Repurposing of coal-fired power stations and coal mines for a JUST transition in South Africa

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Introduction

Since the dawn of the industrial revolution, humans have been extracting large amounts of fossil fuels and burning them indiscriminately in pursuit of economic growth and higher standards of living (The New York Times, 2018). South Africa is the world's 13th largest emitter of greenhouse gasses and is heavily reliant on ageing coal-fired power stations for its electricity (Global Carbon Atlas, 2020). Climate changes are being driven as a consequence of this paradigm and a consensus has formed around the need for an energy transition both globally and in South Africa. However, this transition needs to be "just" and align with the National Development Plan (NDP) which envisages that the country will move towards a 'low-carbon, climate resilient economy and just society', with a reduced dependency on carbon intensive energy sources.

Globally, countries are phasing out their coal use in various linked sectors such as electricity, mining, logistics, manufacturing, and export. These countries are taking different approaches to diversify their economies and energy mixes predominantly due to pledges to reduce greenhouse gas (GHG) emissions (Jeudy-Hugo et al., 2021). South Africa's Integrated Resource Plan (IRP) 2019 determines that approximately 10.6GW will be decommissioned by 2030 from coal-fired power stations in the province of Mpumalanga having direct implications on the entire coal value chain, especially the mining industry currently supplying coal to these power stations. The subsequent closure of both coal power stations, and coal mines will have negative socio-economic impacts, and these impacts will significantly affect the regions where coal continues to play a significant role in employment and economic growth (Strambo et al., 2019). Without proper planning, it is expected that substantial economic losses would be incurred by the South African economy and society at large with further potential to trigger social unrest and violence.

To mitigate the possible negative effects associated with this, this article proposes several repurposing solutions that have the potential to bring about new economic opportunities.

Methodology

A literature review was completed to identify aspects that should be considered to have an effective and just transition when considering repurposing for coal mines and power stations. This review also included possible repurposing options and identification of all coal value chain elements and linkages to other sectors.

Stakeholder engagements with the local research community and European institutes influenced the list of repurposing solutions for coal mines and coal power stations for detailed analysis. These solutions were narrowed down further by the CSIR researchers and various energy experts internally and externally using a multi-criteria decision analysis (MCDA) that was developed based on inputs from technical experts and literature. Prioritization of each criterion and sub-criteria was categorized by technical experts. Finally, the application of the MCDA recommended the top six most suitable repurposing solutions for both coal mines and coal power stations. The details and results for the analysis and conclusions are presented in the sections to follow.

Literature review

Just transition research mapping

This section details the findings from the literature review and stakeholder engagements conducted that aimed to determine what criteria should be considered when identifying options to be pursued for a just transition. Historically, projects and technology selection were based on technical feasibility and pure bankability, however, this narrowed and simplistic approach cannot ensure a just transition.

A desktop literature review was conducted for the international and local just transition landscape. The aim was to understand the aspects considered when carrying out a just transition, identify research gaps and make recommendations. On the local landscape, 28 studies were reviewed emanating from research organizations, companies, institutions, national departments and funders. A high focus, 96% of the studies, was placed on environmental aspects including high emissions and commitments towards their reduction. 86% of the studies focused on economic aspects such as sustainable and quality jobs, economic diversification and skills development. However, social and technical/costs considerations received the least focus with approximately 54% and 39% of the studies, respectively. It was also noted that the studies focused more on aspects at national level, rather than having a regional focus.

19 international studies were reviewed for the international just transition landscape and it was found that these focused more on regional levels and included case studies and lessons learnt from transition efforts. 100% of the sourced studies highlighted the economic dimensions, followed by social aspects such as social protection plans and community participation/consultations. Environmental and technical/cost aspects received the least focus from the studies, with only 5% of the studies focusing on technical/costs. The aspects considered within these various dimensions are summarized in Figure 1 below.

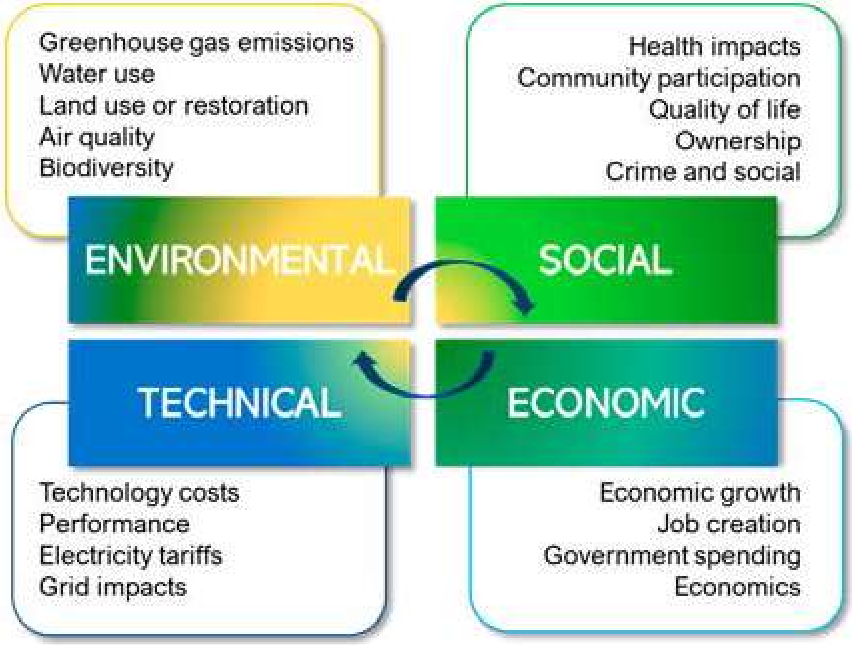

Figure 1: Dimensions and associated aspects considered for selection of pathways and projects for a Just Transition (CSIR Analysis)

The studies reviewed from a local perspective illustrated that there is significant focus on environmental aspects, whereas international research emphasized economic aspects. The gaps highlight the need for more attention to be given to social imperatives. Furthermore, the research addresses a national focus but lacks a regional analysis.

High-level screening of repurposing options

Various countries undergoing coal transition have repurposed their coal-fired power stations and coal mines as listed in Table 1. In this study, the implemented repurposing solutions are screened at a high level in the international and local context. A summary of the reviewed repurposing solutions internationally and locally for coal power plants and coal mines is given in Table 1 below along with the citations.

