The Adoption and Application of Technology Innovations in the Coal Processing Mining Industry- A South African Case Study

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Abstract

The significance of adoption and application of technological innovation in coal processing and/or beneficiation plays an important role in coal mining. Organizations that are competitive and gain global recognition. The South African coal mining industry has been moving towards changing the narrative in coal process technologies over the past years. Therefore, it attracts coal mining process technology manufacturers to see opportunities for improved coal circuit designs that are simple, lean structural design, dry, and cost-effective solutions for quality coal processing and production. Hence, identifying the types of innovation solutions available for coal operations to explore the need for less intensive capital cost technologies to use for the production of Eskom coal product quality at 21MJ/kg. The study looks into the impact of technology innovations applicable throughout the coal industry and the effects it has on production, separation efficiency, environment, and health and safety. However, more importantly, the research identifies the need for coal companies with a focus on understanding the need for process development and technological transformation to adopt new technologies. The drive-by technology transformation is reshaping the coal mining operations. The need for systematic capacity building and partnering with digital technology companies will equip the skills for real data analytics. Therefore, companies are recognizing the need for upskilling to operate 4IR and closing the capability gaps and improvement opportunities within the organization. The study findings reveal that SA is transforming its coal mining operation with the opportunities available for technology transformation. However, more needs to be done by established coal mining companies to collaborate with small and junior coal miners to also move towards realizing the benefits of using innovative coal process technologies. The involvement and partnering of the government, miners, and equipment manufacturers are vital for realizing and fostering business, economic growth, and job opportunities. Also, there is a need for mining organizations to upskill and reskill their employees to be empowered to perform their work effectively and improve business operations to be safer, sustainable, and profitable.

Keywords
Coal Mining, Coal Economy, Coal processing, Plant Design, Innovation

1. Introduction
A study by the Mineral Council South African Report (2019), states that the economic value chain for South African mining has a greater reach to unlock a substantial R213 billion of which 20% is in the coal commodity. SA coal mining companies need to put more focus on adopting and implementing new technological innovations in the coal processing types of equipment and the benefits thereof. The study will also evaluate the technical improvements and economic value the adoption and implementation of these new technologies bring to the industry.

In the past few years, the South African coal industry has been put under competitive pressure to find innovative ways to improve coal processing research and development for new technological equipment and methods. Therefore, the study evaluates the multi-case studies on plant process designs and the impact of new technology and new digital transformation will have throughout the beneficiation processes. The focus is placed on establishing the effects of the slow adoption of technological innovation across coal mining operations and the need for collaboration between government and coal producers to drive coal research and development projects.

While considering the impact of a transitional plan to low carbon emission and the effects on job creation, and socio-economic impacts, the effect of health and safety, environmental compliance, data transformation, production improvement, and asset health. This study explores the technological drive to improve the coal beneficiation processes in the South African coal mining industry to investigate and identify how to close the new technology improvement gap.

1.1 Objectives

The research objective of this study is to comprehensively investigate and analyze the patterns, challenges, and implications surrounding the adoption and application of technological innovations within the coal processing mining industry in South Africa. Through a detailed case study approach, this research aims to achieve the following objectives:

- Assessment of Technological Adoption: Examine the extent to which technology innovations have been adopted across different segments of the coal processing mining industry in South Africa. This objective involves identifying the types of technologies adopted, the rate of adoption, and the factors influencing the decision-making process.
- Identification of Drivers and Barriers: Identify and analyze the key drivers that incentivize and facilitate the integration of technology innovations in coal processing mining operations. Simultaneously, explore the barriers, both technical and non-technical, that impede or slow down the adoption process.
- Evaluation of Economic Impact: Evaluate the economic impact of technology adoption on the coal processing mining industry in South Africa. This includes assessing changes in operational efficiency, productivity, cost-effectiveness, and potential improvements in revenue generation.
- Assessment of Environmental and Safety Implications: Investigate how the adoption of technology innovations affects environmental sustainability and safety measures in coal processing mining activities while exploring the potential reduction of environmental footprint, as well as improvements in worker safety and risk mitigation.
- Examination of Skill and Workforce Implications: Examine the implications of technological adoption on the skill requirements and composition of the workforce in the coal processing mining industry.
- Understanding Policy and Regulatory Factors: Analyze the role of policies, regulations, and government initiatives in shaping the adoption of technological innovations within the coal processing mining sector. This involves exploring alignment or conflicts between industry practices and regulatory frameworks.
- Lessons from International Comparisons: Draw insights from similar international case studies to provide a broader perspective on technological adoption trends and best practices in the coal processing mining industry, offering valuable lessons for South Africa.

2. Literature Review

2.1 Why the Coal Mining Industry?

The data from the Statistical Review of World Energy (2020) report, has seen a global decline in coal mining and coal consumption for electricity use in the past 6 years. Kretschmann (2019), shows the slow decline in coal demand by China has peaked since 2013 and the fact that the Norwegian sovereign wealth fund excluded only coal-related companies for ethical reasons and the need to find ways to reduce coal combustion caused by greenhouse gas emissions (Brauers and Oei, 2020).

While coal prices fell by 14% in China at R888,77/t and 34% in Northwest Europe at R1254,29/t. Since, France, Spain, and Germany depleted their coal production in 2018, Germany is currently importing hard coal from South Africa, Colombia, and Russia with the effect on how sustainable development concepts around ecological, economic, and social dimensions extend in declining markets. The Mineral Council of South African report (2019) gives a further blink picture, with coal prices decreasing to 40% in September 2019 with a 27% recovery in December 2019 when compared to other commodities.

