From Coal to Chlorophyll

Identifying Green Job Opportunities for Youth during South Africa's Just Transition

By Robert Hill, Leigh Neethling and Morné Oosthuizen

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Abstract
In an attempt to mitigate their effect on climate change, a number of economies have already, or are in the process of shifting away from a reliance on coal-based power. This just energy transition means that many existing jobs in the coal industry will be lost in favour of so-called "green jobs", which aim to contribute positively and sustainably to the environment. South Africa is one such economy that is embarking on the process of a just transition. But, given that the coal industry is predominantly represented by young people in the province of Mpumalanga, it is not clear how or if this vulnerable group will transition into newly created green jobs. Making use of occupational relatedness metrics, this research investigates the feasibility of green job opportunities to capture displaced youth in Mpumalanga, depending on their employment history. Results of this desktop study – which forms part of a larger cross-country study funded and led by the University of Cambridge – suggest that green jobs are relatively different to the existing experience and task competences of young people, and thus some form of reskilling programme is likely to be necessary for young people to take full advantage of the employment opportunities offered by green jobs.

Keywords:
Just transition; green jobs; youth employment; occupational relatedness; Mpumalanga

JEL classification:
E24, J24, J40, J62, O13, Q01, Q20

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1. Introduction

Climate change poses a major risk to economic stability due to the rise of extreme weather events, such as floods, droughts or wildfires, that impact infrastructure, ecosystems and livelihoods (Intergovernmental Panel on Climate Change (IPCC), 2022; Presidential Climate Commission (PCC), 2022a). Climate change is also seen to impact vulnerable communities – such as women, youth, and the unemployed – most severely, through additional stresses on food security, as well as financial and economic freedom (PCC, 2022a; UNICEF, 2021). As part of its commitments towards the Paris Agreement to mitigate climate change, and as part of its focus on ensuring a just transition, South Africa has committed to decreasing its carbon dioxide (CO_2) emissions to reach net-zero emissions by 2050 (PCC, 2022a). One of the challenges identified in achieving such an emissions target was the need for extensive investment in new power generation strategies, due to South Africa's current reliance on coal-based power (PCC, 2022b). Indeed, in 2021, approximately 72.1% of South Africa's energy needs were serviced by coal (Eskom, 2021), and the coal energy sector accounted for approximately 41% of South Africa's CO_2 emissions (World Bank, 2023), suggesting that any strategies for decreasing emissions and ensuring a just transition for South Africa are likely to have severe impacts on both the energy and coal industries.

South Africa's coal industry is geographically highly concentrated in the Mpumalanga province, with 80% of coal production occurring in the province (PCC, 2022a). According to estimates by Bhorat et al. (2024), employment in the coal mining sector was between 76 000 and 108 000 workers in 2019, and employment in the broader coal value chain was approximately 107 000 workers. On the other hand, Patel et al. (2020) estimate that the number of workers employed across the coal value chain is upwards of 120 000 and Makgetla and Patel (2021) estimate up to 200 000 jobs in the South African coal value chain. Irrespective of the actual number of estimated jobs, however, the key message is that a substantial proportion of Mpumalanga's labour force (between 5 and 10%) is reliant on the coal industry in some way or other. Bhorat et al. (2024) further show that there is a relative overrepresentation of youth in the coal mining industry, with approximately 48% of all coal mining workers falling between the ages of 15 and 34.[1] This suggests that work done to mitigate climate change in South Africa through a transition away from coal-based energy and the coal industry is likely to specifically impact the youth population in Mpumalanga.

Youth labour market outcomes are generally less favourable than those of non-youth, specifically as regards unemployment rates. Table 1 presents a summary of some key labour market statistics for youth and non-youth in Mpumalanga compared to the rest of South Africa, which indeed highlights that young people are more likely to be unemployed than non-youth, and moreover, young people in Mpumalanga are even more likely than young people in other parts of the country to be classified as unemployed. These statistics highlight that any transitions that may negatively impact the coal industry will specifically impact youth in Mpumalanga, and as a result, special care needs to be taken to ensure sufficient measures to assist and support displaced youth as they attempt to build their livelihoods in non-coal industries.

[1] The official definition of youth in South Africa is all those individuals aged between 15 and 34 years of age. Although there are differences in the definition of youth internationally, for the purposes of this paper, we adopt the South African definition.

Table 1: Labour market indicators for youth and non-youth, Mpumalanga and South Africa

	Youth				Non-youth			
	Mpumalanga		Rest of South Africa		Mpumalanga		Rest of South Africa	
	000s	(%)	000s	(%)	000s	(%)	000s	(%)
Population	1 669	-	19 117	-	1 460	-	18 567	-
Labour Force Participation Rate	-	50,4	-	50,6	-	71,0	-	69,2
Employed	431	-	5 361	-	757	-	9 952	-
Employment-to-population ratio	-	25,8	-	28,0	-	51,8	-	53.6
Unemployed (Narrow)	411	47,4	4 303	44,2	280	27,0	2 905	22,7
Unemployed (Broad)	604	58,4	5 908	52,4	423	35,8	4 131	29,3

Sources: Statistics South Africa (2023a; 2023b; 2023c; 2024a)
Notes: 1. Youth are defined as those individuals aged 15-34 years, while non-youth are those aged 35 to 64.

According to the International Labour Organisation (ILO, 2015), and subsequently summarised by García-García, Carpintero and Biendía (2020), the pursuit of a just energy transition – such as the one being pursued in South Africa – presents three key opportunities and three key challenges: Opportunities include the creation of net employment, the improvement of labour quality, and the promotion of social inclusion, while the challenges presented include substantial socioeconomic restructuring, adaptation to climate change, and the compensation of regressive political effects due to higher energy prices and negative effects of the transition on income distributions. It is clear that the creation of employment in South Africa's context will be an important contribution to economic development, however, it is likely that the just transition will leads to the creation of jobs that are relatively different to those that were destroyed as a result of the shift away from the coal industry.

The aim of this research is to identify which potential employment opportunities, created by a just energy transition, are feasible and accessible to young people. Our focus is on youth in the Mpumalanga province, due to their double vulnerability as a marginalised group likely to be affected by climate change and the just transition, as well as Mpumalanga's position as the nexus of South Africa's coal industry, which is likely to be severely negatively affected due to transitions towards a greener economy. We make use of task similarity measures to construct measures of occupational relatedness, which can proxy for the feasibility of employment transitions between occupations. This paper is part of a broader research project, commissioned by the University of Cambridge, which aims to understand youth perceptions on green jobs as well as how accessible these jobs are for youth. This project acts as an initial quantitative desktop exercise to identify feasible employment opportunities in South Africa, before a more qualitative fieldwork study will interrogate our results for the purposes of policy recommendations.

2. Background and Context

2.1 The labour market effects of the just transition

Research on the labour market effects of the just transition has been carried out across various countries, which are all at various stages of their transition away from coal-reliance. Bulmer et al. (2021) categorise countries into four categories: "advanced transitioners", who have phased out of coal to a significant degree; "partial transitioners", who have more recently moved towards a cleaner energy mix; "accommodators of domestic demand", who have increased reliance on coal due to increased domestic demand for energy; and "expanding coal exporters", who have increased the size of their coal industry in order to take advantage of increased export opportunities. By comparing and contrasting results from each category, key results from different stages of the just transition process can be highlighted, and a better understanding of overall labour market effects of the just transition can be understood.

Amongst advanced and partial transitioners, results on the labour market effects of shifting away from coal production have invariably shown large deleterious effects on employment in the coal mining sector (Bulmer et al., 2021; Hearer & Praston, 2015). The phasing out of coal economies led to the closure of mines in countries such as Poland, Germany and the UK, and at least 3 of every 4 mine workers losing their jobs due to these mine closures (Bulmer et al., 2021). For these displaced workers, new employment opportunities were not necessarily easily accessible in the short run (Sokołowski et al., 2022). Where employment opportunities existed – for example, in industries replacing the coal fields of Wales and the United Kingdom – the quality of the employment opportunity may not have been as favourable as those opportunities previously available in the mining sector (Beatty et al., 2007). A similar scenario presented itself in the United States, where a highly unionised coal sector meant that employment in the coal industry was generally well remunerated, and as a result, it was difficult to find equivalent opportunities in other industries in the event of a loss of coal jobs (Carley et al., 2018).

Studies on the South African labour market and the resulting impacts of the just transition are more recent in nature, given South Africa's position as an "early transitioner". Research aiming to model the employment effects of the just transition on the South African labour market suggest that while the just transition is likely to lead to a net increase in jobs for South Africa as a whole, Mpumalanga is likely to experience a net decrease in jobs due to its primary reliance on the coal industry (Nel, Marais & Mqotyana, 2023). This is consistent with the results of Montt et al. (2018) who find that most economies undergoing a just transition, or a decarbonisation process, are likely to experience net job growth during the transition period.

To further investigate the impact of employment losses in the Mpumalanga province during South Africa's just transition, Bhorat et al. (2024) undertook to measure the level of coal dependency in Mpumalanga. By using numerous data sources to ensure the accuracy of their estimates, Bhorat et al. (2024) estimate that approximately 46 100 coal households[2] exist in Mpumalanga, and for 60% of these households, a coal worker is the sole employed individual in the household. With an average coal household size of 3.6 (Bhorat et al., 2024), this suggests

[2] Bhorat et al. (2024) define "coal households" as households in which there is at least one coal worker.

that the transition away from the coal industry could have far-reaching impacts for a large number of individuals. Indeed, studies by the World Bank (2017) estimate that one additional job in either the coal or agriculture sectors in South Africa could lift up to 1.3 people out of poverty. Bulmer et al. (2021) report that the average wage of coal workers exceeds the average wage of workers in many other sectors of the economy, and thus, coal households are likely to experience large income and welfare shocks, even if alternative employment for coal workers is found quickly.

2.2 In search of "green jobs"

At an international level, the International Labour Organisation (ILO) advocates for policies and actions that mutually support the agendas of decent work and climate change mitigation (ILO, 2016). To do this, the ILO advocates for the creation of so-called "green jobs", which are described as jobs that aid in reducing adverse environmental impacts, are socially just, and which provide economic opportunities to those who are employed in them (ILO, 2016). Given the drive to create these "green jobs" in the context of countries adopting climate change mitigation policies and embarking on a just transition, it is likely that those individuals displaced from the coal industry are likely to be faced with finding employment in one of these green jobs. It is thus imperative to understand what types of jobs fall into this category of "green jobs" and also to what extent these employment opportunities can be accessed by the workers displaced from jobs in the coal industry.

One of the major challenges for understanding the employment opportunities that exist in green jobs is the lack of a universal or cohesive definition around what green jobs are. Valero et al. (2021) report that various studies have been conducted using differing approaches to define what they term "green jobs", and therefore, results surrounding the quantity and quality of green jobs vary by study. Two predominant approaches to classifying green jobs exist in the literature: First, the top-down approach, which defines green jobs as jobs falling within a specified set of industries that are directly related to decarbonisation and the green economy tend to estimate low proportions of green jobs in developed economies such as the United States and Europe (Department for Business, Innovation and Skills, 2015; Valero et al., 2021). On the other hand, bottom-up approaches, which define green jobs by classifying occupations according to their relation to decarbonisation, irrespective of the parent industry, yield higher estimates of green jobs (Consoli et al., 2016; Bowen et al., 2018; Robins et al., 2019; Valero et al, 2021). Yet other studies have analysed green jobs using the bottom-up occupation approach, but only within the context of certain sectors, such as the waste management sector (Kirov & van den Berge, 2012). Finally, some reports simply speak about the term "green jobs" without ever actually defining what is meant by this term (PCC, 2022a).

In an attempt to harmonise research on green jobs, a move was made to adopt the definition of green jobs as put forward by the Occupational Network (O*NET) database. The O*NET database categorises green jobs and occupations as "green new and emerging", "green enhanced skills" and "green increased demand" (Dierdorff et al., 2009). Occupations that are identified as "green new and emerging" or "green enhanced skills" are categorised as directly green due to their direct involvement in sustainability initiatives, while those occupations identified as "green increased demand" are categorised as indirectly green, as they support green economic activity, but do not necessarily involve any green tasks themselves (Dierdorff et al., 2009; Valero et al., 2021).

While the adoption of this taxonomy to identify green jobs is useful in aligning the focus of research, a main criticism of this categorisation is that the categorisation is outdated, since it has not been updated since 2010 (Valero et al., 2021). This will naturally lead to a number of contemporary green occupations being omitted, since they had not been envisioned at the time of the O*NET list's curation. In South Africa, specifically, there does not seem to be any specific formal definition of green jobs adopted by policymakers or government ministries, although the Department of Higher Education and Training (DHET) makes use of an adapted version of O*NET's green occupation list in their definition of green occupations (DHET, 2021).

2.3 Youth employment and green jobs in South Africa

There are multiple past and on-going nationally and locally driven initiatives in South Africa that have promoted the creation of jobs for youth to support environmental improvement programmes, promoted the development of the broader green economy, or both. These environmental improvement programmes include actions, policies, and interventions involving protection, restoration and sustainable management of ecosystems and farming/cultural lands and are also linked into 'green' or 'sustainable' value added industries and enterprise development. Together these actions and interventions can be grouped under the umbrella term "nature-based solutions".

The importance attached to the environment in promoting economic growth is highlighted in the Constitution – one of the key founding documents of democratic South Africa – in Section 24 (b) (iii) which states that everyone has a right to "secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development" (The Constitution of the Republic of South Africa, 1996: 9). This clause in the Constitution serves as basis for several policies and strategies in relation to South Africa's commitment to growing the green economy.

The Department of Environmental Affairs and Tourism launched the National Framework for Sustainable Development (NFSD) in 2008. The purpose of this document was to provide a foundation for the various tiers of government – local, provincial and national – to incorporate "sustainable development goals relating to the economy, society and the environment, and how governance systems will be capacitated to facilitate this process" (Department of Environmental Affairs and Tourism, 2008: 7). Included in the substantive principles of the NFSD are the "efficient and sustainable use of natural resources." (Department of Environmental Affairs and Tourism, 2008:7).

One policy intervention emanating from the NFSD is the Green Economy Accord, developed by the Economic Development Department (EDD), which aimed to create 300 000 new jobs in or supporting the green economy by 2020 (EDD, 2011). Although the policy goals of the Green Economy Accord included broader aims, such as electrification of poor communities, promotion of biofuels for vehicles, and the rollout of solar-water heating systems, commitment eleven of the accord specifically aimed to promote localisation, youth employment, cooperatives and skills development in the green economy (EDD, 2011). Specific commitments made to support the provision of youth employment in the green economy included ensuring that at least 80% of new employees from public and community works programmes designed for the installation of solar-water heating systems would be young people.

