lack of labour market data makes estimates and projections

39 Despite rising temperatures, little is known about the air conditioning market within Fiji, rising demand, and the concurrent impact on skill needs.

challenging. The GGGI predicts a possible total, under different future scenarios, of between 2,058 and 4,245 jobs in 2030, and 5,012 and 11,709 jobs by 2050 (ibid.).

Supply

Fiji National University's (FNU) College of Engineering, Science, and Technology (CEST) appears to be the primary place to seek training to become both a RAC engineer and solar panel installer. To qualify for their Certificate IV in Refrigeration and Air Conditioning, a trainee would need to have completed their Year 12 certificate. They would then complete the two-year course at a cost of FJD3,287.14 (US$1,452) (FNU, n.d.). Similarly they offer a Diploma in Engineering (Renewable and Sustainable), a three-year programme which results in a Level 6 diploma at a cost of FJD$13,391 (US$5,916). CEST have also partnered with the Australia Pacific Training Coalition (APTC) to deliver solar installer training.[40]

Similar to other country case studies, there appears to be other training options available to people seeking to become a solar PV installer. The University of the South Pacific (USP) maintains a Renewable Energy Training (RET) laboratory which, among other things, delivers a Bachelor of Engineering degree. In partnership with Global Sustainable Energy Solutions (GSES), they offer short courses in grid- and off grid-connected design and installation. Between 2011 and 2016, they partnered with USAID to deliver the Vocational Training and Education for Clean Energy (VOCTEC) programme (Arizona State University, 2016).[41] Other donors have also been active in supporting such training. South Korea (through their development arm, KOICA) is supporting the Global Green Growth Institute (GGGI) to deliver community trainings in five communities, under their 'Capacity Building to Strengthen Sustainable Implementation of Renewable Energy Technologies for Rural Energy Access' programme (GGGI, 2021).

Migration

Fiji has a complicated history with emigration. In the late 1980s, a series of military coups changed the constitution and enacted a series of measures that were felt to harm the prospects of many Fijians of Indian descent. It caused one of the largest and fastest movements of skilled workers on record, roughly one-third of the Indian population moved to Australia, New Zealand, and Canada. It also caused a notable jump in human capital investment among the remaining Fijians of Indian descent, to offset the skills lost through this emigration (Chand and Clemens, 2008).

40 APTC is an Australian Aid funded training school which aims to deliver courses in vocational skills relevant to both the Pacific and Australian labour markets. See more at https://aptc.edu.au/. APTC used to offer a Certificate III in Air-Conditioning and Refrigeration, a 22-week course at a cost of FJD3,500 (US$1,546), although no longer appears to do so.

41 VOCTEC provided training, training for trainers, and support for policy and decision-makers in 15 countries (including Fiji). The 'training for trainers' solar course was their most popular, leading them to create a mobile training toolkit which could be taken to remote locations. They managed to deliver 28,464 hours of training and leverage almost US$1 million in non-US government training.

In mid-2019, more than 220,000 people born in Fiji resided abroad, 95 percent of whom were in Australia, Canada, New Zealand and the US (Wainiqolo, 2023). Despite the evidence explored above, and despite understanding the reasons for continued emigration, there is a broad concern about the loss of skilled talent to overseas markets and a reluctance to invest in people who will leave (Lal, 2003). Certainly both Australia and New Zealand are attempting to tempt skilled Fijians into emigrating. They are one of the qualifying countries for Australia's PALM scheme, which provides nine-month visas to people seeking seasonal work in a range of sectors (DFAT, 2022). Similarly, they are eligible for New Zealand's Pacific Access Category Resident Visa (among others), which grants citizenship to those who win a lottery (New Zealand Immigration, 2023). As seen above, both the US and Korea are also investing in green skill training programmes, although there is no evidence that these are (yet) linked to immigration policy.

If Fiji was to become a participant in a labour migration programme, its most likely destination countries would continue to be Australia and New Zealand. Australia's *Clean Energy Generation* report suggests that migration to Australia for work in green transition-relevant jobs could be beneficial to migrant-sending countries in the wider Pacific (Jobs and Skills Australia, 2023b). For Fiji, participation in a Pacific green-skilled migration programme could increase the domestic stock of skills while also supplying remittances. Fiji is already a participant country in the Australia Pacific Training Coalition, which has trained hundreds of Fijians to Australian qualification standards in green transition-relevant skills in HVAC and electronics (APTC, 2022). This programme could be valuably expanded, with an increased focus on skills in solar PV and air cooling. Fiji could also push for investment in parallel, and for proactive qualification recognition agreements. This is especially necessary given that high emigration of skilled workers may already be having a negative effect on the development of the nascent solar PV installation sector (Johnston, 2019).

