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Power, People, and Productivity: Skills Development for South Africa's Just Energy Transition

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Power, People, and Productivity: Skills Development for South Africa's Just Energy Transition

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Abstract

Just over 60 million people call South Africa home; at the same time, the country faces an unemployment rate of 33.2%, alongside persistent inequality, entrenched poverty, and economic stagnation. The Just Energy Transition (JET) presents a critical opportunity to address some of these structural challenges. While the JET is not a panacea, it offers scope to simultaneously strengthen energy security, stimulate the economy and job creation, and address long-standing skills constraints. In what the International Energy Agency terms the "Age of Electricity", global demand for clean energy is accelerating, and it will not wait for South Africa's education and skills systems to adjust. Failure to proactively align human capital development with the energy transition risks entrenching existing inequalities and creating new ones, undermining long-term inclusive growth. This paper argues that skills debates surrounding the energy transition must place greater emphasis on basic education, alongside post-school education and training, despite its relative neglect in the existing literature.

This paper employs a qualitative policy analysisand develops a conceptual framework linking basic education, skills formation, labour market outcomes, and the energy transition to economic growth. A constraint-based diagnostic approach is used to identify key bottlenecks in South Africa's energy skills pipeline. As a result, this paper identifies four interlinked reform levers. First, it recommends a clearly mandated convening authority to align education, skills, energy, and labour-market policies. Second, it highlights basic education as a foundational constraint, calling for the integration of JET-relevant content to expand the future skills pipeline. Third, it points to misalignment in post-school education and training, motivating reforms to SETAs and deeper public-private collaboration. Finally, it emphasises the need for stronger and more decentralised industry participation in skills development. Together, these recommendations emerge from tracing how weaknesses in education, skills formation, and coordination shape employment outcomes, energy security, and long-run economic growth under the energy transition.

Keywords: Just Energy Transition, Employment, Skills, Education, Energy Security

JEL classification: I25, J21, J24, O15

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Executive Summary

South Africa's Just Energy Transition (JET) is not only an environmental or energy policy challenge; it is also a human capital challenge. This paper argues that the country's ability to move toward a low-carbon economy, improve energy security, and unlock inclusive growth fundamentally depends on whether it can strengthen its skills pipeline. In the South African context, the transition is taking place against a backdrop of deep structural inequality, persistently high unemployment, weak growth, and long-standing failures in education and labour-market institutions. The central argument of the paper is that the JET can become a development opportunity, but only if it is deliberately linked to skills development, education reform, and stronger institutional coordination.

The paper makes an important conceptual contribution by shifting the discussion beyond the usual focus on post-school education and training. While much of the existing literature recognises that skills matter for the energy transition, it tends to concentrate on universities, technical colleges, training programmes, or sector-specific upskilling. This paper argues that such an approach is too narrow. It shows that the foundations of the energy skills problem begin much earlier – in the basic education system. Weak foundational learning, especially in mathematics and science, narrows the future pipeline into engineering, technical trades, and other energy-related occupations. As a result, the constraints affecting South Africa's energy transition are not only about the shortage of specialised green skills today, but also about the poor formation of future skills over time.

Using qualitative policy analysis and a constraint-based diagnostic approach, the paper links education, skills formation, labour market outcomes, energy security, and economic growth. It identifies the core question not simply as whether South Africa will transition, but whether it will do so in a way that expands opportunity, rather than reproducing inequality. This is especially important because the country's energy transition is unfolding in an economy with exceptionally high unemployment, weak growth, and electricity shortages that have already imposed major economic costs on the country. In this context, energy security itself is presented as a skills-intensive outcome: a reliable electricity system depends on the availability of workers capable of maintaining, expanding, modernising, and operating the energy system.

The paper shows that South Africa faces a dual challenge. On the one hand, the country has high unemployment, especially among its young people. On the other hand, employers in the energy sector still struggle to find workers with the right technical and applied skills. This reflects a persistent mismatch between the training supply and industry demand. The problem is worsened by the ageing profile of technical workers, retirement of experienced personnel, and slow responsiveness of education and training institutions to changing skills requirements in renewable energy, storage, green hydrogen, and related sectors. The implication is clear: South Africa does not merely face a shortage of people; it faces a shortage of adequately prepared people.

The diagnostic section of the paper identifies several binding constraints. First, an unreliable electricity supply remains a major drag on economic growth. Load shedding reduces industrial activity, discourages investment, and undermines productivity. These impacts are especially severe in electricity-intensive sectors and among smaller firms, which have fewer resources to cope with disruptions. Yet the paper emphasises that the electricity crisis is not only an infrastructure problem. It is also a skills problem. Maintenance gaps, shortages of qualified electricians and artisans, and the erosion of institutional memory have weakened the system's ability to respond effectively. Without a stronger technical workforce, South Africa's electricity system cannot be stabilised or expanded on the scale required.

Second, the paper identifies skills shortages as a direct productivity constraint in the energy sector. These shortages extend well beyond engineers and include technicians, project managers, electricians, and a wide range of support roles, such as finance, planning, customer service, environmental management, and communication. The paper notes that South Africa faces a large artisan shortfall and that institutional weaknesses within the skills formation system, especially the inefficiencies of the SETA system, have created a "leaky pipeline" in which many learners fail to complete programmes or receive certification. The result is project delays, cost overruns, underqualified hiring, and weaker sector performance overall.

Third, the paper demonstrates that weaknesses in the post-school education and training system are closely tied to failures in basic education. Poor mathematics outcomes, weak teacher capacity, inadequate school resources, and low-quality vocational training all combine to restrict progression into energy-relevant fields. The paper points to evidence that only a minority of matriculants take Mathematics, that pass rates in Pure Mathematics have declined, and that many TVET programmes remain too theoretical and insufficiently aligned with industry needs. This creates a structural mismatch between the output of training institutions and the requirements of the energy transition. The consequence is not a temporary lag but a deeper and more persistent failure of alignment.

Fourth, the paper argues that weak public-private coordination is one of the most significant institutional constraints. Although South Africa has a broad policy architecture for education, skills, and energy transition, these frameworks often operate in parallel rather than in an integrated manner. Skills planning is fragmented, labour-market signals are weakly transmitted into curricula, and firms, especially small and micro enterprises, face major barriers to participating in workplace-based learning. The paper shows that this fragmentation undermines the translation of policy intent into employment outcomes. In other words, the problem is not necessarily that South Africa needs better policy, but that it needs stronger coordination and implementation across institutions.

Despite these constraints, the paper also highlights significant opportunities. It notes that the JET could generate substantial employment gains, with projected job creation in renewable energy, non-coal mining, manufacturing, construction, and associated services outweighing likely job losses overall. It also identifies domestic manufacturing of selected renewable components, energy storage technologies, electric vehicles, and green hydrogen as important growth opportunities. However, the paper is careful not to present these outcomes as automatic. Employment gains will depend on whether South Africa builds the skills base needed to participate meaningfully across these value chains, rather than remaining dependent on imports and external expertise.

The paper's policy message is that skills development must be treated as a core economic and energy strategy, not as a secondary social add-on. It proposes four interlinked reform levers. The first is stronger institutional coordination through a clearly mandated convening authority capable of aligning education, labour-market, energy, and industrial policies. The second is a renewed emphasis on basic education, including stronger teacher development, improved mathematics and science uptake, and integrating JET-relevant content into the curriculum. The third is the reform of post-school education and training, including more responsive curricula, stronger workplace-based learning, and reforms to SETAs. The fourth is deeper and more decentralised industry participation, supported by simpler administrative processes, better incentives for firms, and more active engagement of SMEs in skills development.

Ultimately, the paper argues that South Africa's Just Energy Transition must be understood as a people-centred development project. Reliable electricity supports productivity and investment, but the workforce required to sustain that reliability does not emerge on its own. It is built through long-term investments in education, training, institutions, and coordination. If South Africa fails to align these systems, the transition may deepen existing inequalities and miss a major growth opportunity. If successful, however, the JET can

become a vehicle for stronger energy security, broader employment creation, and more inclusive long-term development.

1 Introduction

South Africa has long occupied a central place in human history. Visitors to Maropeng, the visitor centre of the Cradle of Humankind, are often welcomed with the words “Welcome home” – a phrase rooted in the Setswana meaning of Maropeng as a “return to the place of origin”. The guided experience traces humanity’s evolution over millennia, situating South Africa as a foundational site in the story of human development.

As the exhibits unfold, they highlight a central theme that remains deeply relevant today: the role of energy in shaping human progress. From early innovations to modern technological advances, access to energy has consistently expanded human capability. One installation recalls how the discovery of fire more than a million years ago provided heat, light, and protection, while extending productive hours and enabling creativity. Energy, in its many forms, has thus always been a catalyst for development – an insight that resonates strongly in contemporary debates on climate change and the Just Energy Transition (JET).

This reflection is captured in a quotation from the Union of Concerned Scientists displayed at the end of the tour: “No single solution can meet our society’s future energy needs. The solution instead will come from a family of diverse energy technologies that share a common thread – they do not deplete our natural resources or destroy our environment”. Today, this insight frames South Africa’s challenge: transitioning to a low-carbon energy system that supports economic growth, energy security, and social inclusion.

South Africa’s history suggests that such transitions are shaped by critical junctures. Acemoglu and Robinson (2013) define these as major disruptions that can decisively alter a country’s development path. In Why Nations Fail, they identify colonisation and mineral discoveries as such turning points in South Africa’s past. Prior to the late nineteenth century, more inclusive economic arrangements enabled African farmers to prosper and compete in commercial markets. However, the discovery of gold and diamonds intensified demand for cheap labour and triggered policies that dismantled African agricultural success.

The resulting apartheid-era institutions entrenched a state-engineered dual economy, deliberately excluding the majority of the population from skilled employment, entrepreneurship, and advanced education. While apartheid formally ended in 1994, its legacy persists in labour-market segmentation and chronic skills shortages.

Within this inherited structural context, South Africa is now pursuing a Just Energy Transition. The energy transition intersects with the same structural constraints: unequal access to education, skills deficits, and labour-market exclusion. If poorly managed, the transition risks reproducing and deepening existing inequalities. If deliberately aligned with human-capital development, however, it offers an opportunity to expand skills, reduce unemployment, and place South Africa on a more inclusive and sustainable growth path.

1.1 Why Energy Skills Matter in South Africa’s JET

South Africa faces deep socio-economic challenges, including high inequality, persistent unemployment, poverty and sluggish economic growth. At the same time, the country faces several energy-related pressures, including a heavy reliance on coal, ageing coal-fired power stations, recurring load shedding, limited investment in new infrastructure, and weak sector management (Bohlmann et al., 2023; Ramsarup et al., 2024). While the energy transition is not the primary source of these challenges, it can offer meaningful solutions if managed effectively. It offers South Africa the opportunity to reduce carbon emissions while stimulating industrial development, fostering innovation, and promoting economic diversification – actions that can help tackle these long-standing structural issues (Presidential Climate Commission [PCC], 2022).

Nevertheless, while the JET offers opportunities, South Africa cannot overlook its current realities. The country's 2022 critical skills list shows a major shortage of local green skills, with estimates suggesting that approximately 40% of scarce skills may be strictly green-related, while the education system is not adapting quickly enough to meet this demand (Mosomi & Cunningham, 2024). Although, there is limited consensus on this figure due to differences in how 'green skills' are defined. Mosomi and Cunningham (2024) define 'strictly green skills' to include those "that require at least one task that is directly linked to the environment". Still, this failure by education and training systems leaves workers unprepared (Njokwe et al., 2025).

These two challenges are closely interlinked. Skills shortages limit the country's ability to maintain existing infrastructure, expand electricity generation, and deploy new energy technologies. In turn, infrastructure failures place additional strain on the economy and reduce the capacity of firms and institutions to invest in skills development. Addressing these skills gaps is therefore essential, as a timely and effective investment to strengthen the energy sector and contribute meaningfully to South Africa's economic growth (Swiss South African Cooperation Initiative [SSACI], 2024).

1.2 The Energy Skills Gap as a Barrier to a successful JET implementation

South Africa's energy transition is partially being slowed by a widening energy-skills gap. The country lacks enough skilled labour to maintain the grid and connect new generation (South African National Energy Association [SANEA], 2023). Despite high unemployment, especially among youth, firms still struggle to find workers with the right technical competencies, revealing a mismatch between training supply and industry demand. Slow updates to qualifications offered, weak coordination between public institutions and private firms, and poor basic education further restrict the skills pipeline (SANEA, 2023). Unless human-capital policies are strengthened, the JET will face delays, lost economic opportunities, and limited job creation.