A further government initiative aimed at promoting the greening of South Africa's economy is the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), launched in 2011 to replace the process of feed-in tariffs in place at the time (Eberhard, Kolker & Leigland, 2014). The REIPPPP acts as a competitive tender process, whereby stakeholders from the private sector compete to be awarded contracts for the generation of energy via renewable sources, which can be used to supplement South Africa's electricity grid. The REIPPPP, in addition to promoting the greening of South Africa's economy, also has an explicit goal of economic development through job creation and economic empowerment, which is reflected in a heavy weighting (30%) assigned to economic development when assessing potential bids for the project (Eberhard & Naude, 2017).

From 2011 onwards, there were two key development strategies which discussed the green economy. The National Development Plan (NDP), launched in 2012, aimed to eliminate poverty and reduce inequality by 2030. One the key goals outlined in the NDP is to ensure environmental sustainability and an equitable transition to a low-carbon economy (NPC, 2012). To achieve this goal, the NDP suggests investment in skills, technology and institutional capacity which support the transition to a more sustainable economy (NPC, 2012). In particular, South Africa should develop environmentally sustainable products and services in which South Africa has a competitive advantage and which can generate a large number of jobs (NPC, 2012).

The Economic Reconstruction and Recovery Plan (ERRP), launched in 2020 by President Cyril Ramaphosa, aimed to strengthen the stagnating economy, which was further exacerbated by the onset of the Covid-19 pandemic. The ERRP recognised that the green economy could help address South Africa's persistent economic challenges such as unemployment and poverty. The ERRP highlights several interventions to facilitate the growth of the green economy, including (The Presidency, 2020):

- Assistance for as well as cooperatives to seize opportunities within the realm of the environmentally sustainable economy;
- Support for smaller grower farmers through public-private partnerships, particularly within the forestry sector; and
- The development of waste management plans, which, *inter alia*, aim to increase the level of recycling amongst identified products.

Additional programmes that have supported South Africa's green economy include non-specific financial programmes, such as the Black Industrialist Support Programme, supported by the Industrial Development Corporation, as well as capacity building projects such as those rolled out by the National Cleaner Production Centre (United Nations Environment Programme, 2020). Furthermore, tax incentives from the South African government have successfully promoted green R&D ventures, with the proportion of expenditure on Green R&D increasing by between 4.3% and 4.8% per annum between 2010/11 and 2016/17, and more than 100 000 green patents being registered in South Africa between 1977 and 2016 (United Nations Environment Programme, 2020).

Although the number of strategies, frameworks and policy initiatives focusing on the green economy have been plentiful, a lack of co-ordination between the various departments are hampering their efficacy. The ILO (2018) note, for example, that the Department of

Environmental Affairs and the EDD do not coordinate with regards to the Green Accord. The ILO (2018) report also highlights that coordination *within* government departments is poor. For example, there is minimal collaboration between various programmes - such as the active labour market policies, the Technical and Vocational Education Training colleges and on-the-job training initiatives – which are all under the auspices of the Department of Higher Education and Training (ILO, 2018).

A global focus on environmental sustainability has precipitated research into the various economic and social impacts of the just transition and the development of a green economy. In a country like South Africa, high unemployment and low labour market participation sharpens the focus of research on the impact that the greening of the economy will have on outcomes such as employment and economic mobility. Studies vary in terms of methodological approach and external validity; however, these studies all highlight important findings regarding green jobs and the youth.

One such study conducted in the Western Cape province focused on the impact of a public works programme implemented by the Western Cape Department of Environmental Affairs and Development Planning (DEADP). A qualitative study of youth engaged in this study found that the implementation of such a public works programme that opened temporary green job opportunities to youth had positive impacts on future economic outcomes, including employment (Dladla, 2020). Participants in this study were young workers who were primarily engaged to assist with the installation of solar powered geysers and plumbing at low-cost houses built by the government. This type of work required training of young people, which is consistent with the findings of Mwaura and Glover (2021), who suggest that many green jobs are knowledge-intensive and require workers to undergo substantial training before they are viable employment opportunities.

Dladla (2020) further suggests that the results of the public works programme's success are indicative that there is scope to upscale and implement such employment programmes on a broader scale throughout South Africa. Indeed, findings by C40 Cities (2021) suggest that the largest employment opportunities to emerge from greening the South African economy are likely to be in the field of upgrading homes, schools and workplaces to make them more energy efficient. It is estimated that jobs of this sort could account for up to 900 000 jobs created in South Africa by 2030 (C40 Cities, 2021). Thus, the DEADP's public works programme may well have provided youth with key transferable skills that will stand them in good stead for future green job opportunities in South Africa.

Although these studies provide a positive outlook on the impact of greening the South African economy, Mwaura and Glover (2021) highlight some challenges related to green jobs on the broader African continent that may be relevant in the South African case. They suggest, for example, that there is little reason to believe that African youths' attitudes towards green jobs are fundamentally different to attitudes towards jobs in other sectors. This, in combination with the fact that some green jobs are relatively more knowledge-intensive, may be of concern in the South African setting, since the already high rate of youth unemployment may mean that young people will forgo green jobs that require extensive training, for lower-paying jobs since a low wage is preferable to no wage whatsoever (Mwaura & Glover, 2021). This suggests the need to ensure not only the presence of green jobs, but the relevant support mechanisms to

support young people to achieve the skills required to enter these jobs. These findings are well aligned with the focus of our proposed research, emphasising the importance of access to skills as well as perceptions and attitudes towards green jobs as factors contributing to the extent to which green jobs are accessible to and accessed by young people.

3. Data

3.1 The Quarterly Labour Force Survey (QLFS)

One of our main data sources for our analysis is Statistics South Africa's (Stats SA) Quarterly Labour Force Survey (QLFS). The QLFS is an individual-level household survey, comprising approximately 30 000 dwelling units across South Africa, which collects information on a variety of labour market indicators and acts as South Africa's source of official labour market statistics (Stats SA, 2024b). Of particular use to us for our analysis is the presence of variables that provide codes for both current and previous occupations of workers at the 4-digit level of disaggregation according to South Africa's Standard Classification of Occupations (SASCO) taxonomy. The SASCO taxonomy is a localised version of the International Standard Classification of Occupations (ISCO) framework (Stats SA, 2012), where additional digits in the taxonomy refer to more and more disaggregated descriptions of the work being done by individuals within that particular classification. Examples of 4-digit occupation codes in the SASCO taxonomy include "Farmhands and labourers"; "Data entry operators"; and "General managers of hotels, restaurants, and other catering or accommodation services", among others.

The sampling and weighting design of the QLFS ensures that estimates within a given wave are representative at the national and sub-national levels, with representative estimates available down to the individual metropolitan and non-metropolitan area (Stats SA, 2024b). We opt to pool all four quarters of the QLFS data from 2023 into one master dataset for analysis. This is done for a number of reasons: First, one of the key units of analysis in this study is an individual's occupation, and thus, it is important that there are sufficient observations for each occupation to provide meaningful results. This becomes especially key when we consider that we will only be analysing the sample of youth aged between 15 and 34 (inclusive), which accounts for approximately 32% of the total number of observations in a given wave of the QLFS (Stats SA, 2023a; 2023b; 2023c; 2024a). In total, after pooling the data, we are left with a total of 22 007 observations of employed young people across 333 unique 4-digit occupation codes. Of this sample, a total of 1 817 observations were for employed youth in the Mpumalanga province (8.26% of the total; unweighted).

Second, the pooling of four quarters of data will remove the effects of seasonality from the data which could otherwise have been present if only a single quarter of data had been used. By pooling data across an entire year, we should, in theory, capture a more representative picture of the employment structure of Mpumalanga. Related to this point, by its nature, the process of sampling may not capture every single occupation present in Mpumalanga in a given quarter. Since the structure of the QLFS does not result in representativity at the occupation level, it is possible that some occupations will not be captured in some quarters. Pooling multiple quarters of data together, coupled with the rotating panel approach to sampling

employed by the QLFS[3], decreases the likelihood of a given occupation never being sampled, and thus somewhat ameliorates our concern around missing occupations in the sample. Note, however, that this does not in any way guarantee that every possible occupation in Mpumalanga is indeed sampled; rather, it simply suggests that we are better able to capture a wider number of these occupations.

3.2 The Occupational Information Network (O*NET)

Our second source of data used in this analysis is the Occupational Information Network (O*NET). O*NET is an American occupational survey, which includes information on over 1000 standardised occupations, and is compiled through interviews with both incumbent employees as well as occupational experts (O*NET, 2024a). Data collected comprise information on a variety of occupational metrics such as abilities, skills and knowledge measures, which are reported in a way so as to facilitate quantitative comparisons between occupations. These data are freely available to the public and updated quarterly. In this report, we make use of version 28.2, which corresponds to the February 2024 update of O*NET. Although newer versions of the O*NET data are available at time of writing, we opt for version 28.2 as it is the most recent update of the O*NET data following the end of 2023 – i.e., the end of our QLFS sample period.

In this analysis, in order to create a measure of occupational similarity, we only make use of a subset of descriptors provided in the O*NET database: namely, Work Activities indicators. For each of the approximately 1 000 occupations in the O*NET data, there are 41 distinct work activities, which are each graded according to two distinct elements: “importance” and “level”. Work activities, as captured in the O*NET data, are generalised statements based on a qualitative aggregation of 19 450 detailed task statements, using activities, objects, purpose, context and technology to create statements related to generalised work activities (Hansen et al., 2014). Examples of work activities reported in the data include “handling and moving objects”; “thinking creatively”; or “processing information”. The importance of a work activity ranges from 1 to 5 and attempts to measure how critical being able to perform the given task is for an employee in that occupation. The level of a work activity, on the other hand, is a value between 0 and 7 and can be thought of as how complex the given task is for the occupation. As an illustrative example, while the activity of “processing information” is very important for both financial analysts and order clerks, financial analysts are required to perform information processing at a higher level than order clerks.

The use of the O*NET data to understand aspects of the South African labour market raises concerns surrounding the comparability of occupational task content in the United States to the developing world. In particular, the use of the O*NET work activities data is only useful to us in understanding occupational relatedness in a South African context insofar as we believe that the tasks undertaken by occupational incumbents is similar in the United States and South Africa. We nevertheless push forward with this analysis for two main reasons: First, there does not yet exist any comprehensive measure of task content within occupations measured in the

[3] The rotating panel aspect of the QLFS sampling strategy stipulates that the QLFS sample is made up of four equally-sized rotation groups and that every quarter, one of these rotation groups (i.e., 25% of the overall sample) is replaced with newly sampled dwelling units. These newly sampled dwelling units will remain in the sample for four quarters. By design, each of the four rotation groups are constructed so as to have the same distributional pattern that is observed in the sample as a whole (Stats SA, 2024b).

same way as is done through O*NET. Given that the core method of conducting this occupational relatedness analysis is predicated on research that has made use of the O*NET work activities data (Mealy, del-Rio Chanona & Farmer, 2018), the lack of a localised South African equivalent measured in the same or similar ways to O*NET limits the options for diverting from the existing methodologies. Second, existing research on occupational relatedness in the South African labour market has made use of the O*NET work activities data in its analysis (Allen Whitehead et al., 2021; Bhorat et al., 2023), and thus, we adopt the use of O*NET data to ensure the comparability of our results.

3.3 Green Occupations: The Organising Framework for Occupations

As mentioned above, there is no universally accepted definition of green jobs, however, for the purposes of this study, a working definition of green jobs is necessary. To this extent, we choose to adopt the definition of green jobs as put forward by the Department of Higher Education and Training (DHET) in their Organising Framework for Occupations (OFO). The OFO, similar to the SASCO, is an occupational framework developed by DHET closely linked to the 2008 iteration of the ISCO taxonomy, but adapted to the South African context (DHET, 2013). Unlike SASCO, however, the OFO has, since 2013, provided a classification of occupations into categories defined as "green occupations" and "occupations requiring additional critical green skills" (DHET, 2013).

Green occupations are defined in the OFO as those occupations which have as their direct purpose the aim of reducing negative environmental impacts and positively contributing towards sustainability (DHGET, 2013). Specifically, the OFO classifies green occupations as those occupations which include descriptors related to the following objectives:

- Developing and adoption of renewable sources of energy
- Reducing consumption of energy, fossil fuels and raw materials
- Enhancing energy and resource efficiency
- Reducing greenhouse gas emissions
- Decreasing waste and pollution
- Recycling materials
- Preventing the loss of biodiversity and restoration of ecosystems

On the other hand, occupations requiring additional critical green skills are defined as those occupations which require shifts in their focus in order to contribute towards the objectives mentioned above (DHET, 2013). Put differently, an occupation requiring additional critical green skills is an occupation which requires some form of additional or changed skillset to maintain its relevance in a green economy (DHET, 2013).

Overall, the OFO classifies 96 occupations as "green occupations", while there are 51 occupations classified as "occupations requiring additional critical green skills". For the purposes of this study, we focus purely on the 96 green occupations. We opt to exclude the 51 occupations requiring additional critical green skills due to the fact that, by definition, these occupations "do not meet the requirements [for] green occupations" (DHET, 2013:13) and as such are not of particular interest to our study on green jobs.

In the following section, we describe the methods employed on these three datasets to identify those green occupations that act as potentially feasibly employment diversification opportunities for young people in Mpumalanga.

4. Method

4.1 Measuring task similarity

Our study aims to investigate the extent to which green jobs or occupations can be seen as feasible employment opportunities for young people affected by the just transition in South Africa – particularly in the Mpumalanga province. One way of measuring the feasibility of green jobs as potential employment opportunities is through the concept of occupational relatedness. The theory of occupational relatedness suggests that job-to-job transitions are better predicted by measures of task similarity between occupations than through other existing benchmark measures (Mealy, del-Rio Chanona & Farmer, 2018). Thus, measuring the task similarity of green occupations relative to current South African youth jobs could provide a measure of how feasible it is for youth to access green jobs and occupations, given their current employment status and associated skillset.