Colombia

Colombia targets net zero emissions by 2050 and a 51 percent reduction in greenhouse gas emissions by 2030 (USAID, 2023). These goals are likely to be challenged, however, by a decline in fossil fuel revenues, which currently account for 60 percent of Colombia's revenues (Moloney, 2023). Colombia pledged in January 2023 not to award new gas and oil exploration contracts, but has faced pushback.

Colombia is unique among our case studies in that it has substantial demand for both heating and cooling services, given its geography. Yet penetration of such services is low, largely due to the cost of electricity. The government has embarked on a plan to substantially increase the amount of solar generation capacity, which will require a concurrent expansion in the amount of skilled labour. Both for-profit training companies and the national institute SENA are delivering training in both RAC and solar, although the system appears to be largely disjointed and ad-hoc. At the same time, emigration has rapidly increased (largely to the US and Spain), with countries of destination seeking to take advantage of this influx of skilled labour.

Demand

No full economy-wide projections for the green transition's employment effects in Colombia exist (Vega Araújo and Muñoz Cabré, 2023). If the projects awarded between 2019 and 2021 come online, however, there could be 120,000 new jobs created each year until 2030 (Puyo, 2023). Jobs will need to be created for both mitigation and adaptation purposes. Wind and solar currently produce less than 1 percent of Colombia's energy generation, versus 70 percent generated through hydropower. While hydropower is a clean energy source, it is also vulnerable to droughts caused by the unstable El Nino weather system (Bocanegra, 2023), and increased diversification will be necessary.

Temperatures in Colombia have increased by at least 1 degree in the last 20 years, and are projected to rise by another 2 degrees by 2050 (World Bank, 2021). The number of very hot days (over 35 degrees) is likely to increase from 16 to 131 days per year. It is perhaps unsurprising that electricity demand is also expected to rise, by 1.5TWh by the end of the year, compared to the end of 2022 (Casey, 2023). Ríos-Ocampo et al (2022) estimate that the total potential demand for cooling in 13 Colombian cities alone is 650 MW. Most of this demand is in the residential sector (52 percent of per capita electricity consumption) (Ruíz López et al., 2020). Yet some cities in Colombia, particularly those at high altitude, also demand substantial heating services. For this reason Colombia could be an ideal case study for the roll-out of heat pumps, ideally assisted by solar technology (Valencia-Cañola et al., 2023).[42] At present, however, penetration is low, largely due to the cost of fuel. Without adequate supply of clean energy or the development of much cheaper heat pumps, this technology is likely to remain out of reach for many Colombians. Given that 404,000 households did not have access to electricity in 2022 (Rubiano, 2022), this could require greater access to micro-grids or distributed solar for some populations.

Several areas of Colombia—notably La Guajira—have very high potential for solar energy generation thanks to their high levels of radiation (Reingold, 2023; Carvajal-Romo et al., 2019). Currently, however, solar represents less than 1 percent (115 MW) of Colombia's energy mix (Enerdata, 2023), largely due to "expensive solar equipment and a lack of skilled labour" (Ruíz López et al., 2020). In the residential sector, Colombia has historically not implemented sufficient subsidies to increase solar PV installation rates, despite high potential (Morcillo et al., 2022; Guzman and Henao, 2022). The government's 11-year Generation and Transmission Expansion Plan, which started in 2020, aims to add 1.96–4.66 GW of new solar capacity (Enerdata, 2023) through a series of rolling procurements. The first auction, in October 2019, commissioned eight projects (five wind and three solar) from seven companies (Marti and Cárdenas, 2019). The most recent auction, in March 2023, commissioned 147 solar projects, providing almost 6 GW of solar (Ini, 2023). Today, there are 80 renewable energy

42 There is some precedent for the expansion of such technologies. From 2020 to 2022, the government's Fund for Non-Conventional Energy and Energy Efficiency (FENOGE) replaced 10,150 refrigerators and air conditioners with high-efficiency models in low-income households (IEA, 2023c).

projects scheduled, 78 of which are solar, contributing 85 percent of the new generation capacity.[43] If these were implemented, wind and solar would equate to 40 percent of the mix by 2040 (Araújo and Cabré, 2023). Despite this meteoric rise, this would still provide less than a quarter of the renewable capacity goal set out in the government's Energy Plan 2050. In September 2023 a new Memorandum of Understanding was signed between the Wayúu Indigenous communities and the Dutch company Gutami Group for the construction of a 750 MW solar park; if pursued—noting that previous commitments have fallen through (Bocanegra, 2023)—this would represent a significant increase in solar capacity (Gutami, 2023).