2.2 South African Coal Mining Reserves

South African coal mining industry is not immune to the current global trends and suffers immense losses due to reduced coal production and cost of coal with a notion for renewable energy mix with mining companies looking into energy self-sustenance methods. Data from the Statistical Review of World Energy (2020) report, shows that South Africa has about 9,893 million tons of coal reserves that account for 0,92% of the world's coal reserves in 2019. Data from the Mineral Council of South Africa (2019) indicates that over 70% of South Africa's energy requirements (electricity and liquid fuels) are derived from coal. The geographical representation of coal miners in SA is identified to be mostly in the Mpumalanga region as shown in Figure 1.

The SA government's integrated resource plan (IRP) 2018 draft report presents a 2030 plan showing Eskom produced in 2019 from 39,126MW in 2017 difference of up to 6.7 million tons of coal decrease and a 5.279MW electric power. This led to 2,310 job losses and the most affected area in Mpumalanga, thus energy transition projects must be earmarked for the province to mitigate possible untold social, economic, and political instability.

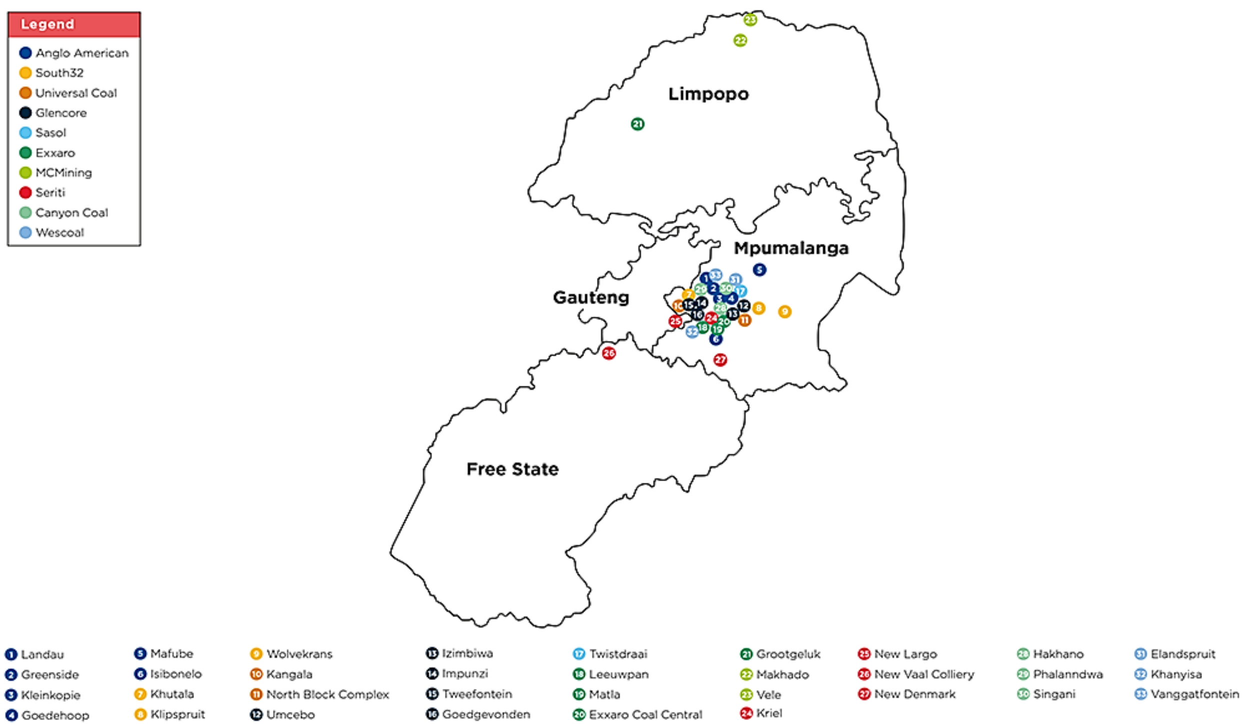

Figure 1: Graphical representation of SA coal mines *(Source: South African Mineral Council, 2018)*

The study conducted by the South African Coal Section, 2016 report indicates that 80% of coal production in South Africa is dominated by the five major coal mining companies, i.e. Anglo American Thermal Coal, Exxaro Resources, Sasol Mining, BHP Billiton Energy Coal SA, and Glencore with the balance from the junior miners. The Mineral Council Facts and Figures 2019 report indicates the total coal sales in 2018 was approximately R146 billions of which 57% or R41.6 billion was exported to India with European Union and Western Asian markets at 15.7% and 14.3% respectively. Furthermore, the South Africa Mineral Council research on the junior and emerging mining sector, 2019 report differentiates the major mining companies from the junior and small-scale miners as outlined in Table 1:

Coal mining is influencing many factors that need to be considered. Chi et al. (2020), According to previous studies, the main influence is economy and technology with objective factors such as water resources and ecological environment, therefore, leading to unlimited coal mining and expansions. The research further indicates that the analysis of the mining scale is based on the production and demand side. When mining for coal, the aim is to have high recovery rates, with the target of about 90% recovery on opencast operations SA Coal Sector Report, (2016). The mining method is used to the coal seams blasted and removed by walking draglines using large scraper baskets of long cranes boom arms. The underlying coal being is out of the pit by heavy-duty trucks and transported to the coal preparation plant for further processing.

Table 1. Definition of Mining Categories *(Source: Mineral and Energy Policy Centre-MEPC, 2019)*

Category	**Activity**	**Operation**	**Gross Asset Value**	**Annual sales value per annum**
Majors	Production, Exploration	Global Markets	>R 1 billion	> 1 billion

Juniors	Contractors, Production, and Exploration Companies	South African Based	>R18 Million but < 1billion	From R30 million to R1 billion
Small Scale (formal)	Producers	Regionally Based	Up to R18 million	Up to R30 million
Small Scale (Informal)	Producers	Locally Based	Up to R150,000	Up to 500,000

2.3 Techno-economic Advancement in Coal Industry

The integration of technological and techno-economic changes in the coal industry has direct effects on coal beneficiation and demand for power resources. These changes will affect the structure of power resource consumption, with a priority orientation on the quality improvement and enhancement of coal competitiveness (Litvinenko, 2016). South Africa's top coal producers have been at the forefront of improving coal processes, the technological paradigm, and considering the general energy market conditions with a focus on coal quality, performance improvement, and expansion spheres, see Figure 2.