1.3 Contribution and Research Questions

This paper examines how South Africa's energy transition intersects with long-standing weaknesses in the country's education, skills, and labour-market systems. It asks how human capital policy can be leveraged to support energy security while simultaneously addressing unemployment and inequality. This focus allows us to contribute a policy-oriented diagnosis of binding constraints and identify reform levers to align skills supply with the demands of the energy transition as an agenda for economic growth.

The literature consistently recognises skills as a key enabler of the energy transition, but analysis is largely confined to post-school education and training, with limited focus on basic education. As a result, there is little examination of how shortcomings in basic education, on both the supply and demand sides, propagate through post-school pathways into the labour market and ultimately affect energy security and long-term economic growth. This paper addresses this gap by arguing that the foundational role of basic education must be more explicitly integrated into skills planning for the energy transition.

Against this backdrop, the purpose of this paper is twofold:

1. How do weaknesses in South Africa's skills pipeline hinder the Just Energy Transition?
2. What skills shortages exist in the South African energy sector and how can the education system respond?

1.4 The Importance of Aligning Skills, Energy, and Economic Growth

South Africa's Just Energy Transition will require an expansion of the energy workforce across multiple segments of the value chain, including generation, transmission, maintenance, and emerging technologies such as storage and green hydrogen. There is a growing demand for engineers, technicians, artisans, and a range of supporting professional roles as the country seeks to both stabilise its existing energy system and expand renewable capacity (SANEA, 2023).

At the same time, the transition is not occurring on a blank slate. For example, a significant share of Eskom's most experienced staff was encouraged to retire early (Walsh et al., 2020). Furthermore, over the next decade and a half, a significant share of workers currently employed in coal-related activities will reach retirement age (Bhorat et al., 2024). This implies that part of the transition may occur through natural attrition, rather than large-scale displacement alone, and the impending loss of institutional knowledge and technical expertise further intensifies the urgency of developing skilled workers to take over.

Although, this does not eliminate the labour-market implications of the transition. While retiring workers will be replaced by new entrants, these entrants are likely to earn lower wages and may not possess the same level of experience or firm-specific skills (Bhorat et al., 2024). While this may reduce some of the immediate fiscal and social costs associated with job losses in high-emitting sectors, without targeted investment in skills development, the transition risks replacing experienced workers with a less-prepared workforce, potentially undermining productivity and the effectiveness of the energy transition.

Looking ahead, projected skills demand is expected to outpace supply, not due to an absolute shortage of people, but because many potential workers are not adequately prepared because of persistent weaknesses in the education and training system (SANEA, 2023). This gap reflects not only the scale of the transition, but also the slow responsiveness of the education and training system to evolving industry needs (Droubi et al., 2023). Without proactive planning, South Africa risks facing a dual constraint: a shrinking pool of experienced workers alongside an insufficient inflow of newly trained entrants. Addressing this imbalance will be central to ensuring that the energy transition is not only technically feasible, but also capable of supporting employment creation and long-term economic growth.

2 Literature Review

After careful consideration of South Africa's history, it is evident that there is a skills gap in the energy sector of the education system, with high inequality exacerbating this problem. The JET framework offers numerous affordable opportunities; however, the energy skills gap poses significant barriers to realising these transitions. In this section, we analyse the existing literature to identify the skills needed in the energy transition and energy expansion. We also explore the partnerships between the public and private sectors needed to take on vocational training, the practical, job-specific skills needed for the energy sector, and the human capital policies that together lower unemployment and promote energy security. With the positions alone, 2.5 million positions were added since 2019; they represent over half of the global energy workforce and more than twice the employment in the broader economy (International Energy Agency [IEA], 2025b). The human capital theory is a useful framework used in this paper, as it analyses how training and education raise productivity and make transitions viable (Teixeira, 2014).

2.1 Conceptual Framework: Skills, Human Capital, and Energy Transitions

In the overarching literature, human capital has been widely recognised as a fundamental input to economic growth. Its central role is recognised by the Department of Electricity and Energy (DEE, 2025), noting that, "South Africa's energy transition depends on its institutional human capital and technological capabilities".

Achuo et al. (2025) summarise the relationship between human capital and economic growth, noting that the literature has not yet reached a consensus on its direction. This lack of agreement can be attributed to differences in geographical focus, time periods, methodologies and data used (Inglesi-Lotz, 2024). Modern economies have become increasingly dependent on high-quality human capital for technological innovation and sustained economic growth. Consequently, high-quality human capital is widely regarded as one of the most important catalysts for economic development (Awode & Oduola, 2025). The Department of Higher Education and Training et al. (2023) reinforces this view by linking human capital development to environmentally friendly behaviour, particularly among youth, and advocates for a stronger focus on digital and green skills to improve employment prospects.

The OECD (n.d.) define human capital as "the knowledge, skills and personal characteristics embodied in people that help them to be productive". Measuring the quality of human capital remains challenging, leading to a range of indicators, such as years of schooling, enrolment rates and literacy levels, being used. Since the energy sector accounts for the majority of global emissions (Inglesi-Lotz, 2024), a successful transition to a low-carbon economy is heavily dependent on the availability of high-quality human capital.

Economists argue that more educated populations exhibit higher productivity (OECD, n.d). However, it is widely acknowledged that the quality of human capital, rather than its quantity, is more critical for total factor productivity growth (Fedderke, 2005). Human capital has also been shown to interact with natural resources in influencing economic growth (Zallé, 2019). While much of the literature focuses on quantitative measures of human capital, it often overlooks aspects such as skills quality, competencies and interactive dynamics (Awode & Oduola, 2025; Fedderke, 2005; Ngepah et al., 2021;Seabela, 2024). In the South African context, a shift from quantity-based to quality-based education depends on both economic and policy conditions. This includes addressing systemic inefficiencies in vocational education and training, strengthening tertiary-level outcomes, and aligning curricula with specific industrial and technological needs (Awode & Odoula, 2025; Bhorat et al., 2016; Department of Electricity and Energy [DEE], 2025).

Achuo et al. (2025) identify several key influences on the quality of human capital. First, technological synergy and research and development tend to have a positive effect. Second, weaknesses in vocational training,

manifested through educational inefficiencies and skills shortages, often exert a negative effect. Third, financial support mechanisms and policy enablers generally have a positive influence.

Economic growth itself is multifaceted and difficult to define precisely. Ngepah (2021) defines economic growth as "the realisation of higher levels of total output generated by an economy through the utilisation of productive factors". Fedderke (2005) emphasises the role of high-quality human capital as a decisive factor in economic growth, while Liu et al. (2025) emphasise the interdependence of the energy transition, the labour market, and GDP systems in OECD countries. Hence, Ramsarup et al. (2024) evaluated the importance of skills in South Africa's current energy transition, stressing that market-driven efforts require adequate skills to support a just transition, yet current skill levels remain insufficient. Azam et al. (2025) highlighted the importance of skills development, education, and innovation capacity for achieving a just transition. Güler et al. (2024) agreed by showing that the implementation of new technologies requires upskilling and reskilling programmes to prevent skill mismatches and to successfully transition labour from fossil fuel sectors to green sectors.

Taken together, the literature suggests a clear linkage in which education and skills development shape labour market outcomes, which in turn influence the capacity to implement the energy transition and ultimately support sustainable economic growth. This interconnected relationship highlights that improvements in human capital are not only beneficial for productivity, but also essential for aligning labour markets with the structural demands of a low-carbon economy.

Policymakers increasingly pursue green industrialisation as a pathway towards low-carbon development (Matsuo & Schmidt, 2019). Montmasson-Clair & Patel (2024) outline green industrialisation as reducing emissions in existing manufacturing at the same time developing and establishing green energy sectors to ensure economic sustainability and social protection. Within this framework, skills development is the most valuable tool for a green digital transition (World Bank, 2025).

Langthaler et al. (2021) emphasise the uniqueness of sub-Saharan African economies, highlighting the dominance of the informal sector, wage structures and the enduring legacy of colonial capitalism and extractive systems. They assess the future of vocational training in South Africa, illustrating the challenges of aligning skills development with the needs of a green economy. Arias et al. (2019) argues that labour markets in sub-Saharan Africa are largely characterised by informality, which constrains economic transformation and makes poverty reduction difficult in the absence of sustained productivity growth. Similarly, Ramsarup et al. (2024) argue that effective skills systems require a shift from a simple market-based supply-and-demand model towards a coordinated, systemic and transformative approach. Such an approach is essential for preparing vocational training systems to manage the energy transition and its associated socioeconomic consequences.

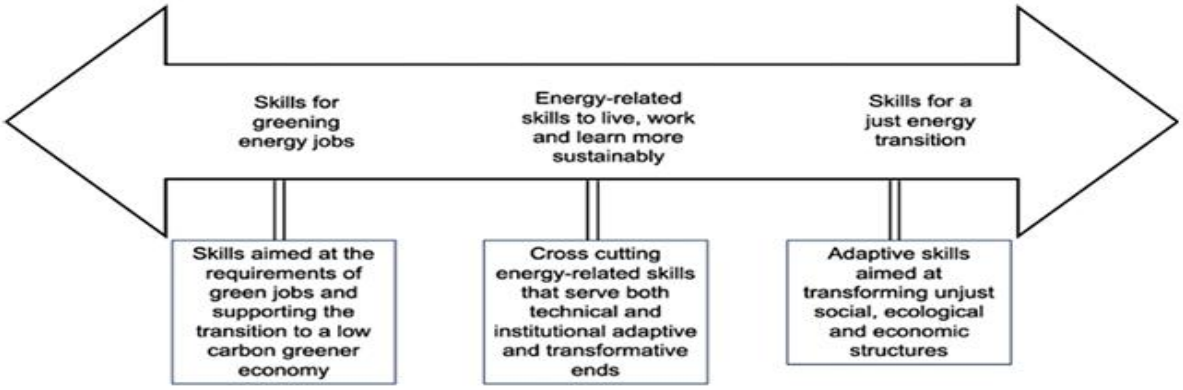
2.2 Empirical Evidence on Critical Energy-Sector Skill Needs

South Africa is facing a shortage of skilled technical workers in the energy and infrastructure sectors, specifically nuclear engineers, electricians, plant operators, and pipefitters (Labour Market Intelligence [LMI], 2022). The supply of qualified artisans has not been able to keep up with demand, with thousands of positions remaining vacant in electricity generation, construction, and maintenance. This shortage may be due to retirements that outnumber young entrants under 25 by approximately 1.5 to 1, putting additional pressure on highly specialised technical roles (Meyer, 2019; LMI, 2022). Despite high national youth unemployment rates, the pipeline of young, employable workers is not entering technical professions fast enough – leaving critical infrastructure projects understaffed and threatening the country's energy security. This mirrors global trends highlighted by the IEA (2025b), which show that shortages of applied technical positions have slowed energy transition efforts. Compared to international applied technical positions, which are composed of line

workers, electricians, pipefitters, plant operators, and nuclear engineers, the supply is short. With these positions alone, 2.5 million positions have been added since 2019; they represent over half of the global energy workforce and more than twice of the employment in the broader economy (IEA, 2025b). The ageing workforce does put a lot of strain on advanced economies. Evidence suggests that retirements outnumber new entrants by 1.7 and 1.4, respectively, putting the most pressure on nuclear- and grid-related professionals (IEA, 2025b).

As mentioned, production plays an important role in economic growth and is a useful indicator of human capital. But for production to be possible it is important to invest in skills, knowledge and innovative capabilities (Türüç-Seraj & Üçışık-Erbilen, 2025). Investing in skills is not always fair, as high-level skills, such as engineers, are in high demand, while entry-level jobs, such as mining or driving, are often overlooked (Ramsarup et al., 2024). This is the case even though some studies do show a need for more technical jobs and skills (Economic Graph Research Institute, 2023). Figure 1 shows which skills are necessary for the type of work needed in the energy sector.