Meeting this demand will require a huge increase in the number of skilled workers. In 2021, only 2,381 workers were employed in the solar industry. While a sharp increase from 360 in 2020, this remains a nascent sector requiring a very high growth rate (IRENA and ILO, 2022). There are many issues inherent within this growth, particularly how to adequately skill new workers and re-skill those working in the fossil fuel industry. In November 2019, the government and the ILO signed a 'Pledge for Green Jobs and Just Transition' which sought to prepare the workforce for the challenges of green growth with a focus on the formalisation of roles, increased productivity, and workforce capacity building (IEA, 2023c). Building on this, the Ministry of Labor is currently drafting a national just transition strategy. Key will be developing "government-funded and well-targeted training programmes"; a carbon tax has been proposed to meet the cost of such training (Puyo, 2023). Similarly, when looking at the cooling industry, our interviewees noted that the job offer in Colombia is very high (pay, benefits, opportunities) and yet there are few engineers or technicians adequately trained to take up these opportunities.

Supply

People seeking a career in air conditioning and refrigeration appear to have two routes available to them. Firstly (especially if they have some prior experience or qualification), they can pay to undertake a Diploma or higher-level certificate at one of the many universities and technological institutes. Most are mechanical engineers who study HVAC or RAC skills as a professional elective.[44] Some specialist training is delivered online. For example, the Special District of Science, Technology and Innovation of Medellín offers a Diploma in Air Conditioning and Refrigeration, including 96 hours of course work delivered remotely and eight hours of evaluation to fulfil the work requirement. It is open to existing engineering students or those with some existing experience, at a cost of COP$1,903,200 (US$477) (ITM, 2023). The Politéchnico Industrial Nueva Colombia offers a Certificate in Air Conditioning and Refrigeration (Level C), this time open to high-school graduates, with a

43 One of the more interesting projects coming online in 2023 is Aquasol, the largest floating solar system in Latin America (Garanovic, 2023). This 1.52 MWp pilot in the reservoir of a hydroelectric power plant in the municipality of Tierralta, Córdoba, is being studied by universities to ascertain the advantage of water-based solar systems.

44 Our interviewees noted that, as for postgraduate courses, most professionals who have a specific Masters degree in HVAC or RAC skills studied in Spain.

focus on maintenance and repair. The six-month course delivered on evenings and weekends costs COP$1,806,000 (US$453) (Politecnico Industrial Nueva Colombia, 2023a).

Secondly (especially if they are a high-school leaver with little experience), they can take advantage of numerous government- and donor-funded projects. The Colombian National Training Service (Servicio Nacional de Aprendizaje, SENA) is a government initiative which aims to improve employment opportunities for Colombian workers by offering free or discounted technical training to millions of people through partner institutions and online (SENA, 2016). They offer training in the 'Maintenance of Refrigeration, Ventilation and Air Conditioning Equipment, Electronics and Basic Sciences,' often through bespoke training institutes (see, for example, this institute in Atlántico: Del Gallego, 2019). This six-month, 710 hour, course is taught in person. The cost varies by institution, but is COP$20,00 per quarter on average (US$5) (Sofia Plus, 2023b). Our interviewees noted that most technicians are trained by SENA. There are also ad-hoc courses, often run by the Air Conditioning and Refrigeration Association (Asociación Colombiana de Acondicionamiento del Aire y de la Refrigeración, ACAIRE). In 2019, they delivered a seven-module training over 100 hours in the theory, installation, commissioning and maintenance of air conditioning and refrigeration equipment (Agudelo, 2019). In 2021, they partnered with GIZ Proklima to deliver a five-day training to instructors from SENA (Green Cooling Initiative, 2021).[45]

The situation appears to be similar for those interested in working as a solar PV installer. The Politéchnico Industrial Nueva Colombia offers a six-month course in the maintenance and installation of solar PV systems at a total cost of COP$2,370,000 (US$578) (Politecnico Industrial Nueva Colombia, 2023b). Some companies offer their own training, such as AutoSolar and ALZ Energy. Other, cheaper, options are available. There are a number of available courses, including the installation of solar panel systems, a 2,200 hour course taught over nine months (Sofia Plus, 2023a; CEET, 2015). International donors have also become involved in renewable energy training. For example, USAID Colombia implemented the 'Scaling Up Renewable Energy Program', in partnership with Tetra Tech and the US Energy Association. 60 early career professionals from 20 organisations were trained between 2020 and 2021 in renewable energies, including solar (NREL, n.d.). The supply of workers in the solar sector is easily absorbed by growing renewable energy industries. In the solar sector alone, employment increased from just 360 in 2020 to 2,381 in 2021 (Vega Araújo and Muñoz Cabré, 2023).