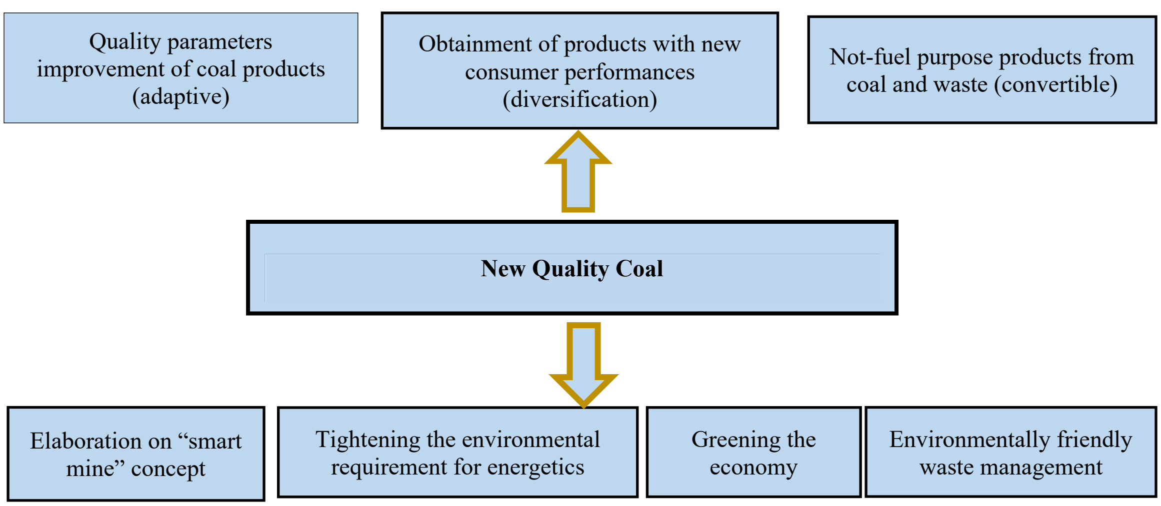

Figure 2: Multipurpose utilization of coal processing technologies *(Source: Litvinenko, 2016)*

The study by Litvinenko (2016), further iterates that up to the year 2030, innovative products and services will cause significant effects on the energy resource extraction, processing, and market therefore these include: Innovative equipment for mineral extraction efficiency improvement in the field of physical, technical, and technological recovery systems and methods of separation. Information systems for mineral extraction efficiency improvement: software and algorithms for the formalization of knowledge extraction, geology survey systems, and supplementary exploration the unconventional energy sources.

Barnwood and Lottermoser's (2020), investigations on the mining industry's general direction and structure for innovative processes and the influencing factors on the implementation of digital technologies are identified. Furthermore, since there's an appraisal of digital trends, implementation, and adoption of digital technologies for specialized mineral processing and beneficiation in the mining industry do not exist. The International mining report (2017), explores the new method called 'in place' or selective mining concept of minimal movement of rocks and processing than moving large rocks to a faraway processing plant. This type of mining and processing reduces surface footprint, tailings generation, high levels of automation, and low-capital-intensive mines. The identification of the three related methods that South African mines recognize include safety risks, declined quality ores, and environmental impact MINTRA, (2018).

2.4 Coal Mining Ecology and Economic Factors

Previous studies and a study according to Chi et al. (2020), identify many influencing factors reasonable for coal mining. However, these studies have mainly focused on the economy and technology, whilst ignoring the factors such as ecological environment and water resources. Since mining is a very crucial part of economies and societies, many emerging economies such as Brazil, South Africa, and Chile rely on the mining sector as part of their mineral rents' contribution to the global GDP Upadhyay (2021).

The global challenges that affect companies such as global competition, environmental awareness issues, and global business warfare are causing a vulnerable situation for companies and economies. This leads companies with multiple business sectors to start rethinking their business design and models to the current challenges Upadhyay (2021). A further study analysis by Chi et al. (2020) indicates that since mining scale is based on both the production and demand side but also the restrictive factors. With the thinking that coal reserves and mining techniques are the basis for mining scale determination. However, mining technology, mining cost, safety, and efficiency play a bigger role and/ or impact on the mining scale. Therefore, it is important to evaluate the mining scale from production with the consideration and influence of the market demand while also taking into account the factors that may cause overcapacities and/or oversupply. Consideration of a rational mining scale requires a realization of a balance between supply and demand to ensure the scientific mining and sustainable development of the coal industry.

2.5 Mining Conditions and Paradigm

One of the main constraints on the coal scale mining is the mining condition. Complex mining, the condition will bring about inevitably difficult mining. Where there is deed mining, and mining disasters such as coal bursts and gas outbursts there is a possible occurrence of coal seam water inrush. Also, with the process of shallow mining ecological problem occurs frequently and the type of mining equipment used is also an important factor Chi et al. (2020). With the rise in demand, the expansion of international trade increased, and there has been an increase in the number of coal-fed engines for railways and electricity generation. When coal demand increased techniques for small-scale mining had to move from only surface extraction and also to deep mining. The move to realize the importance of machines used for coal mining and processing led to the application of both surface extraction and deep shaft mining. The change has significantly changed the condition for production thus improving the mining efficiency. The current shift for coal mining to look into underground gasification and green mining is escalating with some investment in coal being overlooked to new renewables.