Following the method proposed by Mealy, del-Rio Chanona and Farmer (2018), we make use of O*NET data on occupations' work activities, as described in Section 3.2. Specifically, we follow the method used by Mealy, del-Rio Chanona and Farmer (2018) and make use of the importance score for work activities to create Relative Importance Indicator (RII). The RII is based on the definition of Revealed Comparative Advantage put forward by Balassa (1965), but adapted to the occupational context. Mathematically, the formula to calculate the RII for a given work activity, w, and a given occupation, i, is shown in equation (1).

$$RII_{w,i} = \frac{\frac{X_{w,i}}{\langle X_{w,i} \rangle_w}}{\frac{\langle X_{w,i} \rangle_i}{\langle X_{w,i} \rangle_{w,i}}} \quad (1)$$

$X_{w,i}$ here represents the importance score for work activity w in occupation i; $\langle X_{w,i} \rangle_w$ represents the average importance of all work activities within occupation i; $\langle X_{w,i} \rangle_i$ represents the average importance of work activity w across all occupations; and $\langle X_{w,i} \rangle_{w,i}$ represents the average importance score of all work activities across all occupations. Altogether, the construction of the RII can be interpreted as a measure of whether work activity w is relatively more important for occupation i than it is for all other occupations captured in the O*NET data. Although this construction of the RII provides a continuous-scale output, we follow Mealy, del-Rio Chanona and Farmer (2018) and collapse it into a binary indicator ($I_{w,i}$) whereby the new variable is equal to 1 if $RII_{w,i} > 1$ and 0 otherwise. This means that $I_{w,i}$ is an indicator variable depicting whether work activity w is relatively more important in occupation i than it is for other occupations in the labour market.

We make use of the importance of a work activity as a proxy representing the task content of an occupation, and as a result, if occupations have similar work activities flagged as relatively important, we will assume that these occupations have similar task content. A more formal

notion of this similarity between occupations is based on the notion of proximity as proposed by Hidalgo et al. (2007) and applied by Allen Whitehead et al. (2021) to the South African manufacturing sector. Proximity (Φ) is intuitively understood as the likelihood that two occupations, i and j, exhibit the same list of work activities with relative importance. It is technically calculated by computing the minimum[4] of the conditional probability that occupation i has listed a set of work activities as important, given that occupation j has listed that set of work activities as important, and the conditional probability that occupation j has listed a set of work activities as important, given that occupation i has listed that set of work activities as important. Mathematically, this calculation is represented in equation (2) below.

$$\Phi_{i,j} = \mathbf{min}\left\{\frac{\Sigma_w I_{w,i} I_{w,j}}{\Sigma_w I_{w,i}}; \frac{\Sigma_w I_{w,i} I_{w,j}}{\Sigma_w I_{w,j}}\right\} \quad (2)$$

4.2 Linking occupational data across datasets: Crosswalks

The previous sections have outlined the various sources of information that we use in order to conduct our analysis of green jobs in South Africa. However, these datasets cannot be directly linked due to differences in the taxonomies used to classify occupations. O*NET makes use of the O*NET Standard Occupational Classification (O*NET-SOC); our list of green occupations makes use of the OFO taxonomy; and the QLFS makes use of the SASCO taxonomy. Thus, we make use of crosswalks and concordance tables in order to harmonise the occupational taxonomies across the various datasets and bridge the gap between the various occupational taxonomy nomenclatures used by different data sources.

We begin by making use of publicly available crosswalks obtained from the O*NET website as well as through the Institute for Structural Research (IBS), which allow us to move from the O*NET-SOC 19 occupational classification to ISCO occupational classification (O*NET, 2024b; Institute for Structural Research (IBS), 2016). The next step is to merge occupations classified according to the ISCO taxonomy to the South African SASCO taxonomy. Classification of occupations in the QLFS is done according to the SASCO 2003 taxonomy, which is based on the ISCO-88 taxonomy, with occupations added for the South African context. In order to harmonise the SASCO taxonomy with the ISCO-88 taxonomy, a number of SASCO occupation codes were assigned international equivalences with ISCO occupation codes. A list of these occupations and their assigned ISCO equivalence are provided in Table A 1 in the Appendix. Prior to the reclassification exercise, approximately 93.03% of all observations for currently employed youth in South Africa were successfully harmonised using crosswalks, and 94.62% of unemployed youth who had previously been employed. However, after reclassification, the match quality improved to 98.56% of all observations for employed youth and 98.38% for previously employed youth.

The next step of the crosswalk process is to harmonise occupational classifications between the QLFS and the OFO, so as to merge in information about green occupations. The OFO

[4] The minimum of these two probabilities is used to satisfy the condition that any distance function defined on a metric space be symmetric (Khamsi & Kirk, 2001). Given that the proximity between two occupations is inversely related to the distance between these occupations, proximity values must be symmetric to ensure symmetric distance values between occupations.

taxonomy is based largely on the ISCO-08 taxonomy, with only minor changes and adaptations for the South African context. As a result, mapping the 2021 OFO taxonomy to the ISCO-08 taxonomy is relatively straightforward. However, certain assumptions do need to be made at this point. Green occupations in the OFO taxonomy are identified at the 6-digit level of disaggregation, while the level of disaggregation for all other crosswalks up to now has been at the 4-digit level. As a result, we employ the hierarchical structure of the OFO to mark the 4-digit occupation code which includes a given 6-digit "green occupation" as a 4-digit level green occupation in the ISCO-08 taxonomy.

Hereafter, we note that the OFO taxonomy is based off of ISCO-08, while the QLFS occupational taxonomy is based off of the ISCO-88 taxonomy. We thus make use of a correspondence table from the International Labour Organization (ILO) to map occupations from their ISCO-08 to their ISCO-88 equivalences (ILO, 2024). Given changes in the approach to classifying occupations between the two ISCO taxonomies, there are a number of instances where multiple ISCO-08 occupational codes cover a single ISCO-88 occupational code, and vice versa. To translate information on green occupations across the two taxonomies, we assume that any ISCO-88 occupational code that corresponds to an ISCO-08 green occupation code (even if only partly) gets flagged as a green occupation for our analysis.

The harmonisation of this information allows us to combine data on South African occupations with proximity values calculated using O*NET data, as well as information on green occupations as captured in the OFO data. This harmonised dataset forms the basis of much of our further analysis.

4.3 Construction of the occupation space

In the context of world trade, Hidalgo et al. (2007) and Hausmann et al. (2014) present a visual representation of the interconnectedness of products and the underlying capabilities required to produce them. This diagrammatic representation is known as the product space. Based on the notion of producing a visual depiction of the relationships between occupations, Mealy, del-Rio Chanona and Farmer (2018) and Allen Whitehead et al. (2021) followed similar procedures to Hidalgo et al. (2007) to produce network diagrams of the occupation space. We replicate this method to produce our own visualisation of the occupation space.

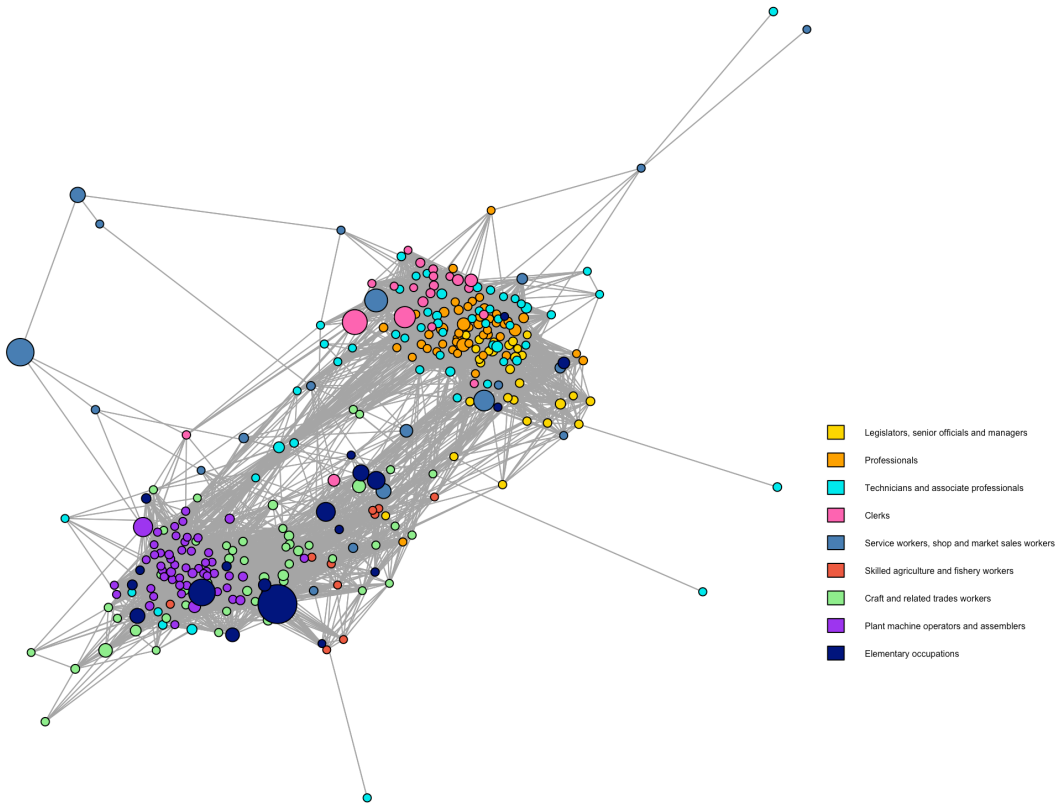
To produce the occupation space, we make use of all pairwise proximity values (calculated according to equation (2) above) transposed into a symmetric proximity matrix, Φ. In creating the network visualisation of the occupation space, we identify occupations as nodes, which are connected by edges. We construct the diagram such that the length of the edges between nodes is inversely proportional to the proximity between occupations, thus meaning that occupations that are more closely related are situated closer to one another visually. We make use of the network visualisation algorithm proposed by Fruchterman and Reingold (1991) to construct an undirected network diagram making use of force-directed spring layout, using the proximity matrix as edge weights.

Consistent with the approaches in the literature (Hidalgo et al., 2007; Hausmann et al., 2014; Mealy, del-Rio Chanona & Farmer, 2018; Allen Whitehead et al., 2021; Allen Whitehead & Bhorat 2021), we do not plot all possible connections modelled by the proximity matrix, but

instead, we filter the connections to only keep the strongest-linked occupations. We follow the same rule of thumb as Mealy, del-Rio Chanona and Farmer (2018) and Allen Whitehead et al. (2021) to determine the optimal number of connections to include in the diagram. This rule of thumb is to plot only those connections which are more than one standard deviation higher than the mean proximity between all occupations.

The resulting occupational space, where nodes are sized according to the share of South African employment in a given occupation, and the nodes are coloured according to the 1-digit SASCO major groups is represented in Figure 1 below. The way in which nodes are sized and shaded will be adapted during the remainder of this paper, however, we opt to present this depiction of the occupation space here as a representation of the broad South African occupation space. Consistent with the occupation space produced by Allen Whitehead et al. (2021), this occupation space is dumbbell-shaped, with a clear dichotomy between production and non-production occupations in the south-west and north-east corners of the occupation space respectively.

Figure 1: The South African occupation space



Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a) and O*NET (2024)
Notes: 1. Nodes sized according to share of total South African employment in the 4-digit occupation represented by a given node. 2. Colour coding of nodes according to 1-digit SASCO major group.

4.4 Identifying occupation bundles

To focus our analysis more specifically on the Mpumalanga province and the green occupations that will be accessible to Mpumalanga's youth population, we create an "occupation bundle"

that represents the occupations that are relatively more prevalent in Mpumalanga's labour market relative to the rest of South Africa. By constructing occupation bundles, we can form a picture of the types of skills and tasks young people in Mpumalanga have, and to what extent these skills and task competencies can be transferred into green jobs.

To do this, we make use of the same concept of Revealed Comparative Advantage as described in equation (1) above but replace the importance scores for work activities with shares of employment in a given occupation. In other words, we make use of the 2023 QLFS data to estimate the share of employment in a given occupation in Mpumalanga and in South Africa as a whole.[5] We then calculate the ratio of Mpumalanga's employment share to South Africa's employment share, and flag occupations as in Mpumalanga's occupation bundle if this ratio is greater than 1, or not in Mpumalanga's occupation bundle if this ratio is less than 1. This exercise is carried out for the population of currently employed youth in Mpumalanga. When constructing an occupation bundle for employed youth in Mpumalanga, there are a total of 85 out of 324 SASCO 4-digit occupations which appear relatively more frequently in Mpumalanga. This accounts for a total of 63.69% of current youth employment in Mpumalanga.

When constructing an occupation bundle for the unemployed youth, it is less clear that a measure of occupational prevalence computed through the method of Revealed Comparative Advantage is of analytic use. This is because it is not clear that having a higher relative concentration of unemployed youth with a specific previous occupation is valuable in identifying future employment opportunities for these youth. Instead, we flag the top 20 previous occupations reported by unemployed youth in Mpumalanga as being in the Mpumalanga unemployed youth occupation bundle. This approach accounts for approximately 72.9% of unemployed youth, and thus, we believe provides a valuable proxy for the types of skills that unemployed youth in Mpumalanga are likely to have.[6]

After applying the relevant crosswalks to this data to obtain information at the 4-digit level for the OFO taxonomy[7], we find that 119 out of 636 occupations are relatively concentrated in Mpumalanga for employed youth, and 45 out of 636 occupations are relatively concentrated in Mpumalanga for unemployed youth who have been previously employed. Details of the occupation bundles, including both ISCO-88 and 2021 OFO codes, are reported in Table A 2 and Table A 3 in the Appendix for the employed youth and unemployed youth in Mpumalanga, respectively.

[5] These shares are weighted using the provided sampling weights in the QLFS data to ensure that the shares are representative of the relevant population of interest.

[6] The choice of the top 20 occupations is somewhat arbitrary. This figure is chosen as a balance between ensuring that the number of occupations in the occupation bundle is not too large (thus rendering the occupational analysis and calculated proximity of occupations redundant) and ensuring that a sufficient proportion of the unemployed population in Mpumalanga is captured, thereby ensuring a reasonable approximation of the types of skills likely held by these individuals.

[7] Given that information regarding employment shares is only available at the 4-digit level of SASCO in the QLFS data, we can only identify those OFO codes in the occupation bundle at the 4-digit level.

4.5 Identifying proximate occupations

As discussed above, the identification of an occupation bundle provides an abstracted construct of the "representative" task competencies and skills of the population of interest. Our analysis then aims to identify which green occupations would be considered proximate enough to the set of occupations in the occupation bundle so as to make the employment transition feasible for youth in the subpopulation of interest – i.e., for those who are currently employed, or for those who are currently unemployed.