Colombia's large workforce in high-emission sectors, especially coal, oil, and gas, will also need support in transitioning to new, low-emission jobs. Previous experiences have not always been positive. In 2020, for example, two coal mines operated by Glencore closed in a town in northern Colombia; of 7,300 workers, 7,000 lost their jobs, costing the local municipality 85 percent of its

45 Another private company, Enel Green Power, has worked in partnership with SENA to deliver training in areas including the assembly of solar panels, and have collaborated with Schneider Electric to build a community-based renewable energy training lab. The aim is to support skills development in the Department of Cesar, Northern Colombia, where their El Paso solar plant is operational (Enel Green Power, 2019).

income (Rubiano, 2022). Across Colombia, some 120,000 workers are employed by coal-mining operations, and nearly 10,000 work for the state energy firm Ecopetrol alone (Picciariello et al., 2022).

Migration

Colombia has witnessed a see-sawing in its relationship with migration. The internal conflict during the 1980s and 1990s caused a large exodus of people at all skill levels, many heading to both Venezuela and Spain. In the 2000s, some returned from Spain and more recently some have returned from Venezuela, due to their respective internal crises. (This is in addition to the millions of Venezuelans who have fled to Colombia, classified as refugees under the Cartagena Declaration—see Box 11). The Ministry of Foreign Affairs (MFA) implemented a policy entitled 'Colombia Nos Une' which aimed to support returnees integrate into the labour market. It has now been translated into the office which aims to support returnees, diaspora abroad, and harness international emigration.

Such international emigration has increased dramatically in recent years. Prolonged conflict, economic challenges, and the COVID-19 pandemic (Chaves-González and Batalova, 2023) have led people to leave, mainly to the US, Spain, Chile, Mexico, Canada, and Germany. Remittance flows have grown six times since 2000, reaching more than US$9.4 billion in 2022, or three percent of Colombia's GDP (World Bank, 2024). In 2022, 547,000 people emigrated, the highest figure since 1998, with the government estimating that 24.3 percent were planning to live abroad (The City Paper Bogotá, 2023). Our interviewees noted that many engineers in particular are emigrating to the US, Australia, and the Middle East. Yet, neither the most recent immigration law (passed in 2021) or any other policies attempt to harness the benefits of emigration and diaspora investment.

This lack of focus on emigration stands in stark contrast to the policies of countries of destination, attempting to harness Colombian immigration. Beginning July 10, 2023, the US will allow up to 100,000 eligible migrants from Colombia, El Salvador, Guatemala, and Honduras to fly to the US and gain work permits, if they have relatives who are US citizens and file applications on their behalf. In doing so, the US hopes to expand temporary work visas and family reunification, while reducing the number of Colombians processed by US southern border authorities (126,000 in FY23, from January to July) (Montoya-Galvez, 2023). Other countries of destination are also approaching Colombia as a source of talent; for example, Germany has a new public employment service agreement with Colombia to promote the mobility of electricians (Kumar et al., 2023).

BOX 11. Including refugees in international labour mobility pathways

Historically, there have been three long-term options (or 'durable solutions') available to refugees: voluntary return to their country of origin; local integration in their host country; and resettlement to a third country. Recently, a fourth has arisen: complementary pathways. These enable refugees to pursue education or employment in a third country, or access other family reunification, humanitarian, or sponsorship schemes. In particular, refugee mobility to meet skill gaps in countries of destination is an increasingly attractive option for all parties.[46]

By the end of 2022, 108.4 million people worldwide had been forcibly displaced due to persecution, conflict, violence, and human rights violations. This number is on the rise, an increase of 19 million people compared to the end of 2021 (UNHCR, 2023a). 29.4 million of these people are classified as refugees, having fled over an international border. The length of time they spend in displacement is increasing: 67 percent of refugees have been displaced for five or more years (World Bank, 2010). Complementary pathways, benefiting all parties, can provide life-changing opportunities to long-term refugee populations while also addressing skill gaps in countries of destination.

There are two ways in which refugees could be included within green-skilled international mobility pathways.