Figure 1: Skills needed for a Just Energy Transition in South Africa



Source: Ramsarup et al. (2024)

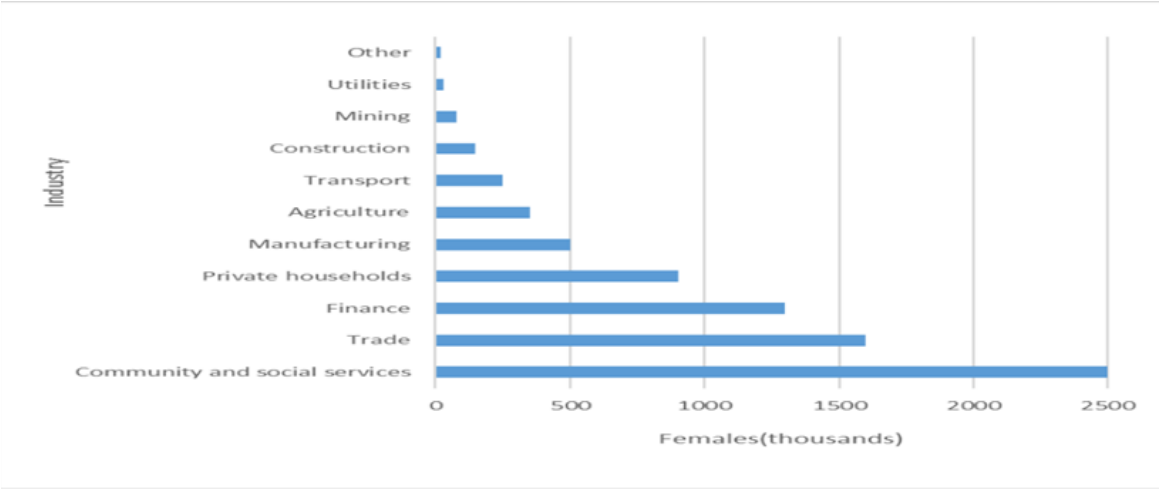
A clear mismatch exists between a high demand and a low supply of skilled workers (Economic Graph Research Institute, 2024). If this persists, then the goals of achieving a skilled energy workforce that have been set will be unattainable, because skilled workers are needed to build and power new infrastructure. Governments' partnerships with educational institutions and the private sector are important to promote a skilled workforce. They further comment more on improving the curriculum by incorporating more practical-based skills to open doors for more work opportunities in the future.

According to the Economic Graph Research Institute (2024), the fastest-growing green skills are in the US, France, the UK, Brazil, Australia and Germany. The IEA (2025c) found that training and skills development are important resources for meeting demand for a skilled workforce, while in the UK practical skills are more favoured than degrees (Valero, 2024). Green skills are growing due to electrification, energy engineering, land-use planning, building performance, and many other factors. As mentioned above, demographics are a characteristic to consider when talking about skills in energy transitions. All of these are possible, but the problem arises from limited access to opportunities, as women are most affected by climate change, and it was found that at least 10% of women have at least one green skill, compared to 17% of men (Economic Graph Research Institute, 2024). Statista shows the high unemployment rate for women (Galal, 2025).

Figure 2 shows the utilities sector, encompassing both water and electricity, employs only 32 000 women relative to women's workforce participation. This highlights the underrepresentation of skilled women in the energy sector and the broader shortage of female talent in technical roles. Combined with the challenges of an ageing workforce and the slow entry of young workers into technical professions, these barriers further

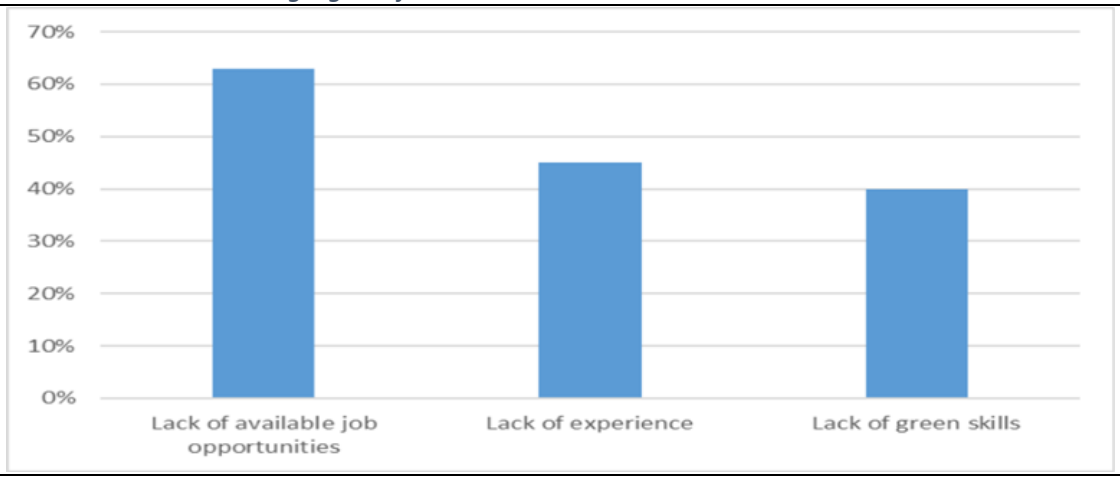
constrain South Africa's ability to meet its energy workforce needs. Figure 3 illustrates key factors that may also limit women's access to green jobs.

Figure 2: Number of female employees in South Africa by industry (2023, Quarter 4)



Data Source: Galal (2025)

Figure 3: Main barriers to securing a green job



Data Source: (Economic Graph Research Institute, 2024)

Although young South Africans are viewed as a key potential source of green skills and future energy workforce population, recent data suggest that only a small portion have the technical capabilities needed to fill these roles (Economic Graph Research Institute, 2024). National statistics show that youth unemployment remains very high, with a significant proportion of young people unable to secure employment that aligns with their skills and training (Afrobarometer, 2025; StatsSA, 2025a). This mismatch between youth skillsets and available jobs is not due to a lack of interest in work, but rather reflects structural barriers in the labour market, including a shortage of technical and vocational training opportunities that meet industry demand and the challenge of translating education into employment (Afrobarometer, 2025; Economic Graph Research Institute, 2025).

Evidence also shows that these barriers are more evident for women, who often face additional challenges in having access to vocational training and technical occupations, further limiting their participation in emerging green and energy sectors (OECD, 2025a). This is particularly relevant to South Africa, where women account for only 14% of employees in the renewable energy sector, their representation at Eskom is 31%, and in the coal sector they account for 21% (Nagel & Lebrun, 2022). Without deliberate policy intervention, these structural inequalities risk being reproduced within new green sectors, making gender-targeted skilling

policies essential to ensuring that South Africa's energy transition reduces, rather than reinforces, women's economic exclusion (Nagel, Research Institute for Sustainability (RIFS), 2022).

2.3 Public-Private Partnerships in Vocational Training

Public-private partnerships in and Technical and Vocational Education and Training (TVET) are defined as "mutual agreements between public authorities, academic institutions, and private industries that are established to create and sustain a more responsive TVET through the provision of resources and expertise" (Fornyuy, 2025). According to the World Bank (2011), public-private partnerships can increase educational access and enrolment while bridging the gap between education and the labour market. These partnerships are particularly associated with the acquisition of modern technologies; for instance, Fornyuy (2025) notes that South Africa integrated solar panel installation programmes into its TVET curriculum, specifically in response to private-sector feedback. Despite these potential benefits, effective vocational training often fails to materialise. This is attributed not to a lack of willingness, but rather to inadequate government funding and a disconnect between training provision and labour market needs, which can result in an oversupply of mismatched skills. Additionally, excessive bureaucracy has been identified as a key factor delaying the creation of appropriate qualifications (Independent Consultant, 2018; Oviawe, 2018).

Regarding outcomes, Jreifi and Lakrarsi (2025) emphasise that governance mechanisms, such as employer co-design of curricula, are associated with higher job placement rates and stronger employer satisfaction. The success of public-private partnerships (PPPs) is driven by operational and inclusive strategies, including strong engagement from the private sector, a clear focus on objectives, and strong goal alignment between partners. Furthermore, PPP success relies heavily on appropriate risk management, building high levels of trust, and maintaining strict accountability. However, PPPs often fail due to high costs and risks, which limit their ability to accommodate new technologies and innovations. In addition, the financial structuring of PPPs tends to favour large firms, thereby creating biases within the economy and marginalising smaller participants. Institutional barriers, including a lack of coordination, weak governance, corruption, and socio-cultural constraints, further hinder their effectiveness (Nel, 2015; Pinilla-De La Cruz et al., 2022; Tshombe & Abiodun, 2025; Udeagha & Ngepah, 2023).

This preference for larger firms can limit inclusive development outcomes. Furthermore, research suggests that effective partnerships in South Africa are essential for work-integrated learning, which allows students to combine classroom teaching with relevant workplace experience (Department of Higher Education and Training, 2024)

2.4 Human Capital Policies, Employment and Energy Security

More countries are moving towards lower-carbon energy systems, and human capital policies are becoming increasingly important to manage energy security and employment. The transition would need technical and regulatory measures across the renewable energy and energy efficiency industries. A planned and calculated investment in workforce planning and skills development is needed to achieve a sustainable energy supply and a smooth transition. Energy security, defined as the uninterrupted availability of energy sources at an affordable price (IEA, 2025c), depends on the reliability and affordability of energy supply. Focusing on a green transition would mean you would need a strong and consistent workforce. This is because renewable energy would depend on specific skills such as knowing how to install specific tools, integration grids and digital control (IRENA & ILO, 2023). Grid stability would be reliant on storage systems, grid management and forecasting tools. Engineering this into the energy transition would lower our dependence on foreign investment and control.

Having the Just Transition Framework approved by the South African cabinet has made moving forward easier and ensures "no-one is left behind", a quote from the United Nations 2030 Agenda, emphasising inclusive development in global policy frameworks (United Nations, 2015). The Department of Mineral Resources and Energy (DMRE) has been able to draft a transition framework that will support the decarbonisation of energy and mining sectors in a manner that is socially acceptable and contributes to the economic development of the country. This focuses on issues that are related to workers in areas such as the coal value chain, specifically coal miners, while also minimising the impact on vulnerable groups such as women and the youth in association with fossil fuels value chains (PCC, 2022).

2.5 Education and Vocational Training

Allais (2012) argues that in South Africa, the education and vocational training system is trapped in a narrow 'toolkit' approach. The system is described as highly bureaucratic, complex, and unequal, and it does not adequately address broader social and economic challenges. This problem is particularly evident in the college sector, which McGrath et al. (2006) describe as ill-suited to its intended purpose.

Due to these challenges, government departments responsible for education and labour, together with sector governance structures, introduced Sector Education and Training Authorities (SETAs) under central control (Allais, 2012). These institutions aim to integrate skills development more closely with the broader post-school education and training system, including universities and TVET colleges. However, the South African Institute of International Affairs (2022) reported that many students struggle to complete their programmes, with only 9% of Level 4 students completing in 2016. Of those who completed, approximately 40% are placed in work-based learning, self-employment or formal employment.

At the same time, Botha and Havemann (2025) note that the government's existing initiatives have failed to address constraints in skills development. Among their findings are systemic inefficiencies, such as registered students failing to graduate. Their analysis further identifies governance failures, including irregular expenditures. Lastly, despite receiving payroll levy grants, institutions struggle to meet targets while reserving 'idle cash' and maintaining high administrative costs (Botha & Havemann, 2025). In addition, policy instruments such as the levy-grant system, college recapitalisation programmes, and bursaries have been introduced to support poor households and historically disadvantaged groups.

The existing literature has paid limited attention to the curriculum and internal learning processes that constitute the educational core of Vocational Education and Training (VET). Zinn et al. (2019) employ both qualitative and quantitative methods to analyse the current state of vocational training in South Africa. Through qualitative analysis, the study examines educational policies, including the guiding philosophy of the education system, as well as the goals, standards, rules, and strategies that shape education. Daniels (2007) also examines the demand and supply of skills in the South African economy, including enterprise training and the role of Further Education and Training (FET) colleges.

However, limited attention is paid to the role of foundational skills acquired in basic education in shaping outcomes in post-school education and training, which in turn feed into the energy-sector labour market and ultimately influence energy security and economic growth. South Africa's distinctive skills profile, productivity challenges, and vocational capacity, therefore, warrant a focused qualitative investigation, which this study seeks to provide. By addressing this gap, the paper contributes to a more integrated understanding of human capital in South Africa's Just Energy Transition and advances policy-relevant recommendations.

