MOVING TOWARDS A CARBON PRICING STRATEGY TO LEVERAGE THE DECARBONISATION OF MINING OPERATIONS IN SOUTH AFRICA

by

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CERTIFICATE OF ORIGINALITY

I hereby certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify and declare that this thesis and the work reported herein was composed by and originated entirely from me. Information delivered from the published and unpublished work of others has been acknowledged in the text and references are given in the list of references.

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ABSTRACT

The aim of this study was to develop a carbon pricing strategy to accelerate decarbonisation in the mining sector. A qualitative study was conducted to draw policy lessons from comparative analysis of the carbon tax policy regimes of the European Union, Switzerland, Canada and the United Kingdom (UK) in order to establish the carbon pricing strategies that will induce South African miners to invest in renewable energy technologies. A review of South Africa’s carbon tax regime highlights that the policy shortcomings may be attributable to low carbon prices, excessive free emission allowances and continued subsidy support of fossil fuels. The comparative benchmarking exercise indicates that significant decarbonisation occurs when there is a cap of emissions for energy-intensive industries, followed by an emissions trade or a penalty system. Furthermore, the carbon price needs to exceed cost of abatement so as to encourage investment in decarbonisation measures. A net present value simulation determines that a carbon price of ZAR 668.62 per tonne of CO_2 would need to be levied in order to incentivise mining entities to invest in solar PV. The current study advances knowledge on carbon pricing within the theoretical underpinnings of Pigou theory of corrective taxes. The study recommends that a fixed CO_2 emissions cap that declines yearly ought to be integrated into the South African carbon pricing regime. The carbon emission cap should further be supported by higher carbon prices for emissions exceeding the threshold so as to ensure that the national emission reduction pledges are successfully achieved.

TSHOBOKANYO

Maikemisetso a thutopatlisiso eno e ne e le go tlhama togamaano ya peotlhotlhwa ya khabone go itlhaganedisa phokotso ya selekano se se ntshediwang mo tikologong sa khabonedaeokosaete mo lephateng la meepo. Go dirilwe thutopatlisiso e e tlhalosang maitemogelo le dikakanyo tsa batsayakarolo go bona thuto mo pholising, go tswa mo tshekatshekong e e neng e bapisa mekgwatsamaiso ya pholisi ya lekgetho la khabone ya European Union, Switzerland, Canada le United Kingdom (UK) ka maikaelelo a go tlhoma ditogamaano tsa peotlhotlhwa ya khabone tse di tlaa tlhotlheletsang baepi ba Aforika Borwa go beeletsa mo dithekenolojing tsa metswedi e e ka ntšhwafadiwang ya maatla. Tshekatsheko ya mokgwatsamaiso wa lekgetho la khabone wa Aforika Borwa e gatelela ntlha ya gore ditlhaelo tsa pholisi di ka tswa di bakilwe ke ditlhotlhwa tse di kwa tlase tsa khabone, ditetlelelo tse di sa duelelweng tsa selekano se se feteletseng sa khabone e e ntshiwang le tshegetso e e tsweletseng ya ketleetso ya metswedi e e ka se kgoneng go ntšhwafadiwa ya maatla. Tiragatso ya go lekanyetsa ka go bapisa e kaya gore go nna le phokotso e e bonalang ya selekano se se ntshiwang sa khabonedaeokosaete fa go na le tekanyetso ya selekano se se ka ntshiwang mo madirelong a a dirisang maatla a mantsi thata, mme e latelwa ke thotloetso ya go fokotsa selekano sa dikgotledi kgotsa tiriso ya kotlhao. Mo godimo ga moo, tlhotlhwa ya khabone e tlhoka go feta tlhotlhwa ya phokotso go rotloetsa peeletso mo mekgwatirisong ya go fokotsa selekano se se ntshiwang sa khabonedaeokosaete. Phopholetso ya bolengpalo jwa lotseno le dipoelo tsa ga jaana e tlhomamisa gore tlhotlhwa ya khabone ya ZAR 668.62 ka tono nngwe le nngwe ya CO_2 e tlaa tlhoka go duedisiwa lekgetho go rotloetsa ditheo tsa meepo go beeletsa mo tirisong ya sediriswa se se fetolelang lesedi la letsatsi ka tlhamalalo go nna motlakase. Thutopatlisiso ya ga jaana e bona kitso ka ga peotlhotlhwa ya khabone mo metheong e e tshegetsang tiori ya ga Pigou ya makgethotshiamiso. Thutopatlisiso e atlanegisa gore tekanyetso ya selekano se se tlhomameng sa CO_2 se se welang tlase ngwaga le ngwaga e tshwanetse go tsenyelediwa mo mokgwatsamaisong wa Aforika Borwa wa peotlhotlhwa ya khabone. Tekanyetso ya selekano sa khabonedaeokosaete e e ntshiwang e tshwanetse go tshegediwa go ya pele ka ditlhotlhwa tse di kwa godingwana tsa dilekano tsa khabone tse di ntshiwang mme di feta seelo se se beilweng go netefatsa gore go fitlhelelwa ka katlego ditsholofetso tsa bosetšhaba tsa phokotso ya selekano se se ntshiwang.

KAKARETŠO

Maikemišetšo a nyakišišo ye e be e le go godiša mokgwa wa tekanyo ya khapone go potlakiša phokotšo goba phedišo ya khapontaoksaete mo lekaleng la meepo. Go šomišitšwe mokgwa wa nyakišišo wa boleng go hlaola dithutwana tša pholisi go tloga go tshekatsheko ya go bapetša ya molao wa pholisi ya motšhelo wa khapone wa Kopano ya Yuropa, Switzerland, Canada le United Kingdom (UK) go utolla mekgwa ya tekanyo ya khapone yeo e tla huetšago baepi ba Afrika Borwa go beeletša go ditheknolotši tša mohlagase wa go šomiša moya goba letšatši. Tshekatsheko ya molao wa motšhelo wa khapone wa Afrika Borwa o tšweletša gore mafokodi a pholisi a ka ba a hlotšwe ke ditheko tša khapone ya fase, ditumelelo tša tokollo ya go lokologa ye kgolo le go tšwela pele ka thekgo ya ditšhelete ya go thekga dibešwa tša malahla le gase. Mošomo wo wa go bapetša katlego o laetša gore phokotšo goba phedišo ya khapontaoksaete ye bohlokwa e direga ge go na le kaonafalo ya tokollo ya diintasteri tša mohlagase wa go tsenelela, wa latelwa ke phetogo ya ditokollo goba lenaneo la dikotlo. Se sengwe gape, theko ya khapone e hloka go feta tefo ye e fokoditšwego gore go hlohleletšwe peeletšo go ditekanyo tša phokotšo goba phedišo ya khapontaoksaete. Mohlwaela wa tšhelete o laodiša gore theko ya khapone ya R668.62 ka tone ya CO_2 e tla swanela go lefelwa motšhelo go hlohleletša makala a meepo go beeletša go PV ya sola. Nyakišišo ya gonabjale e godiša tsebo ka ga theko ya khapone ka go motheo wa kakaretšo ya teori ya Pigou ya metšhelo ya mohola. Nyakišišo e šišinya gore ditokollo tša go se fetoge tša CO_2 tšeo di fokotšegago ngwaga le ngwaga di swanelwa go kopanywa ka go molao wa theko ya khapone wa Afrika Borwa. Tokollo ya khapone e swanetšwe go thekgwa gape ke tefo ya godimo ya khapone ya ditokollo tša go feta mathomong go kgonthiša gore ditshepišo tša phokotšego ya tokollo ya bosetšhaba di fihlelelwa ka katlego.

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ACRONYMS AND ABBREVIATIONS

Carbon Tax Act	Carbon Tax Act (15 of 2019)
CBA	Cost-benefit analysis
CCS	Carbon capture and storage
CO_2	Carbon dioxide
CPI	Consumer Price Index
CPP	Carbon pricing policies
CSP	Concentrated solar power
DCF	Discounted cash flow
DNI	Direct normal irradiation
EU ETS	European Union Emissions Trading System
GBP	British pound sterling
GHG	Anthropogenic Greenhouse Gas
EAA	Equivalent annual annuity
ETS	Emissions trading system
EUR	Euro
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
Income Tax Act	Income Tax Act (58 of 1962)
KW	Kilowatt
KWH	Kilowatt Hour
NPV	Net present value
MPRDA	Mineral and Petroleum Resources Development Act
MW	Megawatt
PV	Photovoltaics
SCC	Social cost of carbon
SACCCS	South African Centre for Carbon Capture and Storage
UK	United Kingdom
UNCCC	United Nations Climate Change Conference
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
ZAR	South African Rand

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Currently climate change has been shown to be an imminent global environmental challenge (Ginanjar & Mubarrok 2020:41; Mikhaylov, Moiseev, Aleshin & Burkhardt 2020:2897; South Africa 2004:1). An increase in anthropogenic greenhouse gas (GHG)[1] emissions from industrialisation and the burning of fossil fuels[2] are attributable to the changes in the Earth's climate (IPCC 2014:235). Globally, increases in the occurrence and gravity of extreme weather events, changing ecosystems and desert land, ocean acidification, and loss of living organisms are all linked to the rising of the earth's temperatures (IPCC 2014:13-20). In this respect, South Africa is currently facing critical climate change challenges; with an annual average temperature increasing at a minimum of 1.5 times in comparison to the global average of 0.65°C between 2004 and 2014 (Ziervogel, New, Archer van Garderen, Midgley, Taylor, Hamann, Stuart-Hill, Myers & Warburtonne 2014:1). Climate change also poses a significant risk to mining operations, causing disruptions and damaging infrastructure (Odell, Bebbingtonne & Frey 2017:205; Lim-Camacho, Jeanneret & Hodgkinson 2019:2).