To do this, we make use of our derived proximity matrix, Φ, to calculate a "distance" between a given green occupation and the relevant occupation bundle. This notion of distance (d) is based on the formula presented by Hidalgo et al. (2007) and Mealy and Teytelboym (2022) for density (ω)[8], and is mathematically given in equation (3) below.

$$d_{i,B} = 1 - \frac{\sum_j RCA_j \Phi_{i,j}}{\sum_j \Phi_{i,j}} \quad (3)$$

Specifically, $d_{i,B}$ represents the distance of occupation i from the occupation bundle, B. The distance between occupation i and occupation bundle B will be a value between 0 and 1, such that larger values of d indicate occupations that are further away from the occupation bundle, and thus, less similar in terms of task similarity, and thus, less feasible as an alternative employment opportunity without reskilling of workers.

5. Results

In this section, we present the results of our analysis. We have divided the results into four sections: First, we provide a simple overview of green occupations in the Mpumalanga labour market as compared to the rest of South Africa. Secondly, we present the results of our occupational analysis for employment diversification in the case of employed Mpumalanga youth. Third, we present the same occupational analysis, but for unemployed youth with a previous occupation. Finally, we combine the results of the occupational relatedness in a way that may provide insight for policymakers as to which occupations may be useful to target as employment opportunities for Mpumalanga youth.

5.1 An overview of green occupations in the Mpumalanga labour market

As discussed above, Mpumalanga is currently the hub of South Africa's coal-based economy, and as a result, it is not clear how easily, or in what context, green occupations will be able to take hold in the Mpumalanga labour market, particularly for the youth. That is to say, it is not clear that the just transition will simply result in a shift from coal-fired power station jobs to equivalent types of jobs in green power stations, for example. It may be that the types of green occupations currently present in Mpumalanga are structurally different to those occupations that are envisioned as employment opportunities as a result of the transition away from a coal-

[8] Distance is defined as the inverse of density (Bustos and Yildirim, 2014), which itself is defined as $\omega_{i,j} = \frac{\sum_j RCA_j \Phi_{i,j}}{\sum_j \Phi_{i,j}}$ (Hidalgo et al., 2007; Mealy & Teytelboym, 2022).

based economy. It is thus important to understand the current state of green employment in Mpumalanga to ensure that any new employment opportunities are sufficiently supported in order to ensure longevity and stability of these jobs in the future.

In Table 2, below, we estimate the proportion of green occupation employment across 1-digit Standard Industrial Classification (SIC) groupings, for youth and non-youth in both Mpumalanga and the rest of South Africa. Overall, the proportion of individuals employed in green occupations is slightly higher in Mpumalanga than in the rest of South Africa, at 12.6% for youth and 13.2% for non-youth. This difference to the rest of South Africa is significant at the 10% level for youth and at the 1% level for non-youth, indicating that Mpumalanga is already significantly “greener” than the rest of the country.

At a more disaggregated level, we can see that the manufacturing and construction industries in Mpumalanga are greener, in terms of employment shares, than they are in the rest of South Africa for both youth and non-youth. Specifically, we note that the share of employment in green manufacturing is approximately 39.0% higher in Mpumalanga relative to the rest of South Africa for youth, and 60.7% higher in Mpumalanga relative to the rest of South Africa for non-youth. Similarly, nearly half of all Mpumalanga youth in the construction industry are employed in green occupations, compared to just over one-third in the rest of South Africa. Although this difference is less stark for non-youth, there is still a 5.7 percentage point greater share of green employment in construction for non-youth in Mpumalanga relative to the rest of South Africa.

Table 2: Share of green occupation employment by population and industry

	Youth		Non-youth	
	Mpumalanga	Rest of South Africa	Mpumalanga	Rest of South Africa
N	428 459	5 333 529	752 443	9 912 134
Agriculture, hunting, forestry and fishing	0.006 [-0.005; 0.017]	0.009 [0.004; 0.015]	0.020 [-0.007; 0.046]	0.010 [0.005; 0.015]
Mining and quarrying	0.060 [-0.006; 0.126]	0.123 [0.08; 0.165]	0.083 [0.033; 0.132]	0.097 [0.066; 0.128]
Manufacturing	0.146 [0.068; 0.224]	0.105 [0.085; 0.126]	0.172 [0.083; 0.261]	0.107 [0.091; 0.122]
Electricity, gas and water supply	0.270 [0.121; 0.418]	0.503 [0.332; 0.673]	0.443 [0.326; 0.561]	0.447 [0.358; 0.535]
Construction	0.485 [0.376; 0.593]	0.357 [0.324; 0.391]	0.381 [0.296; 0.466]	0.324 [0.299; 0.349]
Wholesale and retail trade	0.081 [0.051; 0.111]	0.069 [0.059; 0.078]	0.143 [0.107; 0.18]	0.096 [0.086; 0.106]
Transport, storage and communication	0.045 [-0.018; 0.107]	0.045 [0.027; 0.063]	0.053 [0.011; 0.094]	0.045 [0.031; 0.059]
Financial and business services	0.069 [0.026; 0.113]	0.112 [0.096; 0.129]	0.063 [0.032; 0.094]	0.081 [0.071; 0.091]
Community, social and personal services	0.145 [0.076; 0.214]	0.100 [0.086; 0.113]	0.128 [0.091; 0.164]	0.112 [0.102; 0.122]
Private households	0.000 -	0.001 [-0.001; 0.004]	0.002 [-0.002; 0.007]	0.001 [0; 0.001]
Other	0.000 -	0.000 -	0.000 -	0.065 [-0.046; 0.177]
Total	**0.126 [0.106; 0.146]**	**0.106 [0.101; 0.112]**	**0.132 [0.117; 0.147]**	**0.105 [0.101; 0.110]**

Source: Authors' calculations from Statistics South Africa (2023a; 2023b; 2023c; 2024a); DHET (2021)
Notes: 1. Industries defined according to 1-digit SIC industry codes. 2. All estimates are weighted and corrected for complex survey design. 3. Figures in square parentheses below estimates represent 95% confidence intervals. 4. Youth are defined as those individuals aged 15-34 years, while non-youth are those aged 35 to 64.

On the other hand, youth employment in green occupations is substantially lower in the Mpumalanga utilities sector relative to the rest of South Africa, with only just over one quarter of all youth employed in utilities being employed in green occupations. This stands in contrast to the approximately 50% of youth in the utilities sector employed in green occupations for the rest of South Africa. There is a similar result in the mining and quarrying sector, where the share of youth employment in green jobs is only 6% in Mpumalanga, compared to 12.3% in the rest of South Africa. Interestingly, in both cases, this difference dissipates for non-youth employment shares in green occupations. This result likely reflects the relative concentration in Mpumalanga of South Africa's coal mining sector.

When considering the differences between green jobs and non-green jobs, it is not clear that green jobs differ significantly from non-green jobs in Mpumalanga. Table 3 presents a comparison of green jobs and non-green jobs in Mpumalanga as well as for the rest of South Africa. These comparisons consider differences in the demographic make-up of employees, as well as differences in job characteristics, including measures of job quality. In Mpumalanga, there are very few significant differences between green and non-green jobs, except that our measures of job quality, including access to paid leave, parental leave, and employer

contributions to pension funds and unemployment insurance are lower for green occupations than for non-green occupations. This is particularly interesting given that the share of green jobs in the formal sector seems to be slightly (although not statistically significantly) higher than the share of non-green jobs.

Table 3: Comparison of green jobs and non-green jobs in Mpumalanga and the rest of South Africa

	Mpumalanga			Rest of South Africa		
	Non-green jobs	Green jobs		Non-green jobs	Green jobs	
Female	0.44	0.39		0.46	0.34	***
	(0.02)	(0.04)		(0.01)	(0.01)	
Years of education	11.45	11.39		11.71	11.82	
	(0.09)	(0.23)		(0.03)	(0.08)	
Population group						
African	0.93	0.94		0.77	0.74	**
	(0.01)	(0.02)		(0.01)	(0.01)	
Coloured	0.00	0.00		0.13	0.13	
	(0.00)	-		(0.00)	(0.01)	
Asian/Indian	0.01	0.00		0.03	0.03	
	(0.01)	-		(0.00)	(0.01)	
White	0.05	0.06		0.07	0.10	***
	(0.01)	(0.02)		(0.00)	(0.01)	
Sector						
Formal	0.64	0.69		0.76	0.76	
	(0.02)	(0.04)		(0.01)	(0.01)	
Informal	0.31	0.31		0.20	0.24	***
	(0.02)	(0.04)		(0.01)	(0.01)	
Private Households	0.05	0.00	***	0.04	0.00	***
	(0.01)	-		(0.00)	(0.00)	
Job characteristics						
UIF contributions	0.56	0.43	*	0.64	0.65	
	(0.03)	(0.06)		(0.01)	(0.02)	
Access to paid leave	0.54	0.44	*	0.63	0.62	
	(0.03)	(0.06)		(0.01)	(0.02)	
Access to sick leave	0.61	0.54		0.69	0.66	*
	(0.02)	(0.06)		(0.01)	(0.02)	
Access to parental leave	0.42	0.32	**	0.49	0.52	
	(0.03)	(0.05)		(0.01)	(0.02)	
Pension fund contributions	0.33	0.24	**	0.35	0.39	**
	(0.02)	(0.04)		(0.01)	(0.02)	
Written contract	0.74	0.79		0.81	0.84	*
	(0.02)	(0.05)		(0.01)	(0.01)	

Source: Authors' calculations from Statistics South Africa (2023a; 2023b; 2023c; 2024a); DHET (2021)
Notes: 1. Standard errors presented in parentheses below estimates. 2. Asterisks (*) represent level of statistical significance for test of equality between non-green jobs and green jobs for a given subpopulation: *** p<0.01; ** p<0.05; * p<0.1.

However, when considering how green jobs compare to non-green jobs in the rest of South Africa, a slightly different picture emerges: Firstly, in broader South Africa, employees in green jobs are significantly less likely to be female than employees in non-green jobs. It is not clear whether this is because of a lack of opportunities or simply because of occupation selection, however, the result that green jobs are male dominated is consistent with findings in Latin America (Alvarez, 2024). As a result, this result is important for policymakers, as it suggests that perhaps work needs to be done to promote female employment in green jobs to ensure that women are not further marginalised by the just transition. Secondly, the racial composition of green job employees shows that African individuals are significantly less likely to be employed

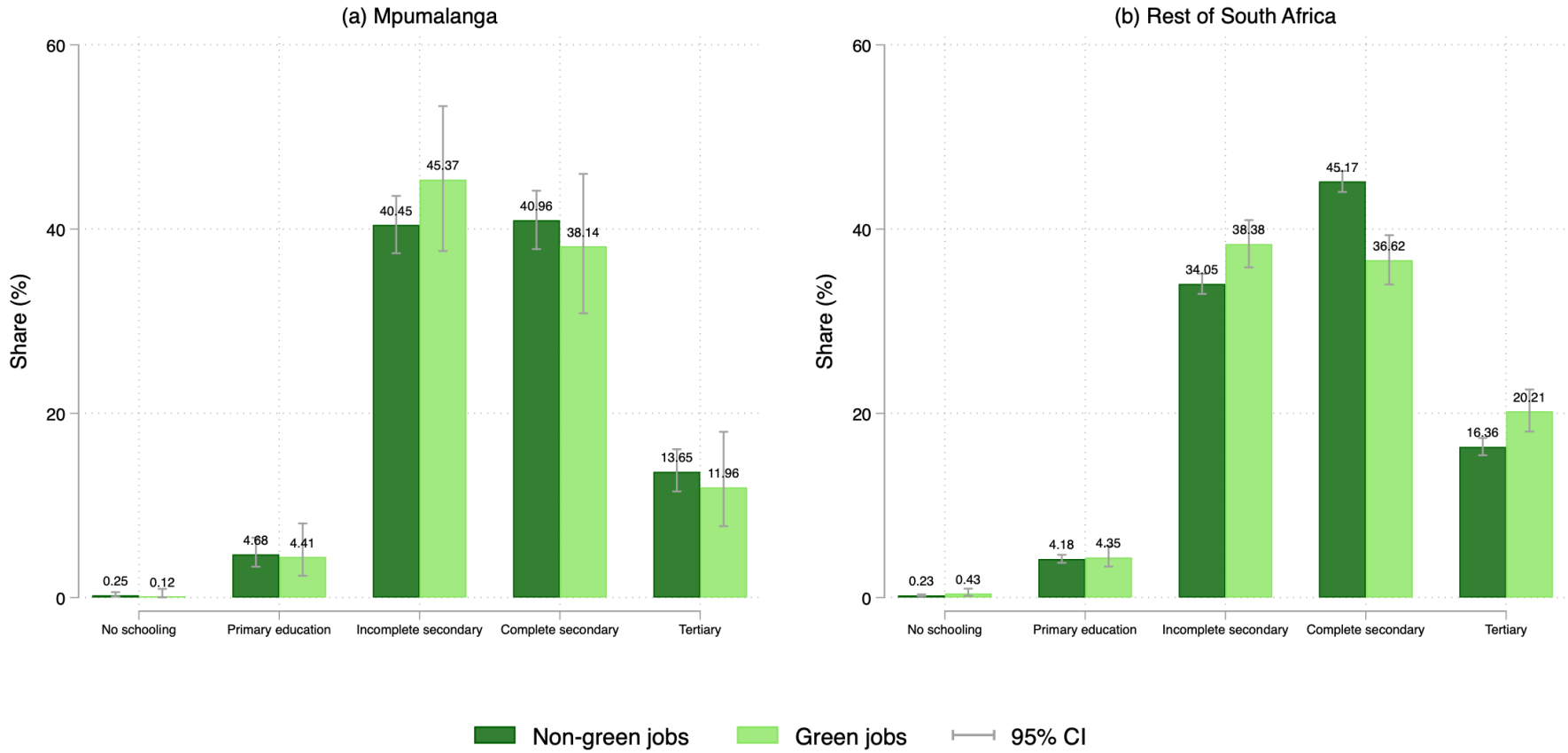
in green jobs, while White individuals are significantly more likely to be employed in green jobs. This result is not replicated in Mpumalanga; however, it is important to ensure that any employment opportunities in green jobs presented by the just transition actively support African employment to ensure that African people are not further marginalised by the transition.

