Identifying the potential for green jobs and associated skills needs: Methodological concepts applied to the South African coal mining industry

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Abstract

The idea of green growth holds much promise but also much uncertainty. It is hard to predict what new jobs might emerge, what new skills will be needed, and just how to achieve a transition that is socially inclusive and economically feasible, while shifting entire systems towards greater environmental sustainability. How should organisations respond, so as to benefit from and contribute to green growth? Based on research to identify environmental skills needed in the South African mining industry, and other sectors, this paper proposes a number of methodological innovations. One is to expand the standard value chain analysis, by using a critical realist methodology that also looks for absences: value that should be there but is currently destroyed or untapped. An example is the restoration of mined land, a form of regenerative economy with the potential to reduce value destruction and create new social, economic and ecological value. Identifying such leverage points can show up the possibility of new or re-configured jobs in the transitions to more sustainable development, in this case a transition away from coal. Another innovation involves the identification of the associated skills requirements. More than technical skills are needed, but just what do so-called 'soft skills' entail, and how can they be developed? The paper concludes with tools to apply at organisational level for green skills needs analysis, using a framework of technical, relational and transformational competencies, in support of the quest for green growth in senescent or at-risk value chains.

Keywords: sustainable development, value chain analysis, leverage points, mine restoration, relational and transformational competencies

Introduction

> "The future is often viewed through the mirror of the past. This can be risky, if past trends are allowed to influence or even determine what is considered a realistic strategy. This is particularly true if such factors are part, or even the main drivers, of the present problems. If we look at the problem of non-sustainability, such factors could be today's use of fossil fuels, today's accounting systems for economic performance (GNP), today's traffic systems, and today's public knowledge about environmental issues. If those factors are allowed to be the main determinants of what is taken to be relevant and realistic in the planning process, the strategy is likely to transfer the problems that are due to these factors into the future." (Holmberg & Robèrt, 2000, p.6)

The idea of green growth holds much promise: to slow and where possible reverse the damage caused to ecosystems by economic activity, in order to sustain natural resources like clean water and fertile soils that in turn sustain all life on the planet; *and* to re-configure economic activity so as to benefit those currently excluded (Stern, 2007); that is, sustainable development (Knudsen et al., 2023; Raworth, 2017). In the process, work opportunities could also be created. The International Labour Organisation (ILO, 2023) estimates that if Europe was to meet the targets of the New Green Deal and become carbon neutral by 2050 it would translate into approximately 2.5 million additional jobs in the European Union by 2030. A Global Commission on the Future of Work (ILO, 2019) reported that implementing the Paris Climate Agenda could lead to global job losses of around 6 million but also job gains of 24 million.

However, the idea of green growth also holds much uncertainty, particularly for work-based skills planning: Where can companies expect such green growth, and how will it happen? Will new policies actually be implemented? Who will invest? Companies may be unaware of global developments or unsure as to whether they should commit, while entire industries may be resistant. Such uncertainties stem from the complex nature of sustainability challenges (Holmberg & Robèrt, 2000) and the nature of sustainable development policies, which are often contested, ambiguous, contradictory, or inconsistently implemented (Chipkin et al., 2018; Death, 2014; Fakir, 2017; PAGE, 2016).

The unpredictable nature of the policy landscape presents a challenge for predicting what new green jobs will materialise and what skills will be needed (McLean, 2018). Skills needs analyses are in some contexts also hamstrung by the dearth of available data (Mwaura & Glover, 2021) and when conventional research instruments are applied in the face of all this uncertainty, the findings can be inconclusive or fail to drive transformation, as the opening lines, quoting Holmberg and Robèrt (2000), suggest.

Based on research to identify green skills needs in the South African mining industry (Rosenberg et al., 2015), as well as other sectors, this paper proposes methodological innovations for approaching skills planning in the face of such unpredictability. These include an extended industry value chain analysis that expands the classic concept of a 'chain' to

recognizing the weblike nature of value creation in industry, and through a dialectical critical realist lens also identifies absences: value that could be there but is currently untapped. Identifying leverage points for change (Meadows, 1999) can show up the possibility of new or re-configured jobs to compensate for job losses occurring in transitions to cleaner, 'greener' economic activity, even when this demand might still be latent, that is, not yet evident in the labour market.

The second proposed innovation involves the identification of the associated skills and skilling, upskilling and re-skilling needs, using a framework of technical, relational and transformational competencies (PAGE, 2016). The paper expands on this competency framework, and shares tools for organisational level skills needs analysis, in support of the quest for green growth and sustainable development.