Firstly, countries of destination could seek to hire refugees from third countries—such as Colombia—who *already* have green skills, supporting their migration through a complementary pathway. There are close to 2.5 million Venezuelan refugees in Colombia, many of whom are highly skilled (Graham et al., 2020). A census of their skills could be taken, with refugees then matched with employers facing skill shortages elsewhere. Their mobility could be facilitated through the USAID-supported Integra centres.[47]

Secondly, countries of destination could train refugees in green transition-related skills, alongside host communities to foster social cohesion, supporting some of them to move. This model is known as a Global Skill Partnership and has several benefits: building skills of those who stay and move, plugging skills gaps in the country of destination, and providing a durable solution for refugee populations (Huckstep and Kenny, 2022).

46 For example, Talent Beyond Boundaries matches skilled refugees with companies in need of those skills, working directly with governments to open up such refugee mobility pathways. See https://www.talentbeyondboundaries.org/.

47 For more information, see https://www.usaid.gov/sites/default/files/2023-01/Integra_Espanol_FactSheet_6.9.22_2.pdf.

Conclusion

All of the countries examined in this paper have committed to ambitious decarbonisation targets, requiring (among other things) a rapid increase in solar PV capacity and energy-efficient heating and cooling systems, such as heat pumps. The former has enormous potential to generate low-cost sustainable electricity—particularly for our countries of origin with predominantly sunny climates—and is getting cheaper every year. Rapidly falling technology costs mean that the major barriers to increased clean energy provision are permitting, grid expansion, and access to skilled labour. In both countries of origin and countries of destination, installation of both solar PV capacity and heat pumps is highly labour intensive.

The latter represents an interesting shift that our examined countries of origin will need to make. As countries warm, air conditioning will be more and more needed to maintain conditions for basic health in many parts of the world. At present, however, air conditioning tends to be managed using stand-alone units, which are cheaper and more readily available. Increasing use of air conditioning is straining electricity grids, which must source and transmit more power, often from unsustainable sources. Ensuring that these countries can access and install heat pumps, learning the lessons from the roll-out of this technology in countries of destination, will be crucial to adaptation to rising heat.

The installation of both of these technologies will require a massive increase in the number of vocationally skilled workers, predominantly at low- and mid-skilled levels. Yet in countries of destination, workforce supply lags some distance behind needs. This is variously due to lack of funding for vocational education systems; a shortage of trainers; insufficient coordination between industry, government, and training providers; the inevitable delay between (anticipated) demand increases and increases in supply; a lack of knowledge of or interest in training options among potential new entrants; a lack of willingness to be retrained among the (often older) existing workforce; and insufficiently developed training infrastructure, such as, for example, a need to formalise and support solar PV apprenticeships. In countries of origin, training systems are also frequently incoherent. We find that there is a vast range of training available, with different costs, timelines, and curricula. We find also that there is a lack of focus on harmonising formal skill provision systems, and that while installation has often received attention, *maintenance* is frequently neglected.

This workforce demand appears to be a more pressing challenge in our countries of destination, where workers are needed in the short-term (e.g., the next 5–10 years), while it will likely be a constraining factor to investment in our countries of origin in the medium-term (e.g., the next 10–20 years). As IRENA (2020) notes, the labour market impacts of the green transition will vary between locations as well as occupations and sectors, according to levels of policy commitment, the navigation of limiting factors, and the availability of investment. While funding is being made available in the Global North, the Global South lacks adequate public and private investment for the renewable transition: to achieve clean energy targets, funding to Global South investments will need to increase

from around US$770 billion in 2022 to up to US$2.8 trillion by 2035 (IEA and IFC, 2023). Of this, 90 percent of funding to Global South countries other than China would need to come from the private sector (Ananthakrishnan et al., 2023). This currently appears unlikely, due to limited private sector interest in multilateral climate funds (Kalinowski, 2023), unstable political climates, macroeconomic fears, and high existing debt (Sembene et al., 2022). In time, however, falling technology prices should mean that what investment is available will go further, with attendant job creation effects.

This anticipated staggered demand for labour presents an interesting opportunity: collaboration between countries of destination and origin to build the global stock of workers with green skills, using international migration models to fill the workforce gaps constraining decarbonisation. Even if, as can be hoped, demand is *not* staggered, these approaches are still valuable in increasing the total stock of workers and bringing missing workers to countries facing labour shortages.

Workers from countries of origin could move to countries of destination to support the green transition there, returning to support their own countries' green transition in the coming years. In the meantime, massive investments should be made in domestic training and reskilling efforts, with efforts in countries of origin supported by countries of destination. Two potential migration models are put forward below, alongside recommendations for both countries of origin and destination seeking to improve their engagement on the green-skilled training and migration agenda.