The review of implemented and proposed repurposing options for coal-fired power stations and coal mines brings out economic, technical, costs, environmental and social dimensions that were considered when selecting the options. Important aspects include re-use of existing infrastructure and access to private and state funding which have enabled timeous implementation of international repurposing projects in the US and EU. Renewable energy such as biomass can reduce emissions and create long-lasting jobs as compared to wind and solar PV. However, sourcing of biomass from forests makes the strategy "unjust", calling for more assessment. The review also brings out the importance of community engagement before development to understand and meet the needs of the surrounding community. Support for locals is also demonstrated through jobs, small, medium, and micro enterprise (SMME) support, grants, skills development and the use of locally manufactured raw materials. In South Africa, repurposing of Komati coal power station is planned in 2022 and includes installing solar PV, battery storage, synchronous condenser conversion, wind turbines and agrivoltaics (Eskom, 2022b). 300,000 jobs can be created by the project which will also supply electricity to off-grid areas. A training center at Komati will help to train workers and local community members.

Table 1: Implemented/in process solutions reviewed for repurposing of coal mines and coal power stations

Repurposing option	Location (status)	Dimension/aspect
		Coal power stations
Combined cycle gas turbines (CCGT)	Paradise combined cycle Gas power plant, France - Complete) (Power, 2017)	**Economic:** • Job creation - 600 construction jobs; 40 permanent and 20 contractor operational jobs **Technology/costs:** • Use existing coal infrastructure • Increasing efficiency 62.22% • Quick response to grid demand fluctuations Environment: 50% emission reduction. Social: electricity for 600,000 households
Biomass firing	Redbank Power Station, Australia (Stalled due to claims of forest destruction, Environmental impact assessment ongoing) (Vatala et al., 2022)	**Economic:** • 265 jobs during recommissioning, 55 permanent jobs, 800 – 900 direct and indirect jobs form the fuel supply chain **Technology/costs:** • Use existing coal infrastructure **Environment: Net Zero CO2 emissions** **Social:** • Improved air quality • Lasting jobs over 30+ years • Electricity to about 250,000 homes
Battery energy storage	Mount Tom Station in USA (Complete) (Teale, 2019)	**Economic:** • Revive dying economy • Stable electric rates **Technology/costs:** • Use existing infrastructure **Environment**: • Eliminate generation emissions • Preservation of close waterways • Protection of rare and endangered habitats **Social:** • Slow down deteriorating health issues • Youth employment and re-training • Early access to retirement packages • Community engagement
Mixed-use development	Battersea power station, UK - leisure, retail and residential areas (To open in October 2022) (Battersea powerstation, 2021)	**Economic:** • Invested about £9 million in local SMMEs • Committed to filling 20% of its long-term positions with locals • Created Battersea Academy for Skills & Employment (BASE) **Technology/costs:** • Use existing infrastructure **Environment:** • Diverted 5,889 tyres for flooring works and saved 36,000 tons of emissions **Social:** • Community engagement
Data center	Widows creek, USA (Completed) (Gammons, 2015)	**Economic:** • ~100 full-time and contractor (plus local) jobs • Training locals in digital skills **Technology/costs:** • Use of existing electricity infrastructure **Environment:** • Preservation of existing terrain • Uses 50% less energy than comparable data centers **Social:** • School and community grants • Increased provision of global internet services
Green hydrogen hub	Moorburg power plant, Germany (Ongoing) (Hydrogen Central, 2022)	**Economic:** • Proximity to potential hydrogen market hence project can cover entire value chain • Create ~5.4 million jobs • Generate €800 bn annually in sales by 2050 **Technology/costs:** • Use existing gas network and grid connection **Environment:** • Reduce CO2 emissions by one million t/yr by 2030

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Repurposing option	Location (status)	Dimension/aspect
		Coal mine repurposing
Pumped hydro energy storage (PHES)	Kidston Gold Mine, Australia (ongoing) (Colthorpe, 2021; Power Technology, 2022)	**Economic:** • Generate AUD 353 million in revenue • 500 jobs and 20 permanent operational local jobs • Stable energy supply/meet peak demand **Technology/costs:** • Use existing mine pits for water storage • Reduce peak power prices **Environment:** • Land rehabilitation **Social:** • Cheaper and stable electricity for people
Solar PV plant	Leipziger, Germany (Complete) (Enkhardt, 2022)	**Economic:** • Area revitalization • Use of locally manufactured materials • Potential for agrivoltaics **Technology/costs:** • Use of existing grid infrastructure • Grid tied project **Environment:** • Less environmental contamination after re-soiling • Reduces ~3,700 tons of CO2 emission • Improved regional water quality **Social:** • Electricity supply to 1800 households • Improved quality of life after mine cleanup
Data center	Lefdal mine, (Complete) (LDM, n.d.)	**Economic:** • $164 million direct economic impact during construction • 225 direct operational jobs annually **Technology/costs:** • Use of existing underground mine terrain • Sea cabling from RE power source **Environment:** • Conserved energy due to nearby cooling water and water re-use • Use RE from hydroelectric and wind sources
Leisure areas: • Hotel • Eco-tourism park	Shenkeng Quarry, India (Complete) (Katyal, 2018) Anglesea mine, Australia (ongoing) (Eden Project, n.d., 2019)	**Economic:** • Use of locally manufactured materials (Shenkeng) • 5000 workers during construction (Shenkeng) • Generate AU$350m within 10 years (Anglesea) • 1,300 new mostly local jobs within 10 years (Anglesea) **Technology/costs:** • Use of existing infrastructure (Shenkeng) **Environment:** • Nature preservation (Shenkeng) • Powered by RE sources (Shenkeng) • Nature creation/biodiversity preservation (Anglesea) **Social:** • Community engagement (Anglesea) • Uplift young people and school groups (Anglesea) • Affordable housing (Anglesea)

Learnings from international experiences can ensure "just" repurposing options for South Africa.

Regional profiling and identifying sector linkages between coal and other value chains

Existing coal value chain in the region and its linkage to other sectors

This section identifies stakeholders within the coal value chain in Mpumalanga who will be most impacted by the repurposing of coal mines and power stations. The objective of this analysis was to inform the socio-economic and industrial risk and vulnerability assessments of transitioning to a green economy. The coal value chain includes manufacturing, mining operations, transportation and storage of mineral and manufactured products, power generation, coal-to-liquid synthetic fuel production, energy feedstock in the manufacturing sector and coal export (see Figure 2 below).