2.6 Technological Innovation drivers for natural resources

Sanchez and Hartlieb (2020) define innovation as a new idea, method, design, or product developed with a process of change to create a new idea or solution to create value and meet new requirements from customers and environmental standards. Technological innovation has an immense potential to increase global incomes and the quality of life of many people across the world (Schwab, 2016). Simultaneously, it also has the huge potential to raise concerns about deepening inequality and potential labor market disruptions, thus leading to the growth in joblessness caused by labor-substituting technologies (Brynjolfsson & McAfee, 2014).

Although technological innovation is not new in the mining sector, the current scale of experiencing this type of disruption faced by the manufacturing, telecommunications, and finance sectors has been occurring at a speedy pace and scale (Schwab, 2016). Jacobs (2017) places Rivard (2014) on the move for the mining sector to keep abreast with innovative developments for operational performance excellence to add value to the mining value chain.

The game-changing potential for mining technology dynamics will not only radically transform the mines but will transform the people's lives, work, and machines used by Marr (2018). Moreover, it will revolutionize the establishment between suppliers and miners with the involvement of the government, local communities, and other sectors. The study conducted by Deloitte report (2021) on the future of mining in SA report gives a much broader approach the mining companies may undertake towards innovation. With the drive to not only look at innovation as a single component but consider innovation as a whole system with socioeconomic association to the entire mining co-evolution system, see Figure 3. The report further states that there is no single innovation will solve the problem on its own and there is a need to consider the whole system.

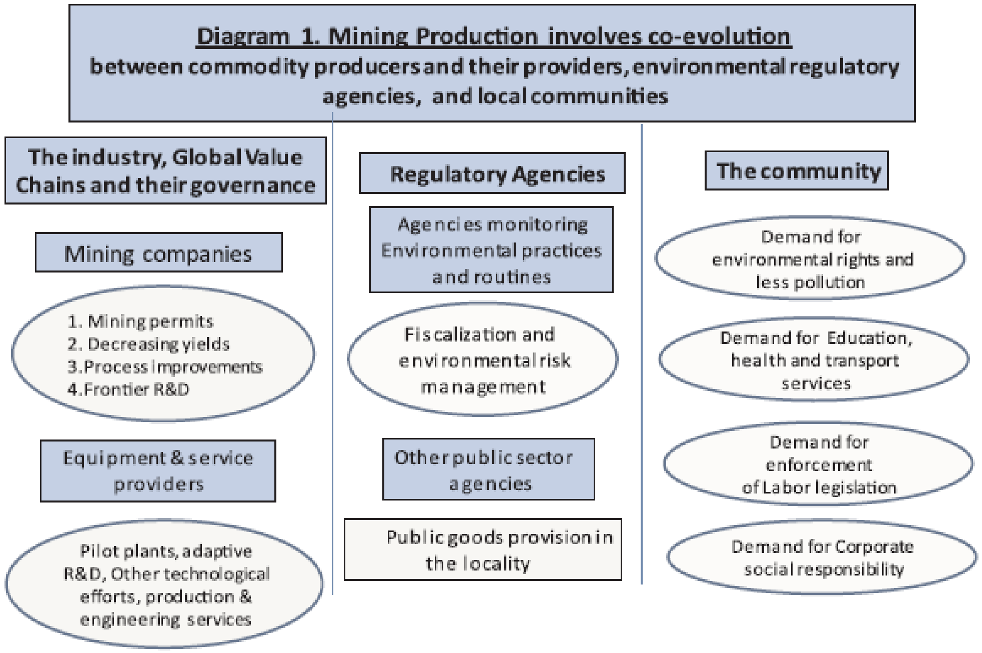

Figure 3. Mining Production co-evolution system (Source: Katz and Pietrobelli (2018)

2.7 Key Technology Trends

The report by the International Institute of Sustainable Development IISD (2019), outlines the technological changes facing the whole mining sector and these include:

- Need for improved health and safety environment
- Need to reduce the operational costs and improve the productivity of assets and efficiency of operation
- Need for reduced costs of asset development as ore grades and upfront capital cost increase.

With changes in innovations happening at a rapid speed, it is, therefore, the variety of fields such as geographic information systems (GIS), Artificial intelligence (AI), sensors, etc. These allow for cost-effective synergistic applications that revolutionize the way the mining industry is done. The IISD (2019) study identifies the mining sector technology developments and adoption as categorized as follows:

- *Enablers of digitization*- technologies that allow the collection of digital data on all aspects of operations. The data is collected in real-time and in huge volumes and is relayed to the operating machinery or central control e.g. drones, smart and /or remote sensors.
- *Technologies trackers* of big data aimed to enhance the mining process and solve complex challenges e.g. Internet of Things (IoT), and blockchain.
- Technologies that optimize operations and processes. These use big data and robotics e.g. data analytics, automation, digital twins, and machine learning.
- Technologies that improve mining processes e.g. renewable power generation and water management technologies.
- Technologies that impact local procurement e.g. manufacturing additives.

2.8 Coal upgrading technologies

South Africa is a water-scarce country, thus the use of wet processing of coal is expensive, and the generation of unwanted environmental impacts of managing slurry dams. The fact that some South African coal requires washing coal because removing impurities is difficult and the only option is to use wet processes to achieve the required qualities. Therefore, coal mines started researching and applying dry coal processing technologies with a special focus on the risk of fine coal dust ignition however with relatively low success Wittmers and Tsedenbaljir (2016).

Rozelle, Leisenring, and Mosser (2018) define coal upgrading as a process of the run of mine coal that is taken through a process before its shipment to the customer. This includes separating and removing stone material present in the run-of-mine coal. The separation process includes physical separation, thermal treatment, and/ or chemical processing. In the US and China coal industry, physical separation is a more dominant method for coal separation techniques which results in the reduction of ash and sulfur content. Mineral-rich coal particles removed through a physical separation may either fall into the coarse refuse or tailings.