Potential migration models

This paper has argued that meeting global green skill needs will require a creative combination of domestic training, re-skilling, and skilled labour migration. This section will provide a brief overview of the two potential international migration models available to countries if they are seeking to expand their engagement in this agenda.[48] It is important to note that these two options are not mutually exclusive; in fact, it is likely that they will need to be pursued concurrently, alongside massive investments in domestic training and reskilling, to be able to produce the skilled workers in the short-, medium-, and long-term. In particular, we must avoid being caught in a binary between domestic training or reskilling and expanding labour migration, as this will undercut the narrative that the green transition will lead to more job opportunities for citizens. Finally, we need to start now. The global green skill needs are already pressing and only become more challenging. Urgent experimentation, scaling the options that work, is key. Without deliberate and proactive investment in workforce pipelines, net zero will be a pipe dream.

1. Circular migration scheme

One option that could be pursued alongside expanding the domestic green-skilled workforce is the establishment of a circular migration scheme. This would provide long-term temporary (perhaps two

48 Future papers will expand on these options taking into consideration specific roles and specific bilateral or multilateral groupings of countries. These papers will be released throughout 2024.

or three year) visas to encourage the migration of *already* green-skilled workers. This could be done alongside financial transfers from countries of destination to countries of origin to support in the establishing of curricula, training of trainers, training institutes, or other development priorities.

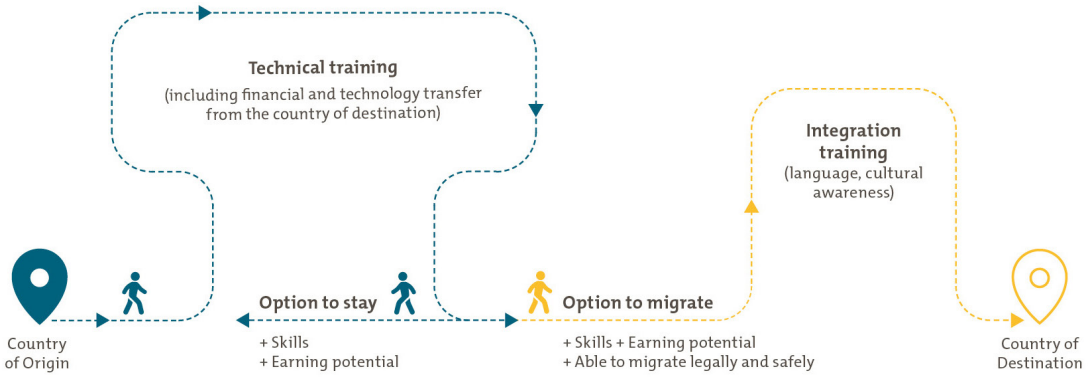
Again, there are many benefits to such a scheme. Workers would earn higher wages while in the country of destination (for example, we estimate that an Indian solar engineer in Germany would earn US$30,700 more per year); remit some of this money home (conservative estimates put this at 15 percent); and contribute their skills and experience when they return home (Huckstep et al., 2023). You could even design the scheme so that the employment pathway of the worker while they are in the country of destination provides them with skills they can explicitly use when they return. Such a scheme could help meet private sector need in a staggered way: countries of destination, which are feeling the impact of shortages currently or soon, would receive skilled labour in the short-term, whereas countries of origin, which will likely feel the impact of shortages in the next 5–10 years, would receive experienced skilled labour in the medium- to long-term.

Yet there are many constraints. Implementing such a scheme usually entails opening up a visa pathway. It is difficult to be specific about the profile of worker who moves under this pathway, and therefore difficult to align the scheme to private sector need. There are also ethical concerns with using a temporary scheme to plug a permanent need (workers would gain skills and experience, make connections, build lives, only to be returned home despite an ongoing need in the country of destination) and macroeconomic concerns (temporary workers invest less in integrating) (Görlach and Kuske, 2023). Temporary schemes often also lead to more ethical and human rights concerns than permanent schemes (OHCHR, 2022). Finally, it means that countries of origin would be bereft of these skilled workers for the space of the programme (two to three years), undermining their green transition efforts. In addition, the global shortage of workers with the skills needed for the green transition (IEA, 2023g), and the likelihood of intense international competition for these workers developing, means that for most countries the option of merely loosening visa regulations is likely to be insufficient.