Details on the main value chain element is provided below:

- **Coal mining operations:** According to 2021 Eskom's report, SA produces an average of 224 million tons of marketable coal annually, positioning the country as the fifth largest coal producer in the world (Eskom, 2021a). In 2021, South Africa's coal production contributed a total gross value added (GVA) of ~R85 billion with Mpumalanga accounting for a share of ~86.2% (Quantec portal, 2022b). This is associated with a total employment of ~100 000 workers, with Mpumalanga accounting for ~82.6% (Quantec portal, 2022a). The economic and social reliance on coal mining operations is evident for the country but more specifically, Mpumalanga. Coal producing areas are predominantly located in Emalahleni, Steve Tshwete and Govan Mbeki municipality jurisdictions which, combined, accounted for

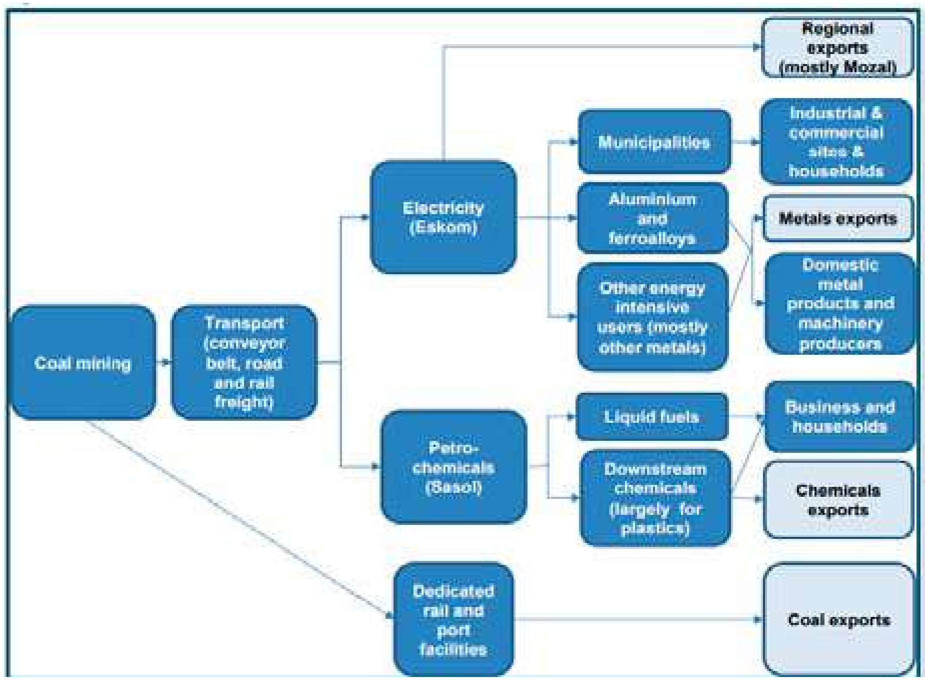

Figure 2: Coal value chain (source: Makgetla and Patel, 2021)

82% of the gross value added of provincial coal production (EasyData/Quantec, 2022). Reserves are running low, and future coal mining activities will move northwest to Waterberg and Soutpansberg, which account for 72% of the remaining supplies (Creamer Media, 2015; Mathu, 2014).

- **Coal transportation and storage:** The transportation of coal to coal fired power stations, predominately utilizing conveyors, road and rail transport, has increased over the past ten years (Strambo et al., 2019). Beneficiation and manufacturing facilities also have coal delivered via conveyor belt, rail and road transportation (Makgetla & Patel, 2021). Furthermore, the transportation of coal has contributed significantly to the transport sector through creation of employment and revenue (Strambo et al., 2019). Mpumalanga houses the most coal resources in the country with 90% of the coal mines located in this province. Subsequently most of the coal fired power stations have been strategically located to these mines in order to reduce substantial transportation costs and further serve most of the electricity demand of the country which is also located in the central and Northeast regions. The substantial cost of transporting coal has directly contributed to continued coal mining in the Mpumalanga province and indirectly supported other coal producing regions such as Limpopo province. Road is the preferred mode of transport for delivering coal from other coal producing regions to coal fired power stations in Mpumalanga (Mathu, 2014). About 57 per cent of the distance travelled by heavy freight occurs on roads that are not constructed for heavy vehicles. Long-distance bulk transport of coal bound for export is predominantly rail-based using the Transnet Freight Rail network to the Richards Bay Coal Terminal (Botha, 2016). Overall, the transport and storage sector accounted for 5 per cent of GVA for Mpumalanga.

- **Coal-fired power generation:** The electricity generation capacity in the country is mainly dominated by Eskom (South African state-owned power utility) (Baker & Phillips, 2019; DPE, 2022). Eskom is a vertically integrated monopoly (DMRE, 2021; Eskom, 2021b; Kessides, 2020). Eskom's total nominal capacity of ~46.7GW is dominated by 15 coal-fired power stations accounting for a proportion of ~38.8GW (83%) (Eskom, 2021b). Twelve of these power stations are located in Mpumalanga province and have a nominal capacity of ~27.9GW (Eskom, 2022a). In 2021, 91.1% (183.6TWh) of the total energy production was from coal fired power stations. Mpumalanga accounts for 76% of the total electricity generation in SA (Nyamadzawo, 2021). At municipal level, electricity production form local municipalities Emalahleni; Steve Tshwete and eHlanzeni account for 78% of the provincial total for electricity. From 2000 to 2020, the contribution of electricity production from coal-fired power stations to the provincial GVA experienced a decline of 2%. Notable reductions were from Pixley Ka Sem; Lekwa; Dipaleseng; Emalahleni and Steve Tshwete municipalities. The electricity GVA of Msukaligwa and Mkhondo municipalities has increased indicating some growth in related economic activities.