The dry and wet processing technologies are widely used for coal separation. However, depending on the coal characteristics some coal beneficiation designs required are compared in this paper, and the pros and cons of the adoption of separation technology. This study looks into the rate of adoption and application of each technology in South Africa's coal mines and the rate of adoption around the world and their benefits towards the additional opportunities for 4IR with the consideration of less environmentally invasive methods in coal mining, Saliman (2018). A representation of the structure for enhancing the efficiency-enhancing coal technologies is shown in Figure 4. This study will look at new technologies of coal beneficiation application in the wet and dry circuit designs and their application analyzing each beneficiation techniques group and determining a comparison of using either wet/water, wet medium based and dry, or a combination of technologies.

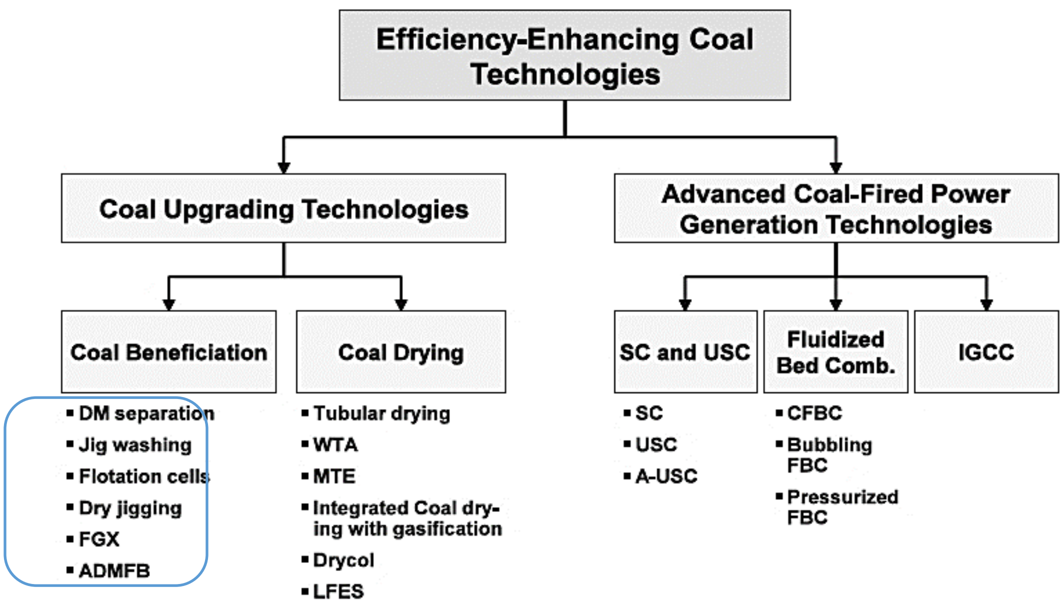

Figure 4. Structural representation of efficiency-enhancing coal technologies (Source: United Nations, ESCAP, (APEF, 2013)

3. Method

The current study adopts the interpretive research paradigm as its main objective is to qualitatively interpret the data obtained from the peer review and /or secondary sources regarding the coal companies that have adopted innovations and technologies in the South African coal mining industry. The primary reason behind choosing the interpretivist research paradigm as opposed to the positivist research paradigm is that, unlike the latter which finds meaning from numerical data, the former enables multiple interpretations of the phenomenon being studied as it interprets the theoretical perspectives of the qualitative data subjectively (Alharahsheh & Pius, 2020).

This research focuses on the underlying area of investigation as acquired from different case studies. It brings to the forefront the meaning that different case studies assigned to the phenomenon of technological adoption and innovation in coal mining companies (Alharahsheh & Pius, 2020). The different patterns, themes, and trends emerging from the study and the real-life situations from the interpretation of the case studies. Interpretivism is therefore the most appropriate research paradigm to be used in this qualitative research as it examines the real-life occurrences of the phenomena through case studies (Irshaidat, 2019). The methodology for this study is highlighted or shown in Figure 5 as described below.