The research from which these conceptual-analytical tools emerged, includes a programme of green skills demand studies conducted over more than a decade. The core of these studies involved a partnership between three South African universities, several government departments and industry partners including Sector Education and Training Authorities (SETAs). Starting in 2015, these studies explored value chains and associated skills needs in the mining industry (Rosenberg et al., 2015), the chemical (Jenkin et al., 2016), petrochemical (Ward et al., 2017) and agricultural (Cobban & Visser, 2017) sectors, as well as government procurement (Ward et al., 2016), and a cross-sectoral green economy learning needs analysis (PAGE, 2016). More recent studies involving land restoration (Human, 2020) and value chain innovations (Royle, 2023) were also included in the analysis. These studies were all conducted in South Africa, but the findings may apply in other contexts as well.

While the meta-analysis for emerging concepts included all these studies, the discussion will for illustrative purposes focus on the coal mining industry and in particular on mine restoration.

Literature Review – Context and Theoretical Roots

In 2015 the South African Mining Qualifications Authority (MQA) commissioned a study to determine environmental skills needs and learning opportunities in the coal mining sector in South Africa (Rosenberg et al., 2015). To design the study, the researchers drew on methodological insights from earlier research. This included a study to produce a skills strategy for biodiversity research and conservation (SANBI, 2010) which found that a holistic systems perspective on skills planning was needed; for example, skills interventions focusing on individuals were not effective unless attention was also given to workplace conditions. This perspective is well captured in the 'nested systems' diagram (Rosenberg & Ramsarup, 2020). Research into learning pathways and transition into green jobs (Lotz-Sisitka and Ramsarup, 2011) was also influential. These studies were in turn informed by research into sustainability transitioning, including the multi-level perspective on change developed by

Rotman and Loorbach (2009) and Geels & Kemp (2012). Rotman and Loorbach introduced a relational approach to studying change in complex systems, which also emerged as an important focus in the South African studies.

Perhaps the most influential theoretical influence on the South African 'green skills' studies was dialectic critical realism (Bhaskar, 1993) which led the researchers to approach skills contexts as a layered or laminated totality, with the interconnections and influences within and between the layers being vitally important (Rosenberg, 2020a). This is a key distinction from multi-level skills research methodology outlined by the ILO (2016, 2019, 2023). It is not only necessary to collect data and analyse it at multiple levels, but it is also necessary to analyse the connections between layers, or for that matter the absences, or connections that should be there, but are not. This intention to not only describe what is (as in a positivist, empiricist study) but also on 'what could be, and should be, but is not', was guided by the transformational dimension of dialectical critical realism (Bhaskar, 1993), which, similarly to Engeström's (2014) transformative development work approach, guides researchers to probe contradictions and absences as leverage points for learning and change.

During the MQA study (Rosenberg et al., 2015) on skills for mining, a number of contradictions were found to characterise the South African mining industry. A mining expert (Digby, 2014) summarised the sector as being at a crossroads with an uncertain future. Once the backbone of a thriving economy, South African mining had been losing its global market share (Baxter, 2016), plagued by declining productivity and increasing energy costs. By 2015 the industry had been operating at a net loss and shedding jobs. Coal mining in particular was being challenged by environmental drivers. The South African Coal Road Map Initiative (SACRMI, 2013) predicted further stagnation and job losses, with coal deposits becoming more inaccessible, coal mining becoming more expensive, alternative energy sources like solar and wind becoming more competitive, and water shortages. The industry has been water intensive as coal is washed before being burned in coal-fired power stations, which in turn also use large volumes of water to generate electricity, a growing concern in a country at risk of crippling water shortages due to climate change. Following the 17th Conference of the Parties, COP17, which was held in South Africa, a Green Economy Accord (EDD, 2011) was struck between industry, labour, government and civil society, committing South Africa to a clean, environmentally sustainable growth path that would reduce the use of coal and other fossil fuels, but at the same time create new jobs. Civil society argued that South Africa could and should develop one million climate jobs (AIDC, 2011). The transition would have to be well thought-through. Energy and sustainability experts (Eberhard, 2011; Eberhard et. al, 2014; Fakir, 2017) published energy transitions studies that outlined the complexities, including the 'locked-in' nature of the minerals-energy complex in South Africa. Currently the coal value chain is at the heart of the just energy transition debates in South Africa (Montmasson-Clair, 2023).