- **Manufacturing sector:** Apart from coal providing primary energy needs for electricity, it also serves as valuable feedstock for energy in the manufacturing industries such as petrochemical, iron and steel production, non-metallic minerals, cement, and lime calcining, among others. ~53% and 33% of locally produced coal are attributed to the petrochemical and metallurgical industry, respectively (Eskom, 2021a). Sasol, the largest producer of petroleum chemical products, has a coal to liquid (CTL) plant in Secunda, Mpumalanga where it produces 25% of SA liquid fuel supplies (petroleum in particular) (Makgetla & Patel, 2021). Major manufacturing industries including petroleum, chemical, metal, machinery, and equipment contributed a significant share of ~42% to South Africa's total manufacturing GVA in 2021 (Quantec portal, 2022b) Similarly, the same industries accounted for ~64% of Mpumalanga's total manufacturing GVA in 2021. Govan Mbeki's local municipality is an economic hub producing petroleum products which contribute 62% to the provincial petroleum refining GVA. Furthermore, it is an important economic activity in Albert Luthuli municipality accounting for 20% of the GVA. Key manufacturing centres for transport equipment include Ehlanzeni; Mbombela and Emalahleni where the GVA contribution from them to the transport sector was 71% in 2020.

- **Export sector:** Over the past ten-years, the coal export sector has successfully recorded an average annual growth of ~10.6%(Quantec portal, 2022b). This is partly attributed to coal and energy intensive industries such as petroleum, chemical, rubber, plastics, and metal refineries including iron and steel, non-ferrous and structural metals. Notably, these industries collectively accounted for ~22% share of GVA contribution to export sector in 2021(Quantec portal, 2022b). Mining and quarrying and manufacturing sectors accounted for 47.2% and 46.8% share of contribution to export sector in 2021, respectively. Furthermore, ~25% of coal production is exported internationally and making SA the third largest coal exporting country (Eskom, 2021a).

Risk and vulnerability assessment for the most affected parties in coal value chain

The next part of the project was to establish a clear understanding of the most vulnerable parties in the coal value chain. This enables more specific and practical assessment of the needs of the most vulnerable parties and alignment with resources. Furthermore, it allows for the most protective implementation plans possible (Makgetla & Patel, 2021).

Communities, workers, and small business have been identified as the most vulnerable in the value chain. Workers and small businesses are direct participants in the coal value chain by being employed and supplying goods and services to coal mining firms, coal-based power generation, and coal-based petrochemical production, respectively. The vulnerability of coal mining workers is mostly triggered by limited access to financial resources, limited mobility in the labour market and relatively low level of skills (Makgetla & Patel, 2021). The affected communities include the residents of mining towns that are impacted indirectly such as partners and families of workers as well as informal and informal businesses (e.g., food accommodation, and other retail services that provide goods and services to workers, managers, and their families) (Makgetla et al., 2019).

Furthermore, based on a host of indicators including, level of employment, education, access to safe water and overall quality of public hospitals and clinics were adopted to assess the sensitivity and adaptability of Municipalities to climate change (Stats SA, 2015, 2018). It is evident that these Municipalities are in a significantly vulnerable condition. The indicators were normalized from 1-10 to give an indication of the relative importance of each indicator across the municipalities, with 1 indicating the lowest relative contribution and 10 indicating the highest relative contribution to vulnerability (see Table 2). The indicators were also color-coded, with red indicating the intensity.

In the medium to long term, foreign policy risks in a form of reduced importation of SA's coal production, reduced investors' appetite to invest in coal related activities and the global pressure to move away from coal will have a high impact on coal value chain (Makgetla et al., 2019). Similarly, domestic market and policy risks in a form of reduced demand for coal-based electricity through demand efficiency and adoption of low carbon intensive power generation technologies are also expected to have a high impact on coal value chain. The impacted role players in coal value chain include coal mining, Eskom, Transnet Freight Rail (TFR), coal transporters, small businesses, Richards Bay Coal Terminal (RBCT) and Sasol (Makgetla et al., 2019). Furthermore, to minimise the potential risks, businesses over time will have to write off coal reserves and capital investments and resulting job losses will occur. Therefore, diversifying Mpumalanga region into new economic activities is critically important (Makgetla, 2021).

MCDA framework development

As mentioned above, the MCDA method was selected for analysis of repurposing options. The development of the MCDA framework followed three steps:

1. The development of selection criteria within the dimensions of just transition,
2. Weight allocation for each criterion based on relative importance and prioritisation and
3. Development of a platform and method for the analysis and conclusion of the proposed solutions.

Significant details about the development of the MCDA framework are provided in the sections below.

Criteria development and associated weighting

The MCDA criteria used to assess the shortlisted solutions was developed through literature reviews

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Table 2: Relative importance of indicators and vulnerability aspects across different municipalities in Mpumalanga province

Type of indicator	Vulnerability aspect	Msugalikwa	Govan Mbeki	Emalahleni	Steve Tshwete
Employment	Unemployed	7.2	6.4	6.3	5.9
Education	No education	6.1	3.9	2.8	3.3
Distance to main drinking water	Hh >500 m	6.4	3.9	1.8	2.1
Access to safe water supply	Hh with no access	3.6	1.4	10.0	4.1
Mun water interruption - past 3 months	Hh with interruptions	5.9	5.0	7.0	3.1
Length of water interruption	Hh with>14 d in total	4.2	0.5	2.9	0.1
Alternative water source during interruptions	Hh using stagnant water /none	3.3	3.4	1.6	2.8
Main dwelling currently living in	Hh in informal dwellings	3.9	8.9	9.0	6.0
Overall quality of the local public hospital	Hh with no access	10.0	2.2	3.5	4.8
Overall quality of the local public hospital	Hh that do not use	4.2	5.8	5.3	7.7
Overall quality of the local public clinic	Hh with no access	7.8	2.8	5.5	3.1
Overall quality of the local public clinic	Hh that do not use	3.9	6.4	5.3	7.6
Refrigerator/ Freezer	Hh without fridge/freezer	7.9	3.7	9.8	4.6
Motor vehicle	Hh without motor vehicle	8.7	7.7	8.0	6.8
Radio	Hh without radio	5.9	6.0	8.1	6.2
TV	Hh without TV	6.7	3.4	10.0	3.9
Landline	Hh without landline	9.6	9.3	9.6	9.5
Cell phone	Hh without cell phone	6.8	4.8	6.9	4.0
Aircon	Hh without aircon	9.5	9.1	9.6	9.6
Run out of money to buy food in past 12 months	Hh no money for food	4.8	4.4	4.5	6.5
Run out of money to buy food for 5 or more days in past 30 days	Hh running out of food	7.6	7.3	7.9	7.0
Skipped meal in past 12 months	Hh skipping meals	4.4	4.7	4.5	7.1
Skipping meal for 5 or more days in the past 30d	Hh skipping meals	7.7	7.4	7.5	7.4

and stakeholder engagements with representatives from the Department of Mineral Resources and Energy (DMRE), Department of Forestry, Fisheries and Environment (DFFE), National Treasury, SASOL, South African Photovoltaic Industry Association (SAPVIA), Congress of South African Trade Unions (COSATU), ESKOM, the Mineral Council South Africa, and CSIR.