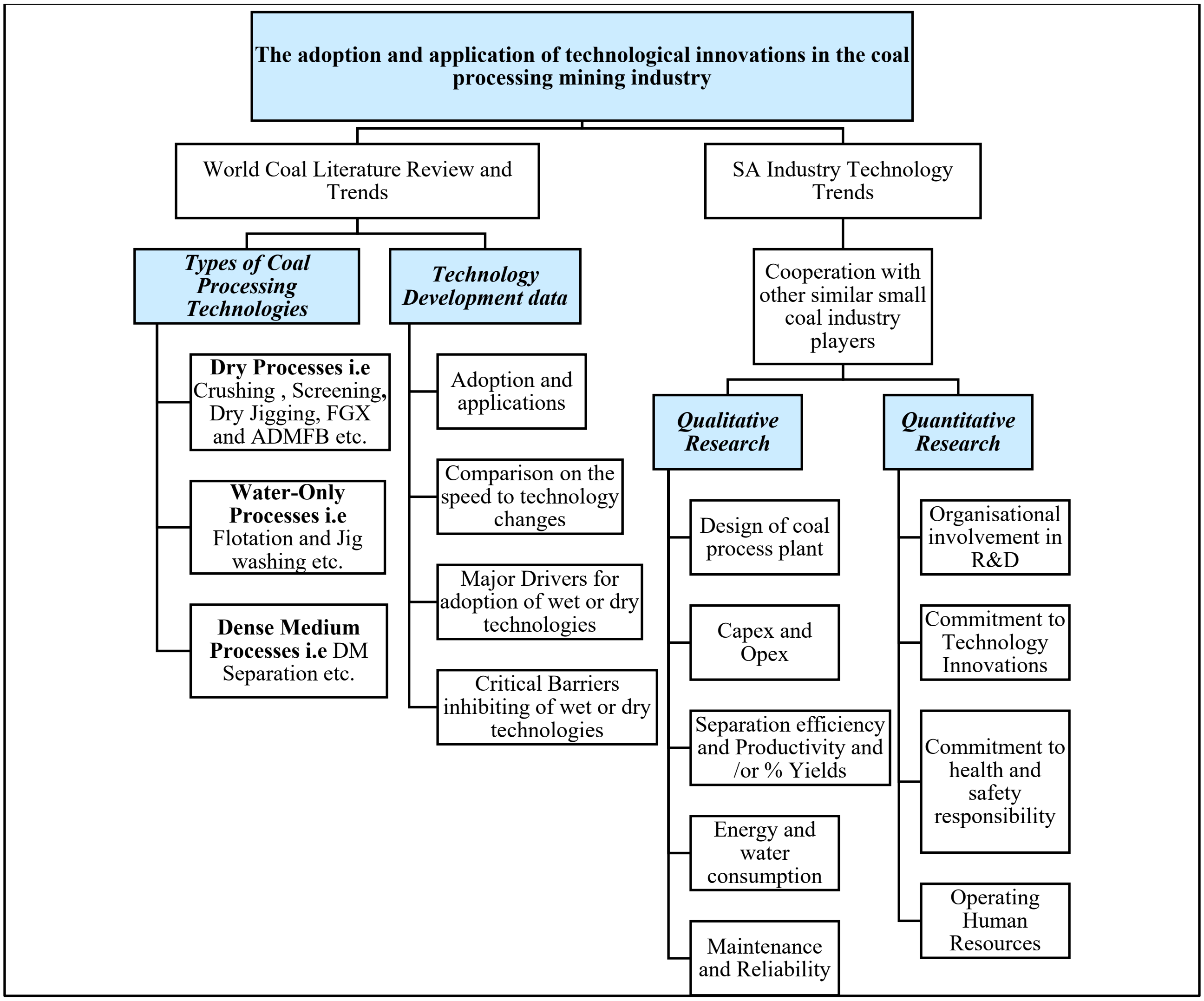

Figure 5. Research Framework

3. Data Collection

The data source is generated using the Microsoft Excel program for reporting all the components as addressed through comparison with the technical understanding and applied solutions for engineering equipment selections. The main focus is on the following components if and when available:

- Capex and Opex
- Separation efficiency and quality
- Productivity and /or % Yields
- Energy and water consumption
- Maintenance and Reliability
- Design of coal process plant
- Consideration of new 4IR technologies for both beneficiation technologies.

Data process from different peer-reviewed studies presents the determination and representation of similar work done and the data for each technology application as samples comparison in China, the USA, and South Africa. The information is therefore interpreted as analysis to make technical and economic judgments for the technological application in the coal industry in terms of the following:

- The need to understand the benefits of the two technologies and applications
- Their applicable process reliability and performance scale.

- Technical and economic viability
- Impact on environment i.e. waste, and slimes dam management

The analysis of data aims to give more technology advantages in information sharing and benefits to the independence and assessments for differences from large to small coal miners and the drive to the technological innovation equipment and openness to changes to less complex and lean plant

5. Results and Discussion

South Africa's coal run-of-mine (ROM) production has declined by close to 5% percent to 318 Mt in 2020. This is owing to the impact of the COVID-19 pandemic since mines were not in full production and some were put on care and maintenance. Mines were led to operate with reduced staff due to COVID-19 regulations of social distancing and control of the spread of the virus. Opencast mining remains the leading method for coal production, accounting for up to 69.65% which is a decrease from 70.13% in 2019 of the total ROM production. South Africa saw a 6.45% decrease in saleable coal production to 248.1 Mt in 2020 from 265.1 Mt in 2019, owing mainly to the aftermath of the COVID-19 pandemic lockdowns (Table 2).

Table 2. World Coal Reserves, Production and Exports, BP Statistical Review of World Energy (June 2021)

COUNTRY	RESERVES			PRODUCTION			EXPORTS		
	Mt	%	Rank	Mt	%	Rank	Mt	%	Rank
South Africa*	66699	6,21	6	248,1	3,1	7	73,2	5,701	4
China	143197	13,33	4	3902	50,4	1	-	-	-
India	111052	10,34	5	756,5	9,8	2	-	-	-
Russia	162166	15,1	2	399,8	5,2	6	212	16,52	3
USA	248941	23,18	1	484,7	6,3	4	63	4,91	5

Data from Table 3, illustrates the highest and lowest SA coal prices experienced in the years 2003 to August 2021. The data was extracted within the 3year phase and reconstituted to formulate the statistical range therefore determining the highest and minimum coal prices per coal, See Table 3 below:

Table 3. Statistical SA Coal Price Data Review (DMRE report, 2022)

STATISTICAL RANGE	YEARS					
	JUL-03 TO JUL-06	AUG-06 TO AUG-09	SEP-09 TO SEP-12	OCT-12 TO OCT-15	NOV-15 TO NOV-18	DEC-18 TO AUG-21
Average ($/t)	48,4	81,5	98,2	72,2	81,1	79,2
Median ($/t)	48,5	64,7	98,5	73,8	85,4	76,3
Highest ($/t)	70,1	162,9	125,0	89,4	106,0	138,5
Min ($/t)	30,3	47,9	60,3	50,1	49,7	52,9

It can be seen that there are incidental price increases in each year range where there was a significant coal price increase, which was one of the highest coal prices, and then it was further reduced to median coal price. The observation on coal price doubled from $48,5/t during the years (Jul-03 to Jul-06) to (Sep-09 to Sep-12) and increased to $73,8. The SA coal price was at its highest at$162,9/t in Aug-09 and $138.5/t in Aug-21 during Covid-19 which escalated due to coal export market demand. The research data studies compared the performance of FGX and DMS separation research in South Africa by De Korte between the years (2010-2015) in Table 4, performed by CSIR in conjunction with Exxaro and CoalTech2020 using both the small 10t/hr and large 350t/hr FGX unit. The tests performed indicate a separation of coal to discard when looking at the calorific values of the raw mined coal within the range of 14.6MJ/kg and 16.18MJ/kg. When comparing the FGX and DMS studies, one can extract from the yields results that the DMS plant results are higher than that of the FGX with yields ranging up to 74% while the FGX received 61.74%yield.