In conclusion, the literature consistently shows that human capital and skills development are central to achieving a successful and inclusive energy transition in South Africa. Existing studies highlight persistent

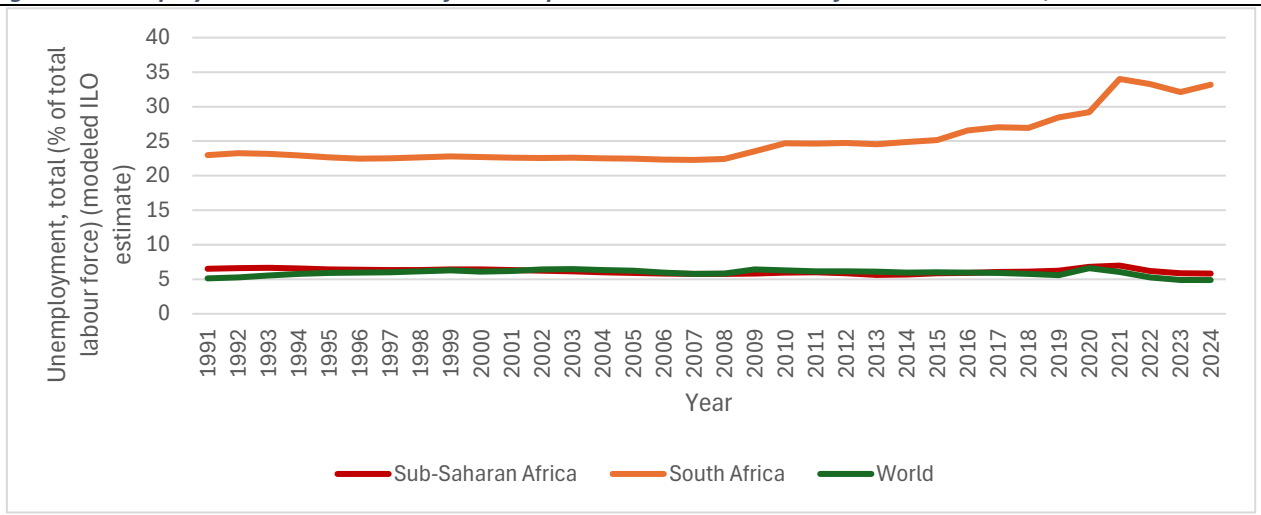
shortages of technical and vocational skills, mismatches between education outcomes and labour market needs, gender and youth disparities, and structural inefficiencies within the vocational training system. Evidence also emphasises the importance of public-private partnerships, coordinated policy frameworks, and targeted investments in human capital to support energy security, employment, and green industrialisation. However, despite this growing body of knowledge, several gaps remain. Limited empirical work examines how foundational education outcomes translate into energy-sector skills, how vocational training systems can be effectively aligned with emerging green technologies, and how institutional arrangements influence the quality – not just the quantity – of human capital. In addition, there is insufficient evidence on the effectiveness of existing policies and partnerships in addressing structural inequalities and ensuring inclusive participation in the energy transition. Addressing these gaps is essential to developing a more integrated understanding of the human capital requirements for a just energy transition and to informing more targeted, evidence-based policy interventions.

3 South Africa's Energy, Employment, Education, Skills, and Policy Landscape

3.1 Macroeconomic Context

Figure 4 shows that South Africa's unemployment rate is significantly higher than both the sub-Saharan African and global averages. While unemployment levels in the latter two have remained relatively stable, South Africa has experienced a sharp rise since 2008. This growing pool of unemployed individuals represents a large reserve of skills at risk of becoming obsolete or depreciating over time (OECD, 2017). These challenges are further deepened by the enduring effects of apartheid, which continue to drive disparities in education and employment (Nesongano et al., 2026; Njokwe et al., 2025; OECD, 2017).

Figure 4: Unemployment rates in South Africa compared with sub-Saharan Africa and the world, 1991-2024



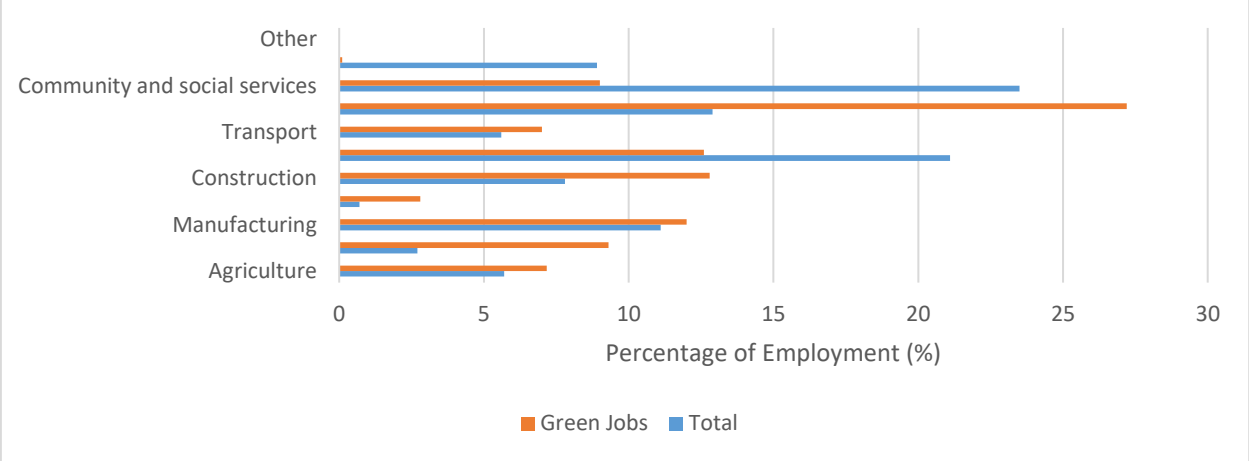
Data Source: World Development Indicators (2025)

Youth unemployment in South Africa has worsened over the past decade, with young people – who make up half of the working-age population – facing persistently high joblessness, increasing from 36.9% in 2015 to 46.1% in 2025 (Stats SA, 2025a). The negative effects that early labour-market setbacks like these can have on a person's future outcomes could be long-lasting (OECD, 2023). As the OECD (2023) notes, the continued disadvantage of the youth is therefore particularly concerning, not only from a social perspective but also because it undermines the long-term productive capacity of the economy. Despite this, youth aged 24-40 currently dominate the green job market, which Njokwe et al. (2025) attribute to the "emerging nature of the green economy" and the greater adaptability of younger workers in obtaining new transition-related skills.

Figure 5 and Figure 6 reveal notable differences in how industries and occupations participate in South Africa's green labour market. In industries, green jobs represent a disproportionately higher share in sectors such as finance, construction, manufacturing, and utilities. Conversely, traditionally large sectors like trade and community services show relatively low green job intensity, while those who work for private households, such as domestic workers, remain almost entirely outside the green economy. Across occupations, green jobs are mostly in craft and related trades, sales and services, technical roles, and managerial positions. This suggests that green employment is strongest in mid- to high-skill categories that require technical expertise or sector-specific competencies. In contrast, elementary, domestic, and clerical workers have very limited representation in green jobs. These trends indicate that South Africa's green economy is expanding more quickly in skilled, technical, and service-oriented segments, while lower-skilled, labour-intensive sectors lag behind.

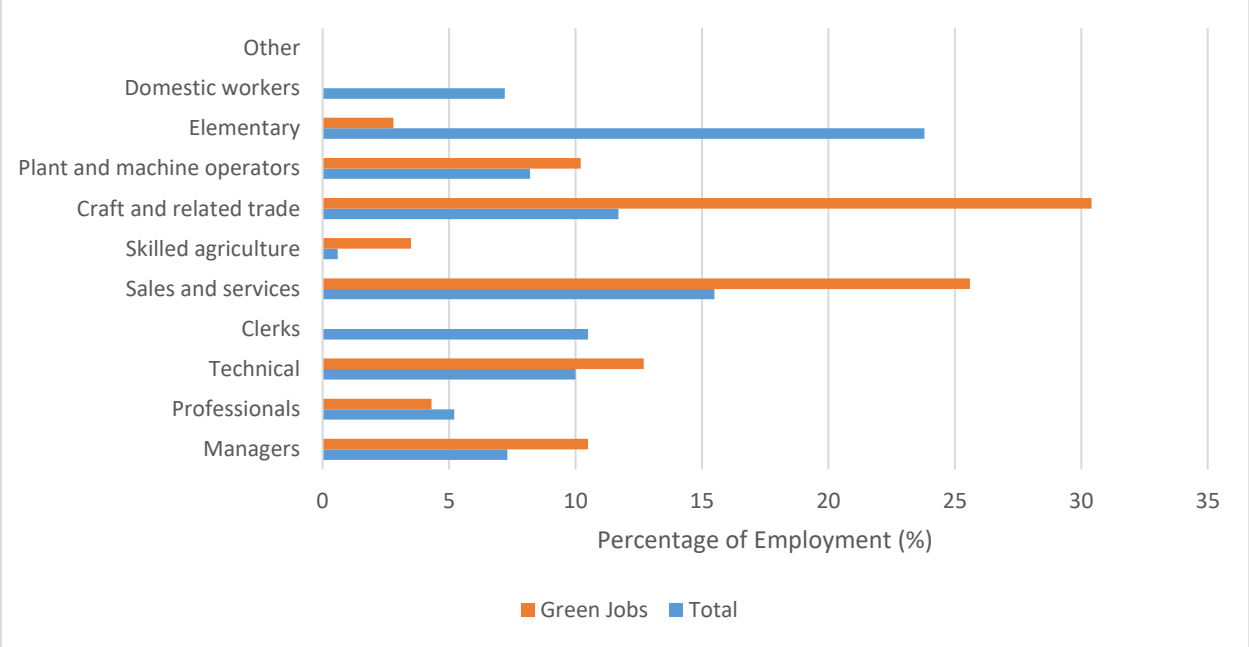
South Africa remains deeply dependent on coal, which accounted for 69% of its total energy supply in 2023, as visualised in Figure 7 (IEA, 2025a). The country also ranks first in Africa in terms of total coal supply (IEA, 2025a). Nearly half of South Africa's greenhouse gas emissions come from the electricity sector, making the economy energy-intensive (coal contributes 82% of generation), and its ageing coal-fired power stations are scheduled for decommissioning over the next thirty years, with 22 GW expected to be taken offline by 2035 already (Davidson et al., 2025; IEA, 2025a; PCC, 2022; Ramsarup et al., 2024). Although coal dependence has begun to decline and renewable energy capacity has increased, progress remains slow.

Figure 5: Share of Green Jobs and Total employment by industry in South Africa



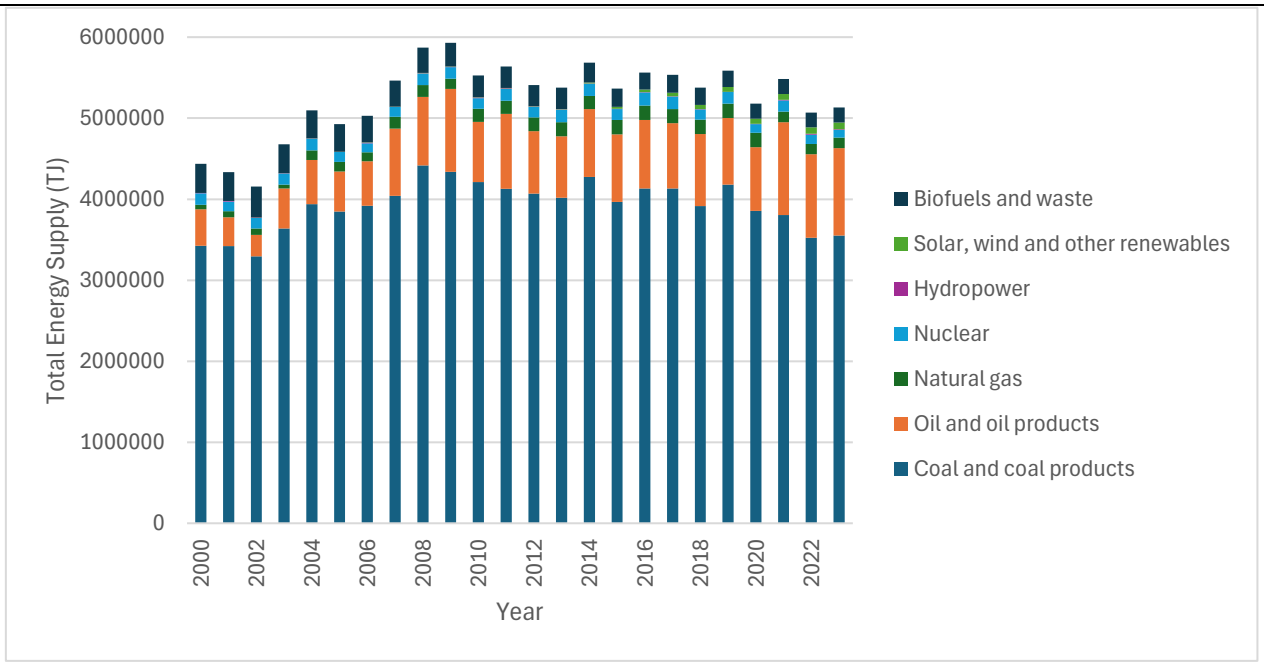
Data Source: (Njokwe et al., 2025)