Furthermore, green jobs are significantly more likely to be in the informal sector than non-green jobs, although this difference is predominantly accounted for by the presence of private household employment among non-green jobs. Finally, most job quality differentials present between green and non-green jobs in Mpumalanga disappear in the rest of South Africa, and in fact, where significant differences between green jobs and non-green jobs do exist, they are generally in favour of green jobs – i.e., greater proportions of employees in green jobs are employed on the basis of a written contract, as well as a greater share of green job employees having employer pension contributions.

Although Table 2 shows no significant differences in the average years of education required for a green job and a non-green job, we opt to investigate this result further. According to Consoli et al. (2016), green jobs generally require higher levels of education and skills than non-green jobs. To further investigate this in the South African context, we plot out the distribution of employee education levels in both green jobs and non-green jobs as a proxy for the educational requirement for employment in these types of jobs. The resultant plot is presented in Figure 2, where panel (a) shows the results for Mpumalanga and panel (b) shows the results for the rest of South Africa.

Interestingly, in the South African case, the modal education level for green jobs is actually lower than that for non-green jobs, although for South Africa more broadly, the share of green jobs requiring tertiary education is significantly higher than the share of non-green jobs requiring tertiary education. In both Mpumalanga and South Africa more broadly, the modal level of education for those individuals employed in green occupations is currently an incomplete secondary education, while the modal education level attained by employees in non-green jobs is a complete secondary education. Differences in the share of employees with different educational attainment levels are only significant in the case of the broader South African economy, whereas the distribution over education levels in the Mpumalanga economy generally do not differ between green jobs and non-green jobs. Although these results seem to stand in contrast to the literature, Consoli et al. (2016) do suggest that future green occupations that arise due to the greening of the economy are likely to rely more heavily on on-the-job training, and that formal education does not serve as a specifically distinctive trait characterising new and emerging green occupations. Thus, it is conceivable that perhaps green occupations in the South African context have been less stringent in their formal education requirements but have instead focussed on practical on-the-job training for workers who are employed in green occupations.

Figure 2: Distribution of education levels for green jobs vs non-green jobs in Mpumalanga and the rest of South Africa



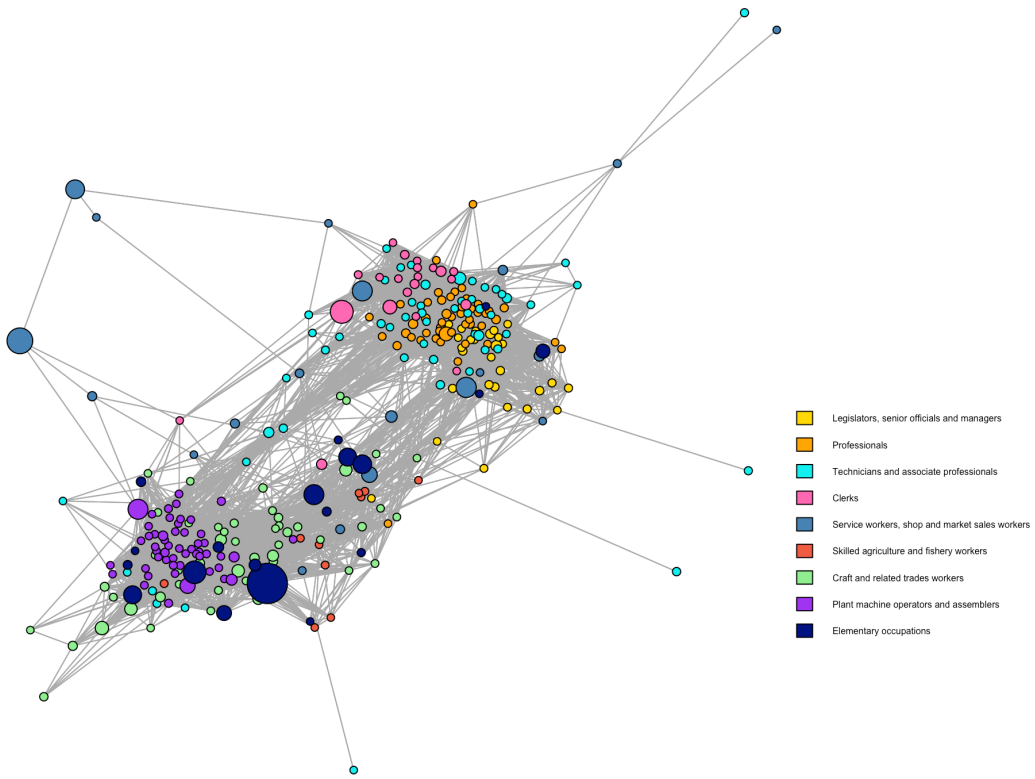
Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); DHET (2021)

This section has aimed to provide an overview of green occupations for youth and non-youth, both within the context of the Mpumalanga labour market, as well as the broader South African labour market. With this understanding of what constitutes green occupations, we now shift our focus to the identification of which green occupations may serve as potential employment diversification opportunities for young people in Mpumalanga in the context of the just transition.

5.2 Identifying green occupations for employment diversification

In order to identify potential employment diversification opportunities for young people in Mpumalanga within the context of the just transition, we return to the occupation space, which we developed in Section 4.3. However, within the context of Mpumalanga, we rescale the size of the occupation nodes to be representative of the share of Mpumalanga youth employment in the 4-digit occupation represented by the relevant node. This recalibration of the occupation space, with nodes sized according to Mpumalanga youth employment shares is presented in Figure 3, below. Note that we make use of the same underlying structure of the occupation space, which is constructed based on linkages between occupations' task content. We do not remove occupations for which Mpumalanga has a zero-employment share, as these occupations are still linked to other occupations due to task similarity. However, if such occupations are identified as potential diversification opportunities for Mpumalanga youth, then an assessment of the feasibility of introducing such occupations to the Mpumalanga labour market may be advisable ahead of the launch of job creation programmes.

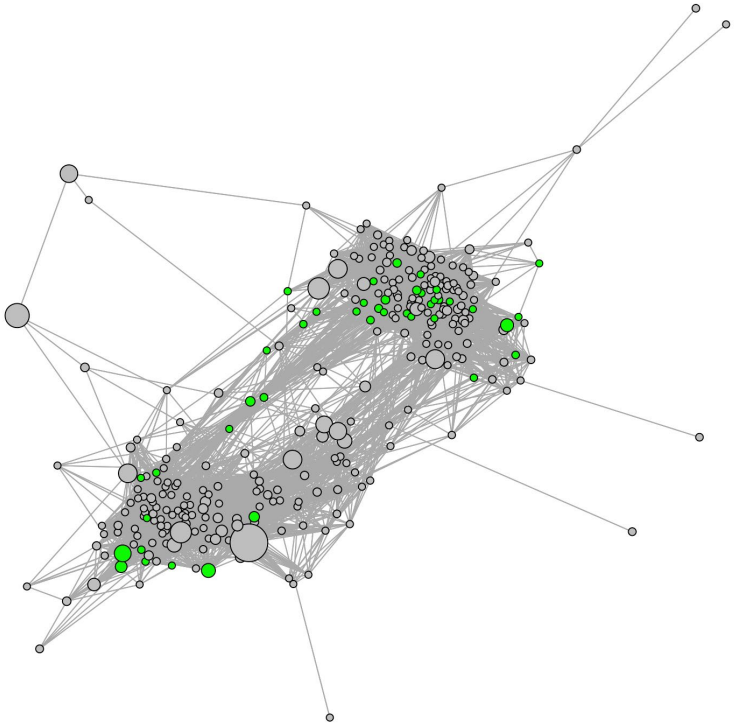
Figure 3: Occupation space with nodes sized by Mpumalanga employment share



Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a) and O*NET (2024a).
Notes: 1. Nodes sized according to share of Mpumalanga employment in the 4-digit occupation represented by a given node. 2. Colour coding of nodes according to 1-digit SASCO major group.

Using the occupation space, we are able to identify green occupations, as defined by the list provided by DHET in their OFO taxonomy (DHET, 2021). Figure 4 highlights the 4-digit occupations classified as green occupations according to the OFO, after implementing the crosswalk that converts OFO occupation codes into the ISCO codes used to construct the occupation space. The first result that is fairly clear to observe is that the green nodes (representing green occupations) are more densely clustered in the north-east quadrant of the occupation space than they are in the south-west. This suggests that generally speaking, green occupations are clustered amongst non-production type occupations, such as clerks, technicians, professionals, and managers. This result is consistent with the findings of Consoli et al. (2016), who suggest that green occupations are significantly more likely to make use of non-routine analytic skills than non-green jobs. In their paper analysing the structure of the occupation space, Allen Whitehead et al. (2021) show that the north-east quadrant of the occupation space is characterised by significantly lower values of a routineness index, indicating that these occupations are more non-routine in nature.

Figure 4: Green occupations in the occupation space

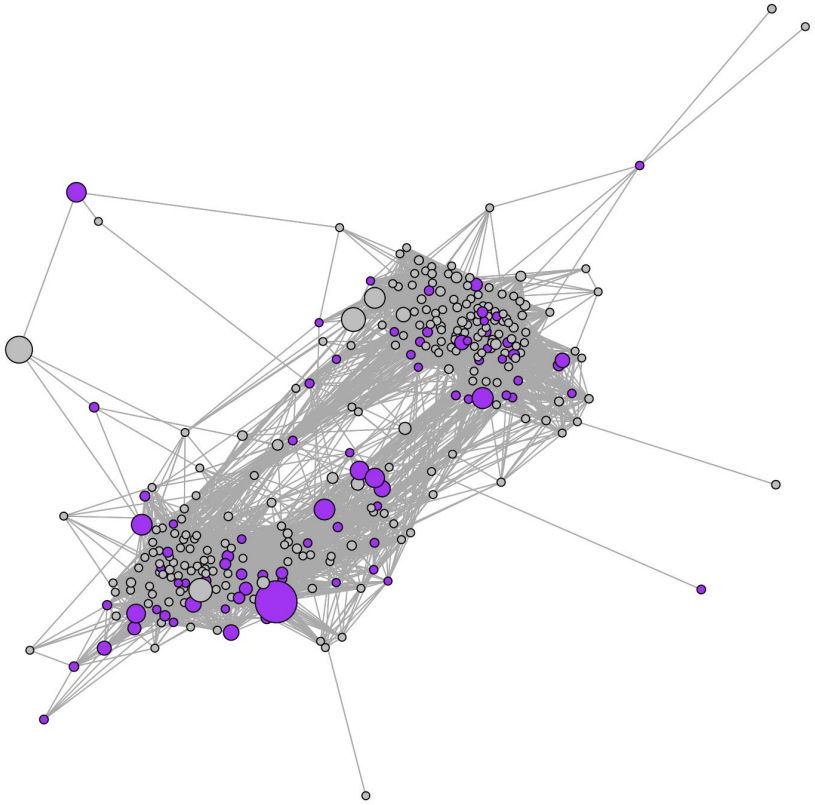


Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); O*NET (2024a); DHET (2021)
Notes: 1. Nodes sized according to share of Mpumalanga employment in the 4-digit occupation represented by a given node. 2. Green nodes represent ISCO-88 occupation codes that were identified as "green occupations" via OFO green occupation definition.

Another interesting result presented in Figure 4 is the fact that the nodes representing green occupations are generally smaller in size than those representing non-green occupations. This suggests that the share of employment in green occupations in Mpumalanga is generally low. This supports the results presented in Table 2, which show that only 12.6% of all youth employment in Mpumalanga is in green occupations. In fact, out of 49 ISCO-88 occupation codes identified as green occupations, 55% (27 occupations) exhibit a zero-employment share in Mpumalanga during 2023.

To identify which of these green occupations may be potential avenues for employment diversification, we make use of the occupation bundle for Mpumalanga employed youth. This occupational bundle is calculated as described in Section 4.4, and these occupations are highlighted in purple in Figure 5, below. It is clear that the occupations in Mpumalanga's occupation bundle for employed youth are generally more concentrated in the south-west quadrant of the occupation space, although there is still a reasonable spread of occupations in the north-east.

Figure 5: Occupation bundle for employed Mpumalanga youth



Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a) and O*NET (2024a).
Notes: 1. Nodes sized according to share of Mpumalanga employment in the 4-digit occupation represented by a given node. 2. Purple nodes represent ISCO-88 occupation codes that were identified as part of Mpumalanga's employed youth occupation bundle.

Comparing Figure 4 to Figure 5 gives an indication of the feasibility of Mpumalanga youth shifting into green occupations during the just transition. Key points to note here are the clustering of green jobs in the non-production north-east corner of the occupation space, and the clustering of Mpumalanga's occupation bundle in the production-heavy south-west quadrant of the occupation space. This dichotomy indicates that, in general, the transition from Mpumalanga's current employment structure into the employment opportunities offered by green jobs is likely to face some challenges. Of course, there are certain green occupations in the south-west quadrant which offer easier, feasible employment opportunities for Mpumalanga youth because of similar task content, however, if the just transition leads to large-scale layoffs of youth, then there will likely be too many youth with production-type skills that will require extensive retraining to bridge the gap to those occupations in the non-production heavy, north-east quadrant.

By listing the occupations in order of distance to the current Mpumalanga employment bundle, we are able to better understand this concept. Table 4, below, presents 48 green occupations (at the 6-digit OFO occupation classification level[9]) along with their distance to the current employed Mpumalanga youth occupation bundle. These occupations have filtered out all occupations in which Mpumalanga has a high relative share of employment – i.e., all occupations for which the calculated comparative employment share figure between Mpumalanga and South Africa as a whole is greater than or equal to one. The top 3 closest occupations that present viable and feasible employment diversification opportunities for Mpumalanga youth are those of "Insulation Installer", "Waste Materials Plant Operator", and "Water Plant Operator".

Strikingly, the only occupation in the full list of 48 green occupations that does not fall into the major groups associated with either managers, professionals, or technicians is that of "Insulation Installer", highlighting the limitations around new green occupations that can grow in the Mpumalanga labour market. This in itself suggests that the employment opportunities for those individuals who are currently employed in production-type jobs, characterising the south-west quadrant of the occupation space, are likely to be limited. This is an important result for policymakers, as it suggests that intensive reskilling or skill top-up programmes will be required in the event of large-scale layoffs due to the just transition.

[9] We opt to report occupations according to the 6-digit OFO taxonomy, as this is the taxonomy used to identify green occupations in OFO framework. Where multiple 6-digit OFO codes fall within the same 4-digit ISCO-88 code, they are assigned the same distance to the occupation bundle.