The situation is to some extent representative of the rest of the world, in the sense that South Africa experiences strong external and some internal pressures to reduce its reliance on coal;

there is an espoused commitment by the government to decarbonise the economy; but there are also significant drivers for the status quo to remain. It is perhaps most similar to Australia, where coal has been a backbone of the economy with the mining industry taking pride in its world leader status, and where there have been political divides on the extent to which the country will phase out coal. These were reflected in significantly different commitments by consecutive governments, between 2015 and 2022, to the Intended Nationally Determined Contributes required by the Paris Convention (Weldegiorgio, 2025). In Germany, by contrast, there has been a more consistent commitment to an energy transition (*Energiewende*) that enjoyed decadal, multi governmental support (Cheung, Davies & Bassen, 2019).

In South Africa, the sustainability context around 2015 was dynamic but largely uncoordinated, with the transition towards green growth more of an intention than a coherent programme of action. Skills planning needed a new approach. South African universities, with national government and international partners like UNITAR (United Nations Institute for Training and Research) had some success with a multi-method national study to determine Green Economy Learning Needs (PAGE, 2016). This study produced a framework for competencies that stretched beyond the technical, to make 'soft skills' more visible and producible, by conceptualising them as 'relational' and 'transformational'. The technical-relational-transformational competency model (PAGE, 2016; Rosenberg et al., 2018) drew on a systematic review of sustainability competencies by Wiek et al. (2011) as well as Otto Scharmer's (2009) transformational leadership model.

This paper shares what has been ascertained in the 2015 study regarding skills and competencies needed to shift the coal mining industry towards sustainable development. These findings will be followed by a discussion which will also refer to findings from more recent studies, thus providing an update on an earlier analysis of the 2015 study (Rosenberg, 2020b).

Methodology: Meta-Review of Selected Studies

This paper provides two sets of findings, based on two methodological processes which are both outlined here. Firstly, the conceptual findings in the paper, regarding the merit of the emerging conceptual-analytic tools for green skills studies, are based on the author's meta-review of a selection of green skills studies undertaken in South Africa from 2015 - 2023 (Table 1). The intention of this review is not to compare one methodological approach with others and there is therefore no attempt to be comprehensive in reviewing all green skills studies undertaken in South Africa or internationally. The aim is to explore whether certain analytical tools have merit, and the selection in Table 1 is therefore intentionally restricted to those studies in which the author has close knowledge of the study design and outcomes.

This small-scale meta-review is a version of a theory mining review (Okoli (2015) and informed by the understanding that theory is proposed by identifying key concepts and postulating the relationships between them (Sayer, 2010), which is the purpose of Table 1.

Secondly, the paper also shares empirical findings, to illustrate the identified concepts and demonstrate their proposed merit. Although the methodology of the study on coal mining is the subject of this paper, since some of that study's findings are also reported here, its methodology will also be summarised here. It is a laminated methodology, with a mixed method approach, and in the case of the green skills for coal mining study (MQA, 2015), the main methods and data sources were:

- Document analysis (iterative macro-level and meso-level analysis of relevant Acts, policies, policy guidelines and sector strategies)
- Site visit at the micro-level (workplace) to a coal mine
- In-person interviews and email consultations with mine employees, mine management and various mining and environmental experts,
- Audit of available courses and learning programmes based on a review of university websites and email engagements for clarification.

Table 1 lists the studies, showing the conceptual-analytic tools identified as useful; and the relationships between the concepts that emerged in the studies. While the emphasis in the discussion will be on coal mining, the other studies listed and reviewed served as 'test cases' to further test and refine the methodology for green skills determination. As noted in the Literature Review, the MQA (2015) study was already informed by the developing methodology explored in previous studies, some of which will also be referred to in the discussion.

Table 1: Concepts and relationships identified through theory mining

Study	**Concepts That Proved Useful**	**Relationships Between Concepts Identified**
Report on Green Skills research for the Mining Qualifications Authority (Rosenberg et al., 2015)	Extended value chain - value network or value web	Absences in the value network / web (non-circularity) due to historical factors - notably rehabilitation, compliance, waste management are missing
	Multifactorial driver analysis (qualitative) with history added (PHESTLE)	Historical considerations explain current contradictions in skills needs data
	Contestation in skills needs; conflicted job demands	Absences in the identification of skills needs; contradictory data