The criteria were categorised into 6 segments i.e., economic, environmental, technical, project feasibility, social and other. The final set of criteria was consolidated to include assessable criteria.

To determine the weights for each criterion, stakeholders ranked each criterion and once the rankings were received from the stakeholders, these

were converted into average weights using the equation defined in section 4.2 below. The last step was to normalise the weights to 100% (Alfares & Duffuaa, 2008). Various stakeholders provided inputs in this regard, some of the main stakeholders included ESKOM, COSATU, SASOL, Sam Tambani Research Institute (SATRI)/ National Union of Mineworkers (NUM), Coal Tech, CSIR, Indalo, Earth life, SAPVIA, DMRE, DFFE, South African Wind Energy Association (SAWEA) and the IPP Office (IPPO).

Formula used to derive criteria weights

To develop aggregated criteria weights, an empirical rank-weight relationship was used (Hesham & Duffuaa, 2008) . This linear relation specifies the average weight for each rank of an individual criterion. Furthermore, the linear relation assumes that the aggregated weight of all the criteria ranks is 100%. For any set of ranked criteria, the percentage weight of criteria ranked r is given by the equation/s below:

$$\omega_{r,n} = 100 - s_n(r-1),$$

$$\text{Where } s_n = 3.195 + \frac{37.758}{n}, \; 1 \le n \le 21, \; 1 \le r \le n, \; r \; \textbf{n and r are integers}$$

There is an upper limit of 21 i.e., total maximum number of criteria. The aggregation data is criterion specific, therefore the criteria for coal power stations and coal mines cannot be combined. There were 21 and 18 criteria identified for coal power stations and coal mines, respectively.

The method however does have the following limitations (Hesham & Duffuaa, 2008):

- The methodology cannot recognise the different intensities of preference among individual decision makers, thereby giving equal weight to each individual criterion that is ranked and
- The approach to collect the data (rankings) is not a decision-making process. The presence of concrete decision alternatives might therefore influence individual criteria ranks.

Furthermore, to determine performance scores or ranking, experts' inputs were again solicited to assist in scoring the shortlisted solutions against each criterion using discrete scoring range values (see results in section 5.2). The scoring ranges were developed by experts and were 0-1, where 0 is least favourable and 1 favourable.

MCDA for solutions

The final step was to multiply the weighting by the scores received from various technical experts to obtain the overall score and ranking of solutions. Surveys containing the description of the projects and the scoring ranges for each criterion was sent out to these. The stakeholders had to score each solution based on their experience, expertise, and knowledge. The list of solutions and associated criteria was quite extensive, therefore different stakeholders assessed different sets of projects. Each stakeholder was required to score 4 different projects.

Results and discussion

Criteria development

This section provides the consolidated set of criteria that was developed for the MCDA application. Figure 3 and Figure 4 show the set of criteria which was used to assess the repurposing solutions for coal power stations and coal mines, respectively.

Criteria weighting and scoring range

This section provides the results obtained for the final criteria weighting and scoring ranges for each criterion. Table 3 and Table 4 detail this information for coal power stations and coal mines, respectively.

It is evident that, for coal power stations, significant priority was assigned to technical feasibility (7.04%) followed by access to funding (6.77%), reduction of GHG emissions (6.46%) and job creation (6.44%). While for coal mines, significant prioritization was access to funding (7.73%) followed by financial sustainability (7.35%) and job creation (7.23%).

Coal power stations repurposing solutions

Experts from group 1 assessed the following set of solutions: Conversion to data center, mixed used

TECHNICAL
- Technical feasibility (LCOE, etc.)

ECONOMIC
- Financial sustainability
- Access to funding
- Economic diversification
- Labour - job creation/increase in income for the local community
- Reskilling & skills requirements (need for specialist workforce) & skills

ENVIRONMENTAL
- Reduction of GHG emissions
- Water usage and conservation
- Rehabilitation of land (and required funding)

SOCIAL
- Diversity aspects (gender, racial, equality, disability, etc)
- Positive changes in livelihood (community development)
- Improved health impacts

PROJECT FEASIBILITY
- Ease of implementation
- Timeline to implement the project
- Locality of the project
- Investment mandate (key for donors)

OTHER CRITERIA
- Solution meeting Just Transition mandate

Figure 3: Criteria developed for repurposing of coal power stations

ENVIRONMENTAL
- Water usage and conservation - acid mine drainage impacts
- Rehabilitation of land (and required funding) and current land use in surrounding areas
- Effects on biodiversity (climate regional flora and fauna)

TECHNICAL
- Re-use potential of mine facility
- Required machines and equipment availability
- Reskilling requirements (need for specialist workforce) & skills development
- Replicability/modularity/transferability

ECONOMIC
- Access to funding
- Financial sustainability
- Labour - job creation/increase in income of local community
- Export earning impact/potential

SOCIAL
- Diversity aspects (gender, racial, equality, disability, etc)
- Positive changes in livelihood qaulity (community development)
- Tourist attraction
- Mining company policy

PROJECT FEASIBILITY
- Ease of implementation (i.e., the less complex the better)
- Timeline to implement the project (i.e., shorter is better)
- Locality of the project
- Investment mandate (key for donors)