The energy industry is the primary source of GHG emissions, accounting for 80% of the total GHG emitted in South Africa (South Africa 2020:12). The industry produces electricity and liquid fuels from coal and crude oil, with 90% of the total electricity derived from coal (South Africa 2020:9,12). Electricity generation accounts for 42% of the total GHG emitted in South Africa (South Africa 2020:12-13; Eskom 2021). The mining sector is energy-intensive, predominantly in the case of underground mining; where the ore production, ore transportation, and operation of safety technologies all require electricity (Immink, Louw & Brent 2018:14-23). The South African mining sector consumed approximately 14%[3] of

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[1] Johnson, Franzluebbers, Weyers, and Reicosky (2007:107) define GHG as radiative gasses in the atmosphere making warmer than it otherwise would be.
[2] Fossil fuel is material containing hydrocarbon from the Earth's surface and includes coal, petroleum, and natural gases.
[3] This is based on the gigawatt hours of electricity of 28 030 over the gross gigawatt hours of electricity sold of 205 688 for Eskom's 2022financial year.

energy generated by Eskom[4] in the 2022 financial year (Aliyu, Modu & Tan 2018:2507; Eskom 2022:152). Based on these estimates it can be extrapolated that the mining sector indirectly accounts for 5.15%[5] of national GHG emissions. South Africa's mining sector is the fifth largest in the world, based on gross domestic product (GDP) value, contributing 8.1% to GDP in 2019 (Minerals Council South Africa 2019:9). The economic multiplier effects of the mining sector are evident from its contribution of 4.68% towards employment, as reported in December 2020 (Statistics South Africa 2020). Additionally, the mining sector supplies coal for electricity generation (South Africa 2020:9). Sonter et al, (2020:1) recommend the use of renewable energy technologies in order to reduce carbon dioxide (CO_2) emissions. Renewable energy infrastructure will require substantial minerals inputs, resulting in increased demand for mining of minerals (Sonter et al 2020:1, World Bank 2017a:1). The significant CO_2 emission contribution of the mining industry warrants a transition to low-carbon sustainable mining practices.

The United Nations Framework Convention on Climate Change (UNFCCC) (2000:76-78) reports that one such strategy to reduce CO_2 emission in the coal mining sector, involves the removal or capture of CO_2 emissions before they reach the environment using carbon capture, utilisation and storage technology (CCUS). The World Bank (2017a:6) supports the suggested climate change mitigation strategy. Immink et al (2018:15) adds that aging mines may face infrastructure challenges to support climate change mitigating technologies. Mining entities would need a significant investment in administering these decarbonising technologies and associated infrastructure (Hodgkinson & Smith 2018:1).

Failure to invest in climate change mitigating technologies might result in global median temperatures increasing by a minimum of 1.5°C above pre-industrial levels between 2030 to 2052 (South Africa 2020:1). Hoegh-Guldberg et al (2019:2-3) state that, with a 1.5°C temperature increase above that of pre-industrial levels, the heat intensity will increase the rate of occurrence of both droughts and heatwaves in South Africa. Hoegh-Guldberg et al (2019:3) add that, at a 2°C temperature increase above pre-industrial levels, hot and dry

[4] Eskom is the South African electricity public utility entity that is responsible for the supply of approximately 90% of South African's energy supply.

[5] This percentage is derived as follows 5.15% = 13.62% x 90% x 42%. The consumption level of 90% of coal electricity resulting in 42% of the Greenhouse gas emissions.

conditions magnify in intensity and duration. The detrimental effects of climate change could potentially jeopardise South Africa’s socio-economic development (South Africa 2020:1).

Climate change is not a country-specific problem, and efforts to curb the negative environmental consequences of climate change can only be achieved as a collective shared goal (Parties to United Convention 2015:2). The Intergovernmental Panel on Climate Change (IPCC) established a global collective in November 1988, which led to the creation of the UNFCCC in 1992. The UNFCCC was then formed to evaluate the impact of climate change and to find ways to mitigate the GHG emissions in the atmosphere to a level that would lessen adverse weather conditions (South Africa 2004:1-2).

In 1997, the South African government endorsed the UNFCCC, and became a member of the Kyoto Protocol in 2002 (South Africa 2004:1-2). The Kyoto Protocol was formed to strengthen the climate change response, committing members to tangible emission targets (South Africa 2020:2). The Kyoto Protocol aimed to reduce CO_2 emissions from industrialized nations to 5% below their 1990 levels by the year 2012 (McKitrick 2016:3). This target was inadequate to mitigate climate change and therefore required the UNFCCC to engage in regular climate change conferences to advance the global responses to climate change (South Africa 2020:1-2).

At the United Nations Climate Change Conference held in Paris 2015, there was unanimous consensus from 197 participating countries that there would be a need to limit the global temperature rise to 2°C above levels prior to the industrial revolution (Parties to United Convention 2015:2). Participating countries submitted Intended Nationally Determined Contributions (INDC), detailing their intentions to address climate change and efforts to contain the temperature increase to 2°C above pre-industrial revolution levels (Rogelj, Den Elzen, Höhne, Fransen, Fekete, Winkler, Schaeffer, Sha, Riahi & Meinshausen 2016:631). The INDC were either specific emissions-reduction measures, or a commitment to reduce the total country emissions to a specified level (Levin, Rich, Bonduki, Comstock, Tirpak, Mcgray, Noble, Mogelgaard & Waskow 2015:8). South Africa opted for the latter option, having committed to reducing its own total GHG emissions by 34% below the baseline by 2020, and by another 42% by the year 2025 (Davis Tax Committee 2015:4).

Carbon dioxide emission reduction requires a multifaceted approach and globally, a carbon-pricing policies (CPPs) are integral instruments in promoting a reduction in CO_2 emissions (Steinebach, Fernández-i-Marín & Aschenbrenner 2021:277). CPPs consist of a carbon tax or emissions trading system (ETS) (South Africa 2010:27), the former places a price on pollutant emissions. ETS provides a threshold to allowable emissions with an option to purchase additional CO_2 emission allowances or set offs approved carbon-reducing scheme credits on CO_2 emissions that exceed the threshold (South Africa 2010:27). Globally, carbon tax is the preferred instrument, due to its ease of implementation and monitoring, when compared to a CO_2 emissions capping system (Green 2021:1; McKitrick 2016:1; South Africa 2010:58). There has been much criticism, however, over the current carbon tax rates. (Baranzini, Van den Bergh, Carattini, Howarth, Padilla & Roca 2017:12; Boyce 2018:52; Rosenbloom, Markard, Geels & Fuenfschilling 2020:8865; South Africa 2010:59; Van der Wolk 2021:8). They are argued to be too low to effect any real change in behaviour away from carbon-intensive operations (Baranzini, Van den Bergh, Carattini, Howarth, Padilla & Roca 2017:12; Boyce 2018:52; Rosenbloom, Markard, Geels & Fuenfschilling 2020:8865; South Africa 2010:59; Van der Wolk 2021:8).

1.2. RATIONALE

Mining is an energy-intensive industry and contributes significantly to global warming through the consumption of fossil fuel-generated energy and release of GHG in return (Farjana, Huda, Mahmud & Saidur 2019:1200; Katta, Davis & Kumar 2020:1). Evidence of excessive air and water pollution[6] was found in Emalahleni, situated in the Mpumalanga Province of South Africa. Emalahleni's air and water pollution has been caused by coal mining and energy generation (Olufemi, Bello & Mji 2018:28; Nkambule & Blignaut 2012:85). Polluting substances cause cancer and respiratory illnesses, as well as ozone layer loss that fuels climate change (Almetwally, Bin-Jumah & Allam 2020:24815). The air and water pollution in Emalahleni has been found to have adverse health effects on the people living in the area (Olufemi et al 2018:28). Air pollution from mining business processes is an urgent problem in South Africa that warrants immediate action to avoid any adverse effects on living beings (Olufemi et al 2018:28) caused by the advancement of climate change.

[6] Contamination of the natural environment.

Carbon pricing policies (CPPs) have been central to climate change mitigation due to providing an option to choose less carbon-intensive and efficient solutions (McKitrick 2016:1; Steinebach et al 2021:277). Carbon tax is a form of Pigouvian tax, internalising the external cost by requiring polluters to pay for CO_2 equivalent emitted in the atmosphere (Ball 2018:134). An effective carbon tax needs to equate the cost of pollution to the cost of abating it (OECD 2010:98) to advance decarbonisation efforts. Research on the effectiveness of carbon pricing to encourage decarbonisation in the mining industry has been limited, with previous studies primarily examining its country-wide impact on GDP, competitiveness, and profits (Datta 2017:10; Modiba 2019:142; Ulrich, Trench & Hagemann 2022:14; Van der Meijdena & Withagen 2019:1; Van Heerden, Blignaut, Bohlmann, Cartwright, Diederichs & Mander 2016:728). Zharan and Bongaerts (2017:163) also identifies the renewable energy integration into mines investment decision-making framing process as an under-developed research area. There are no prior research studies has evaluated the adequacy of South African carbon price to incentivise mines to invest in carbon reducing technologies available using net present value (NPV[7]).