Table 4: Green occupations, sorted by distance to employed Mpumalanga youth occupation bundle

	OFO 6-digit code	OFO Occupation title	Distance from occupation bundle
1	2021-642401	Insulation Installer	0.779
2	2021-313202	Waste Materials Plant Operator	0.784
3	2021-313201	Water Plant Operator	0.784
4	2021-213201	Agriculture Consultant	0.791
5	2021-213202	Agricultural Scientist	0.791
6	2021-216401	Urban and Regional Planner	0.791
7	2021-216201	Landscape Architect	0.791
8	2021-216101	Architect	0.791
9	2021-311905	Industrial Engineering Technician	0.794
10	2021-214601	Mining Engineer	0.797
11	2021-214602	Mining Engineering Technologist	0.797
12	2021-214604	Metallurgical Engineering Technologist	0.797
13	2021-214605	Metallurgist	0.797
14	2021-214603	Metallurgical Engineer	0.797
15	2021-214607	Petroleum Engineer	0.797
16	2021-311601	Chemical Engineering Technician	0.797
17	2021-134901	Environmental Manager	0.798
18	2021-143901	Facilities Manager	0.798
19	2021-313301	Chemical Plant Controller	0.798
20	2021-314201	Agricultural Technician	0.798
21	2021-314301	Forestry Technician	0.798
22	2021-314302	Forestry Research Technician	0.798
23	2021-311401	Electronic Engineering Technician	0.799
24	2021-311302	Electric Substation Operations Manager	0.799
25	2021-311301	Electrical Engineering Technician	0.799
26	2021-211101	Physicist	0.799
27	2021-213304	Earth and Soil Scientist	0.799
28	2021-213308	Brownfield Redevelopment Specialist	0.799
29	2021-213301	Conservation Scientist	0.799
30	2021-213306	Water Quality Analyst	0.799
31	2021-213305	Air Quality Analyst	0.799
32	2021-213302	Environmental Scientist	0.799
33	2021-213307	Park Ranger	0.799
34	2021-311201	Civil Engineering Technician	0.800
35	2021-311202	Surveying or Cartographic Technician	0.800
36	2021-311203	Town Planning Technician	0.800
37	2021-311702	Metallurgical or Materials Technician	0.800
38	2021-311704	Geophysical Technician	0.800
39	2021-213105	Biotechnologist	0.802
40	2021-211402	Geophysicist	0.802
41	2021-211401	Geologist	0.802
42	2021-216502	Surveyor	0.803
43	2021-242215	Fraud Examiner	0.803
44	2021-215201	Electronics Engineer	0.805
45	2021-215202	Electronics Engineering Technologist	0.805
46	2021-332202	Sales Representative (Building and Plumbing Supplies)	0.811
47	2021-263203	Geographer	0.812
48	2021-263101	Economist	0.819

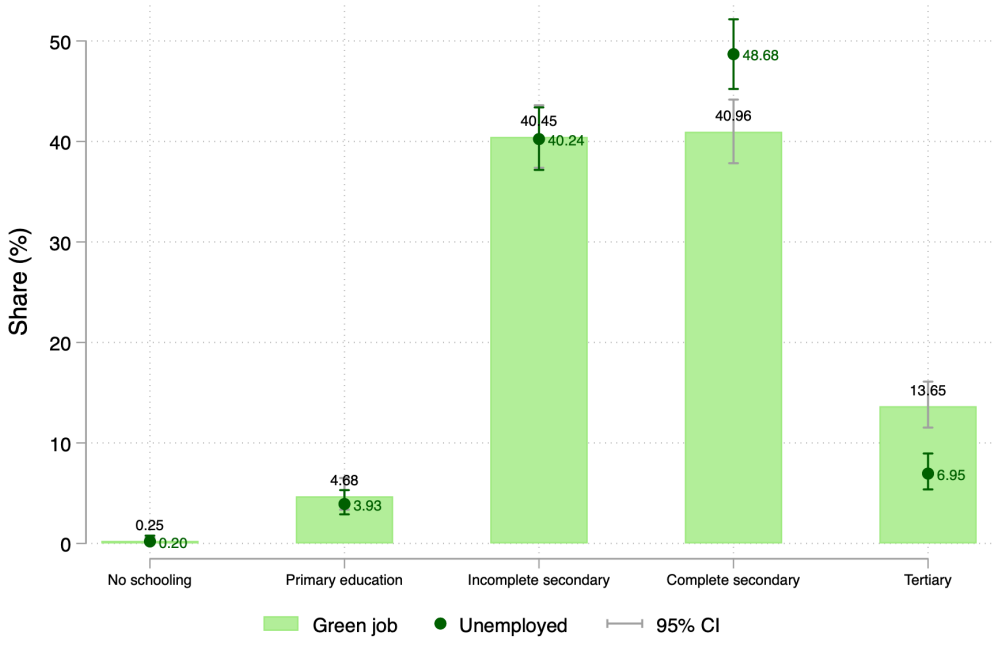
Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); O*NET (2024a); DHET (2021)

5.3 Identifying employment opportunities for unemployed youth

In the previous section, we identified the potential employment opportunities that existed for those youth in Mpumalanga who are currently employed, however, this only accounts for a small part of the youth labour market. Since the broad youth unemployment rate in Mpumalanga was approximately 58.4% in 2023 (Stats SA, 2023a; 2023b; 2023c; 2024a), the unemployed youth are an equally – if not arguably, more – important subgroup to focus on in this type of analysis. To this extent, this section aims to characterise the employment opportunities and challenges facing unemployed youth in Mpumalanga as far as green jobs are concerned.

In Figure 6, we present the same distribution of educational attainment for youth employed in green jobs as we presented in Figure 2, however, in this case we overlay the relative distribution of educational attainment for the unemployed youth in Mpumalanga. Here, we see that, relative to what education would be required for employment in green jobs in Mpumalanga, there is a relative oversupply of unemployed youth with a complete secondary education, and a relative undersupply of unemployed youth with some form of tertiary education. For those individuals with less than a completed secondary education, the distribution of educational attainment is approximately consistent with what would be required for employment in green jobs. The concern, however, is that for those youth with a completed secondary education, but no tertiary education, this transition to a green economy may further marginalise them and limit their employment options.[10]

Figure 6: Education profile of Mpumalanga youth employed in green jobs compared to unemployed Mpumalanga youth



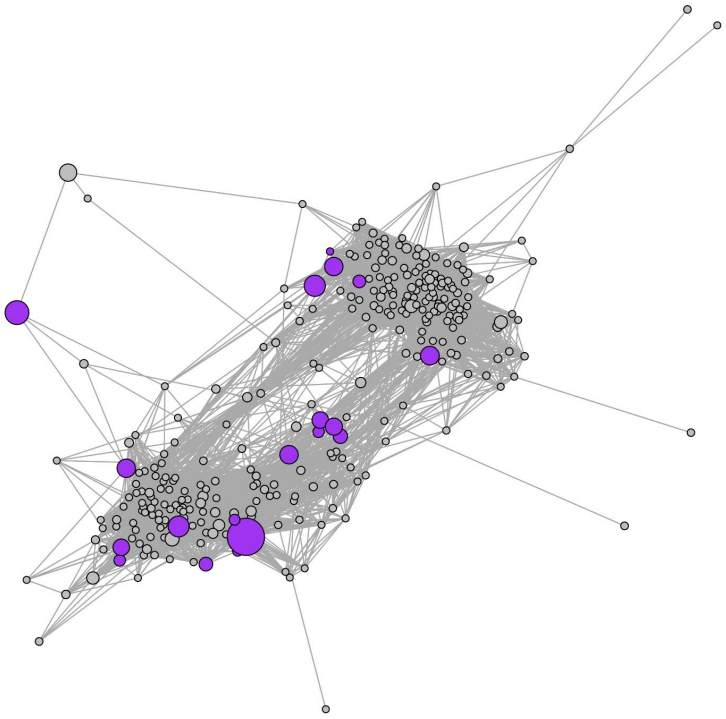
Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); DHET (2021)

[10] A very similar result holds when you disaggregate the unemployed youth into those who have been employed before and those who have never been employed before. The results of this are plotted in Figure A 1 in the appendix.

Note: 1. Unemployed youth are all those categorised as unemployed under the broad definition of unemployment.

The result that unemployed youth may fall prey to further marginalisation is supported further when we consider the analysis of the occupation bundle for unemployed youth.[11] Recall that green occupations were, for the most part, clustered in the north-east quadrant of the occupation space. Looking at Figure 7, below, which plots the occupation bundle for those unemployed youth in Mpumalanga who have been previously employed, we can see that the highlighted nodes are even more clustered to the south-west of the occupation space than for currently employed youth in Mpumalanga. Given that proximity to jobs with similar tasks can be visually represented by distance between nodes in the occupation space, this suggests that the transition to green occupations will require substantial skills interventions in order to equip unemployed youth with the skills required to take on green occupations.

Figure 7: Occupation bundle for unemployed youth in Mpumalanga who have been previously employed



Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a) and O*NET (2024a).
Notes: 1. Nodes sized according to share of Mpumalanga employment in the 4-digit occupation represented by a given node. 2. Purple nodes represent ISCO-88 occupation codes that were identified as part of Mpumalanga's unemployed youth occupation bundle.

When sorting green occupations by distance from the unemployed youth occupation bundle, it is clear that there is likely to be a large skill gap for unemployed youth should the transition to a green economy take place. Table 5 presents the list of green occupations, sorted by distance from the unemployed Mpumalanga youth occupation bundle. This is the same list as

[11] By definition, the occupation bundle for unemployed youth can only be constructed for those youth who have been previously employed. However, given that previous employment will likely have provided youth with some form of on-the-job skilling and task competency, all results that are presented for the subset of youth who have been previously employed are likely to be even starker for those youth with no previous employment experience.

for the employed Mpumalanga youth; however, the ordering of occupations has changed given the different underlying structure of the unemployed youth occupation bundle. However, the same stark results hold: Employment opportunities for youth are likely to be severely limited without some form of skill-related intervention to support them during the transition to a green economy.

Table 5: Green occupations, sorted by distance to unemployed Mpumalanga youth occupation bundle

	OFO 6-digit code	OFO Occupation title	Distance from occupation bundle
1	2021-642401	Insulation Installer	0.945
2	2021-313202	Waste Materials Plant Operator	0.946
3	2021-313201	Water Plant Operator	0.946
4	2021-313301	Chemical Plant Controller	0.949
5	2021-311905	Industrial Engineering Technician	0.955
6	2021-311702	Metallurgical or Materials Technician	0.955
7	2021-311704	Geophysical Technician	0.955
8	2021-314301	Forestry Technician	0.956
9	2021-314302	Forestry Research Technician	0.956
10	2021-314201	Agricultural Technician	0.956
11	2021-311401	Electronic Engineering Technician	0.957
12	2021-311301	Electrical Engineering Technician	0.957
13	2021-311302	Electric Substation Operations Manager	0.957
14	2021-213201	Agriculture Consultant	0.958
15	2021-213202	Agricultural Scientist	0.958
16	2021-311601	Chemical Engineering Technician	0.958
17	2021-216201	Landscape Architect	0.958
18	2021-216101	Architect	0.958
19	2021-216401	Urban and Regional Planner	0.958
20	2021-311202	Surveying or Cartographic Technician	0.958
21	2021-311201	Civil Engineering Technician	0.958
22	2021-311203	Town Planning Technician	0.958
23	2021-134901	Environmental Manager	0.959
24	2021-143901	Facilities Manager	0.959
25	2021-242215	Fraud Examiner	0.961
26	2021-211101	Physicist	0.962
27	2021-332202	Sales Representative (Building and Plumbing Supplies)	0.962
28	2021-213105	Biotechnologist	0.962
29	2021-215201	Electronics Engineer	0.962
30	2021-215202	Electronics Engineering Technologist	0.962
31	2021-211402	Geophysicist	0.962
32	2021-211401	Geologist	0.962
33	2021-214602	Mining Engineering Technologist	0.963
34	2021-214605	Metallurgist	0.963
35	2021-214603	Metallurgical Engineer	0.963
36	2021-214607	Petroleum Engineer	0.963
37	2021-214601	Mining Engineer	0.963
38	2021-214604	Metallurgical Engineering Technologist	0.963
39	2021-216502	Surveyor	0.963
40	2021-213301	Conservation Scientist	0.964
41	2021-213306	Water Quality Analyst	0.964
42	2021-213302	Environmental Scientist	0.964
43	2021-213307	Park Ranger	0.964
44	2021-213304	Earth and Soil Scientist	0.964
45	2021-213308	Brownfield Redevelopment Specialist	0.964
46	2021-213305	Air Quality Analyst	0.964
47	2021-263203	Geographer	0.964
48	2021-263101	Economist	0.966

Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); O*NET (2024a); DHET (2021)

5.4 How to prioritise green occupations in Mpumalanga

Our results on potentially feasible employment opportunities for young people in Mpumalanga differ according to whether the underlying bundle against which distance of a green occupation is measured represents employed or unemployed youth in Mpumalanga. Given that both employed and unemployed youth are going to be impacted by the just transition, it may be worthwhile trying to synthesise the results from our two separate analyses to try and identify a priority list of occupations for government and policymakers to develop and support in skills programmes related to the just transition.

One method to create such a list would be to create an average ranking of green occupation distance across the employed youth occupation bundle and the unemployed youth occupation bundle. This would then provide policymakers with a list of occupations, ranked according to their importance for servicing both employed and unemployed youth in the just transition. To do this, we take an agnostic view of how a policymaker may choose to weight the relative importance of balancing employment-to-employment transitions and unemployment-to-employment transitions, and we opt to weight the two lists of occupations equally. One could just as easily weight the different rankings from different bundles according to the prevalence of employed or unemployed youth in the population of interest, however, we see no *a priori* reason to impose such a weighting on the bundles.

Table 6 presents the results of our ranking exercise. Specifically, one is able to see the distance-related rank of occupations relative to the employed youth occupation bundle, or the unemployed youth occupation bundle, as well as the average rank of the green occupation after taking both of these distance rankings into account. Strikingly, the top three closest occupations to both employed and unemployed occupation bundles remain completely unchanged, and this suggests that a focus on promoting skills related to employment opportunities in occupations such as “Insulation Installer”, “Waste Materials Plant Operator”, and “Water Plant Operator” are likely to benefit both currently employed and currently unemployed youth. However, from position 4 onwards, there is substantial variation in the rankings of occupations between the two bundles, suggesting that a more targeted approach for the upskilling of different subpopulations may be required to ensure equitable employment opportunities for youth, depending on their employment history.