	Skills needs extend beyond technical know-how, to relational and transformational	Rehabilitation not possible under current social conditions and governance arrangements
	Skills needs extend beyond technical know-how, to relational and transformational	'Lock-ins' in the energy-minerals complex and historical economic practices
Green skills in the South African surface coatings sector: A focus on paint (Jenkin et al., 2016)	Multifactorial analysis (qualitative) with history added (PHESTLE)	Meso - and micro-level interactions
	Cross-occupational work tasks	Employee groups need to work across organisational divisions and occupational levels on sustainability tasks
Green Skills for Climate Smart Agriculture: A Case Study of Poultry, Winter Grains and Deciduous Fruit Value Chains in the Western Cape (Cobban, Visser, et al., 2017)	Multifactorial analysis (qualitative and quantitative) with history added (PHESTLE)	Meso - and micro-level interactions
	Innovation occurs in niches, but policy is mostly at industrial scale	Contradiction: small scale circularity and innovation towards local, organic production and waste reduction, whilst policy and training foregrounds (counter-productive) industrial scales
Occupationally directed skills development for green public supply chain management (Ward et al., 2016)	Multifactorial (quantitative) driver analysis	Strategic leverage points to green or sustainable public procurement can be quantified, while taking social, employment, cost savings and environmental benefits into account
Green Economy Learning Needs Assessment South Africa (PAGE, 2016)	Overlapping technical, relational and transformational competencies Transdisciplinary and distributed competence	Unstructured and networked nature of developing 'new skills'
Developing social indicators for the evaluation of natural resource management	Technical, relational and transformational competencies	Meso - and micro-level interactions

programmes using a capability approach in the Eastern Cape, South Africa (Human, 2020)		
Social Learning and Regenerative Sustainability: Unlocking value created in sustainability projects in higher education (Royle, 2023)	Technical, relational and transformational competencies	Unstructured and networked nature of developing 'new skills'

Analytical Tools and Associated Empirical Findings

Determining latent demand: The value of an expanded value chain analysis

In sectoral research it is standard practice to map an industry value chain (Herr & Muzira, 2009). In a document analysis of various industry publications, the typical presentation of the mining value chain was found to be:

Figure 1: Typical value chain representation for the coal mining industry

The MQA (2025) study showed however that, based on a macro-level analysis of international and national policies and Acts related to environmental management and the protection of water resources, as well as interviews with mining and sustainability experts, the typical conceptualisation of the coal value chain should be expanded: Before mining even starts, investment in exploration is needed, as well as research and development (R&D). To obtain what is termed in South Africa 'the social license to mine', companies must produce plans for local socio-economic development, but this is not included in the typical value chain. Neither is environmental management, nor a commitment to concomitant rehabilitation, remediation, reclamation and restoration at the point of mine closure, all of which are legal requirements. For coal mining this is a stark omission, because much of what is mined is not

saleable, and it is estimated that miners annually add more than 65 million tons of coal discards to the existing two billion tons of coal fines already deposited on the South African landscape. Despite this significant feature of coal mining, waste is not depicted in the value chain; an example of the externalisation of environmental costs (Raworth, 2017). Neither is the regulatory function, nor the financing and insurance that allows mining to proceed. In order to identify environmental skills needs, the simple linear value chain needed to be expanded to trace the full web of functions that are all needed to create value for the industry, including R&D, financing, insurance, corporate governance and sustainability reporting, regulation, prospecting, mining, processing, logistics, procurement, beneficiation, and waste management, as well as local development and human resource development. Education and training, including worker training in Occupational Health, Safety and Environment, emerged as scarce skills in the 2015 study.

For skills studies, the tasks that create the value in the chain (or web) must be mapped in some detail, together with the skills (occupational roles and associated competencies). In the MQA study the mapping of the value web was started with document analysis but also required interviews and site-based observations, to identify what occupations are or should be involved, what tasks they entail, and the specific competencies (knowledge, values, capabilities) needed for these tasks. 'Skills' is the term used in this paper for these occupations and associated competencies.

Through the extended value web analysis, the study found that green skills needed in coal mining, include:

- design innovation for safer and less damaging mining practices
- design innovation for cost-effective, water-efficient mining and beneficiation and dry processing
- management of discards and spoils
- remediation and reclamation science
- resource economics to determine rehabilitation and reclamation costs and benefits
- sustainability reporting (at head office level)
- procurement of environmentally sustainable goods and services (at the mine)
- environmental management (on site)
- occupational health, safety and environment officers (on site)
- environmental compliance enforcement (in government) and
- environmental regulation (e.g. issuing of mining and water licenses),
- among others.

With such a large number of green skills needs identified, an analytic tool was needed to identify which skills were the most important, so as to guide training and training programme development and resourcing.