This research study addresses that research gap and explores whether the current South African carbon prices encourage the mining industry to invest in carbon reducing technologies using NPV. Mines investing in carbon reduction technologies facilitates the vital transition to low carbon operations. This research is necessary in order to evaluate whether the South African carbon pricing mitigation strategy encourages decarbonisation efforts for the mining industry, as the mining industry is the significant contributor of GHG emissions. Where the South African carbon pricing regime does not encourage decarbonisation efforts, this study further proposes strategies that will aid decarbonisation of the mining industry and slow the advancement of climate change.

Decarbonisation requires the mining industry to integrate renewable energy and CCUS to reduce the effects of fossil fuel use (Igogo, Awuah-Offei, Newman, Lowder & Engel-Coxmining 2021:1). The use of energy-efficient technologies, renewable technologies, and CCUS are climate mitigation options that many research scholars endorse to significantly

[7] Cost benefit analysis of the current cashflow of the investment cost against future benefits expected to be derived from an investment.

decarbonise the mining industry (Haszeldine, Flude, Johnson & Scott 2018:1; Igogo et al 2021:1; Katta, Davis & Kumar 2020:1; Shafiee, Alghamdi, Sansom, Hart & Encinas-Oropesa 2020:1; Sugiyama, Akashi, Wada, Kanudia, Li & Weyant 2014:397; World Bank 2017:16). Katta et al (2020:15-16) discovered evidence that fifteen energy-efficient technology improvement options implemented in the various stages of the mining production-cycle significantly contributed to decarbonising the Canadian mining industry in a cost-effective manner. Sugiyama et al (2014:397) also deem energy efficiency to be a necessary component in climate change mitigation strategies over the short to medium term. The integration of these GHG reducing technologies require large financial investments.

Investment decisions are influenced by a fixed tax rate (Haites 2018:956). Furthermore, investments are central to firm value creation, a fact that supports the notion that corporate taxes influence the investment decision because the timing, amounts, and uncertainty thereof affect the value of an investment (Hanlon & Heitzman 2010:147). Investment decisions are evaluated under capital budgeting theory and evaluation techniques (Hanlon & Heitzman 2010:147). Oke and Conteh (2020:13) define capital budgeting as an investment approach that commits current cash resources to enabling the attainment of desired returns. Investment decisions are often evaluated using discounted cash flow (DCF) and NPV models (Botín 2019:67-68). Under such models, future cash flows are evaluated against the cost of the investment, with a positive NPV[8] signifying the acceptance of an investment (Drury 2019:312-314; Oke & Conteh 2020:17). The investment evaluation would be conducted under Cost-benefit analysis (CBA) that is defined as an analytical investment assessment of the costs and benefits that stem from an investment decision (Sofia, Gioiella, Lotrecchiano & Giuliano 2020:1). Therefore, an entity would invest in a project so long as benefits exceeded the costs (Hanlon & Heitzman 2010:147). Carbon tax rates need to exceed the cost of investing in decarbonising technologies to incentivise decarbonisation efforts.

The NPV analysis is necessary to evaluate the ability of the South African carbon tax to encourage the mining entities to decarbonise. Furthermore, benchmarking the

[8] The projected cashflow generated by an investment discounted for their present value in today's South African rand terms. It is assumed that an investment with a positive NPV will be profitable, and a negative NPV will result in a net loss.

decarbonisation strategies and carbon pricing regimes adopted by international markets such as the EU, The United Kingdom, Switzerland, and Canada provide valuable policy lessons that may assist in improving South Africa's Carbon Tax. The improvement of the South African carbon pricing regimes and resultant decarbonisation efforts will aid in climate change advancement mitigation efforts.

1.3. PROBLEM STATEMENT

The change in climate is mainly attributable to the burning of fossil fuels for energy generation (IPCC 2014:235). Climate change has detrimental effects on the environment and has been assessed by the Government of South Africa as a threat to broader socio-economic development (South Africa 2020:1). Climate change can be mitigated by transitioning into the use of low-carbon intensive technologies, as well as sequestration of CO_2 emissions already in the atmosphere (Haszeldine et al 2018:1; Igogo et al 2021; Katta et al 2020:1; Sugiyama et al 2014:397; World Bank 2017:16).

Globally, carbon pricing and emission trading systems have been the main tax policy instruments used to influence behaviour towards reducing CO_2 emissions. South Africa introduced a carbon pricing system in 2019, taxing the emitters that continue to pollute the environment beyond. Mining is an energy-intensive industry that contributes to pollution through the substantial consumption of fossil fuel-generated energy, as well as their own emissions from the production process. The mining industry contributes 26% of global emissions (The Guardian 2019) and requires the industry to reduce the CO_2 emissions to mitigate climate change effects. The above dimensions provide the contextual problem informing this research study.

For carbon pricing to be effective in climate change mitigation, the carbon prices need to be correctly priced to incentivise climate mitigation options and do away with excessively generous tax-free emission allowances. The mining sector in South Africa has a collective tax-free emission allowance of 90%, rendering their effective carbon price at R13.40 (USD 0.71[9]) per tonne of CO_2 emissions in 2021. At this pricing level, it is cheaper for the mining

[9] Translated at ZAR19 to1 USD.

industry to pay for polluting the environment than investing in carbon mitigating technologies.

It has been argued that current carbon pricing is insufficient to achieve the required decarbonisation targets pledged by South Africa under the Paris agreement (Rosenbloom et al 2020:8665; Van der Wolk 2021:4). Pricing models have been conducted on establishing the effective carbon price (Moore et al 2017:1; Nordhaus 2016:1518; South Africa 2010:55; World Bank 2017:50). These prices are yet to be evaluated at entity level if they incentivise investment, in CO_2 emissions mitigating technologies for the mining operations in South Africa. These considerations support the gap in Pigou's theoretical underpinnings that informs this research study, in the sense that carbon pricing is broadly under-theorised, where this research responds to place this theory within the specifics of the mining context in South Africa.

1.4. THESIS STATEMENT

In pursuit of the Paris agreement emission targets, the current carbon price is set too low to encourage the mining industry to invest in CO_2 emissions mitigating technologies required to aid decarbonisation in the South Africa.

1.5. RESEARCH QUESTION

The study is organised around the following research question:

1. What carbon pricing level incentivises mines in South Africa to invest in CO_2 emissions mitigating technologies?

1.6. RESEARCH OBJECTIVES

The primary objective of this study is to establish a carbon pricing strategy that will encourage the decarbonisation of the mining industry in South Africa. To explore this objective, a cost benefit analysis (CBA) will be conducted to evaluate the decision-making trade-offs between paying a carbon tax, against investing in carbon mitigating technologies. To make this determination and explore related issues, the specific objectives are to:

1. Review the existing carbon tax policy and its role in decarbonising of the mining industry in South Africa;
2. Compare international carbon pricing models in relation to varying carbon price levels and the reciprocal reductions in CO_2 emissions;
3. Explore the CO_2 emissions mitigating technologies available to decarbonise the mining industry in South Africa;
4. Conduct CBA of existing carbon prices against the investment cost of available CO_2 emissions mitigating technologies, using NPV analysis and,
5. Make recommendations as to which CO_2 emissions mitigating technologies incentivise investment at the different carbon pricing levels.

1.7. DELIMITATIONS AND LIMITATIONS

- The word incentivise in the study is used in the context of motivating or encouraging a course of action, and does not intend to reference legislated tax incentives.

- This research exclusively investigates the identification of an efficient carbon pricing mechanism tailored to the mining industry. Although carbon pricing stands as a pivotal aspect of decarbonisation efforts, it constitutes only a part of a holistic decarbonisation strategy. Such a strategy should encompass various supplementary elements, including policy interventions, technological advancements, regulatory structures, and initiatives aimed at fostering social and behavioural changes.

- The carbon pricing policies and information on emission levels is available at country level in South Africa. This information is not available specifically for the South African mining industry. The information is aggregated with other industries, and it was not possible to evaluate the effect of the carbon price on mining industry specific emissions.

- This study will not model an effective carbon price that will achieve emission targets pledged under the Paris agreement. The study will instead rely on the existing South

African carbon price to explore the investment decision, and the study does not evaluate the effectiveness thereof in decarbonising the environment to achieve emission targets as pledged under the Paris agreement.

- Investment decisions are also influenced by the strategic objectives of a business. Where the strategy is to transition to low-carbon operations, an entity may invest in CO_2 emissions mitigating technologies despite the cost exceeding the benefit. This may be achieved to enhance their corporate social responsibility profile. This study does not intend to explore the impact of strategic objectives on the investment decision. The exploration will be solely from a CBA and qualitative analysis (excluding strategic considerations) of the investment.

- Financing decisions of green technologies are omitted, and investment decisions are based solely on the economic viability of the project using discounted cashflow evaluation models. An investment is accepted when the future cash inflows are more than the cost of the investment. Once a good investment is identified, financing options are assessed. This research aims to only assess the investment decision. Energy efficiency measures are not evaluated, due to the varied technology options each mining entity can implement in the varied resource production processes.

- The study is framed within its declared context, theoretical confluence and methodology, where, as such, research decisions have been made that excluded other contexts, theories and alternative methodologies. The findings thus emerge within the parameters of the selected context, theories, and methodologies.

1.8. UNDERLYING ASSUMPTIONS

- Funding green technologies is not a barrier to investment in decarbonisation technologies and the investment decision is based solely on cost versus benefit analysis. Investments will be discounted at the cost of capital of 11.75% with the assumption that it will be primarily funded by debt at the prime rate of 11.75 percent.