2. Global skill partnership

A Global Skill Partnership is a bilateral labour migration agreement between a country of origin and a country of destination. The country of origin agrees to train people in skills specifically and immediately needed in both the country of origin and destination. Some of those trainees choose to stay and increase human capital in the country of origin (the 'home' track); others migrate to the country of destination (the 'away' track). The country of destination provides technology and finance for the training and broader systems support, and receives migrants with the skills to contribute to the maximum extent and integrate quickly (see Figure 8) (Adhikari et al., 2021).

FIGURE 8. The Global Skill Partnership model



The benefits of such a model are numerous. It ensures that countries of destination get the exact workers they need; both the skills they are trained for and their profile. Countries of origin get green skilled workers, as well as contributions from remittances and other investments in improving training infrastructure. The skills needed for the green transition are relatively static (the same skills will be in need for decades to come) making it an obvious choice for the establishment of a long-term talent pipeline, and a sensible investment for governments aware that long-term legal commitments oblige an increase in their access to a skilled workforce. Despite being expensive, research has shown that the benefits largely outweigh the costs (Navarra and Fernandes, 2021). Finally, these schemes are already being trialled by countries around the world. These pilot schemes can easily be adapted and scaled to meet 'green' skill needs.[49]

Yet there are also a number of constraints. These schemes can be difficult to design, making them expensive and time-consuming. Depending on the level of training needed, countries of both origin and destination may not get the trained workers that they need for at least two to three years. Given the lead-in times for wider preparations for the green transition, this may be less of a problem in some areas than in others. Ideally, the marginal cost per worker trained would reduce as the project scales, and these costs should be outweighed by the benefits, but it is difficult to get political buy-in for a project that is initially expensive and will not immediately produce workers. Finally, it can be difficult to align the needs of both countries of origin and destination. As this paper has shown, countries of destination may need different workers with higher levels of skills; we must avoid producing a pipeline of talent who are unnecessarily over-skilled for roles in countries of origin or under-skilled for roles in countries of destination.

49 See https://cgdev.org/bettermigration.

Recommendations

For countries of origin and destination

- *Survey skill needs*. It is difficult to build a national picture of the skills needed to support the green transition; much of this information is held at the individual company level, and governments rarely have a clear mandate to aggregate this information. Yet the G20 has called on countries to map their skill gaps and explore what role migration could play in filling these gaps (G20, 2023). Countries should follow in the footsteps of India's SCGJ and the UK's 'Green Jobs & Skills for Net Zero' unit, tasking a central team with undertaking skill gap analysis, developing occupational standards, and working with international partners to explore new migration models. Information should be shared at the international level using harmonised mapping criteria, to facilitate the development of labour mobility partnerships.
- *Prioritise domestic training and reskilling*. The green transition can't happen without a skilled workforce. Despite this, scaling up vocational training and apprenticeship schemes is rarely prioritised in policy documents and investments. For example, only one percent of the JETP funding being provided to South Africa is focused on skilling, despite the large challenges they face in re-skilling the fossil fuel workforce. All countries need to support educational institutions, in close partnership with the private sector, to produce the workers needed.
- *Harmonise training requirements with partner countries*. In countries of origin in particular, it is often unclear which qualifications and skills are needed for different types of implementation. For example, a four-year engineering degree with a solar module may be required to work on a utility-scale solar plant, while a five-day course delivered by the local solar society may be required to install and maintain rooftop solar PV. Countries should work to develop and formalise curricula, outlining the skills and experience needed for different types of roles. As above, this work could be done by dedicated units, following the example of the UK or India. Countries should also seek to harmonise or align curricula with partner countries, making international mobility more feasible. This work could be done at the regional level, by organisations such as ASEAN and APEC, and at the international level by organisations such as UNESCO and the ILO.
- *Engage more closely with the private sector*. While government policy priorities are largely driving the green transition, it is companies that must adapt to meet these priorities. They have the best understanding of their own skill needs, both in the short- and long-term, and yet they are rarely well connected with governments. This can be seen in the failure of many apprenticeship schemes to meet green-skill needs, and in the lack of collaboration with companies who are *already* doing much to expand training and up-skilling, and even migration (such as Daikin Industries, see Box 8). Greater alignment would help increase the size of both the domestic and international pipeline of talent.
- *Stabilise public and private procurement*. Workers will not invest in green skills if they do not see a promising career pipeline ahead of them, and companies will not invest in training without a stable investment landscape. In many countries, there has been a boom-and-bust

cycle of procurement, with a spike in roles available as new projects come online and a large decline in those roles as they are established. Especially concerning utility-scale projects, governments should work to stabilise this investment pipeline to encourage new entrants into the workforce.