In this case a quantitative approach was not feasible; there was limited available data about activities across the vast value web and it was unrealistic to generate this. More importantly, there was some contestation about what skills were actually needed. Government reported that there was adequate investment in remediation science, whereas universities reported they were under-resourced. The Department of Mineral Resources and Energy (DMRE) reported that it had enough, well qualified staff to process mining applications, but an environmental agency reported that the staff with this role were not up to the task. It took an interview with a former employee to ascertain that while well qualified graduates had the task of vetting mine applications, it was a difficult job because there was pressure to approve applications quickly, but also pressure to mitigate against pollution and protect scarce water resources. This micro-level data led back to the macro-level analysis of policies, to find that the occupational task was made difficult by conflicting policies: the Minerals and Beneficiation Act, which encourages mining, and both the National Environmental Management Act and the National Water Act, which demand environmental protection. This suggested that among employees, navigating this dual mandate successfully requires more than technical competence.

Before elaborating on this finding, it is important to note that data was needed at the level of macro-economic and national and international policies; at the meso-level of industry specific policies and practices; and at the micro-level of actual workplaces, be these the mine or the regulatory office. Moreover, the analysis of this data needed an iterative relational analysis across the levels. This analytic process resonated with our chosen methodological framework that was not only multi-level but *laminated* (Bhaskar, 1993) and iterative (Rosenberg, 2020a).

A conceptual framework for analysing competencies needed

A few occupations identified as important environmental skills for coal mining will be mapped here to demonstrate the competencies needed.

First, consider the already mentioned 'conflicted graduate' who has to process license applications under time pressure. High levels of technical knowledge are needed, not only of the use of the application system, but also of the relevant laws, policies and guidelines that should be applied, and the technical content behind them, e.g. regarding water management, solid waste, air pollution, environmental and human health, the role of mining in the national and regional economies, and more. Some of this knowledge would be developed as part of an Environmental Science degree; some would be developed on the job (e.g. the online application system used by the DMRE). But it is clear that individual licensing officers were unlikely to have *all* the necessary technical knowledge, and as in other complex sustainability related occupations (PAGE, 2016), they may need to draw on other internal or external experts. They also need to engage with the applicants, and they may need to report to senior management that the task is challenging and warranted additional support.

These required competencies, the so-called 'soft skills', can be described as 'relational' (PAGE, 2016). One could further argue that transformational competencies are also needed: by the managers of the licensing officers, to develop new work systems and processes that would shield staff from external pressures; and higher up in the system among policy makers, to address the policy ambivalences.

Another occupation that was reported to be associated with almost intolerable pressure in the workplace is the compliance officer, who is employed by the DMRE to do inspections on the mines. As she arrives on site, she finds her fellow graduates, employed by the mining industry, working with tight production targets and unwilling to collaborate with her to monitor environmental compliance. The reception she receives is also affected by the fact that while she has the same qualifications as the mine environmental managers, she earns less. It takes a particular relational skills set on top of high levels of technical competence and commitment, to see this job through. The DMRE reported high levels of turnover in the position, implying that not many are willing to do this work, leading to scarcity. It confirms an observation in SANBI (2010) that investing in skills is not enough; workplace conditions are also important. These workplace conditions are created by Human Relations and other corporate management occupations, which therefore also need good relational and transformational competencies, and also need to be included in value web analyses, if the intention is transformation.

Another occupation that needs technical, relational and transformational competencies is the project manager tasked with mine closure. The closing of a mine is a tension-filled time and space often characterised by violent reactions from employees and neighbouring communities whose livelihoods are now in jeopardy. In the context of gold mining, Secombe (2014) reported this as one of the reasons why mine closures are often rushed or incomplete. The project manager needs competencies that range from the technical ability to organise and oversee the operation of earth moving equipment, to the relational competence to engage disgruntled employees; the entire operation also needs to envisage alternative development options.

Mine rehabilitation can immediately provide value in the form of jobs but also restore some value to the area for future use. The standard practice in South Africa is however *not* to fully rehabilitate and reclaim coal mines. Mines are either sold, un-closed, to a new owner who nominally takes on the rehabilitation responsibility, or simply abandoned (Liefferink, 2016). To shift this practice, resource economists and others are needed to innovate in the value chain so as to find resources to pay for rehabilitation. The Green Economy Learning Assessment South Africa (PAGE, 2016) found "making the case" for government and corporates to invest in environmental protection, to be one of the top seven competencies needed for transitioning to a green economy (PAGE, 2018). In the case of enforcing and financing mine restoration, the technical, relational and transformational competencies required include resource economics and innovation in accounting systems. Blignaut et al.

(2013) argue for a change in accounting practices; 'natural accounting' where investment in the restoration of land and water as assets, are counted as positives on the balance sheet, rather than deducted as costs.

For these more complex tasks at the leverage points towards more sustainable development, no single individual can hold the necessary competencies - teams are needed, or put differently, distributed competencies.