- Energy intensive and power producers are the biggest contributors to GHG emissions, and due to the absence of mining-specific policies and emission levels, countrywide emission reductions are extrapolated to represent these two industries, due to their significant contribution to GHG emissions.

- The evidence for this study, within its bespoke context and according to its theoretical lens, is primarily qualitative.

1.9. RESEARCH METHODOLOGY

This study was positioned qualitatively, within an interpretive paradigm. An exploratory descriptive design was first conducted to incorporate a qualitative review of literature on environmental fiscal policies, amounting to a documentary review (Ahmed 2010) to map the terrain of comparative carbon pricing, and to benchmark this with the South African experience. Thereafter, comparative carbon pricing analysis was used as an input diagnostic to draw lessons that might improve the South African carbon pricing regime. A comparative analysis of the European Union, Switzerland, Canada, and the UK carbon tax policy regimes was conducted in order to establish the carbon pricing strategies that will induce South African miners to invest in renewable energy technologies. A CBA and a NPV simulation were conducted, to supplement the overall qualitative inquiry. Numerical data can be used as a supplement to a larger process approach to the research and maintain its legitimacy as a qualitative research strategy (Maxwell 2010:480).

1.9.1. Research processes

The chosen qualitative approach seeks a better understanding of complex situations (Williams 2007:70; Pellizzari & Wall 2015:1), and in this study, serves to gain understanding, through a detailed secondary review (Ahmed 2010:1) of the role of carbon pricing in encouraging decarbonisation of the mining sector and other mitigation options available for the mining sector. Qualitative documentary review (Ahmed 2010:1) is undertaken in the collection of secondary data based on carbon pricing themes to draw inferences from the findings. Furthermore, the study gathers costing data of carbon mitigating technologies to explore whether the South African carbon price levels incentivise investment into these technologies.

This exploration is conducted through an NPV. The NPV established in this study provides a summative numerical method or methodology intended to clarify the key findings of the qualitative analysis. Sandelowski observes in this regard that displaying information numerically can result in patterns to emerge more clearly or, at the very least, generate new questions or new lines of analysis, and also provide clarification to the meaning (Sandelowski 2001:233). Sometimes qualitative data displays are so overloaded with words or verbal explanations are so complex that the reader will have difficulty absorbing all the information conveyed in them. Reducing qualitative data to numbers can sharpen the focus on a key finding (Sandelowski 2001:233).

A quantitative approach involves the collection of numerical data to perform statistical and mathematical modelling analysis to support or refute a given phenomenon (Williams 2007:66). The study does not conduct any statistical or mathematical modelling and therefore does not claim quantitative traditions. The numerical costing data collected is used to complement the overall qualitative review inquiry in this study, and to, as signalled above, use enumerative findings (Sandelowksi 2001:233) to establish illustrative meaning to the qualitative dimensions that lie at the core of the findings.

1.10. ETHICAL CONSIDERATIONS

The research study primarily evaluates secondary data and literature that already exists; therefore, the work of others will be adequately referenced and cited as such. The objective choice in data inputs for the NPV investment decision will be systematically substantiated and will not therefore be subjected to biasness. Ethical clearance approval was obtained from the University Ethics Committee.

1.11. SIGNIFICANCE OF THE STUDY

This research study fills the knowledge and empirical gap relevant to the unexplored trade-offs of carbon pricing relative to the investment decision into low-carbon transition technologies. Prior research studies focused on the effects of carbon tax on the profitability and competitiveness of mining entities in South Africa (Datta 2017: 10; Modiba 2019:142; Ulrich, Trench & Hagemann 2022:14; Van der Meijdena & Withagen 2019:1; Van Heerden, Blignaut, Bohlmann, Cartwright, Diederichs & Mander 2016:728). Therefore, there has been minimal research conducted on the impact of carbon pricing on decarbonising mines in South Africa. This research study provides significant contribution towards carbon pricing strategies and levels that will encourage decarbonisation of an industry that significantly contributes to climate change. Decarbonisation of an industry that significantly contributes to climate change (Farjana, Huda, Mahmud & Saidur 2019:1200; Katta, Davis & Kumar 2020:1), and might accelerate climate change mitigation, reducing the future harmful effects of climate change.

Decarbonisation necessarily requires investment in green technologies. The determination of carbon pricing level and policy strategies that will encourage investment in green technologies informs the South African government carbon pricing levels that need to be implemented to mitigate the advancement of climate change and the related adverse effects. Determining the impact of a carbon tax on decarbonisation efforts is essential to informing a more effective carbon pricing system in the second phase of the South African carbon tax regime since 31 December 2025. The research study contributes to the knowledge gap of carbon tax policy strategies required to decarbonise the mining industry in South Africa. In return, this will facilitate the much-needed transition to a low carbon economy.

1.12. CHAPTER OVERVIEW

To satisfy the objectives outlined in section 1.5, this study has been structured into seven chapters:

Chapter 1: Introduction

This chapter sets the context to the study and justifies the importance to transit towards a low-carbon economy. It articulates the research problem around the inadequacy of the current carbon price to incentivise investment into carbon mitigating technologies. The research objectives and methods the study uses to collect and analyse data are discussed. A chapter overview broadly outlines the approach to the study.

Chapter 2: South Africa's carbon pricing systems

This chapter reviews the South African Carbon Tax regime. The role of carbon pricing in decarbonising the mining operations in South Africa is discussed. Carbon pricing policy impediments towards investments in the CO_2 emissions mitigating technologies are identified.

Chapter 3: International carbon pricing systems

This chapter reviews international carbon pricing systems from the European Union, Switzerland, Canada, and the UK to draw on lessons from the reported analysis of the relationship between carbon prices and the corresponding carbon emission reduction. A comparative framework will be compiled based on the international and South African pricing systems, to evaluate the reported effectiveness of carbon pricing levels and to establish at which point the extrapolated carbon prices are most effective. These carbon prices will be applied to the cost benefit analysis conducted in Chapter 5.

Chapter 4: Carbon dioxide mitigating technologies

This chapter describes the CO_2 emissions-mitigating technologies available to the mining sector in South Africa. Solar photovoltaics (PV) was found to be the most feasible technology that can be integrated in mining operations and was selected for investment decision analysis.

Chapter 5: Methodology

This chapter detailed the qualitative method adopted in this study. Qualitative content analysis is conducted to gain an understanding of how carbon pricing can encourage entities to adopt decarbonising measures in their operations. The study gathers secondary data available from literature on the role of carbon pricing in mitigating climate change, CO_2

emissions mitigating technologies available, and models a carbon pricing level required for mines to invest in solar PV.

Chapter 6: Investment decision analysis

This chapter analyses solar PV investment decision. The South African carbon tax rate is evaluated against the cost of investing in solar PV over a 20-year period. A price level that encourages investment in solar PV is determined.

Chapter 7: Conclusions and recommendations

This chapter concludes the study and provides policy recommendations on carbon pricing in the South African mining sector. Based on the analysis at which price, if any, carbon pricing incentivises investment into solar PV. Recommendations for future research are identified.

CHAPTER 2

SOUTH AFRICA'S CARBON PRICING SYSTEMS

2.1. INTRODUCTION

Climate change is arguably this century's most eminent environmental global challenge (South Africa 2004:1; Ghazouani, Xia, Jebli & Shahzad 2020:1; Ginanjar & Mubarrok 2020:41; Mikhaylov, Moiseev, Aleshin & Burkhardt 2020:2897; Wolde-Rufael & Mulat-Weldemeskel 2021:22392). It causes significant damage to the environment and all living organisms (Ghazouani et al 2020:1). If it remains unabated, climate change could potentially jeopardise South Africa's socio-economic development (South Africa 2020:1).

Environmental policy instruments have been central to governments' response to climate change mitigation (Pacheco-Vega 2020:620). The policy responses comprise of regulatory, market, and information-based instruments. Regulatory instruments prescribe mandatory carbon emission levels and/or technology standards that must be employed to reduce the carbon emission levels (Gupta 2020:3; Liao 2018:1112; South Africa 2010:25; Steinebach 2019:227). Market-based instruments use taxes and emission trading schemes to influence the economic behaviour away from the carbon-intensive operations (Wills, La Rovere, Grottera, Naspolini, Le Treut, Ghersi, Lefèvre & Dubeux 2022:49). Information base instruments are voluntary instruments that require entities to report environmental information to governments and other stakeholders (Liao 2018:1113). Command and control and market-based instruments were the two commonly used policy instruments to ameliorate the climate-change problem (Cardona, De Freitas & Rubí-Barceló 2021:654; Tang, Li, Zhang, Wu & Wu 2020:1; Tang, Qiu & Zhou 2020:2; South Africa 2010:25).

Globally, market-based instruments have taken preference over regulatory instruments, due to the perception that they are the most effective in reducing CO_2 emissions (McKitrick 2016:1; Steinebach, Fernández-i-Marín & Aschenbrenner 2021:277; Wolde-Rufael & Mulat-Weldemeskel 2021: 22392). This chapter explores the framework for improving carbon pricing schemes. The South African carbon pricing regime and available environmental policy instruments to mitigate climate change are currently being reviewed. The chapter concludes with an evaluation of the impact that the Carbon Pricing Policy has had on the South African mining industry since its inception.