Table 6: Ranking green occupations according to both employed and unemployed occupation bundles

OFO 6-digit code	OFO occupation title	Rank in employed youth bundle	Rank in unemployed youth bundle	Average rank
2021-642401	Insulation Installer	1	1	1
2021-313202	Waste Materials Plant Operator	2	2	2
2021-313201	Water Plant Operator	3	3	3
2021-311905	Industrial Engineering Technician	9	5	4
2021-213201	Agriculture Consultant	4	14	5
2021-213202	Agricultural Scientist	5	15	6
2021-313301	Chemical Plant Controller	19	4	7
2021-216201	Landscape Architect	7	17	8
2021-216401	Urban and Regional Planner	6	19	9
2021-216101	Architect	8	18	10
2021-314301	Forestry Technician	21	8	11
2021-314201	Agricultural Technician	20	10	12
2021-314302	Forestry Research Technician	22	9	13
2021-311601	Chemical Engineering Technician	16	16	14
2021-311401	Electronic Engineering Technician	23	11	15
2021-311301	Electrical Engineering Technician	25	12	16
2021-311302	Electric Substation Operations Manager	24	13	16
2021-134901	Environmental Manager	17	23	18
2021-143901	Facilities Manager	18	24	19
2021-311702	Metallurgical or Materials Technician	37	6	20
2021-214602	Mining Engineering Technologist	11	33	21
2021-311704	Geophysical Technician	38	7	22
2021-214605	Metallurgist	13	34	23
2021-214601	Mining Engineer	10	37	23
2021-214603	Metallurgical Engineer	14	35	25
2021-214604	Metallurgical Engineering Technologist	12	38	26
2021-214607	Petroleum Engineer	15	36	27
2021-211101	Physicist	26	26	28
2021-311202	Surveying or Cartographic Technician	35	20	29
2021-311201	Civil Engineering Technician	34	21	29
2021-311203	Town Planning Technician	36	22	31
2021-213105	Biotechnologist	39	28	32
2021-242215	Fraud Examiner	43	25	33
2021-213301	Conservation Scientist	29	40	34
2021-211402	Geophysicist	40	31	35
2021-213306	Water Quality Analyst	30	41	35
2021-213304	Earth and Soil Scientist	27	44	35
2021-332202	Sales Representative (Building and Plumbing Supplies)	46	27	38
2021-215201	Electronics Engineer	44	29	38
2021-211401	Geologist	41	32	38
2021-213308	Brownfield Redevelopment Specialist	28	45	38
2021-213302	Environmental Scientist	32	42	42
2021-215202	Electronics Engineering Technologist	45	30	43
2021-213307	Park Ranger	33	43	44
2021-213305	Air Quality Analyst	31	46	45
2021-216502	Surveyor	42	39	46
2021-263203	Geographer	47	47	47
2021-263101	Economist	48	48	48

Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); O*NET (2024a); DHET (2021)

6. Conclusion

The just energy transition in South Africa presents a number of opportunities for South Africans, but at the same time, it raises a number of challenges. In particular, youth displaced from coal mining work in South Africa's Mpumalanga province are at risk of further marginalisation due to the destruction of well-paying and secure jobs in the coal sector. Although alternative employment opportunities may arise in the form of "green jobs", it is not clear that these jobs will be suited to the existing skillset and task competences of the youth population who seek to find employment in these new jobs.

By making use of occupational relatedness measures based on task similarity between occupations, this research aimed to identify which green occupations may present feasible and accessible employment opportunities for youth in Mpumalanga who are displaced as a result of a transition away from the coal economy. Following the methods described by Mealy, del-Rio Chanona and Farmer (2018), we constructed a visual representation of the relationship between occupations in the form of the occupation space, which highlighted a clear divide between production and non-production occupations. Using representative survey data, we identified bundles of occupations that represented the types of jobs youth currently exhibited relative task competence in, and compared these occupation bundles to the bundle of green occupations identified by the Department of Higher Education and Training in their Organisational Framework for Occupations framework. As a result, we could extract a measure of distance between the current occupation bundle and a relevant green occupation, which provided a proxy measure for how accessible a particular green job was to young people from a particular occupation bundle.

Overall, our results suggest that the transition from a coal-reliant economy to a green economy will require intervention on the part of policymakers. In particular, young people looking for employment opportunities in green jobs are likely to need reskilling or upskilling in order to make the most of new employment opportunities available to them. These skills programmes should specifically focus on ensuring the attainment of post-secondary education, as green jobs in the South African context are more likely to require post-secondary education, and there is likely to be a shortage of these post-secondary skills amongst youth in Mpumalanga when the just transition occurs.

Given their different skill profiles and task competences, feasible employment opportunities for young people will differ depending on their employment history. This suggests that different policy interventions are required to ensure smooth employment transitions for unemployed youth compared to youth who become displaced from existing coal jobs. However, the top three proximate jobs for both employed and unemployed youth are the same irrespective of their employment history, offering policymakers a potentially clear focus area for the short-term in order to provide feasible employment opportunities during the just transition: Insulation installers; waste material plant operators; and water plant operators are identified as the top three feasible employment opportunities for youth.

Although this research has contributed to the discourse on how to ensure feasible employment opportunities for youth in the context of a transition away from coal, it is based purely on quantitative desktop research. Because of this, there are certain gaps in knowledge

surrounding the practical feasibility and market conditions that would contribute to these employment opportunities being successful in absorbing youth in Mpumalanga. As a result, the next stage of this research aims to supplement these desktop findings through gathering qualitative information from youth and key informants in the field. The qualitative aspect of this research, coupled with partner research from other African institutions partnered with the University of Cambridge, aims to determine whether identified green jobs are indeed attractive and desirable for youth, as well as whether they contribute positively to young people's career goals and ambitions. It is only by qualitatively stress-testing the quantitative desktop-based results presented in this paper that we will truly understand the feasibility of green jobs as a vehicle to tackle challenges of youth unemployment and economic vulnerability.

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Appendix

Table A 1: SASCO 2003 occupations with recoded ISCO-88 classifications

		QLFS 2023 employed		QLFS 2023 employed			
SASCO 2003 occupation code	SASCO 2003 occupation title	Number of observations	Share of total observations	Number of observations	Share of total observations	ISCO-88 occupation code	ISCO-88 occupation title
1110	Legislators	15	0.07	2	0.02	1120	Senior government officers
1390	General managers not elsewhere classified	5	0.02	1	0.01	1239	Other managers/department managers not elsewhere classified
2142	Civil engineers	11	0.05	5	0.05	2149	Architects, engineers and related professionals not elsewhere classified
2159	Physical sciences technologists	3	0.01				
2210	Scientist	3	0.01	1	0.01	2190	Physical, mathematical and engineering science professionals not elsewhere classified
2429	Legal professionals not elsewhere classified	26	0.12	1	0.01	2421	Advocates, attorneys and related occupations
2490	Other professionals not elsewhere classified	3	0.01	1	0.01		
3220	Optometrists' assistants	1	0			3221	Medical assistants
3310	Primary education teaching associate professionals	206	0.94	29	0.31	2331	Primary education teaching professionals
3330	Special education teaching associate professionals	4	0.02	2	0.02	2340	Special education teaching professionals
3340	Other teaching associate professionals	8	0.04	1	0.01	2359	Other teaching professionals not elsewhere classified
3391	Teaching associate professionals	78	0.35	15	0.16	2359	Other teaching professionals not elsewhere classified
3461	Social work researcher	1	0			3460	Social work associate professionals

		QLFS 2023 employed		QLFS 2023 employed			
SASCO 2003 occupation code	SASCO 2003 occupation title	Number of observations	Share of total observations	Number of observations	Share of total observations	ISCO-88 occupation code	ISCO-88 occupation title
3479	Art, entertainment and sport associate professionals not elsewhere classified	34	0.15	16	0.17		
3490	Other associate professionals not elsewhere classified	1	0				
4144	Scribes and related workers	1	0				
4214	Pawnbrokers and moneylenders	10	0.05				
4290	Customer services clerks not elsewhere classified	3	0.01	6	0.06		
5124	Tavern and shebeen operators	50	0.23	10	0.11	5123	Waiers, waitresses and bartenders
5164	Armed forces	17	0.08	5	0.05	0110	Armed forces
5231	Spaza shop owner	74	0.34	1	0.01	5230	Stall and market salespersons
6211	Subsistence farmers	4	0.02	1	0.01	6210	Subsistence agricultural and fishery workers
7346	Silk-screen, block and textile printers (including apprentices/trainees)	2	0.01	3	0.03		
7490	Other craft and related trades workers not elsewhere classified (including apprentices/trainees)	10	0.05	2	0.02		
8171	Automated assembly-line operators	1	0	1	0.01		
8320	Taxi drivers, informal	398	1.81	62	0.67	8322	Car, taxi and van drivers
8321	Motor cycle drivers	4	0.02	3	0.03		
9120	Shoe cleaning and other elementary street services occupations	93	0.42	35	0.38		
9162	Sweepers and related labourers	335	1.52	217	2.35	9161	Garbage collectors
9190	Elementary sales and services occupations not elsewhere classifed	43	0.2	17	0.18		

SASCO 2003 occupation code	SASCO 2003 occupation title	QLFS 2023 employed Number of observations	QLFS 2023 employed Share of total observations	QLFS 2023 employed Number of observations	QLFS 2023 employed Share of total observations	ISCO-88 occupation code	ISCO-88 occupation title
9212	Forestry labourers	82	0.37	51	0.55		
9321	Assembling labourers	1	0	1	0.01		
9999	Unspecified	6	0.03	6	0.06		

Source: Statistics South Africa (2023a; 2023b; 2023c; 2024a) and ILO (2024).

Table A 2: Mpumalanga's employed youth occupation bundle, ISCO-88 and OFO 2021 taxonomy

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga employment (%)
1210	Directors and chief executives	2021-1121	Managing Directors and Chief Executives	0.47
1224	Production and operations department managers in wholesale and retail trade	2021-1421	Retail and Wholesale Trade Managers	0.81
1233	Sales and marketing department managers	2021-1221	Sales and Marketing Managers	0.20
1235	Supply and distribution department managers	2021-1324	Supply, Distribution and Related Managers	0.07
1239	Other department managers not elsewhere classified	2021-1213	Policy and Planning Managers	0.16
1312	General managers in manufacturing	2021-1321	Manufacturing Managers	0.13
1312	General managers in manufacturing	2021-1322	Mining Managers	
1313	General managers in construction	2021-1323	Construction Managers	0.22
1315	General managers of restaurants and hotels	2021-1411	Hotel Managers	0.21
1315	General managers of restaurants and hotels	2021-1412	Restaurant Managers	
1316	General managers in transport, storage and communications	2021-1324	Supply, Distribution and Related Managers	0.18
1316	General managers in transport, storage and communications	2021-1331	Information and Communications Technology Service Managers	
2143	Electrical engineers	2021-2151	Electrical Engineers	0.28
2145	Mechanical engineers	2021-2144	Mechanical Engineers	0.47
2146	Chemical engineers	2021-2145	Chemical Engineers	0.17
2149	Architects, engineers and related professionals not elsewhere classified	2021-2141	Industrial and Production Engineers	0.29
2149	Architects, engineers and related professionals not elsewhere classified	2021-2143	Environmental Engineers	
2149	Architects, engineers and related professionals not elsewhere classified	2021-2149	Engineering Professionals not Elsewhere Classified	
2331	Primary education teaching professionals	2021-2341	Primary School or Foundational Phase Teachers	1.67
2453	Composers, musicians and singers	2021-2652	Musicians, Singers and Composers	0.07
3111	Chemical and physical science technicians	2021-3111	Chemical and Physical Science Technicians	0.22
3115	Mechanical engineering technicians	2021-3115	Mechanical Engineering Technicians	0.11
3118	Draughtspersons	2021-3118	Draughtspersons	0.16
3132	Broadcasting and telecommunications equipment operators	2021-3521	Broadcasting and Audio-visual Technicians	0.21

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga employment (%)
3132	Broadcasting and telecommunications equipment operators	2021-3522	Telecommunications Engineering Technicians	
3211	Life science technicians	2021-3141	Life Science Technicians (Excluding Medical)	0.10
3211	Life science technicians	2021-3212	Medical and Pathology Laboratory Technicians	
3222	Sanitarians	2021-2263	Environmental and Occupational Health and Hygiene Professionals	0.08
3222	Sanitarians	2021-3257	Environmental and Occupational Health Inspectors and Associates	
3223	Dieticians and nutritionists	2021-2265	Dieticians and Nutritionists	0.22
3241	Traditional medicine practitioners	2021-2231	Traditional and Complementary Medicine Professionals	1.23
3241	Traditional medicine practitioners	2021-3231	Traditional and Complementary Medicine Associate Professionals	
3320	Pre-primary education teaching associate professionals	2021-2342	Early Childhood Educators	0.23
3449	Customs, tax and related government associate professionals not elsewhere classified	2021-3359	Government Regulatory Associate Professionals not Elsewhere Classified	0.07
3472	Radio, television and other announcers	2021-2642	Journalists	0.06
3472	Radio, television and other announcers	2021-2656	Announcers On Radio, Television and Other Media	
3480	Religious associate professionals	2021-3413	Religious Associate Professionals	0.07
4141	Library and filing clerks	2021-3341	Office Supervisors	0.40
4141	Library and filing clerks	2021-4411	Library Clerks	
4141	Library and filing clerks	2021-4415	Filing and Copying Clerks	
4143	Coding, proof-reading and related clerks	2021-3252	Medical Records and Health Information Technicians	
4143	Coding, proof-reading and related clerks	2021-3341	Office Supervisors	0.08
4143	Coding, proof-reading and related clerks	2021-4413	Coding, Proof-reading and Related Clerks	
4212	Tellers and other counter clerks	2021-4211	Bank Tellers and Related Clerks	0.69
5113	Travel guides	2021-5113	Travel Guides	0.14
5122	Cooks	2021-3434	Chefs	2.14
5122	Cooks	2021-5121	Cooks	
5122	Cooks	2021-8411	Fast Food Preparers	
5131	Child-care workers	2021-5311	Child Care Workers	3.34
5131	Child-care workers	2021-5312	Teachers' Aides	
5132	Institution-based personal care workers	2021-3258	Ambulance Workers	0.28
5132	Institution-based personal care workers	2021-5321	Health Care Assistants	