In addition to determining skills demand, the MQA study (Rosenberg et al., 2015) also conducted an audit of courses offered by education providers to meet the demand, and possible gaps. In keeping with the study's iterative, laminated approach, the provider audit was conducted throughout the second half of the study and informed by the findings regarding skills needed, as they emerged. As the researchers realised that it took more than technical competencies to process a mining license, or project manage mine closure, they started looking in the provider audit for programmes that develop relational and transformational competencies alongside or in relation to, more technical skills. These turned out to be upskilling and reskilling programmes for mid-career professionals, who had identified these competency needs in their own experience in the workplace.

While other studies (e.g. Ramsarup, 2017) showed that extensionists, engineers and other professionals working in the cross-disciplinary sustainability space had few if any clearly laid out learning pathways, the mining sector is quite structured and so are associated training opportunities. Thus, there were undergraduate programmes in mine rehabilitation (e.g. at the University of Venda), and sustainability courses at postgraduate level for mining professionals (e.g. at Wits University). The latter programme focused on strategic leadership for mid-career professionals and made use of expertise from a variety of fields, case study analyses, interactive and deliberative learning activities. Such programmes were reported to be (human) resource intensive. Overall, education providers reported their programmes to be sought-after but under-resourced, and the number and size of programmes available to learners was found to be very limited compared to the need.

Discussion

Analytic Concepts Applied to Mine Restoration

To illustrate the application of the above two analytic tools for green skills demand and supply studies, consider how a company or industry may determine the skills needed for the restoration and rehabilitation of mined areas in South Africa.

Given the complexity of the systems within which skills need arise, the analysis would be laminated (systemic and relational). One laminated layer would involve a macro-analysis, looking at global and national trends, policies and legislation that might shape the demand for rehabilitation skills. This is a standard practice in skills studies (ILO, 2016; UNEP, 2008), but the analysis deepens at the point of considering interactions between factors, both within and between the layers, and history. For example, in this case, the South African Constitution and associated legislation (such as the National Water Act and the National Environmental Management Act) aim to ensure citizens a healthy environment free of pollution; with principles including Polluter Pays and Precautionary Principle. The Mining and Minerals Act states that the right to mine is dependent on the owner undertaking to close the mine on completion of operations and rehabilitate the land; rehabilitation should also occur concurrently with operations while mining is still active. In combination with the National Water Act and the National Environmental Management Act, this means taking all reasonable precautions to prevent pollution. Given the stipulations of the mining license, reasonable precautions include rehabilitation and restoration, both concurrent and at the end of operations. On the basis of this set of regulations, mine rehabilitation would be one of the most in-demand job opportunities in the country.

In the MAQ (2015) study, mine executives agreed that concurrent rehabilitation is best practice; however, this does not seem to be applied in practice. The Centre for Environmental Justice reported the existence of 6,000 abandoned and derelict coal mines. Thus, the potential for employment creation and environmental restoration remains untapped, because mining companies do not rehabilitate the sites they leave behind (Liefferink, 2016). Employment will only be unlocked if a mechanism is found to disrupt this 'lock-in' (Fakir, 2017). Looking at both macro-level current trends and historical lock-ins as well as interactions between them is important for skills needs predictions, but clearly not sufficient.

At the meso-level one would look at the industry itself, as shaped by global and national but also regional trends. The South African coal mining industry has been described as at the heart of the country's Just Transitions challenges (Montmasson-Clair, 2023). The coal value chain has been analysed for employment vulnerabilities by Makgetla et al. (2019) who found that more mines are likely to close due to the reduced demand for energy in a stagnant economy that has previously obtained virtually all its electricity from coal. Reiterating the commitment of the 2011 Green Economy Accord, which pledged support for climate change commitments to reduce greenhouse gas emissions on a green, low-carbon and labour-

intensive development path (EDD, 2011), the South African president in 2020 launched a National Climate Change Adaptation Strategy with a commitment to

> "… a new, inclusive economy that creates employment and fosters sustainable growth. An important aspect of this new economy is that it must be able to withstand the effects of climate change. A climate-resilient economy is necessary to protect jobs, ensure the sustainability of our industries, preserve our natural resources and ensure food security" (Ramaphosa, 2020)

But *will* coal-fired power stations and coal mining be phased out in the foreseeable future? Why, given the availability of cleaner alternatives which are now more cost-efficient than coal, has this not yet happened? The skills analyst needs to consider that there are counter-pressures from various sources (Fakir, 2017; Chipkin, et al., 2018). As is the case in the United States and Australia (Weldegiorgio, 2025), South Africa's coal mining is regionally concentrated. In these regions, local economies are largely undiversified, and highly dependent on coal, both for direct and indirect employment (Montmasson-Clair, 2023). Coal workers are largely semi-skilled and unskilled, with a majority not completing high school, but better paid than similarly qualified workers in other sectors; they are also highly (74%) unionized and enjoy strong political backing (*ibid*).