This chapter is laid out as follows: Environmental policy instruments to combat climate change are discussed in Section 2.2. Section 2.3 discusses where the environmental taxes fit in the bigger scheme of taxation. Section 2.4 expounds on the tax design considerations. Section 2.5 reviews South Africa's response to climate change, and Section 2.6 presents the conclusion to the chapter.

2.2. ENVIRONMENTAL POLICY INSTRUMENTS TO COMBAT CLIMATE CHANGE

Regulatory, market, and information-based instruments have been central to climate change mitigation strategies implemented by governments' globally as a response to the climate-change problem. The policy instruments are explained in detail below.

2.2.1. Command and control instruments

Command and control instruments, often cited as regulatory policies, instruct polluters to reduce pollution through prescribed performance and technology standards (Gupta 2020:3; Liao 2018:1112; South Africa 2010:25; Steinebach 2019:227; Tang et al 2020:2; Zhang, Wang, Xue & Yang 2018:765). Performance standards prescribe the carbon emission levels or rate (Liao 2018:1112). The carbon emission levels prescription grants the entity a choice of technology or cut in production to reduce the CO_2 emissions (Gupta 2020:4), where the technology acquisition is not available. Reducing the production of negatively impacts the economy, and Gupta (2020:5) argues that may be the reason economists advocate for market-based instruments.

Technological standards prescribe the technology to be used by entities to limit emission levels. The technology or performance requirements are mandatory, and non-compliance can result in either fines or imprisonment (Gupta 2020:4; Liao 2018:1112). Command and control instruments are suitable in environments where monitoring pollutions levels is difficult or comes at a great cost (Gupta 2020:5). Command and control instruments are effective environmental regulations mandating pollution reduction, regardless of the cost of pollution abatement (Gupta 2020:5).

2.2.1.1. Drawbacks of command and control instruments

Dissanayake, Mahadevan & Asafu-Adjaye (2020:2) and Pacheco-Vega (2020: 627) argue that command and control instruments are no longer efficient in terms of reducing pollution goal and for investment in the green technologies. Command and control instruments are criticised for their non-flexibility in allowing polluters options to abate pollution emission levels (Guo, Fu & Sun 2021:1; Gupta 2020:12; Li, Gu, Liu & Li 2019:34789; Pacheco-Vega 2020: 627; South Africa 2013:8; Tyler & Cloete 2015:376). Entities bear the risk of a change in the regulated technology for pollution abatement (Gupta 2020:5), an investment they may not be able to afford when regulations are changed, resulting in penalties. Entities are not incentivised to reduce pollution emission levels beyond the prescribed targets or when standards are outdated (Guo et al 2021:2; Sánchez & Deza 2015:69). Information failure occurs when entities have more knowledge about their industries than do regulators, which may result in entities withholding information or releasing emissions illegally to avoid penalties (Guo et al 2021:16; Li et al 2019:34789).

Regulators need to remain up to date with technological advancements to prescribe efficient technologies to abate pollution. Continued tracking of technological advancement may increase the environment regulatory cost (Gupta 2020:5). Command and control instrument policies are focused on large polluting entities and fail to establish frameworks that accommodate smaller polluting entities, resulting in higher implementation costs for the small polluting entities (Gupta 2020:5; Li et al 2019:34789 Sánchez & Deza 2015:69). Implementation of smaller units leads to higher implementation cost (Gupta 2020:5).

2.2.1.2. Command and control instruments in the African context

Oshionebo (2017:36) argues that command and control regulations are ineffective for regulating activities of extractive industries in Africa. Command and control regulations originate from the premise that companies would want to avoid litigation, and therefore be incentivised to comply with the law (Oshionebo 2017:36). However, Oshionebo (2017:36) argues that inadequacy of regulatory agencies, lack of funding for regulatory agencies, corruption, and lack of political will to enforce laws and regulations and political involvement in extractive activities renders command and control regulations ineffective for extractive entities in Africa (Oshionebo 2017:36-37). Blackman (2010:234) concurs with assertion that regulatory agencies lack adequate funding, expertise, workforce, and pollution control facilities in developing countries. Oshionebo (2017:36) further argues that the ineffectiveness is further exacerbated by private citizen's inability to enforce laws due to the high costs of litigation, and general poverty (Oshionebo 2017:36). In South Africa, Section 38 of the constitution allows its citizens to privately prosecute entities infringing a right contained in the bill of rights. Section 24 of the constitution grants South Africans a right to a clean and health environment, which pollution necessarily violates.

Esterhuyse, Vermeulen and Glazewski (2019:1-19) studied environmental policy instruments that can be used to protect ground water during oil and gas extraction using hydraulic fracking. Hydraulic fracking is the process of injecting liquids at high pressure into underground rocks, to facilitate opening that enable oil and gas extraction. Esterhuyse et al (2019:13) further supports Oshionebo (2017:36-37) and Blackman (2010:234) in their assertion that command and control instruments are not suitable in Africa. Esterhuyse et al (2019:13) found that command and control regulations would be difficult to enforce for the South African mining industry, due to limited regulatory oversight, monetary, and human resource capacities.

2.2.2. Information-based instruments

Information-based instruments constitute informal voluntary regulations that require entities to report on the specific environmental information to governments and the public (Liao 2018:1113). In the climate change context, this could be information relation to pollutant emissions and their associated threat to the environment. The release of this information could result in social pressure to reduce pollution, enhance environmental protection awareness, or lead to entities reducing pollution voluntarily, in order to be seen as good corporate citizens (Liao 2018:1113). Voluntary instruments encourage co-operation from entities and due to the voluntary nature thereof, provide flexibility for the entities (Walter

2021:6). Bowen, Tang, and Panagiotopoulos (2020:1) advocate for the use of information-based instruments in scenarios in which information disclosure is a primary mechanism to stimulate behavioural change.

Despite the growth in voluntary instruments, the policy effectiveness evaluation thereof led to mixed results (Walter 2021:6). Blackman (2010:235) asserts that formal regulation is necessary for an informal instrument to be effective. Participation by entities may be encouraged by the view that failure to participate may result in stringent compulsory regulation. Participation may also be encouraged by entities charging a premium on products for customers seeking responsibly produced products (Walter 2021:23). In an era where consumers are increasing their awareness of sustainability measures, such an instrument can be effective, where consumer and investment support is increased for entities with increased sustainability measures.

2.2.2.1. Drawbacks of Information-based instruments

The voluntary nature creates the inherent weakness in the instrument, where entities are less likely to take on significant abatement of environmental damage, due significant decarbonising costs (Walter 2021:23). The policy instrument works when there is a belief of negative repercussions for non-participation. Voluntary adoption without any negative repercussions for non-adoption will be limited, due to the high abatement costs of investing in decarbonising technologies. Participation is further limited by the inability of entities to transfer the carbon charge to consumers and charge a premium for low carbon cost (Walter 2021:23) due to market determined prices of most commodities in the mining industry.

2.2.3. Market-based instruments

Market-based instruments use financial incentives to influence behaviour towards a more environmentally friendly solutions (Gupta 2020:3; South Africa 2010:25; Steinebach 2019:227; Zhang, Wang, Xue & Yang 2018:765). Stavins (1997:293) asserts that this is achieved by taxing harmful activities or the use of emissions trading systems (ETS).

2.2.4. ETS

ETS instruments is believed to limit the carbon emission levels in a country. The permitted CO_2 emissions are either allocated freely to certain entities or industries, and the remaining CO_2 emissions are sold on the open market. Entities would then be required to purchase carbon credits on the open market to allow them additional CO_2 emissions over the prescribed limit (Dong, Shen, Chow, Yang & Ng 2016:510). The ETS instrument's objective is to regulate market participants to manage and control CO_2 emissions through a price instrument (Chen & Lin 2021:1; Dissanayake et al 2020:2). Chen and Lin (2021:2) assert that ETS promotes carbon emission reduction and investment in low-carbon technological innovations, due to the cost advantages in reducing emissions.

An ETS system requires many permit trades and enough traders for this market to operate efficiently, providing credible carbon prices (South Africa 2013:34; South Africa 2017:3). The National Treasury found the ETS will not to be suitable for South Africa, due the CO_2 emission being highly concentrated between a handful of large emitters (South Africa 2013:34; Tyler & Cloete 2015:375). South Africa (2018:4), South Africa (2017:3) and South Africa (2013:34) assert that the system is overly complex, and unsuitable for South Africa, due to its limited administrative oversight capacity. An environmental tax would, then, be more suitable for South Africa due to ease of integration into the current tax system, without significant capacity expansion (South Africa 2013:34). A discussion on how ETS fits with carbon pricing design is discussed in section 2.3.6.

2.2.4.1. Drawbacks of ETS

An ETS system is complex to implement and determines the maximum carbon emission threshold for each sector (Hazra 2022:10; South Africa 2013:34). The measurement of the CO_2 emissions under ETS system comes with high compliance costs (Hazra 2022:10). The trade nature thereof depends on sufficient availability of permits to trade and trading of permits to ensure a credible market pricing (South Africa 2013:34; South Africa 2017:3). The system does not work efficiently where permit trade is limited (Hazra 2022:10). The complexity and difficulty in measuring emissions makes the EFT system susceptible to emission fraud schemes (Hazra 2022:10).