Figure 6: Share of Green Jobs and Total employment by occupation in South Africa



Data Source: Njokwe et al. (2025)

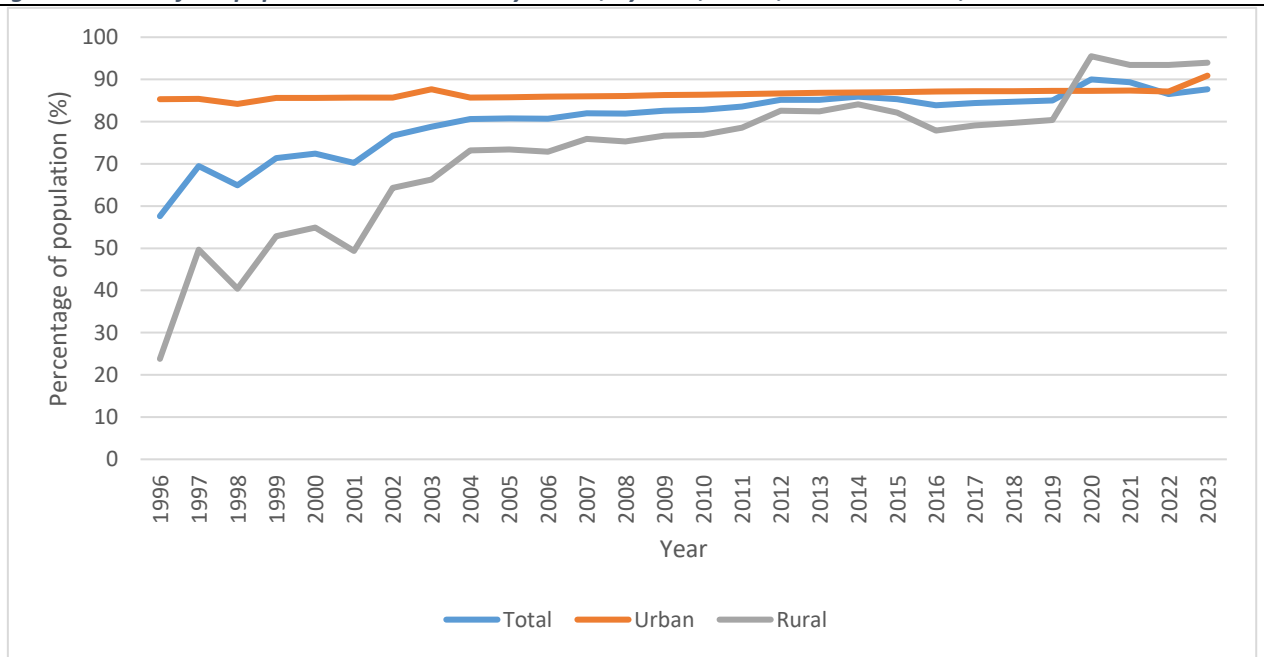
Figure 7: South Africa's total energy supply by source, 2000-2023



Data Source: (IEA, 2025a)

Figure 8 illustrates electricity access in South Africa, broken down by total, urban, and rural populations. Overall access reached 87.7% in 2023, down from 90% in 2020. While rural electrification has increased significantly over the years, urban access has remained largely stable. Despite the high overall rate, a last-mile problem persists, and it is important to note that 'access' refers only to basic services, such as lighting, powering a radio for four hours, or charging a phone (WDI, 2025), which is insufficient to meet the demands of a growing economy. At the same time, recurrent load shedding demonstrates that electricity demand has outpaced Eskom's ability to supply reliably. This constraint is increasingly salient as the IEA predicts an "Age of Electricity", raising questions about how countries like South Africa will meet rapidly rising electricity demand (IEA, 2024).

Figure 8: Share of the population with electricity access, by total, urban, and rural areas, 1996-2023



Data Source: World Development Indicators (2025)

3.2 Energy Sector Employment and Green Jobs

According to the SANEA's 2023 Energy Skills Roadmap, most workers in the country's energy sector are employed in coal and in oil and petroleum (see Figure 9). In the former, employment is concentrated in mining and transport. In the latter, over half of all workers (52%) are based in retail forecourts and convenience stores, 12% in financial and business services, 11% in agriculture, 5% in transport, and 4% in mining (SANEA, 2023). South Africa's most emissions-intensive sectors, such as electricity, mining, and manufacturing, also employ many workers with skills that could be transferred to the green economy with some retraining, according to Davidson et al. (2025).

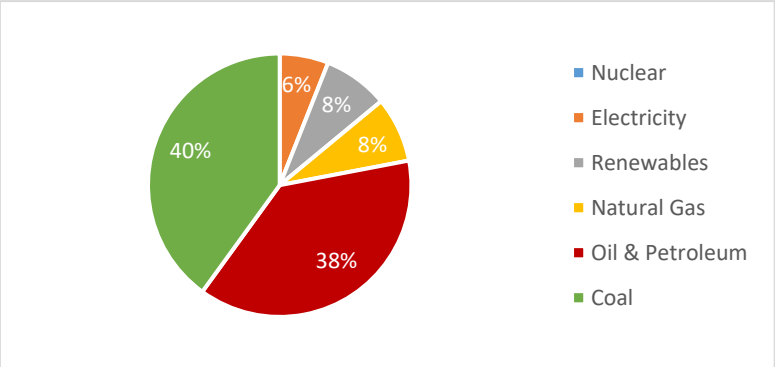
A common critique of the JET is the potential loss of coal-sector jobs, especially in Mpumalanga. Home to the country's coal belt, the province contains a large share of high-emitting municipalities and workers in emissions-intensive industries (Davidson et al., 2025). While these workers face transition risks, they also appear relatively well-positioned to move into green economy jobs, given the nature of their existing skills.

However, a more concerning pattern emerges in other municipalities where employment is both highly exposed to the transition and characterised by limited potential for reskilling into green occupations. These areas often exhibit higher levels of poverty and unemployment, yet receive less policy attention. Current JET efforts remain heavily concentrated in Mpumalanga, raising the risk that other vulnerable regions may be overlooked. (Davidson et al., 2025).

Gwatidzo and Simbanegavi (2021) argue that the concern for job losses in the coal sector is often based on a static view of employment. They note that the persistent lack of reliable electricity access is already eroding jobs and discouraging investment by weakening production and competitiveness, suggesting that an overemphasis on preserving existing jobs may ultimately constrain economic growth and foreclose future employment opportunities. This means that without a broader spatial approach, the energy transition could exacerbate existing regional inequalities rather than alleviate them.

Ramsarup et al. (2024) state that while there is an adequate supply of traditional technical professionals like electrical engineers and electricians, specialist skills in emerging areas such as clean energy are scarce, highlighting the need to upskill the existing workforce rather than create entirely new qualifications in order to enable the JET in South Africa.

Figure 9: Estimated employment structure of the South African energy sector



Data Source: (SANEA, 2023)
Note: The estimated share of employment in the nuclear sector is negligible and therefore appears as zero in the data.

3.3 Basic Education

Despite substantial public spending on basic education and near-universal access to schooling, learning outcomes in South Africa remain persistently weak. The country performs below the regional average on several education indicators, even when compared to less developed Southern African countries that spend significantly less on education. Moreover, these shortcomings are highly unequal: learner performance varies

markedly across schools, with those serving poorer, predominantly black communities consistently underperforming relative to schools attended by more affluent black and white learners (UNICEF South Africa, 2022).

The number of teachers in South Africa has been declining since 2013, even as student enrolment has increased with population growth, resulting in bigger class sizes and further strain on already limited resources (UNICEF South Africa, 2022). At the same time, too many teachers specialised in subjects such as science, technology, engineering, and mathematics are retiring (Department of Higher Education and Training, 2024).

Subject choice trends at the secondary level are also cause for concern: in 2025, only 34% of matriculants enrolled for Mathematics, with the majority opting for Mathematical Literacy, and pass rates in Pure Mathematics declining (Pongweni, 2026). As a result, a large share of learners exit the schooling system without the competencies required to pursue further study in STEM-related fields, thus narrowing the pipeline into energy occupations at an early stage.

These shortcomings have implications that extend well beyond the education system. Weak foundational skills propagate through the broader skills pipeline, contributing to misalignment in post-school education and training and ultimately constraining labour-market outcomes (SANEA, 2023). The Department of Higher Education and Training (2024) also directly links the poor quality of Mathematics education at the school level to high dropout rates and extended completion times in fields such as engineering. In the context of the energy transition, this results in a constrained supply of workers capable of supporting the development, expansion, maintenance, and deployment of energy infrastructure. Ensuring that the basic education system delivers strong foundational literacy and numeracy skills is therefore essential, as highlighted by the BRICS Energy Research Cooperation Platform (2023), particularly to enable workforce adaptation in a rapidly evolving energy landscape.

3.4 Energy Education and Training

A common explanation for South Africa's constrained growth prospects is the persistent shortage of skilled workers (OECD, 2017). The country's energy sector is no different and exhibits chronic underperformance that is closely tied to human-capital constraints.

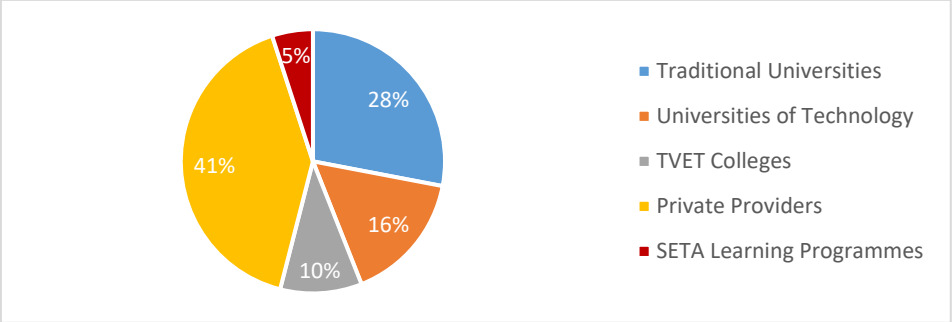
South Africa's energy skills pipeline spans the full education and training system, yet JET-relevant content remains largely absent from the basic education curriculum (SANEA, 2023). This omission leaves learners without access to post-school opportunities effectively excluded from participation in transition-related jobs. Recognising this gap, the Department of Higher Education and Training's JET Skills Desk has prioritised "strengthening the foundational education system through curriculum reform, educator development, and institutional readiness", as highlighted by Deputy President of the Republic of South Africa and Chairperson of the HRDC, Mr Paul Mashatile (2025).

The basic education curriculum can be updated by integrating climate change, energy transition, and social justice concepts – grounded in geography, history, and human rights – while promoting critical thinking, environmental awareness, and active citizenship (Droubi et al., 2023). This includes embedding sustainability, coexistence with nature, and practical understanding of clean energy into teaching, supported by stronger teacher training and more engaged, participatory learning approaches. Two countries that have made progress in this area, and can serve as valuable examples to South Africa, are Cambodia and Argentina (Ellerbeck, 2022). Since 2020, Cambodia has incorporated climate change into an expanded earth science curriculum at the secondary level. Similarly, Argentina has mandated environmental education across all levels of schooling, ensuring early and continuous exposure to sustainability-related topics.

Ramsarup et al. (2024) divide post-school education and training courses into two broad categories: core, such as renewable energy, green hydrogen, energy efficiency, and electric vehicles, and supporting or enabling disciplines, including areas like social sciences, finance, and legal expertise. As shown in Figure 10, most core energy courses are offered by private providers and traditional universities, which may lead to an inequitable energy transition for individuals at entry and intermediate levels (Ramsarup et al., 2024).

The mismatches that exist between the current supply of skills and the demands of the country's evolving energy sector are clear. While universities produce many traditional energy qualifications, industry increasingly needs specialised skills – areas where current programmes are lacking (SANEA, 2023). TVET colleges are also not providing the practical, location-specific skills required by industry, leaving shortages in key fields (SANEA, 2023). Weak foundations in basic education further limit the number of students who can succeed in energy-related tertiary courses (SANEA, 2023), constraining the future talent pipeline.