Unlike in the case of consistently supported energy transitions such as Germany's *Energiewende* (Cheung, Davies & Bassen, 2019), the extent to which climate related agreements will affect South Africa's coal industry is therefore unclear. However, whether mines close or not, and workers lose jobs or not, the restoration of mined land remains a significant social and environmental concern, and it can generate jobs for thousands that are not yet employed. Montmasson-Clair (2023) makes the point that any just transition in South African starts from a current point of injustice, with Africans, in particular the poorest, producing a far smaller share of the worlds' greenhouse gas emissions, but bearing the brunt of climate crises like floods and droughts. He also confirms the importance of rehabilitation as part of transformative justice, noting the importance of structural reforms and paradigm shifts.

What is furthermore clear, is that if employment in mine rehabilitation and remediation is unlocked, the skills required will not only be technical. Technical skills will indeed be necessary, to clean up polluted water and soil; reclaim valuable minerals; restore soil fertility through a range of means. Technical skills are not limited to technical knowledge; they would include adaptive management, because, as a mine-based environmental manager shared in the MQA (2015) study, technical know-how needs to be applied in the workplace, and then further refined, as one needs to learn from the often unexpected or incomplete outcomes of restoration and other environmental management actions.

At the micro- or company level of the laminated skills analysis, perhaps through case studies of individual mine closures, one would note that in addition to technical competencies, relational or social competencies will also be vital for any company wishing to rehabilitate a

mine site, particularly at the point of closure, when there would be high levels of dissatisfaction among workers about-to-be retrenched, and neighbouring communities. To move into such a situation with rehabilitation teams, will require the ability to analyse context, politics, culture, gender relations and more. This may be the case even before mine closure. In one study involving soil and wetland rehabilitation (Human, 2020) it was found that rehabilitation work is allocated by local leaders to residents on a roving basis, involving an intricate mix of cultural norms (governed by a traditional authority system) as well as national (democratic) government procurement criteria. Here again the importance of a systemic vantage point and considering interactions, in this case between the meso- and micro-levels of the laminated systems affecting skills needs, is evident: Based simply on national or environmental priorities, skills for rehabilitation may be needed at the most degraded sites but in practice, they may be employed elsewhere, based on local considerations that exceed the technical. To mediate between these competing demands, project managers will need relational competencies.

The transformational skills to unlock a new practice of investment in mine rehabilitation has been outlined above. For these more complex tasks at the key leverage points towards more sustainable development, no single individual can hold the necessary competencies - teams are needed, or put differently, distributed competencies. In a study on the chemicals industry, Jenkin et al (2018) termed these 'occupational teams', and a paper reflecting on the Green Economy Learning Assessment for South Africa (Rosenberg et al., 2018) elaborated on the distributed nature of sustainability competencies in other contexts, too.

Undertaking the hypothetical 'skills for restoration' study would be a worthwhile exercise, because several studies including Liefferink (2016) and Maia et al. (2011) have shown that there is a demand for restoration of degraded land and the rehabilitation of mine contaminated ecosystems and that restoration and other natural resource management activities can create as many, or more, jobs than any other sector, including energy, or mining itself.

But what about the individual workplace? Geels and Kemp (2012) argued that it is from micro contexts (niches) that sustainability transitions will spring, and this has also been the experience in South Africa. This might mean that individual workplaces will have sustainability skills needs that are best determined at their own level, with the bigger picture in mind. The tools in the Appendix 1 (Tables 2 and 3) have been designed in the PAGE (2016) study and can be used by individual companies and organisations, but also by 'teams' with members from more than one workplace, who may need to work together on, for example, environmental impact assessments, cleaning up spills in rivers that span several management contexts, and so on, to determine skills needs in those specific contexts. The tools are simple, but have significant features, the first of which is this recognition of the need to skill a team, rather than only one individual. The second important feature is that reference to relational and transformational skills are built into the template, to remind employers, employees, planners and providers, of the need for more than technical skills. The tool

should ideally be used with a guide on what the different types of competencies might entail (definitions such as those developed in PAGE, 2016) as well as an audit of existing providers and the types of learning opportunities they offer. Attention is needed to whether the learning opportunity is likely to build the type of competency needed in the particular context. For example, sending an individual licensing officer on a short course to enhance her technical skills on the online application system might not be as effective as sending an entire team on a short course where a learning network can be activated, to also learn from and build a community of practice with others in similar challenging situations.