2.2.5. Environmental taxes

Environmental taxes are taxes that regulate activities having a negative impact on the environment (Kotlán, Němec, Kotlánová, Skalka, Macek & Machová 2021:1). Environmental taxes provide a double-divided by raising revenue for the State and influencing the behavioural changes towards the use and consumption of environmentally friendly technologies to limit environmental damage (Miceikiene, Lideikyte, Savickiene & Cesnauske 2019:31; Wolde-Rufael & Mulat-Weldemeskel 2021: 22395; Wills, La et al 2022:50; Zhang, Abbas & Iqbal 2021:241). In the climate change context, the objective of the environmental taxes is to control CO_2 emissions and promote consumption of clean energy (Khan, Ponce & Yu 2021:3). Carbon tax is an environmental tax with the objective of regulating CO_2 emissions and the impact thereof on the environment. Economists and international organisations have strongly supported a tax on CO_2 emissions and argue that it is an efficient method of reducing CO_2 emissions and adding additional revenue to national budgets (Ghazouani, Xia, Ben, Jebli & Shahzad 2020:2; Miceikiene et al 2019:31-32). Pricing carbon is argued to be cost efficient, by allowing entities the flexibility to choose the most cost-effective mechanisms to reduce CO_2 emissions in comparison to regulatory instruments (Wills et al 2022:49).

Carbon tax policies are generally designed following the Pigouvian framework (Halkos & Kitsou 2018:2; Heal & Schlenker 2019:3). Pigou first proposed the use of economic incentives to correct the unaccounted-for negative externalities caused by pollution (Jaqua & Schaffa 2021:1; Li & Deng 2022:4; Wang & Zhang 2019:2). Negative externalities are defined in economic theory as the omitted cost of pollution in final costs of goods resulting in a market failure (South Africa 2018:3).

Levying a carbon tax would correct the market failure by internalising the cost of pollution, and thereby increasing cost of goods and services (Dissanayake et al 2020:2*;* Halkos & Kitsou 2018:2; Li & Deng 2022:4; Wang & Zhang 2019:2). The increased cost of goods reduces the quantity of goods consumed, reducing the profitability for entities. This then creates an incentive for entities to change behaviour towards environmentally friendly solutions (Dissanayake et al 2020:2*;* Jaqua & Schafa 2021:2; South Africa 2010:21; Sterner & Robinson 2018:237; Tan, Wu, Gu, Liu, Wang & Liu 2022:2).

2.2.5.1. Drawbacks of environmental taxes

Rosenbloom et al (2020:8664) argue against carbon pricing, viewing the emission of carbon as a negative externality leading to market failure. Rosenbloom et al (2020:8664) asserts that climate change is a systematic problem, with technologies, regulations, and infrastructure deeply ingrained in the combustion of fossil fuels. Reducing the advancement of climate change requires systematic changes, and that cannot be achieved by a single driver in the form of carbon taxes.

Gupta (2020:12) finds that, when the cost of reducing pollution exceeds the carbon tax payable, entities would rather pay the tax than invest in pollution reducing technology. Researchers find carbon taxes to negatively impact their international competitiveness (Köppl & Schratzenstaller 2021:23; Miceikiene et al 2019:31). The competitiveness is affected when carbon tax increases the cost of goods, and the same increase is not experienced by entities in countries without a carbon tax. The entities can then leverage off lower cost of goods to increase competitiveness in the international market. Figure 2-1 provides a summary of the benefits and disadvantages of the ETS and Carbon tax regimes discussed above.

Figure 2-1: Comparing carbon taxes and emissions trading schemes

Design issue	Instrument	
	Carbon tax	ETS
Administration	Simple administration.	Impractical for capacity constrained countries.
Uncertainty: price	Price certainty can encourage the development and acceptance of clean technology.	Price volitility can pose challenges; however, implementing price floors and adjusting caps can mitigate this volatility.
Uncertainty: emissions	Emission levels are uncertain but tax rate can be periodically adjusted to assiting in controling emission levels.	Emission levels are certain.
Revenue: efficiency	Usually the revenue is directed to the finance ministry for various general purposes, such as reducing other taxes or making general investments.	Free permits enhance acceptability but reduces revenue, while revenues from auctions often tend to be designated for specific purposes.
Revenue: distribution	Revenues can be recycled to make overall policy distribution remains impartial or progressive.	Free allowance allocation or earmarking may limit restrict the possibility of achieving favorable distributional results.
Political economy	Implementing new taxes can be politically challenging; effective communication and determining revenue allocation are crucial.	More politically acceptable than taxes.
Competitiveness	More robust border carbon adjustment than other measures such as threshold exemptions or output-based rebates.	Allocating free allowances proves efficient at moderate levels of emission reduction; however, border adjustments, particularly export rebates, face higher levels of legal ambiguity.
Price level and emissions alignment	Periodic estimation and adjustement is required to align with emissions goals.	Automatic alignment of prices with targets where emissions caps are consistent are mitigation goals.
Compatibility with other instruments	Compatible with overlapping instruments.	Overlapping instruments decrease the price of emissions without impacting emissions directly, though caps can be set or adjusted accordingly
Pricing broader GHGs	Amendable to taxation or similar measures based on existing business tax frameworks.	Less suitable for ETS; involving additional sectors through offsets might raise emissions and is not cost efficient.
Global coordination regimes	The most appropriate instrument for establishing an international minimum price for carbon.	Capable of adhering to an international minimum price level; beneficial exchanges through linking ETSs are possible, yet it falls short of meeting global emissions standards.

Source: Source: Parry, Black & Zhunussova (2022:17).
Note: Green indicates an advantage of the instrument; blue indicates neither an advantage nor disadvantage; red indicates a disadvantage of the instrument.

2.3. ENVIRONMENTAL TAXES IN THE CONTEXT OF OTHER TAX TYPES

Taxes in South Africa can be categorised into the following three main categories based on the tax base used to determine the tax (Davis Tax Committee 2018:8):

1. Income taxes are levied on income earned by individuals, businesses, and trusts. Income taxes are progressive in nature, increasing the tax rate levied as the income increases. The progressive nature of the income taxes is aimed at accomplishing redistribution goals such as creating opportunities for the poor to lessen the gap between the rich and poor (Davis Tax Committee 2018:52).
2. Consumption taxes are levied on the resources consumed and takes forms such as Value Added Tax, customs and excise taxes, fuel levy, electricity levy, international

air passenger departure tax, plastic bag levy, incandescent light bulb levy, and carbon tax. Carbon tax, as an environmental tax, forms part of the consumption taxes and is levied on the consumption of carbon intensive products and resources. Consumption taxes are regressive, as they are mainly being passed on to end consumers (Moz-Christofoletti & Pereda 2021:5), which adversely affects poorer households with limited purchasing power.

3. Wealth taxes are levied on an individual's net assets that considers assets and liabilities held by a taxpayer. Estate duty, donations tax, securities transfer tax and transfer duties[10] are examples of wealth taxes levied on asset values in South Africa. The wealth taxes are tools that can be used to lessen the inequality gap in the country (Davis Tax Committee 2018:6).

2.4. TAX DESIGN CONSIDERATIONS

The design of any tax system should encapsulate the meaning and purpose of taxation. Messere and Owens (1987:94) define tax as a compulsory payment made to a government. Kiprotich (2016:345) asserts that the purpose of a good tax policy should conform to the 'Five Rs', namely: raises revenue; reprices incorrectly priced goods and services; redistributes wealth; raise representation within the democratic process; and reorganises the economy through fiscal policy (Kiprotich 2016:5). A carbon tax policy would seek to reprice incorrectly priced goods, that exclude the cost of CO_2 emissions from the product cost. Carbon prices also raise revenue to fund transition to a low carbon economy (South Africa 2010:43).

2.4.1. Good tax principles

The design of any taxes, including environmental taxes, should first conform to a generally accepted principle of good taxation. A tax system design should have theoretical underpinnings of principles of good taxation (Shome 2021:54). Equity, certainty, convenience, and simplicity were the first four principles of a good tax developed by Adam Smith in his 1776 treaties *The Wealth of Nations* (AICPA 2017:3; Kiprotich 2016:5). These

[10] Tax levied on the purchase of immovable property (Davis Tax Committee 2018:60).

principles have been extended over the centuries (AICPA 2017:3). The South African government highlights efficiency, equity, certainty, simplicity, and cost minimisation as core principles that were necessary to uphold in the design of a relevant carbon tax (South Africa 2006:26-27).

2.4.1.1. Simplicity

A simple tax has clear rules, that are easy to understand, with a clear scope and not overly difficult to comprehend (Kiprotich 2016:5; Nichols 2005:14; OECD 2014:30-31; Tucker 2021:2). Clarity of taxation law is important in order to ease tax compliance for taxpayers (Kiprotich 2016:5; Shome 2021:56). The clarity of tax provisions enables taxpayers know where they stand, and aids in informed decision making in response to the tax policy (OECD 2014:30-31). The OECD (2014:30) asserts that complex tax rules influence behaviour towards aggressive tax planning, resulting in losses to the economy. Complex tax adversely affects taxpayer compliance and results in revenue losses for governments.

2.4.1.2. Administrable

The tax design should be practical to both implement and maintain (Nichols 2005:14). Tax administrations must maintain transparency and impartial application of taxation rules (Shome 2021:56). Administration costs for both tax administrations and taxpayers should be kept as low as possible (AICPA 2017:3). Revenue collection should be administratively efficient, regularly modernising tax collection systems and limiting the compliance burden of taxpayers (Kiprotich 2016:5).