OTHER CRITERIA
- Does the project meet JET mandate

Figure 4: Criteria developed for repurposing of coal mines

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Criteria and description	Dimension	Weighted (W)	Scoring Range (SR)
Access to funding	Economic	6.77%	- 0.5: Difficulty in obtaining funding - 1: Funding is easily available
Financial Sustainability	Economic	6.08%	- 0:Market anticipated but still nonexistent, Return on Investment (ROI) >8 years and Net Present Value (NPV) not certain - 0.5: Market still developing, ROI in 4-7 years and positive NPV - 1: Market-ready, ROI within 3 years and high NPV
Economic diversification	Economic	4.15%	- 0: No diversification from coal - 0.25: New fossil-fuel energy applications with lower emissions - 0.5: New industry which still relies on coal, e.g., steelmaking - 0.75: New sustainable non-energy markets created e.g., agriculture, tourism - 1: New sustainable markets/New sectors in "clean" energy - e.g., solar, wind, green hydrogen
Labor - job creation/ increase in income for local community	Economic/Social	6.44%	- 0: Little to no job absorption (0-20%) - 0.25: Some jobs absorbed i.e., new employees (21% - 49%) - 0.5: Significant number of jobs absorbed (50% - 79%) - 1: Majority to all jobs absorbed (80% 100%)
Reduction of GHG emissions	Environmental	6.46%	- 0: Little to no reduction in emissions (<10%) - 0.3: Minimal to low reduction in emissions (10% - 39%) - 0.6: Significant reduction in emissions (40% - 79%) - 1: Near total reduction in emissions (80% - 100%)
Water usage & conservation	Environmental	4.77%	- 0: Unsustainable use of water - 0.5: Minimal reduction in water usage - 1: Sustainable use of water
Rehabilitation of land (and required funding)	Environmental	4.11%	- 0.25: Total rehabilitation of land required - 0.5: Partial rehabilitation of land required - 1: No rehabilitation required
Generation plant supplying power into the grid	Technical	4.64%	- 0: Does not add generation capacity to the grid and no grid support - 0.5: Not adding generation capacity to the grid but assisting with grid support - 1: Adds generation capacity to the grid and assists with grid support
Technical feasibility	Technical	7.04%	- 0.25: Promising technology but not proven beyond the small scale (TRL <4) - 0.5: Technology currently at demonstration stage (TRL 5-7) - 1: Commercially available and proven technologies (TRL 9)
Use of existing infrastructure in the power station	Technical	4.26%	- 0.25: Minimal use of existing infrastructure - 0.5: Some use of existing infrastructure - 1: Maximum use of existing infrastructure

Table 3: Criteria weighting and scoring ranges for coal power station repurposing solutions

Use of existing infrastructure to integrate power	Technical	3.57%	- 0.25: Minimal use of existing infrastructure - 0.5: Some use of existing infrastructure - 1: Maximum use of existing infrastructure
Required machines and equipment availability	Technical	2.55%	- 0: <10% of the equipment is available locally - 0.25: 11% - 30% of the equipment is available locally - 0.5: 31% - 60% of the equipment is available locally - 0.75: 61% - 80% of the equipment is sourced locally - 1: 81% - 100% of the equipment is locally sourced
Reskilling requirements (Need for specialist workforce) & skills development	Technical	4.82%	- 0.25: High reskilling requirements - 0.5: Moderate reskilling requirements - 1: Minimal reskilling requirements
Replicability/modularity/ transferability	Technical	2.50%	- 0.1: Very difficult - 0.5: Moderately difficult - 1: Easy
Diversity Aspects (Gender, racial equality, disability etc.)	Social	3.44%	- 0: Will result in less inclusivity - 0.3: Will not change status quo - 0.6: May result in more inclusivity - 1: Will result in more inclusivity
Positive changes in livelihood quality (community development)	Social	5.48%	- 0.25: Minimal improvement in livelihood quality - 0.5: Moderate improvement in livelihood quality - 1: Significant improvement in livelihood quality
Improved health	Social	4.46%	- 0.25: No improvement in the quality of health - 0.5: Minimal improvement in the quality of health - 1: Significant improvement in the quality of health (linked to reduction in GHG emissions)
Ease of implementation and timeline to implement the project	Project feasibility	5.04%	- 0.25: Difficult to implement/ execute - 0.5: Manageable (can be executed with support) - 1: Easily implementable
Locality of the project	Project feasibility	4.13%	- 0.25: Minimal use of local resources - 0.5: Some use of local resources - 1: Make use of local resources
Investment within government mandate	Project feasibility	3.84%	- 0: No government support - 0.5: Possibility of public and private partnership - 1: Full government support with policies in place
JET Mandate	Other	5.26%	- 0.5: Meet some aspects of the JET mandate - 1: Meet JET mandate
Total		**100%**	

Criteria and description	Dimension	Weighted (W)	Scoring Range (SR)
Access to funding	Economic	7.73%	- 0.5: Difficulty in getting funding - 1: Funding is easily available
Financial Sustainability	Economic	7.35%	- 0: Market anticipated but still nonexistent, Return on Investment (ROI) >8 years and Net Present Value (NPV) not certain - 0.5: Market still developing, ROI in 4-7 years and positive NPV - 1: Market-ready, ROI within 3 years and high NPV
Export earning potential	Economic	4.50%	- 0: No potential to earn any income - 0.25: Target market mostly local - 0.75: Target market mostly international - 1: Target market exclusively international
Labor - job creation/ increase in income for local community	Economic/Social	7.23%	- 0: Little to no job absorption (0-20%) - 0.25: Some jobs absorbed i.e., new employees (21% - 49%) - 0.5: Significant number of jobs absorbed (50% - 79%) - 1: Majority to all jobs absorbed (80% - 100%)
Effects on biodiversity (Climate Regional flora and fauna)	Environmental	6.17%	- 0: Little to no reduction in emissions (<10%) - .3: Minimal to low reduction in emissions (10% - 39%) - 0.6: Significant reduction in emissions (40% -79% - 1: Near total reduction in emissions (80% -100%)
Water usage & conservation- acid mine drainage impacts	Environmental	5.94%	- 0: Unsustainable use of water - 0.5: Minimal reduction in water usage - 1: Sustainable use of water
Rehabilitation of land (and required funding)	Environmental	6.12%	- 0.25: Total rehabilitation of land required - 0.5: Partial rehabilitation of land required - 1: No rehabilitation required
Re-use potential of mine facility	Technical	5.26%	- 0.25: Minimal use of existing infrastructure - 0.5: Some use of existing infrastructure - 1: Maximum use of existing infrastructure
Required machines and equipment availability	Technical	4.70%	- 0: 10% or less of the equipment is available locally - 0.25: 11% - 30% of the equipment is available locally - 0.5: 31% - 60% of the equipment is available locally - 0.75: 61% - 80% of the equipment is sourced locally - 1: 81% - 100% of the equipment is locally sourced
Reskilling requirements (Need for specialist workforce) & skills development	Technical	5.59%	- 0.25: High reskilling requirements - 0.5: Moderate reskilling requirements - 1: Minimal reskilling requirements
Replicability/modularity/ transferability	Technical	3.26%	- 0.1: Very difficult - 0.5: Moderately difficult - 1: Easy