Table 4. Multi-case studies on FGX Dry and DMS Separation performed in SA (de Korte (2013)

Case Studies	SA Projects			
Coal Particle Size (mm)	**(50X6)**	**(50X8)**	**(50X6)**	
Unit test	**FGX @ 10t/h**	**DMS @ 135t/h**	**FGX @ 350t/h**	**DMS @ 350t/h**
Raw coal %Ash content	48,9	48,9	40,4	40,4
Raw coal CV (MJ/kg)	14,6	14,6	16,18	16,18
Product yield %	61,74	74,21	55	71
Product CV (MJ/kg)	19,83	23,2	20,12	21
Product %Ash content	35,1	30,01	30,65	28,56
Total moisture of the product	6,88	8,82	7,5	10,4
Discard %Ash content	-	-	52,3	69,5
Yield to Discard	38,26	25,79	45	29
D50	-	1,644	1,8	1,91
Ep	-	0,017	0,252	0,023

Further, a cost comparative financial standing for adoption and application implementation of both technologies from the data collection model when running a 350t/hr with an increase of 30% units cost from 2013 to 2021 is extracted from (de Korte (2013) shown in **Table 5.** The cost for material handling from sample preparation (crushing and screening) is up to R15 mil in 2013 which could be up to R19.5Mil CAPEX at R417 835.6 per annum for operating cost inclusive with the complete processing plant.

Table 5. Cost comparison of FGX Dry and DMS Separation in SA (de Korte (2013)

350t/hr		**FGX**	**DMS**
2013	**Capex (R)**	17 500 000	70 000 000
	Opex (R)	321 412	344 722
2021	**Capex (R)**	22 750 000	91 000 000
	Opex (R)	417 835,6	448 138,6

Similar to the SA research, India also embarked on comparing FGX to the DMS plant tests. The data results on the coking coal tested indicate an increase in CV values when comparing the raw coal to product CV values from 13.57MJ/kg to 21.3MJ/kg for FGX and 22.15MJ/kg for DMS at the particle size 50X6mm raw coal. The research conducted in India on both technologies indicates the coal test-work product yields to be 65.34% and 66.77% at a cut density of 1.8 and 1.75 respectively, see **Table 6** below.

Table 6. Multi-case studies on FGX Dry and DMS Separation performance in India

Case Studies	**India**	
Coal Particle Size (mm)	**(50X6)**	
Unit test	**FGX (10t/hr)**	**DMS**
Raw coal %Ash content	50,6	50,6
Raw coal CV (MJ/kg)	13,57-15,45	13,57-15,46
Product yield %	65,34	66,77
Product CV (MJ/kg)	20,30-21,31	22,15
Product %Ash content	32-36,56	35,49
Yield to Discard	34,66	33,23

D50	1,8-2,2	1,75

The test-work results in **Table 7** indicate the research work on the varying particle size was not compared with DMS but was more focused on testing the effectiveness of the FGX dry technology. One can see from the results the discard %ash content that the FGX separation of coal to discard was high especially when treating medium-coarse coal size (20x0,25X0 and 25X6) mm fractions. The coal to discard upgrading is effective with product CV values reaching up to 27.99 MJ/kg.

Table 7. Multi-case studies on Dry FGX Separation tests performed in Poland (Blaschke (2016)

Case Studies	**Poland**						
Coal Particle Size (mm)	**20X0**		**(20X6)**	**(20X8)**	**50X25**	**(25X6)**	**(25X0)**
Unit test	**FGX (10t/hr)**						
Raw coal %Ash content	31,7	30,17	10,6	35,9	38,4	28,15	18,4
Raw coal CV (MJ/kg)	15,412	17,59	21,49	16,29	19,26	22,76	25,52
Product yield %	77	76	89,2	81,4	49,2	83	77
Product CV (MJ/kg)	21,56	22,38	23,1	20,9	25,08	25,85	27,99
Product %Ash content	21,2	24,8	5,5	28	19,9	19,8	12,2
Total moisture of the product	9.0	5.0	17,8	6,9	2,6	4,8	7.0
Discard %Ash content	80,5	85,7	19,7	86,1	65	82,2	75,6
Yield to Discard	18	7.0	10,8	14.0	37,1	10,8	22.1

5.2 South African Companies adopting Coal Processing Technology applied

The DMRE 2022 report, shows the export coal price data extracted from www.globalcoal.com in US dollars per ton from the years July 2003 to August 2021. This data was tabulated, and a graphical representation was constructed as shown in **Figure 6**.

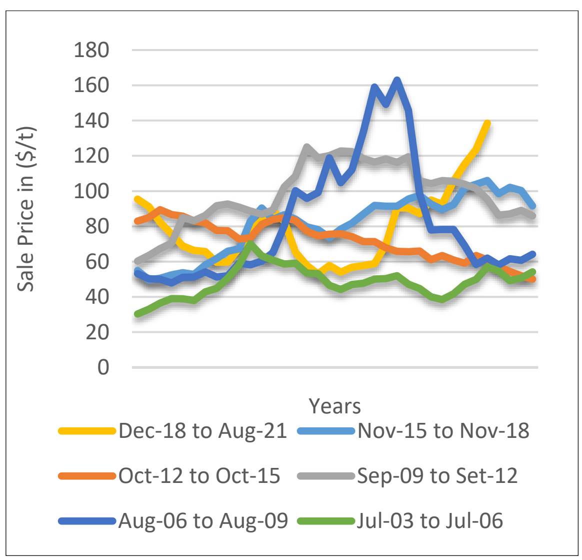

Figure 6. Graphical representation of Historical South Africa Coal Export Price (Source: DMRE Report (2022).