2.4.1.3. Neutrality

Proposed taxes should maintain neutrality and remain equitable across taxpayers (OECD 2014:30-31; Shome 2021:55). A neutral tax policy enhances efficiency through optimal distribution of the means of production (Kiprotich 2016:7). A tax that is not neutral alters prices that change the supply and demand patterns that would not occur had the tax not been implemented. This distortion results in a loss of economic prosperity (Kiprotich 2016:7-8). Therefore, taxation should strive for neutrality, reducing the potential for bias towards or against varied economic choices (Kiprotich 2016:7-8). Taxation should be based on the same principles for all business types while considering factors that could otherwise make it difficult to implement such principles equally and impartially (OECD 2014:30-31).

2.4.1.4. Effectiveness and Flexibility

Taxation should be effective in proving the correct tax liability and avoiding double taxation or unintended tax consequences (OECD 2014:30-31). Taxation systems must be adaptable to keep up with technology and commercial advancements (OECD 2014:30-31). The lack of keeping up the date increases the difficulty in administer the taxes and impacts the tax revenue collection. It is imperative for tax authorities to keep up with relevant technological advancements and skillsets to be able to collect environmental taxes. The quantification of GHG gasses is complex, and require collaboration with environmental bodies, in efforts to minimise untaxed emissions in the environment.

2.4.2. Carbon tax design considerations

The effectiveness of a carbon tax is dependent on its design. Policymakers consider a variety of design features while drafting carbon tax legislation, such as the selection of the tax base, use of revenue collected, simplifying tax compliance, and addressing possible adverse effects from the proposed design of the carbon tax. This section discusses carbon taxes design as well as issues policy makers should consider in designing their carbon taxes.

2.4.2.1. The choice of the tax base

Governments need to consider the tax base and the fossil fuel sources subject to the carbon tax (Parry 2012:29; Sumner, Bird & Dobos 2011:924). The carbon tax should aim to cover as many fossil fuel sources as possible, so as to have a substantial impact on emission reduction efforts (Parry, Black & Zhunussova 2022:29). Maximum coverage is achieved when carbon tax should be levied upstream[11] in the fossil fuel supply chain (Parry 2012:29;

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[11] Emissions that arise from production of goods and services.

Parry et al 2022:29). The tax base informs the carbon tax rate that can be charged. The carbon tax should be high enough to incentivise decarbonisation efforts (OECD 2017; Sumner et al 2011:924). Higher carbon tax rates encourage consumer behaviour towards transitioning into low carbon operations (Sumner et al 2011:924). This is as a result of carbon tax liabilities exceeding the cost of decarbonising in the long term. Free CO_2 emissions allowances reduce the effective carbon price and limit the ability of carbon tax to encourage decarbonisation efforts (Baranzini et al, 2017:12; OECD 2017:8).

2.4.2.2. How tax revenues might be used

Carbon taxes can add a substantial new revenue source for governments (Parry et al 2022:32). The use of revenues affects the sustainability of the policy instrument (Sumner et al 2011:924). Parry et al (2022:33) argue for the use of carbon tax revenues to boost economic efficiencies by funding the reduction of other taxes that distort the economy. Reducing the other taxes increases the incentives of trade (Parry et al 2022:33) and the increased returns can be used to boost economic activity. The OECD (2017:8) argues that revenues collected should ideally be used to supplement the regressive effects of carbon tax. This will aid in addressing any potential harm to the welfare of lower-income households (ICC 2022:9). Other uses of carbon tax revenues can be directed to environmental programmes or fund government budgets (Sumner et al, 2011:924). The funding of environmental programmes can further aid in the decarbonisation efforts and mitigate the advancement of climate change (Sumner et al, 2011:937).

2.4.2.3. Address concerns about distributional effects on competitiveness

Policy makers need to consider the adverse effects of carbon taxes on entities trading in the international markets (ICC 2022:9). Tax incentives and reductions can be used to reduce the adverse effects of carbon tax on entities' competitiveness (ICC 2022:9). The alteration of broader tax rates applicable to industries negatively impacted, could provide relief from the adverse effects of carbon tax on the competitiveness (Parry et al 2022:35). International co-operation through cross-border adjustment of carbon prices can be implemented when businesses competing with one another abroad do not have to pay comparable carbon prices (OECD 2017:10). Domestically, free carbon emission allocations can be used as mechanism to cushion the adverse effects of carbon tax on the competitiveness of entities (OECD 2017:9). The free emissions would reduce the overall effective carbon tax rate. Considerations of competitiveness and carbon leakage are necessary, however should be balanced with the environmental needs to decarbonise.

2.4.2.4. How to simplify administration and compliance

The carbon tax collection should maximise emissions coverage while minimising administrative and compliance costs (Parry et al 2022:37). Ease of administration is achieved, where a smaller population is subject to carbon tax (Parry et al 2022:37), while maximising the emissions covered to achieve decarbonisation targets. The manner of carbon tax collection, and tax base selected should limit the chances of taxpayers evading the payment of required carbon taxes (Parry et al 2022:37). Policymakers should consider the ease of verification and control of CO_2 emissions data submitted (ICC 2022:9). The ability of governments to verify CO_2 emissions levels aids in the ability to enforce compliance, and collection of the correct carbon tax due for the respective emission levels.

2.5. SOUTH AFRICA'S RESPONSE TO CLIMATE CHANGE

South Africa's climate change responses principles are guided by constitutional rights and international agreements pledges (South Africa 2010:5). Section 24 of the Constitution gives South Africans a right to an environment that is not harmful to their health and well-being. While pollution negatively affects citizens, polluters bear no cost to remedy the damage perpetrated (South Africa 2010:25). This warranted government intervention, using environmental policy instruments to curb pollution levels (South Africa 2010:21). South Africa (2010:58) initially evaluated all the policy instruments available and found market-based instruments to be more suitable. There have since been proposed policy changes to include policy mix of carbon pricing and regulatory mechanisms, in the form of mandatory carbon budgets (South Africa 2022:47).

South Africa's earlier climate mitigation measures focused on tax policy to incentivise investment in climate mitigating initiatives. Catalano, Forni, and Pezzolla (2020:5) state that fiscal incentives aim to encourage private investment in climate change mitigation solutions.

The tax incentives described below, were introduced to encourage energy efficiency, as well as to provide for environmental rehabilitation allowances, and renewable energy production.

2.5.1. Energy efficiency incentive

Section 12L of the Income Tax Act (58 of 1962) (hereafter referred to as the Income Tax Act), came into effect on 1 November 2013 to provide a tax incentive allowance for entities that implement energy efficiency measures (South Africa 2013b). The entities will receive a deduction of 95c per kilowatt hour (kWh) on the value of energy consumption saved. From its inception, this has assisted to promote energy efficiency investments of ZAR three billion in energy-intensive industries like mining (South Africa 2020:54). The Section 12L incentive was scheduled to be phased out in 2020, in order to cushion the effects of possible adverse of carbon tax effects; however, it was extended to the year of assessments ending 31 December 2022 to align with the first phase of the carbon tax regime (South Africa 2018:14).

2.5.2. Renewable energy production incentive

Section 12B of the Income Tax Act came into effect on 1 January 2013 to provide a tax incentive allowance for costs incurred from investing in assets that produce renewable energy. The allowance is available on new and unused assets used in the production of electricity from the following renewable sources:

1. wind power;
2. solar energy;
3. hydropower to produce electricity less than 30 megawatts (MW); and
4. biomass.

The allowance permits a deduction of the cost of the asset over three years, with 50% in the first year; 30% in the second year; and 20% in the third year. From 1 January 2016, an amendment to Section 12B Income Tax Act allowed for 100% deduction in the first year for self-consumption electricity generation from embedded solar PV with a generation capacity limited to 1 000 kilowatts (KW). Additional enhancement to the permitted deduction has been proposed in the 2023 draft Taxation Laws Amendment Bill.

2.5.2.1. Proposed changes in draft Taxation Laws Amendment Bill

The tax amendment bill proposes the inclusion of Section 12BA of the Income Tax Act to enhance the deduction for assets used in the production of renewable energy (South Africa 2023:29). The section will permit the deduction of 125% of the costs incurred by a taxpayer in respect of new and unused machinery, plant, implement, utensils, or articles owned by a taxpayer. These assets should be brought in to use for the first time between 1 March 2023 and 1 March 2025 to qualify for the deduction and be used for energy generation from:

1. wind power;
2. solar energy from both Solar PV and concentrated solar energy;
3. hydropower to produce electricity; or
4. biomass.

2.5.3. Low-carbon initiatives incentive

Section 12K of the Income Tax Act came into effect on 11 February 2009 to incentivise certified emission reduction credits arising from clean development mechanism projects of the Kyoto Protocol. This section aims to incentivise “investments in eligible low carbon initiatives including renewable energy and energy efficiency projects in South Africa by partially offsetting the high project registration, monitoring and credit verification costs incurred by project developers” (South Africa 2019a:34). Section 12K has since been repealed in 2019 due to the benefit being embedded in the Carbon Tax Act (15 of 2019) (hereafter referred to as the Carbon Tax Act), that allows for CO_2 offsets allowances up to a maximum of 10% of the total GHGs.

2.5.4. Mining rehabilitation incentive

Section 37A of the Income Tax Act came into effect in 2006. Section 37A aims to align the tax treatment with environmental regulations as contained in section 38 of Mineral and Petroleum Resources Development Act (28 of 2002) (hereafter referred to as the MPRDA).

In accordance with these stipulations, miners are required upon ceasing of mining activities to rehabilitate mining sites to an acceptable, and sustainable level.