Figure 10: Share of core energy courses offered at South African institutions



Data Source: (Ramsarup et al., 2024)

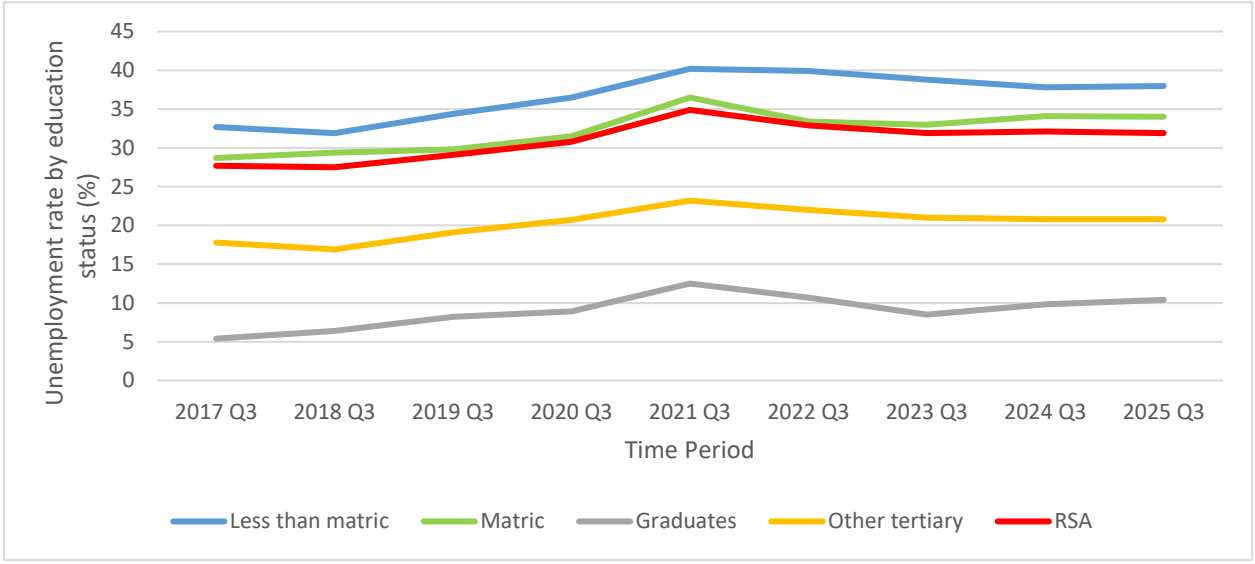
Recent trends indicate that engineers, project managers, technicians, scientists, and policy and planning professionals are essential to supporting the JET in South Africa (SANEA, 2023). However, as stated by Ramsarup et al. (2024), little attention is given to entry-level positions, with the focus mainly on high-level and some intermediate roles.

South Africa's target for annual engineering graduates is 14 477, yet only 11 936 students graduated in 2022 (Department of Higher Education and Training, 2024). While traditional engineering and science-related disciplines are relatively well represented across the post-school education and training system, with a range of qualification levels on offer, gaps remain in areas directly relevant to the energy transition (SANEA, 2023). According to SANEA (2023), most TVET colleges continue to focus on conventional electrical engineering, installation, and infrastructure programmes, with limited emphasis on renewable energy and energy efficiency. Community colleges, in particular, offer very few (if any) relevant courses in these emerging fields.

As a result, specialised skills in renewable energy technologies and clean energy areas remain underdeveloped across all levels of the education system (SANEA, 2023). This gap not only constrains the country's ability to support the energy transition but also limits its potential to move up the value chain – from being primarily an exporter of critical minerals to becoming a producer of higher-value, technology-intensive energy goods and services.Individuals with tertiary education are disproportionately represented in strictly green jobs compared to the broader labour market, whereas broadly green jobs are largely filled by workers with lower levels of education. However, because South Africa's workforce is predominantly mid- and low-skilled, the largest share of strictly green roles is still held by those with matric or less, highlighting a green economy that relies heavily on lower-skilled labour despite requiring many high-skill occupations. (Mosomi & Cunningham, 2024). Available graduation data further illustrate this imbalance. In 2022, approximately 14,363 graduates were produced in Engineering and Related Studies, compared to significantly larger numbers in fields such as Business and Management (40,452) and Education (<Masters)

(40,336), suggesting that the pipeline of technical graduates remains relatively limited for supporting specialised green economy roles. Moreover, these figures do not indicate the extent to which engineering curricula incorporate renewable energy or energy-transition-specific competencies, highlighting that both the quantity of graduates and the relevance of their training remain important considerations. (National Advisory Council on Innovation [NACI], 2025).

Figure 11: Unemployment rate by education status, 2017-2025 (Quarter 3)



Data Source: Stats SA (2025b)

Graduates and individuals with other forms of tertiary education consistently record the lowest unemployment rates (see Figure 11), while those with matric or less face rates well above the national average. The benefits of education are evident. As Njokwe et al. (2025) note, the energy transition presents an important opportunity to reduce youth unemployment, as younger individuals typically have fewer years of work experience and schooling and can more readily be upskilled for new green opportunities. This stresses the importance of strengthening basic education, particularly through investment in infrastructure and teacher quality, to ensure a strong pipeline of well-prepared learners entering the post-school education and training system (SANEA, 2023).

3.5 Policy Backdrop

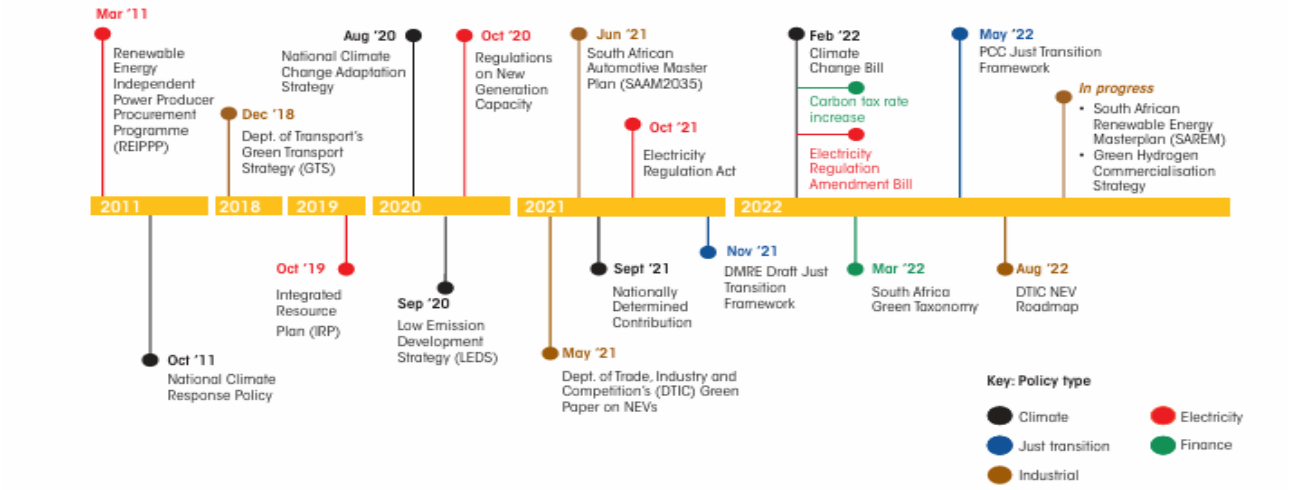
Per Bohlmann et al. (2023), South Africa's policymakers must navigate three interconnected pressures: first, ensuring sufficient energy supply to meet rising population needs; second, expanding the use of cleaner energy sources to curb greenhouse gas emissions; and third, limiting the socioeconomic disruptions (such as job, income, and trade losses) that may arise from the transition. While these objectives are clearly articulated across policy frameworks, the extent to which they are coherently integrated and effectively implemented remains a key concern.

The main policy frameworks guiding South Africa's energy transition are the Just Energy Transition Investment Plan (JET-IP), the National Development Plan (NDP), and the Integrated Resource Plan (IRP). Figure 12 presents the suite of policy and strategic documents underpinning South Africa's energy transition.

The JET-IP outlines the investment needs to meet South Africa's decarbonisation commitments and aligns with the country's Nationally Determined Contribution (NDC) (PCC, 2022). It is also grounded in the NDP's priorities of reducing poverty, inequality, and unemployment (PCC, 2022). The IRP is a forward-looking strategy that sets out to balance electricity supply and demand through the allocation of the country's

primary energy resources in a least cost manner to the economy and the environment (Department of Electricity and Energy [DEE], 2025).

Figure 12: Key policy milestones shaping South Africa's energy transition



Source: PCC (2022)

South Africa's skills landscape is supported by a wide-ranging policy framework aimed at strengthening education, training, and workforce readiness (SSACI, 2024). Key legislation, such as the 1998 Skills Development Act and the 2006 Continuing Education and Training Act, establishes the foundations for vocational training, SETA-led skills planning, and workplace-based learning. Complementary frameworks (including the 2013 White Paper on Post-School Education and Training, the NDP, and the National Skills Development Strategy and Plan) aim to build a capable, inclusive workforce aligned with the country's growth and employment goals. Sector-specific initiatives, including the South African Renewable Energy Masterplan (SAREM), further highlight the growing demand for skills to support renewable energy manufacturing and the broader energy transition. (SSACI, 2024).

However, these frameworks tend to operate in parallel, with limited alignment between energy planning, industrial strategy, and skills development. These coordination failures are most evident at the level of implementation. Despite strong policy emphasis on skills and employment within the JET, training initiatives often remain misaligned with labour-market demand. In the mining sector, for example, adult education, learnerships, bursaries, and other training initiatives face low participation, a narrow focus on coal-specific skills, limited access for non-permanent workers, strict eligibility criteria, and programmes often restricted to operational or management staff, with some lacking proper accreditation (Mhaka & Mahlangu, 2025).

The private sector plays an important role in closing South Africa's skills gaps, particularly through skills development and training, with many companies taking part in workplace-based learning and corporate social responsibility initiatives (SSACI, 2024). While several public-private partnerships support energy-related training, there is still no unified platform that brings the private sector and all key stakeholders (including government) together to coordinate green economy skills development (Mhaka & Mahlangu, 2025).

Thus, these gaps suggest that the primary constraint is not a lack of policy, but rather weak institutional coordination and siloed efforts across the policy landscape, which undermines national competitiveness, resilience and, ultimately, the effectiveness of South Africa's energy transition (South African National Energy Association [SANEA] & Energy & Water Sector Education and Training Authority [EWSETA], 2024).

4 Diagnosis of Growth and Employment Constraints

4.1 Unreliable Electricity Access as a Binding Constraint on Economic Growth

Electricity shortages are associated with lower economic growth, as power outages reduce industrial activity, deter investment, and weaken productivity (OECD, 2025a). These effects are not evenly distributed across firms: small enterprises are disproportionately affected, facing greater barriers to entry and progress, while improved access to electricity is associated with higher rates of firm creation and economic growth (OECD, 2025a). The burden is particularly severe for electricity-intensive manufacturing sectors, such as steel, which are more exposed to supply disruptions than less intensive industries like paper and textiles (Ndubuisi et al., 2025; Walsh et al., 2020). The prolonged electricity crisis has therefore imposed substantial economic costs through lost employment opportunities, reduced investment, and lower export revenues, leaving lasting structural damage on South Africa's post-apartheid growth trajectory (Creamer, 2021; Walsh et al., 2020).

Addressing these challenges requires urgent attention to skills constraints within the electricity sector. South Africa is in dire need of maintenance skills (SANEA, 2023). For example, the shortage of qualified electricians has serious consequences, including the proliferation of unqualified practitioners, which compromises safety, quality, and industry standards (Gerber & Crafford, 2025). This undermines economic growth, diverts demand away from skilled professionals, and constrains both industry development and the training of future talent (Gerber & Crafford, 2025). According to Walsh et al. (2020), skills losses have further constrained the country's response to the electricity crisis, partly due to sector reforms and transformation policies that incentivised early retirement among some of Eskom's most experienced technical personnel, which created a loss of institutional memory. The age profile of workers in the energy and water sector is skewed toward mid-career employees, with 52% aged 36-50 (EWSETA, 2023). While this reflects valuable experience, it also highlights the need to increase youth participation in the sector, particularly given persistently high youth unemployment.

The issue is not reform or transformation per se, but the mismatch between adequate skills formation and the simultaneous erosion of existing technical capacity. Regarding skills formation, Gerber and Crafford (2025) highlight a lack of awareness within educational institutions as a key constraint on the development of the future workforce.

4.2 Skills Shortages as a Productivity Constraint in the Energy Sector

Electricity generation, transmission, and distribution rely on a wide range of occupations spanning technical, operational, and support functions (SANEA, 2023). These roles extend beyond engineering and maintenance to include customer services, environmental and safety management, finance, human resources, marketing, performance planning, and property management (SANEA, 2023). Despite this breadth, critical foundational and job-related skills – particularly management, leadership, customer service, computer, technical, and communication – remain in short supply (SSACI, 2024).