Comparison with international contexts

How does this range of competency requirements compare to other contexts, internationally? A study for the Minerals Council of Australia (MCA, 2019) is informative. Focusing on the impact of technology, but also sustainability requirements, it predicts that the industry's skills demand will be for a great increase in non-routine, cognitive tasks, and some increase in non-route manual tasks. Routine cognitive tasks will decline, and so will routine manual tasks, due to digitalisation and automation. The study further reflects that the technology transformation will create a demand for technical skills like systems evaluation and systems analysis, but also skills like "active listening", "active learning", "judgement and decision making" (MCA, 2019:18) - what in the framing of this study, we could call relational and transformational competencies. The similarity to the South African findings is striking, even when comparing the impact of technology transitions, with the impact of sustainability transitions.

A key similarity between coal mining in South African and coal mining in Australia is in the level of uncertainty with regards to the socio-political commitment to phasing out coal. The laminated (systemic and relational) methodology for skills determination may be particularly suitable for such uncertain contexts, and the MCA (2019:8) report also recommend "iterative review, feedback and testing" to be incorporated in the development of a skills roadmap for Australian coal mining. The methodology discussed here may be less needed in contexts of greater certainty, with fewer regional differences in terms of the reliance on a coal economy, and/or a more stable policy context, e.g. in Germany's consistently implemented socio-technological plan for an energy transition (Cheung, Davies & Bassen, 2019). However, uncertainty is to a greater or lesser extent a feature of most work contexts today; as the MCA (2019:3) puts it: "We face a future of work with more unknowns than knowns". This finding may be echoed by other authors in this Special Issue reflecting on the challenges experienced by vocational education providers, to respond to industry needs that are not easy to pin down in relation to transitions at different levels (Gustavsson, Halvarsson Lundkvist and Thunqvist, 2025).

Conclusions

In summary, a theory mining analysis of a series of green skills studies undertaken in South Africa since 2015 has shown that a critical realist laminated methodology is useful for identifying latent jobs and latent skills needs. By looking for what is there, but also for value that could and should be there but is not, in the expanded value chain of coal mining, through the interplay between macro, meso and micro level findings, the researchers determined that a range of skills are needed, from innovation in mining design and financing, through to remediation and restoration, environmental governance, and the technical, relational and transformational competencies to achieve the sustainable development goals, particularly in the context of an industry as challenging as coal mining.

The rehabilitation of mined land is a regenerative economic activity in which value that is either destroyed, or untapped, is potentially recreated. To achieve this potential, technical skills needed include mine water remediation, soil and wetland restoration and rehabilitation. Some of these skills already exist, as do relevant courses and research programmes, albeit under-resourced. Technical and transformational skills are needed to reconfigure accounting practices in order to finance rehabilitation and the associated jobs, as well as skilling and reskilling of retrenched workers. Again, more than technical skills are needed, to start and sustain rehabilitation initiatives, in contested and uncertain socio-political contexts. The range of competencies needed to innovate towards greater environmental sustainability in coal mining will be distributed across groups, as has been found to be the case elsewhere. In the contexts of high potential but also high levels of unpredictability, employers and skills planners can determine context specific requirements through tools that look for skills needs in groups, rather than individuals, and plan accordingly. It would seem that these findings are also applicable in other contexts navigating the changing nature of work, with high levels of uncertainty, in transitions towards environmental sustainability.

APPENDIX: Tools for Workplace Level Green Skills Planning

At each leverage point for change towards sustainability or green growth, ask the following questions in the team/ unit/ department:

	In relation to the tasks in the first column, and our competencies…		
What are …	**What are the strengths in our team?**	**What are our competency gaps?**	**How can we improve our competency mix and levels?**
The technical task(s)?			
The people related task(s)?			
The transformational task(s)? (What change do we want and why?)			
Hint: Use the tasks and competencies discussed in the Green Economy Learning Assessment (PAGE, 2016) to guide you in completing these columns			Hint: Use the next table and a database of available sustainability courses for this column

Table 2. Tool for Localised Learning Needs Assessment (PAGE, 2016)

Learning options	Is good for:	Not good for:	Good in combi-nation with:	Possible providers, places, resources, people: *Hint: Start with a database of available courses, explore further*	Decision
Enroll for a long course (degree, certificate)					
Attend a short course or workshop					
Online course					
Conference					
Informal networks					
Professional association					
Monitoring or coaching					
On the job learning					
Brown bag lunches					
Reading, guided or sharing					
Own action research					

Table 3. Green Economy Learning Options Decision Making Tool (adapted from PAGE, 2016)

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