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga employment (%)
5132	Institution-based personal care workers	2021-5329	Personal Care Workers in Health Services not Elsewhere Classified	
5141	Hairdressers, barbers, beauticians and related workers	2021-5141	Hairdressers	2.96
5141	Hairdressers, barbers, beauticians and related workers	2021-5142	Beauticians and Related Workers	
5161	Fire-fighters	2021-5411	Fire fighters	0.44
5230	Stall and market salespersons	2021-5211	Stall and Market Salespersons	0.78
5230	Stall and market salespersons	2021-5246	Food Service Counter Attendants	
6112	Tree and shrub crop growers	2021-6112	Tree and Shrub Crop Growers	0.09
6121	Dairy and livestock producers	2021-6121	Livestock and Dairy Producers	0.06
7111	Miners and quarry workers	2021-3121	Mining Production / Operations Supervisors	0.93
7111	Miners and quarry workers	2021-7111	Miners and Quarriers	
7124	Carpenters and joiners	2021-6415	Carpenters and Joiners	0.50
7129	Building frame and related trades workers not elsewhere classified	2021-3123	Construction Supervisors	
7129	Building frame and related trades workers not elsewhere classified	2021-6411	House Builders	0.92
7129	Building frame and related trades workers not elsewhere classified	2021-6419	Building Frame and Related Trades Workers not Elsewhere Classified	
7131	Roofers	2021-6421	Roofers	0.16
7132	Floor layers and tile setters	2021-6422	Floor Layers and Tile Setters	0.27
7136	Plumbers and pipe fitters	2021-6426	Plumbers and Pipe Fitters	1.31
7137	Building and related electricians	2021-6711	Building and Related Electricians	0.93
7212	Welders and flamecutters	2021-6512	Welders and Flame Cutters	0.59
7213	Sheet-metal workers	2021-6513	Sheet Metal Workers	1.27
7214	Structural-metal preparers and erectors	2021-6514	Structural Metal Preparers and Erectors	0.16
7231	Motor vehicle mechanics and fitters	2021-6531	Motor Vehicle Mechanics and Repairers	1.54
7231	Motor vehicle mechanics and fitters	2021-6534	Bicycle and Related Repairers	
7233	Agricultural- or industrial-machinery mechanics and fitters	2021-6427	Air Conditioning and Refrigeration Mechanics	0.22
7233	Agricultural- or industrial-machinery mechanics and fitters	2021-6533	Agricultural and Industrial Machinery Mechanics and Repairers	
7241	Electrical mechanics and fitters	2021-6712	Electrical Mechanics and Fitters	0.42
7243	Electronics mechanics and servicers	2021-6721	Electronics Mechanics and Servicers	0.33
7243	Electronics mechanics and servicers	2021-6722	Information and Communications Technology Installers and Servicers and Related Occupations	

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga employment (%)
7321	Abrasive wheel formers, potters and related workers	2021-6614	Potters and Related Workers	0.60
7322	Glass-makers, cutters, grinders and finishers	2021-6615	Glass Makers, Cutters, Grinders and Finishers	0.09
7322	Glass-makers, cutters, grinders and finishers	2021-6849	Craft and Related Workers not Elsewhere Classified	
7432	Weavers, knitters and related workers	2021-6618	Handicraft Workers in Textile, Leather and Related Materials	0.05
7432	Weavers, knitters and related workers	2021-7152	Weaving and Knitting Machine Operators	
7437	Upholsterers and related workers	2021-6834	Upholsterers and Related Workers	0.25
8111	Mining-plant operators	2021-3121	Mining Production / Operations Supervisors	0.67
8111	Mining-plant operators	2021-7111	Miners and Quarriers	
8131	Glass and ceramics kiln and related machine operators	2021-7181	Glass and Ceramics Plant Operators	0.05
8141	Wood-processing-plant operators	2021-7172	Wood Processing Plant Operators	0.09
8161	Power-production plant operators	2021-3131	Power Production Plant Operators	0.09
8290	Other machine operators and assemblers	2021-3122	Manufacturing Supervisors	0.09
8290	Other machine operators and assemblers	2021-7183	Packing, Bottling and Labelling Machine Operators	
8290	Other machine operators and assemblers	2021-7189	Stationary Plant and Machine Operators not Elsewhere Classified	
8290	Other machine operators and assemblers	2021-7219	Assemblers not Elsewhere Classified	
8322	Car, taxi and van drivers	2021-7322	Car, Taxi and Van Drivers	3.26
8324	Heavy truck and lorry drivers	2021-7332	Heavy Truck and Lorry Drivers	2.01
8331	Motorised farm and forestry plant operators	2021-7341	Mobile Farm and Forestry Plant Operators	0.90
8332	Earth-moving- and related plant operators	2021-7342	Earthmoving and Related Plant Operators	0.16
8333	Crane, hoist and related plant operators	2021-7343	Crane, Hoist and Related Plant Operators	0.52
9111	Street food vendors	2021-5212	Street Food Salespersons	2.72
9112	Street vendors, non-food products	2021-8521	Street Vendors	1.67
9131	Domestic helpers and cleaners	2021-8111	Domestic Cleaners and Helpers	3.26
9132	Helpers and cleaners in offices, hotels and other establishments	2021-8112	Cleaners and Helpers in Offices, Hotels and Other Establishments	2.90
9132	Helpers and cleaners in offices, hotels and other establishments	2021-8412	Kitchen Helpers	
9133	Hand-launderers and pressers	2021-8121	Hand Launderers and Pressers	0.11
9141	Building caretakers	2021-5153	Building Caretakers	0.14
9142	Vehicle, window and related cleaners	2021-8122	Vehicle Cleaners	0.37
9142	Vehicle, window and related cleaners	2021-8123	Window Cleaners	

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga employment (%)
9142	Vehicle, window and related cleaners	2021-8129	Other Cleaning Workers	
9151	Messengers, package and luggage porters and deliverers	2021-8621	Messengers, Package Deliverers and Luggage Porters	0.53
9161	Garbage collectors	2021-8611	Garbage and Recycling Collectors	2.73
9161	Garbage collectors	2021-8612	Refuse Sorters	
9211	Farm-hands and labourers	2021-8211	Crop Farm Workers	
9211	Farm-hands and labourers	2021-8212	Livestock Farm Labourers	
9211	Farm-hands and labourers	2021-8213	Mixed Crop and Livestock Farm Labourers	8.64
9211	Farm-hands and labourers	2021-8214	Garden and Horticultural Labourers	
9311	Mining and quarrying labourers	2021-8311	Mining and Quarrying Labourers	0.78
9313	Building construction labourers	2021-8313	Building Construction Labourers	1.93
			Total share of Mpumalanga employment in occupation bundle	**63.69**

Source: Authors' calculations based on Statistics South Africa (2023a; 2023b; 2023c; 2024a) and DHET (2021)

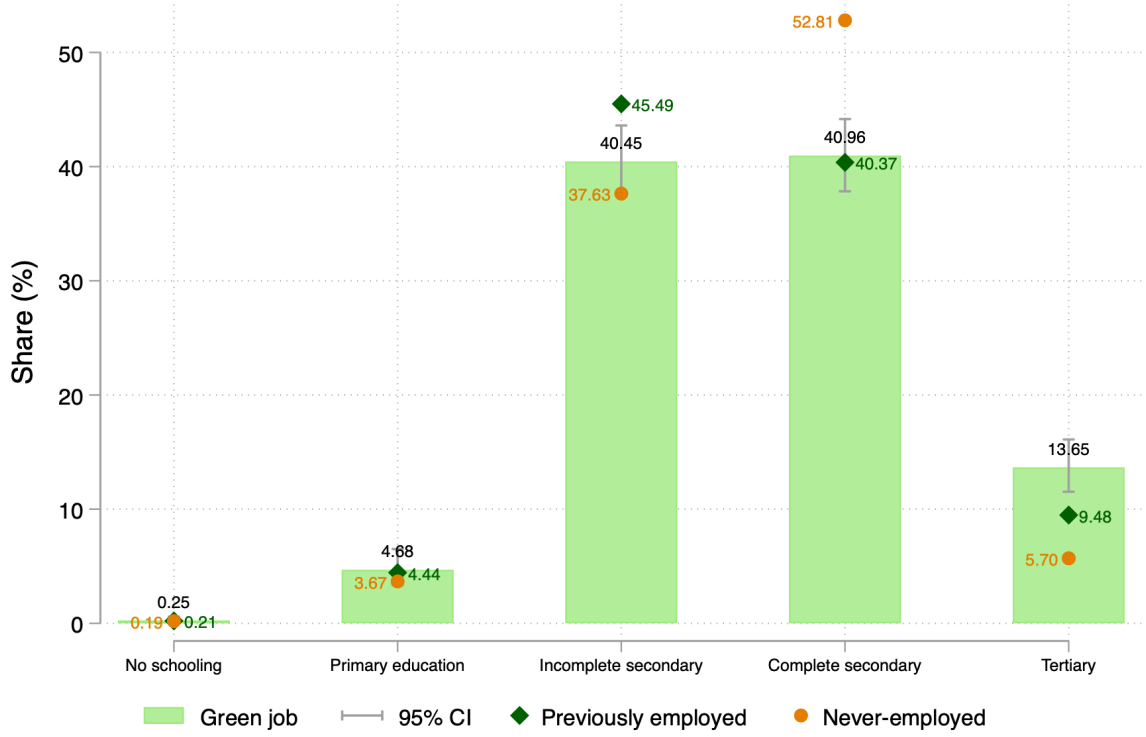
Table A 3: Mpumalanga's unemployed youth occupation bundle, ISCO-88 and OFO 2021 taxonomy

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga unemployment (%)
4143	Coding, proof-reading and related clerks	2021-3252	Medical Records and Health Information Technicians	
4143	Coding, proof-reading and related clerks	2021-3341	Office Supervisors	1.85
4143	Coding, proof-reading and related clerks	2021-4413	Coding, Proof-reading and Related Clerks	
4190	Other office clerks	2021-3341	Office Supervisors	
4190	Other office clerks	2021-4111	General Office Clerks	
4190	Other office clerks	2021-4227	Survey and Market Research Interviewers	2.20
4190	Other office clerks	2021-4416	Personnel Clerks	
4190	Other office clerks	2021-4419	Clerical Support Workers not Elsewhere Classified	
4211	Cashiers and ticket clerks	2021-4211	Bank Tellers and Related Clerks	
4211	Cashiers and ticket clerks	2021-4212	Bookmakers, Croupiers and Related Gaming Workers	4.33
4211	Cashiers and ticket clerks	2021-5231	Cashiers and Ticket Clerks	
5122	Cooks	2021-3434	Chefs	
5122	Cooks	2021-5121	Cooks	1.75
5122	Cooks	2021-8411	Fast Food Preparers	
5131	Child-care workers	2021-5311	Child Care Workers	8.49
5131	Child-care workers	2021-5312	Teachers' Aides	
5169	Protective services workers not elsewhere classified	2021-5414	Security Guards	4.28
5169	Protective services workers not elsewhere classified	2021-5419	Protective Services Workers not Elsewhere Classified	
5220	Shop salespersons and demonstrators	2021-5222	Shop Supervisors	
5220	Shop salespersons and demonstrators	2021-5223	Shop Sales Assistants	
5220	Shop salespersons and demonstrators	2021-5242	Sales Demonstrators	
5220	Shop salespersons and demonstrators	2021-5245	Service Station Attendants	5.17
5220	Shop salespersons and demonstrators	2021-5246	Food Service Counter Attendants	
5220	Shop salespersons and demonstrators	2021-5249	Sales Workers not Elsewhere Classified	
7122	Bricklayers and stonemasons	2021-6412	Bricklayers and Related Workers	3.04
7122	Bricklayers and stonemasons	2021-6413	Stonemasons, Stone Cutters, Splitters and Carvers	
7129	Building frame and related trades workers not elsewhere classified	2021-3123	Construction Supervisors	2.20
7129	Building frame and related trades workers not elsewhere classified	2021-6411	House Builders	

ISCO-88 4-digit code	ISCO-88 Occupation title	OFO 2021 4-digit code	OFO 2021 4-digit title	Share of Mpumalanga unemployment (%)
7129	Building frame and related trades workers not elsewhere classified	2021-6419	Building Frame and Related Trades Workers not Elsewhere Classified	
7136	Plumbers and pipe fitters	2021-6426	Plumbers and Pipe Fitters	2.64
8322	Car, taxi and van drivers	2021-7322	Car, Taxi and Van Drivers	1.67
9111	Street food vendors	2021-5212	Street Food Salespersons	1.45
9131	Domestic helpers and cleaners	2021-8111	Domestic Cleaners and Helpers	2.56
9132	Helpers and cleaners in offices, hotels and other establishments	2021-8112	Cleaners and Helpers in Offices, Hotels and Other Establishments	4.27
9132	Helpers and cleaners in offices, hotels and other establishments	2021-8412	Kitchen Helpers	
9161	Garbage collectors	2021-8611	Garbage and Recycling Collectors	1.77
9161	Garbage collectors	2021-8612	Refuse Sorters	
9211	Farm-hands and labourers	2021-8211	Crop Farm Workers	12.49
9211	Farm-hands and labourers	2021-8212	Livestock Farm Labourers	
9211	Farm-hands and labourers	2021-8213	Mixed Crop and Livestock Farm Labourers	
9211	Farm-hands and labourers	2021-8214	Garden and Horticultural Labourers	
9312	Construction and maintenance labourers: roads, dams and similar constructions	2021-8312	Civil Engineering Labourers	2.92
9313	Building construction labourers	2021-8313	Building Construction Labourers	4.62
9322	Hand packers and other manufacturing labourers	2021-8321	Hand Packers	3.66
9322	Hand packers and other manufacturing labourers	2021-8329	Manufacturing Labourers not Elsewhere Classified	
			Total share of Mpumalanga unemployment in occupation bundle	**71.36**

Source: Authors' calculations based on Statistics South Africa (2023a; 2023b; 2023c; 2024a) and DHET (2021)

Figure A 1: Education distribution of Mpumalanga youth employed in green jobs compared to unemployed Mpumalanga youth, by previous employment status



Source: Authors' calculations from Stats SA (2023a; 2023b; 2023c; 2024a); DHET (2021)
Note: 1. Unemployed youth are all those categorised as unemployed under the broad definition of unemployment. 2. Youth are categorised into categories of "Previously employed" or "Never-employed" according to the "Previous occupation or industry" question in the QLFS. Any respondent with no response to their previous occupation or industry was classified as "never-employed".

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