Table 4: Criteria weighting and scoring ranges for coal mines

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Diversity Aspects (Gender, racial equality, disability etc.)	Social	5.06%	- 0: Will result in less inclusivity - 0.3: Will not change status quo - 0.6: May result in more inclusivity - 1: Will result in more inclusivity
Positive changes in livelihood quality (community development)	Social	6.73%	- 0.25: Minimal improvement in livelihood quality - 0.5: Moderate improvement in livelihood quality - 1: Significant improvement in livelihood quality
Tourist attraction	Social	2.68%	-0: No tourist attraction - 0.5: Predominantly local - 0.75: Predominantly international - 1: Tourist attraction (local and international)
Ease of implementation and Timeline to implement the project	Project feasibility	5.29%	- 0.25: Difficult to implement/ execute - 0.5: Manageable (can be executed with support) - 1: Easily implementable
Locality of the project	Project feasibility	6.09%	- 0.25: Minimal use of local resources - 0.5: Some use of local resources - 1: Make use of local resources
Mining Company policy	Social	4.76%	- 0.25: No policy for post mining rehabilitation - 0.5: Moderate policy requirements - 1: Mandated existing clear policies for rehabilitation
JET Mandate	Other	5.53%	- 0.5: Meet some aspects of the JET mandate - 1: Meet JET mandate
Total		100%	

development, data center and industrial park as illustrated in Figure 5. From the responses from stakeholders and subsequent analysis for this set of solutions, conversion to learning and development center scored the highest (0.68), followed by mixed used development (0.59) and data center (0.56) and lastly industrial park.

Experts from group 2 assessed the following set of solutions: conversion to natural gas power plant, conversion to renewable energy cluster, conversion to biomass power generation and the development of green hydrogen hub as illustrated in Figure 6. From the responses from stakeholders and subsequent analysis for this set of solutions, conversion to renewable energy cluster scored the highest (0.66), followed by conversion to biomass power generation (0.60) and natural gas power plant (0.51) the green hydrogen hub (0.49).

Experts from group 3 assessed the following set of solutions: conversion to battery storage facility, RE manufacturing hub, agrivoltaic development and ash greening cement as illustrated in Figure 7. From the responses from stakeholders and subsequent analysis for this set of solutions, agrivoltaic development scored the highest (0.65), followed by conversion to battery storage facility (0.64) and ash greening cement (0.62) then RE manufacturing hub (0.57).

Overall, the top 6 scoring solutions across all groups were conversion to learning and development center, conversion to renewable energy cluster, agrivoltaic development, conversion to battery storage facility, ash greening cement and conversion to biomass power generation.

Coal mine repurposing solutions

Experts from group 1 assessed mixed development, pumped storage hydro, conversion to hotel powered by RE and conversion to data center solutions as illustrated in Figure 8. From the responses from stakeholders and subsequent analysis for this set of solutions, conversion to hotel powered by RE scored the highest (0.63), followed by conversion to pumped storage hydro (0.56) and mixed development (0.53) then conversion to data centre (0.49).

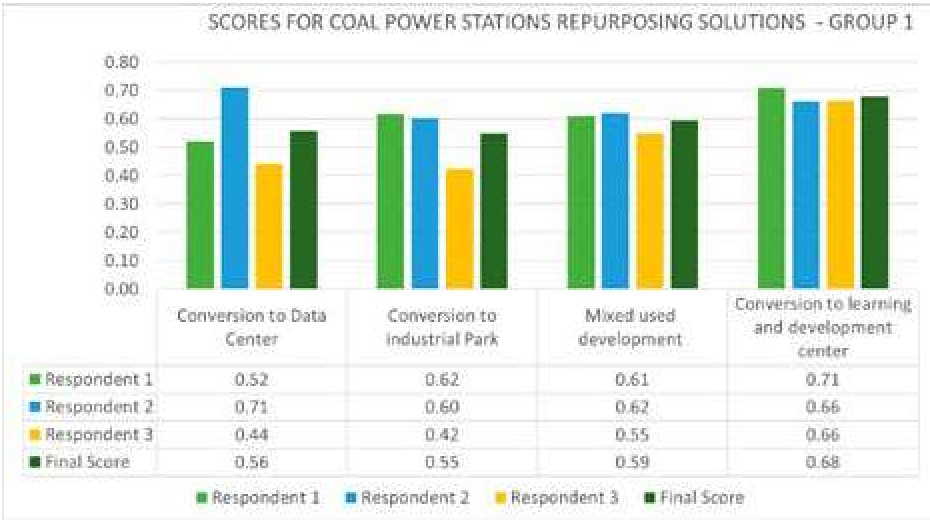


Figure 5: Overall scores for repurposing solutions for coal power stations – Group 1