Several occupational bottlenecks directly constrain productivity in the energy sector. Estimates indicate that South Africa faces a shortfall of approximately 40 000 artisans, and the EWSETA identifies Air-Conditioning and Refrigeration Mechanics, Civil Engineering Technicians, and Construction Project Managers as particularly hard-to-fill occupations (SANEA, 2023). Addressing these skills gaps is essential to ensure that energy-sector jobs and tasks are performed efficiently and to required technical standards (SANEA, 2023).

According to Botha and Havemann (2025), the SETA system "was a well-intentioned state-led intervention" designed to address skills shortages in South Africa. However, they identify significant inefficiencies, including certification costs that in some cases exceed those of a university degree and a "leaky pipeline" in which a

substantial number of learners exited training programmes without obtaining certification. These challenges are compounded by widespread underqualification in the labour market. Evidence suggests that underqualification is more prevalent than overqualification in South Africa (OECD, 2017), leading firms to employ workers without the requisite skills. In the energy sector, this practice contributes to project delays, cost overruns, and reduced productivity (Gerber & Crafford, 2025).

Toegther these skills shortages constitute a binding constraint on productivity in South Africa's energy sector. The combination of occupational bottlenecks, institutional inefficiencies in skills formation, and underqualified hiring practices limits the sector's capacity to deliver reliable electricity, scale renewable energy, and maintain critical infrastructure.

4.3 Post-School Education and Training (PSET) System Failures

Weaknesses in the skills pipeline emerge as early as basic education, thereby undermining student progression and completion in relevant tertiary-level programmes (Allais, 2024; SANEA, 2023). Entry into key disciplines such as engineering, life and physical sciences, and teacher education typically requires a National Senior Certificate Mathematics pass mark of at least 60%. However, a large share of learners fail to meet this threshold (EWSETA, 2023), limiting access to energy transition-relevant fields of study. In 2025, only 34% of matriculants enrolled for Mathematics, with the majority opting for Mathematics Literacy; during the same period, the Pure Mathematics pass rates declined from 69% to 64%, while Physical Sciences pass rates rose marginally to 77% (Pongweni, 2026). These trends constrain the pipeline into STEM fields and, by extension, limit enrolment in energy-related courses critical to supporting the JET. According to the OECD (2017), high dropout rates, weak Matric outcomes, and low minimum passing standards are symptomatic of persistent shortcomings in the quality of basic education in South Africa. These challenges are closely linked to factors such as insufficiently trained teachers, staff shortages, inadequate infrastructure, and limited learning resources (OECD, 2017).

Vocational education in South Africa is widely perceived as low-quality, constrained by limited practical expertise among many Technical-Vocational Education and Training (TVET) lecturers and by outdated, insufficiently aligned curricula (OECD, 2017). Nthako and Khumalo (2025) identify major constraints within the TVET system, including inadequate resources, misaligned curricula, and limited opportunities for practical training, all of which reduce graduates' readiness for the labour market. In the energy sector specifically, community and TVET colleges have been slow to respond to evolving skills requirements and are not adequately preparing students for current and future local demand (SANEA, 2023).

The primary reason employers cite for not recruiting learners in the South African energy sector is the lack of suitable job opportunities, with 51.5% of respondents reporting this as a constraint (EWSETA, 2023). Evidence suggests that curricula in renewable energy and energy efficiency lag significantly behind industry needs, primarily because they remain overly theoretical and lack the practical competencies demanded by industry, particularly in installation, construction, operation, and maintenance of renewable-energy systems (Winberg & Hollis-Turner, 2023). This lag is exacerbated by limited engagement between industry and training institutions in the country (Winberg & Hollis-Turner, 2023). As a result, education and training systems struggle to supply skills that match current demand, reinforcing shortages and constraining productivity in the energy sector. This indicates not a short adjustment delay, but a structural and prolonged misalignment between training provision and sector requirements.

4.4 Weak Public-Private Coordination as an Employment Constraint

There is a clear disconnect between public and private actors. While the private sector increasingly employs specialists in emerging and future-oriented fields to advise clients and inform policy, the public sector

remains largely focused on current occupations and immediate challenges (SANEA, 2023). In light of the weak basic education pipeline identified in Section 4.3, SANEA (2023) recommends that both the national government and the private energy sector prioritise and invest in improving basic education provision to ensure a sufficient supply of high-quality entrants into the PSET system. According to EWSETA (2023), "training providers and employers understand that collaboration is essential for skills planning and for a smoother transition from education to work". However, research suggests that the primary constraint lies not in capacity, but in weak coordination and fragmented engagement among public and private institutions and stakeholders in South Africa (Molepo et al., 2025; PCC, 2023).

Weak public-private coordination also constrains employment creation through limited workplace-based learning opportunities. Drawing on evidence from Franz et al. (2022), small and micro-enterprises (MSEs), which have substantial potential to absorb young workers, face multiple barriers to participating in formal workplace-based learning schemes. These include information gaps regarding available programmes, incentives, and administrative procedures, as well as capacity constraints arising from competitive market pressures and limited resources for human capital development. In addition, many firms perceive a misalignment between formally accredited qualifications and their actual skills needs, reducing the incentive to engage with public training systems. Where firms do attempt to participate, complex and time-consuming bureaucratic requirements, often involving external skills development facilitators, further raise costs. Although financial incentives exist to encourage firm participation in workplace-based learning, these are frequently inaccessible, administratively burdensome, or poorly aligned with firm realities. Moreover, SETAs are often perceived by MSEs as insufficiently proactive in engaging smaller firms, as meeting learner targets is more cost-effectively achieved through partnerships with a limited number of large firms rather than with numerous small and micro enterprises.

According to Allais (2024), formal education primarily provides foundational knowledge that supports multiple occupational pathways or preparation for a specific occupation. This focus, however, often frustrates employers and learners because much of the theoretical content is not immediately applicable to workplace needs. Job- and process-specific skills are more effectively developed through workplace-based learning or through institutions that collaborate closely with employers to design and deliver training. In this regard, SETAs have largely failed to facilitate such effective workplace-linked training, contributing to persistent skills mismatches (Botha & Havemann, 2025). Collectively, these challenges reflect fragmented coordination between public institutions and private firms (World Bank, 2024), weakening the translation of education and training initiatives into meaningful employment opportunities.

In the context of the JET-IP, the weighting and costing allocated to skills development have been criticised as insufficient (PCC, 2023). Stakeholders identified South Africa's weak skills base for the energy transition, alongside concerns about poor coordination among training institutions and the lack of speed and scale required to meet transition demands. This points to inadequate integration of skills considerations into national planning frameworks. More broadly, roles across public and private actors remain highly fragmented, further constraining employment creation. Gumede (2025) argues that these challenges are reinforced by structural failures within the SETA system, including weak alignment with key state institutions responsible for economic management (e.g., Statistics South Africa, the Department of Labour, National Treasury, and the Department of Trade and Industry) as well as limited linkages with higher education institutions and industry-based training providers. Together, these coordination failures undermine the effectiveness of skills development in supporting employment outcomes during the energy transition.

Experiences from other countries highlight the importance of aligning vocational education and training systems closely with evolving green-sector demands. Many have introduced targeted apprenticeship in areas such as renewable energy, electric vehicles, and energy-efficient construction, while also embedding sustainability across a broader range of occupations (OECD, 2025b). Countries such as Denmark and the

United Kingdom demonstrate the value of institutional support structures, including dedicated knowledge centres, national toolkits, and coordinated frameworks, to continuously update curricula and build educator capacity (OECD, 2025b). Finally, both top-down strategies and bottom-up initiatives have proven effective. Thus, a flexible, multi-stakeholder approach is critical for developing a responsive and future-oriented skills pipeline for the energy transition. However, it is equally important to learn from countries' failuress, not only their successes. For instance, while Chile has made notable progress in expanding renewable energy capacity, the transition has been criticised for insufficient social inclusion (Flores-Fernández, 2020). Forgetting the *Just* in the JET is the risk of pursuing decarbonisation without adequately addressing equity considerations

4.5 Human Capital Constraints and Energy Security

In general, human capital constraints reduce productivity, increase the cost of remedial training, constrain innovation, and slow structural transformation (SSACI, 2024). In the short term, energy security is affected by, among other factors, skills shortages and inadequate or poor-quality infrastructure maintenance – challenges exacerbated by an especially acute lack of maintenance and technical skills in the country (SANEA, 2023).

Grid expansion will require specialised skills related to investment mobilisation, financial structuring, coordination, and project implementation, increasingly at sub-national levels such as districts and municipalities (SANEA, 2023). Without deliberate investment in these capabilities, skills shortages threaten safety, quality, and industry standards (Gerber & Crafford, 2025), thereby weakening energy system performance and jeopardising the country's energy security during the transition.

Mabugu and Inglesi-Lotz (2022) show that when electricity supply exceeds consumption in South Africa, economic growth is strengthened, necessitating sustained expansion of electricity supply alongside improvements in energy efficiency. By contrast, periods of load shedding reflect the opposite mismatch (when demand outstrips supply), thereby undermining energy security. Without the appropriate skills to support grid expansion, infrastructure maintenance, and the operation of a high-quality energy system, the risk of demand surpassing supply increases, ultimately threatening both energy security and long-term economic growth.

5 Opportunities for Growth, Job Creation and Reform

5.1 Untapped Growth Potential in the Energy Transition

It is estimated that the JET could generate around 1.6 million direct and indirect jobs in the industries most affected by the shift, while approximately 0.6 million jobs may be lost, yielding a net employment gain of about one million jobs (World Bank, 2024). While these projections are inherently sensitive to modelling assumptions, definitions, and methodologies, they nonetheless provide a useful indication of where employment opportunities and risks are likely to arise. Job creation is expected to be concentrated in non-coal mining activities and renewable energy generation, with additional (though smaller) employment gains along renewable energy value chains, green manufacturing, construction, and, to a lesser extent, services and utilities (World Bank, 2024).

Despite clear opportunities for expansion and employment, several segments of the renewable energy value chain remain underdeveloped in South Africa. While progress has been made in deploying renewable generation capacity, domestic manufacturing of key components remains limited and fragmented, leaving the sector heavily dependent on imported solar panels, batteries, inverters, and related equipment (PCC, 2023; SANEA & EWSETA, 2024). Gwatidzo and Simbanegavi (2021) and the PCC (2023) identify the local manufacturing of selected components – such as PV cells, energy storage technologies, inverters, and electric vehicles – as a potential short-term "quick win", particularly given South Africa's endowment of transition-relevant minerals. Although the renewable energy market offers substantial scope for economic growth, job creation, and social inclusion by leveraging existing industrial and service capabilities, this potential remains largely untapped. In addition, the PCC (2023) highlights that the expansion of the new energy vehicle sector could deliver important benefits by supporting job retention and transformation in vulnerable automotive manufacturing hubs, notably in Gauteng, KwaZulu-Natal, and the Eastern Cape.

Another promising growth area is green hydrogen. SANEA and EWSETA (2024) emphasise that South Africa must "move from strategies to implementation" in this space. Green hydrogen could catalyse industrialisation across four core sectors: renewable energy, mining, agriculture, and beneficiation; as well as three enabling sectors: transport, manufacturing, and construction (PCC, 2023). While the employment potential along the green hydrogen value chain is substantial, realising these gains will depend on the timely design and rollout of targeted, high-quality skills development programmes.

5.2 Skills Development as a Growth and Employment Lever

The JET presents an opportunity to strengthen skills development and improve basic education. Research shows that a higher share of renewable energy is associated with net employment gains, with most jobs in renewable power generation concentrated among workers with post-Grade 12 qualifications, although employment is also created across other skill levels (CSIR et al., 2019). At the same time, improved energy security (through reduced load shedding) and expanded electricity access support job creation and economic growth more broadly, as firms are able to channel resources toward productive investment and workforce expansion rather than costly measures simply to 'keep the lights on'.

Adequate talent and skills are identified as one of the three most critical drivers of performance in South Africa's energy sector (SANEA & EWSETA, 2024). What is required is a coherent, system-wide vision supported by coordinated action across several key enablers of skills development; however, such an integrated approach remains largely absent (SANEA, 2023). The severity of this gap was better understood in 2023, South Africa's worst year for load shedding and related infrastructure failures, which placed unprecedented strain on the energy skills system, affecting not only energy supply but also downstream users who increasingly adopted contingency measures (SANEA & EWSETA, 2024).