South Africa's coal sales distribution between local and export is represented in **Figures 7&8** and shows significantly higher use of coal locally when compared to export sales. This indicates SA is a country that is reliant on and uses most of the coal production for electricity generation. To determine the % sales growth throughout SA, a formula was used to calculate as follows:

$$\% \text{ Sales from 1992 to 2020} = \frac{\text{Mass (2020)} - \text{Mass (1992)}}{\text{Mass (2020)}}$$

The data results indicate a significant increase in coal sales when looking at both the local and export sales from the years 1992 to 2020. With increases in sales of up to 28% in local sales, 32.1% in export sales, and a total sale of up to 26% in coal sales throughout South Africa. However, there is a clear decrease trajectory in coal sales in 2020**.**

The current status of South Africa's top six major coal producers is as follows, Exxaro, Sasol Mining, Anglo American, South32, Seriti Coal, and Glencore are amongst the top coal producers that have adopted and implemented the new technological innovations. The top 5 technologies are as follows:

- Advanced process control
- Clean Technology
- Water management technology
- Use of renewable energies

While many other technologies are implemented in various coal mining spaces. The drive for efficient, waterless, and lean processing is a new way to produce the final coal product cost-effectively, with minimum resources and less operational cost (Table 8).

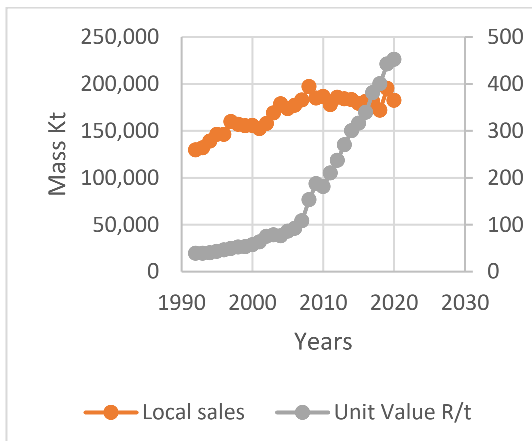

Figure 7. South Africa's Local coal sales distribution (Source: DMRE report (2022)

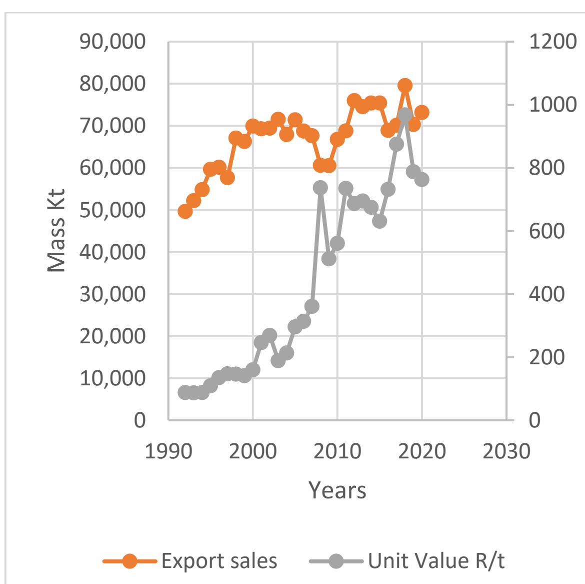

Figure 8. South Africa's Export coal sales distribution (Source: DMRE report (2022)

Table 8. Adopted technologies in the SA Case study

Types of technological Innovation	Coal Mining Categories in South Africa		
	Major	**Juniors**	**Small Scale**
Water Saving Technology	X	X	-
Tailings management and recovery	X	X	X
Smart Energy System	X	X	-
Electric Mining Equipment	X	X	-
Biological Technologies	X	-	-
Innovative Bio-mining and Bio-mineralization Technologies	X	-	-
3D and 4D Printing	X	-	-
Sensor Technology	X	X	-
Connected wearable	X	X	-
Drones	X	X	-
GPS	X	X	-

6. Conclusion

The overall data gathered from DMRE and McKenzie (report 2020), indicate the need for technology adoption throughout the full coal value chain for mining companies around the world and also in SA coal mining. However, due to the extensive use of water and medium costs, this technology is more effective for coal separation with near-dense material. The major impact of wet DMS technology is its significance to operations flowlines and management of slime dams, operations maintenance, and high management costs.

The costs for putting up the dry FGX and DMS separation plant in SA have shown a significant difference in the capital cost as indicated in Table 7. The evaluation criteria of technology, innovations is the performance of the equipment to reach a criterion for quality and price. This research performed in SA coal has shown innovation adoption for using dry FGX separation technology for the production of Eskom products as an alternative to the wet DMS technology for producing Eskom products (CV values) of up to 21 MJ/kg

The effect of selective mining and automation has a huge impact on job displacement thus South Africa needs to focus on creating new opportunities in the upstream sector, especially in the production of equipment used in mining operations such as truck fleets, excavators, crushers, and conveyor belts, and the chemical solutions used for extraction leaching processes. The emerging digital technologies in automated material characterization and online analysis can be built into the equipment and pre-programmed for specific mines in South Africa.

The implementation of new technologies studies and investigation in the South African context is the much-needed answer to competitiveness improvement, coal quality, and the required expansion of coalfield usage and reduction of environmental pollution and CO_2 emissions. The move towards a low-carbon growth trajectory and the realization of the potential of the Fourth Industrial Revolution enable systems of production and consumption to generate a clearer picture of how exactly the mining industry and the technological advancement, performance improvement of separate stages of coal processes and liquefaction products processing that significantly increases method efficiency is carried out in most countries

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