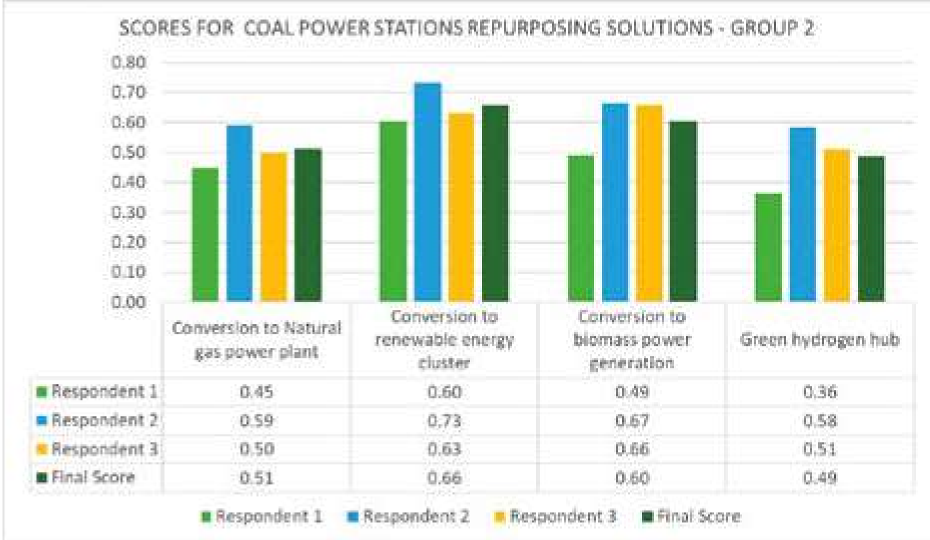
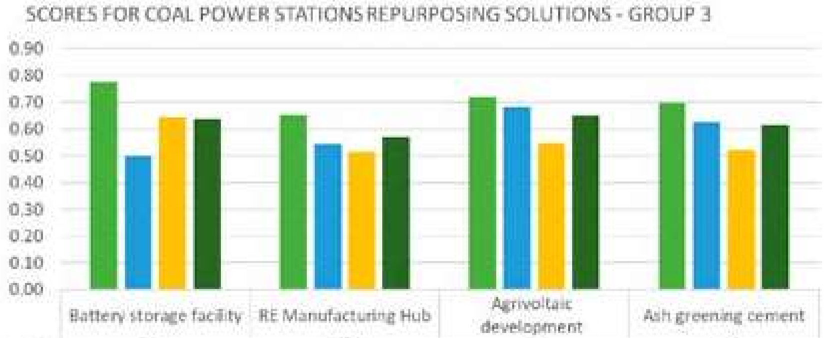


Figure 6: Overall scores of repurposing solutions for coal power stations - Group 2

Experts from group 2 assessed solar PV plant, wind farm facility, solar CSP, ecotourism park and science/art/cultural park solutions as illustrated in Figure 9. From the responses from stakeholders and subsequent analysis for this set of solutions, ecotourism park scored the highest (0.64), followed by conversion to a solar PV plant (0.60), wind farm development and science/art/culture parks having the same score of 0.59 and then solar CSP development (0.52).

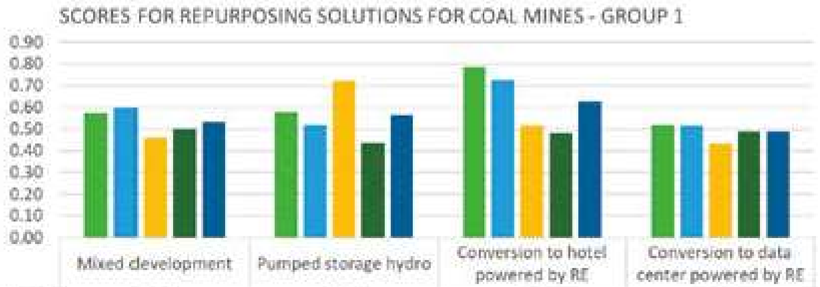
Overall, the top 6 scoring solutions across all groups were conversion to ecotourism park, hotel powered by RE, conversion to solar PV plant, wind farm development and development of science/art/culture parks.



	Battery storage facility	RE Manufacturing Hub	Agrivoltaic development	Ash greening cement
Respondent 1	0.78	0.65	0.72	0.70
Respondent 2	0.50	0.54	0.68	0.63
Respondent 3	0.64	0.52	0.55	0.52
Final Score	0.64	0.57	0.65	0.62

■ Respondent 1 ■ Respondent 2 ■ Respondent 3 ■ Final Score

Figure 7: Overall scores for repurposing solutions for coal power stations - Group 3



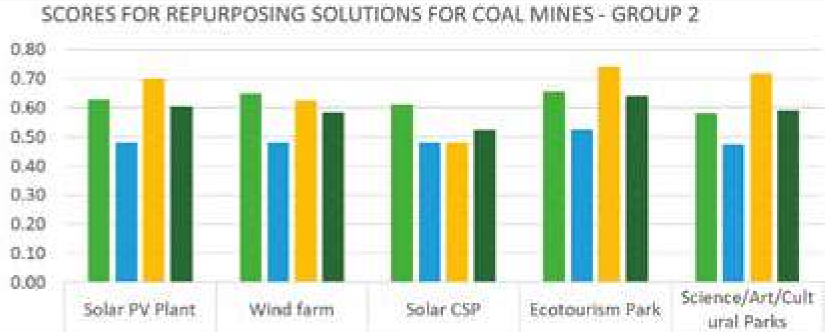
	Mixed development	Pumped storage hydro	Conversion to hotel powered by RE	Conversion to data center powered by RE
Respondent 1	0.57	0.58	0.79	0.52
Respondent 2	0.60	0.52	0.72	0.51
Respondent 3	0.46	0.72	0.52	0.43
Respondent 4	0.50	0.44	0.48	0.49
Final Score	0.53	0.56	0.63	0.49

■ Respondent 1 ■ Respondent 2 ■ Respondent 3 ■ Respondent 4 ■ Final Score

Figure 8: Overall scores for repurposing solutions for coal mines – Group 1

Conclusion

This article provided insight into the dimensions that should be considered when evaluating repurposing options for coal mines and coal power stations for a "just" transition. Technical, environmental, economic, and social imperatives must be considered, and these must be prioritized to incorporate social justice at the level and context of the project. The literature review details some findings from projects that have been or are currently being implemented internationally. The review also identified sector linkages between coal and other sectors in the coal value chain. It is well noted that Mpumalanga will be significantly



	Solar PV Plant	Wind farm	Solar CSP	Ecotourism Park	Science/Art/Cultural Parks
Respondent 1	0.63	0.65	0.61	0.66	0.58
Respondent 2	0.48	0.48	0.48	0.53	0.48
Respondent 3	0.70	0.62	0.48	0.74	0.72
Final Score	0.60	0.59	0.52	0.64	0.59

■ Respondent 1 ■ Respondent 2 ■ Respondent 3 ■ Final Score

Figure 9: Overall scores of repurposing solutions for coal mines - Group 2

impacted as the predominant portion (>80%) of the coal value chain activities are housed in this province.

This research project used findings from the literature review and stakeholder inputs for the development of a multi-criteria decision analysis (MCDA) framework for coal power stations and coal mines. The implementation of the MCDA concluded that the top three solutions for coal power stations were conversion to learning and development center, conversion to renewable energy cluster and agrivoltaic development; and for coal mines conversion to ecotourism park, hotel powered by renewables and conversion to solar PV plant.

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