- *Support training of existing immigrant and refugee populations*. Many countries already have relatively large populations of migrants and refugees, many of whom may be working below their skill level or be unable to obtain work due to language or bureaucratic constraints. Assistance with training, job matching, and internal relocation to areas with large labour market needs may be efficient and equitable. Governments could also consider providing pathways to regularisation via training into shortage occupation roles.

For countries of destination

- *Develop skill partnerships*. There is a global shortage of workers with the necessary skills. Conventional migration pathways will not meet the increased demand for green-skilled workers, especially in roles requiring greater knowledge, such as electrical engineering. While it is the case that access to migration through particular training pathways can result in greater demand for those training pathways and consequent scaling up (Abarcar and Theoharides, 2021), the extremely constrained timeframes of the green transition means that there is insufficient time for this to take place. Countries of destination should therefore support training in countries of origin in advance of skill needs, guaranteeing the development of the necessary workforce. This requires collaboration in undertaking skill gap mapping; preparation of training courses that meet both partner countries' needs; investment in training infrastructure, including the training of trainers and provision of necessary equipment; assistance in securing visas; and alignment of accreditation recognition approaches. Once scaled, these programmes may be cost-efficient compared to domestic training. To meet the green transition's milestones, these programmes must be piloted and scaled unusually rapidly.
- *Integrate the development impacts of migration partnerships*. If managed well, skill partnerships can benefit migrants and both partner countries, and can support both mitigation in countries of destination and, depending on the technology in focus, adaptation in countries of origin. To maximise the impact of these programmes, countries of destination should also consider supply-side factors—such as the number of unemployed persons, and the size of the fossil fuel workforce—in countries of origin, supporting a cross-border just transition.
- *Expand mid-skill visas (long-term temporary and permanent)*. The green transition already faces a pronounced shortage of necessary skilled workers in many countries. While the creation of skill partnerships is likely to be necessary, increased direct immigration of the existing international skill stock will be needed in the short-term to meet immediate decarbonisation needs. The skill level of these migrants will predominantly be at the vocational level. Depending on the role, migrants could come for a range of timeframes. In some countries, it may be most efficient to create a dedicated visa for the green transition; in others, alterations to shortage occupation lists and existing visa pathways will be adequate.

- *Ensure that international recruitment is undertaken equitably, with respect for migrants' rights*. International recruitment frequently exposes migrant workers to rights abuses, including recruitment fees; withholding of wages; and exploitative or dangerous working conditions. Governments in countries of destination should cooperate with employers, regulatory agencies, migrant organisations, and unions to ensure that migrants' rights are respected. Given the physical nature of much of the work undertaken in the context of the green transition, moreover, care should be taken to ensure that migrant workers have access to adequate insurance.
- *Consult with unions and employers to ensure that migration policy addresses needs*. In many countries, the green transition is 'sold' to electorates with promises of job creation. It is possible that, while necessary, the use of migration policy tools to meet skill shortfalls may trigger a political backlash. To ensure that migrant workers complement domestic workforces in filling gaps, governments should engage proactively with both employers and unions.

For countries of origin

- *Focus on the whole spectrum of skill needs*. Many of our countries of origin tended to prioritise the installation of low-carbon technologies and de-prioritise their maintenance. This translated through into the number of workers formally trained in installation compared with maintenance, which is often left to the informal sector. Depending on the subsector, ongoing tasks (maintenance and repair) may require workers with fewer or lower skills, and can therefore be a good option if countries are seeking to provide employment opportunities to rural and vulnerable people.
- *Invest in low-cost apprenticeship schemes*. Three of our countries of origin maintained apprenticeship schemes which trained school leavers in green skills (among others): India's *Suryamitra* solar skill development programme (see Box 6); South Africa's learnership programme; and Colombia's SENA programme. These schemes enable countries of origin to train marginalised groups (such as those with little education, those from a rural background, and women) in skills needed for the future economy. They could also be adapted to support refugees, such as Venezuelans in Colombia. Ideally, these schemes would be expanded and connected with international labour markets, with countries of destination providing financial support to provide training at levels needed for overseas employment.
- *Actively harness emigration*. Despite the benefits of doing so (remittances, reduced pressure on domestic labour markets, international investment), very few of our countries of origin sought to export labour abroad. These countries should seek to actively partner with countries of destination to prepare trainees for international labour markets, advocating for substantial investment in return (e.g., in training infrastructure). Countries could then support migrants with top-up training, visa support, and language provision (see, for example, the work of the New Skill India International Centres). Finally, they should ensure that their *existing* skilled migration programmes (such as Fiji's collaboration with Australia on the PALM scheme) are re-tooled to provide opportunities for green-skilled workers.

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