As firms and households responded to supply instability, demand rose for a broader mix of skills. Beyond core technical competencies, the sector now requires capabilities in procurement, finance, human resources, environmental management, and social liaison to plan, finance, install, and operate new energy solutions effectively (SANEA & EWSETA, 2024). In parallel, rapid growth in small-scale backup and distributed energy solutions, particularly for residential and commercial users, has sharply increased demand for qualified installers and maintenance technicians (SANEA & EWSETA, 2024). Together, these dynamics position skills development as a central lever for restoring energy system performance while unlocking growth and employment opportunities across the value chain.

Workplace-based learning and apprenticeships are critical for bridging the gap between classroom-based instruction and the practical skills demanded by industry, but the current system in South Africa is not working. Botha and Havemann (2025) argue that persistent failures within the SETA system could be addressed by converting the skills development levy into a tax-based training incentive, thereby decentralising decision-making, reducing administrative burdens, and enabling firms to invest directly in skills aligned with their needs while encouraging private co-investment. Shifting the decision-making power to firms allows them to scale up workplace-based learning, apprenticeships, and artisan training more rapidly and cost-effectively.

Education empowers individuals by building the skills and capabilities needed to participate meaningfully in the economy and society, and it is a cornerstone of a resilient and efficient energy system. When people are adequately equipped with relevant knowledge and technical skills, they are better able not only to operate and maintain energy infrastructure, but also to innovate, adopt new technologies, and respond to changing energy needs. Over time, this empowerment enables individuals to become entrepreneurs, create new firms, and develop locally appropriate energy solutions, strengthening both employment outcomes and the sustainability of the energy system.

5.3 Public-Private Coordination and Institutional Reform

Weak stakeholder coordination is identified as a high risk to implementation in the JET Implementation Plan (PCC, 2023). Assigning a clear convening and coordinating mandate to an institution such as the Presidential Climate Commission would directly address the current fragmentation across skills, climate, and energy governance structures (World Bank, 2024). Importantly, implementation of the JET-IP itself is expected to stimulate both skills demand and improved coordination through proposed mechanisms such as a JET Skills Desk, a National JET Skills Advisory Forum, and Skills Development Zones focused on priority technologies (SANEA & EWSETA, 2024). While these initiatives do not yet resolve deeper institutional misalignments, they provide a constructive foundation for building a more coherent skills ecosystem.

Incentive structures need to be redesigned to better engage SMEs in training provision. Research by Franz et al. (2022) identifies bureaucracy and high entry barriers as the primary constraints on SME participation in workplace-based learning, suggesting that a key, relatively low-cost reform lever is reducing administrative complexity associated with these programmes. Simplifying procedures would significantly improve public-private coordination and lower the cost of participation for smaller firms. In parallel, stronger incentives are needed for SETAs to proactively facilitate and support workplace-based learning within SMEs, rather than prioritising engagement with larger firms where compliance is easier but employment spillovers are more limited (Franz et al., 2022).

There is also scope to deepen public-private partnerships in South Africa's basic education. Some progress has been made through initiatives such as the Collaboration Schools Pilot Project, which sought to introduce additional management capacity and innovation into the public school system (Feldman, 2020). However, Feldman (2020) emphasises the need for more critical and rigorous engagement among all stakeholders in

the design and implementation of such models. If carefully structured, these partnerships could help address skills mismatches linked to the JET, particularly for lower-skilled occupations where a matric certificate is sufficient, while also easing pressure on public finances. At the same time, as Feldman (2020) and Swartz et al. (2019) caution, effective accountability mechanisms are essential, and private partners must be responsive to community concerns and local educational contexts to ensure legitimacy and equitable outcomes.

Chivige and Magidi (2025) argue that the core challenge of unemployment is structural: the education system operates largely in isolation, without mandatory and frequent industry feedback to inform curriculum content or the scale of graduate output in high-demand fields. Embedding industry-led standards and certification within the education and skills pipeline could help close these gaps by ensuring vocational training remains responsive to evolving labour market needs.

While the energy transition presents opportunities for job creation and skills upgrading, realising these gains is not automatic. Without deliberate policy intervention, existing skills gaps and institutional weaknesses risk limiting the transition's employment and growth potential. Section 6, therefore, focuses on the policy implications of this analysis.

6 Conclusion and Policy Implications

South Africa now confronts another critical juncture: the Just Energy Transition. The legacy of apartheid continues to shape present-day outcomes through persistent labour-market segmentation, skills shortages, and unequal access to quality education. As the global economy increasingly shifts toward low-carbon development, South Africa cannot opt out of this trajectory. Failing to plan deliberately for the just component of the transition, therefore, risks entrenching – and potentially exacerbating – existing inequalities.

For years, South Africa has experienced persistently weak economic growth, driven by multiple structural constraints. Among these, Walsh et al. (2020) argue that the economic damage from load shedding is comparable to that of the global financial crisis, emphasising the central role of reliable electricity in sustaining productivity and investment. Yet energy security itself is fundamentally a skills-intensive outcome: maintaining, expanding, and transforming the electricity system depends on the availability of appropriately trained workers. In a context where education and training systems are underperforming, the energy transition presents a rare opportunity to address interlinked challenges of skills formation, employment creation, and long-term growth.

The impact of the energy transition on growth operates through two closely connected channels. First, reliable and affordable electricity underpins productivity in firms and households and is essential for restoring investor confidence. Second, the transition can act as a catalyst for employment creation across energy value chains and related sectors, supporting incomes, demand, and capital accumulation.

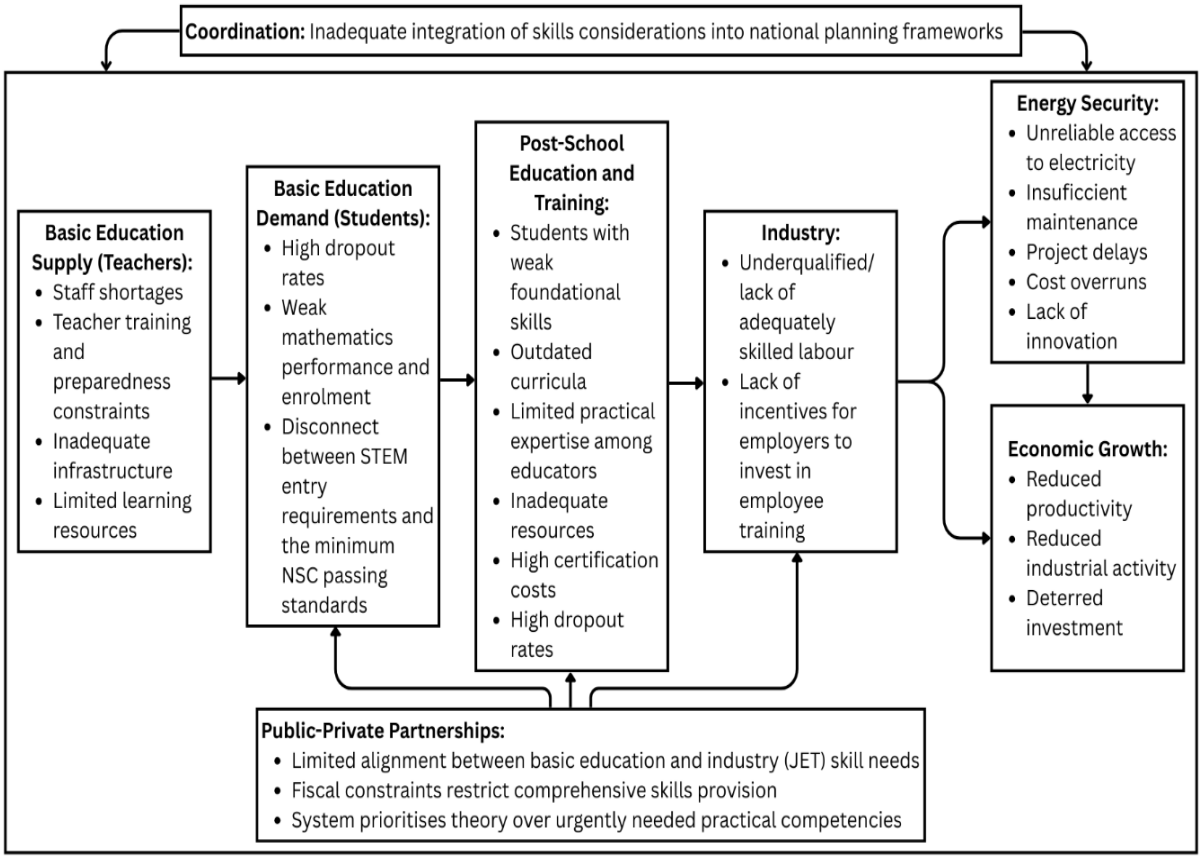
Skills are widely recognised in the literature as critical to the success of the energy transition. However, existing research predominantly focuses on post-school education and training, with relatively limited attention to the role of basic education. In particular, the literature does not examine how constraints in basic education (on both the supply and demand sides) cascade through post-school education and training into the labour market, ultimately shaping energy security and long-run economic growth.

Regardless of domestic debate, the global energy transition is already underway – driven not only by climate objectives but increasingly by energy security considerations. The central policy question is therefore not whether South Africa will undergo an energy transition, but whether policymakers will leverage it to mobilise investment, finance, and technology in ways that support inclusive growth and shared prosperity.

6.1 JET Skills to Economic Growth Conceptual Framework

This study's diagnosis identifies the binding constraints within South Africa's skills pipeline, particularly in foundational education, post-school education and training, and institutional coordination. These constraints condition how the energy transition will translate into employment outcomes, skills demand, and, ultimately, energy security and economic growth, as illustrated in Figure 13. The next section therefore shifts from diagnosis to opportunity, examining how the energy transition can be leveraged to unlock growth, job creation, and reform.

Figure 13: Conceptual framework linking the skills pipeline to energy security and economic growth in South Africa



Source: Authors' design

6.2 Policy Recommendations

The policy recommendations in this section respond directly to the growth and employment constraints identified in Section 4, and to the growth and employment opportunities outlined in Section 5. The focus is on translating diagnostic insights into actionable reforms (see Table 1) that can support both economic growth and a just energy transition.

Table 1: Policy levers to support South Africa's Just Energy Transition

	Coordination across four constraint areas			
	Build on the JET Skills Desk, National JET Skills Advisory Forum, and Skills Development Zones, but move beyond fragmented initiatives. Assign a **clear convening and coordinating mandate** to a single institution to align education, skills, energy, and labour-market policies across government, industry, and civil society.			
Constraint Area	**Basic Education Supply (Teachers)**	**Basic Education Demand (Students)**	**Post-School Education and Training**	**Industry Participation**
Key Reform Priorities	• Strengthen teacher training and retention, particularly in Mathematics and Physical Sciences. • Expand partnerships with the private sector to support teacher development, curriculum support, and school management capacity.	• Integrate JET-relevant content into the basic education curriculum to further strengthen foundational competencies, reduce the need for remedial post-school certification, and give learners an early advantage in energy-related pathways. • Use public–private partnerships to promote Mathematics and Physical Science uptake and improve pass rates. • Introduce job shadowing and career exposure in energy-related fields. • Encourage targeted private-sector investment in schools, especially in underserved areas.	• Expand public–private partnerships in curriculum design and delivery. • Reform SETAs, including consideration of converting the Skills Development Levy into a tax-based training incentive (Botha & Havemann, 2025). • Regularly update curricula to reflect evolving energy-sector needs. • Scale up workplace-based learning, apprenticeships, and learnerships.	• Decentralise skills investment decisions to firms closer to skills demand. • Reduce administrative burdens associated with workplace-based learning. • Incentivise private investment and co-investment in education and training. • Encourage SETAs to more actively engage SMEs in skills development.

One “quick win” policy lever that cuts across all identified constraints is improved data availability and clearer identification of critical energy skills, which are currently lacking in South Africa. The Energy Skills Roadmap highlights this gap and recommends comprehensive skills-ecosystem mapping alongside the development of an occupations-and-skills atlas to support coordinated public-private action (SANEA, 2023). South Africa would further benefit from a live, interoperable data platform linking education, labour-market, and energy-system information, complemented by sub-national data to track geographically specific demand for energy-related occupations.

Ultimately, the success of the recommendations outlined in Table 1 hinge on effective institutional coordination. A clearly mandated coordinating body that brings together government, industry, and civil society would help align JET-related policies with education, skills development, and employment strategies, ensuring they reinforce rather than undermine one another. Such coordination is essential to translate the energy transition into a coherent pathway for inclusive growth, sustainable energy security, and shared prosperity for all who call South Africa home.

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