Section 41 of MPRDA requires mining entities to provide adequate financial resources to rehabilitate mining sites, upon ceasing or withdrawal of mining activities. Mining entities are allowed a deduction towards contributions paid into a rehabilitation funds that complies with section 37A.

2.5.5. Environmental treatment, recycling, and waste disposal asset incentive

Section 37B of the Income Tax Act came into effect in 2007 to incentivise manufacturers for acquiring new and unused environmental treatment, recycling assets, or environmental waste disposal assets. The allowable deduction on the cost for environmental treatment and recycling assets is 40% in the first year and 20% per year for the next three years. The cost of waste disposal assets can be deducted over 20 years, at five percent of the cost each year.

2.5.6. Carbon Tax

South Africa's climate change mitigation strategy includes the introduction of the Carbon Tax Act (South Africa 2020:2). The carbon tax rate was introduced at ZAR 120 per tonne of CO_2 equivalent of the GHG emissions of a taxpayer. The tax payable is calculated using the following formula:

$$X = < \{[(E - S) \text{ x } (1 - C)] - [D \text{ x } (1-M)]\} + \{P \text{ x } (1 - J)\} + \{F \text{ x } (1 - K)\} > \text{ x}$$

- X- represents the amount to be determined that must not be less than zero.
- E- represents the total fuel combustion-related greenhouse gas emissions expressed as a CO_2 equivalent.
- S-represents the sequestrated emissions certified by the Department of Environmental Affairs.
- C- represents the aggregate sections 7,10,11,12and13 allowable emissions allowances that vary per industry.
- D- petrol and diesel emissions expressed as a CO_2 equivalent.
- M- represents the aggregate sections 7,12, and 13 allowable emissions allowances that vary per industry.
- P- represents total industrial process-related greenhouse gas emissions expressed as a CO_2 equivalent.

- J- represents the aggregate sections 8,10, 11,12, and 13 allowable emissions allowances that vary per industry.
- F- represents total fugitive greenhouse gas emissions expressed as a CO_2 equivalent.
- K- represents the aggregate sections 7,9,10,11,12, and 13 allowable emissions allowances that vary per industry.
- R – represents the tax rate of ZAR 120 (2019 rate) per tonne of CO_2.

Table 2-1: Carbon emission allowances

Carbon Tax Act	Allowance	Mining sector emission allowances
Section 7	Fossil fuel combustion	60%
Section 8	Industrial process emissions	0
Section 9	Fugitive emissions	0
Section 10	Trade exposure	10%
Section 11	Performance allowance	5%
Section 12	Carbon budget allowance	5%
Section 13	Offset allowance	10%
Total Allowances *		90%
*The emissions allowances are subject to section 14 of the Carbon Tax Act that limit the allowances with an aggregate of 100% to 95%. This limitation is not applicable to the mining sector, with aggregate allowances of only 90%.		

Source: Author's own compilation based on the Second Schedule of the Carbon Tax Act.

South Africa considered various factors in the carbon tax design. The South African carbon tax design is attributable to administrative feasibility and practicality to cover most GHG emissions (South Africa 2018:4). Additionally, the necessity of a sustained, long-term transition to a low-carbon economy is considered (South Africa 2018:4). The following transitionary measures, and the impact on different stakeholders were considered.

2.5.6.1. Tax base and administration

Three tax-based options were considered for the carbon tax, namely: a direct tax on CO_2 emissions, a tax on fossil fuel inputs, and a tax on energy outputs (South Africa 2013a:46). A direct tax is imposed on the relevant entity's GHG emissions (South Africa 2010:30). Tax on fossil fuel inputs and energy outputs exist as proxy[12] taxes. Proxy taxes are imposed either downstream, on emitters at the point where fuels are combusted, or upstream on fuels as they enter the economy based on their carbon content (South Africa 2010:30). South Africa applies a direct tax on the total GHG emissions from combustion, fugitive, and industrial process (South Africa 2017:5). The carbon tax applies to Scope 1 CO_2 emissions,

[12] Proxy taxes is a representative for the actual GHG emissions from combustion (South Africa 2010:7).

which are caused by direct fuel combustion, gasification, and non-energy industrial processes (South Africa 2013a:47). This upstream tax on fossil fuels ensures a maximum coverage of CO_2 emissions (Parry 2012:29) extending the coverage for decarbonisation efforts. Flues and Van Dender (2020:48), however, argues that direct emission taxes are more expensive to implement in comparison to fuel-based tax approaches. This is because of the need to procure new monitoring systems, whereas fuel-based approaches can be easily integrated to existing sales systems.

The new system costs vary, depending on the cost of measurement per source, the number of distinct carbon emission sources that must be covered, and the extent to which measurement is done primarily for regulatory and compliance purposes, rather than as part of routine business operations (South Africa 2010:30). Direct taxes on GHG emissions are necessary, as they target the pollutant source, which achieves the decarbonisation objectives of the instrument (South Africa 2010:30). Additionally, the investment in the monitoring system can be justified by the multipurpose of use for reporting and decarbonisation efforts.

2.5.6.2. Distributional effects

A carbon tax can have a wide range of effects on different segments of the society, depending on a variety of factors including the tax's design as well as the jurisdiction's geographic, economic, and social reality. Taxes influence taxpayer behaviour, resulting in a shift of the tax burden to other parties. The economic burden from tax does not fall on business with statutory obligation to pay the tax to the government (PMR 2017:101). Through the rising of cost of goods and services, the tax burden falls on consumers. When the carbon tax falls disproportionately on populations, it can have negative distributional effects, causing the expense of the tax to be distributed unevenly or unfairly (PMR 2017:101). Mining entities cannot shift the carbon tax burden, due to the market determined prices of the mined commodities. The inability to shift the carbon tax burden, increases mining operational costs and reduces the profitability levels.

Compensatory measures to offset regressive impacts were considered in the design of the carbon tax instrument, as well as spending programmes (South Africa 2010:37). Measures such as personal tax relief, targeted roll-out of free basic water, and electricity services were considered appropriate relief measures in the South African context (South Africa 2010:39). A phased-in approach was also considered to limit the adverse impact of carbon tax and giving businesses time to implement decarbonising measures.

2.5.6.3. Competitiveness

The imposition of a carbon tax has different effects on the international competitiveness of various industrial sectors (South Africa 2010:39). International competitiveness refers to a company's ability to maintain or increase its international market share (PMR 2017:100). The level of input costs is crucial for determining an entity's level of competitiveness. The lower the input costs, the greater the capacity for an entity to reduce selling prices, increasing their competitiveness in the market. Carbon tax increases input costs in emission and energy intensive industries (PMR 2017:100). Competitiveness is also affected by the structure and ability of entities to pass on costs (South Africa 2010:39).

Mining entities are price takers, with their selling prices dependant on quoted market prices. Mining entities would therefore aim to reduce input costs to remain competitive. Entities in South Africa are subject to carbon tax and may be subjected to undue competitive disadvantage against entities in countries without a form of carbon pricing. This results in international relocation of carbon-intensive production to countries that do not have a carbon tax levy (South Africa 2010:39). In efforts to avoid adverse effects on competition, various sectors were allocated free carbon emission allowances (South Africa 2010:39). Studies have found varied results on the impact of carbon tax on entity competitiveness.

PMR (2017:14) modelled the impact of South Africa's carbon tax and discovered that the tax had a minor impact on South Africa's trading position, with a small increase in the compound annual growth rate of exports from 4% to 4.2% between 2014 and 2035, resulting in a 3.5% increase in exports by the year 2035 compared to the baseline scenario. Flues and Van Dender (2020:43) exert that the carbon prices either have a minor impact on competitiveness of entities, or improve their competitiveness. Modiba (2019:142) found carbon tax with 90% free emissions allowances had the potential to cause adverse effects on the profitability of mining entities in South Africa.

2.5.6.4. Border adjustments

Border tax adjustments based on CO_2 entail taxing imports at the same rate as domestically produced products and services based on the production associated emissions (South Africa 2010:41). Imports are subject to a levy equal to the carbon price imposed on a comparable domestic good. This eliminates the competitive advantage of goods and services imported from countries without a carbon tax and enables local goods to compete at the same fiscal level. Border tax adjustments addresses carbon leakage, where a taxing on country's emissions decline which increases the neighbouring countries' emissions (South Africa 2010:41). The tax border adjustment would ensure that the neighbouring countries also undertake decarbonisation efforts to reduce or eliminate the imposition of carbon tax on goods exported to South Africa (South Africa 2010:41).

2.5.6.5. Transition Support

Transitionary support measures include substantial tax-free allowances and a phased-in approach to minimise the adverse effects on competitiveness (South Africa 2018:4; South Africa 2013b:46). To mitigate the policy's impact, tax incentives and revenue recycling mechanisms will be implemented in the first phase. The carbon tax will have no impact on electricity pricing, reducing adverse effects of increased costs for energy-intensive industries like mining (South Africa 2018:4). Tax credits embedded into electricity rates would be used to avoid electricity prices in the first phase of the carbon tax (South Africa 2018:4).

2.5.6.6. Carbon Tax Act tax liability implications

South Africa's climate change mitigation strategy included the introduction of the Carbon Tax Act (South Africa 2020:2). The carbon tax rate was introduced at ZAR 120 per tonne of CO_2 equivalent of the GHG emissions of a taxpayer. The carbon tax is levied on direct emissions from fuel combustion, fugitive emissions, and industrial process emissions as per the following formula:

X **= < {[(E – S) x (1 – C)]- [D x (1-M)]} + {P x (1 – J)} + {F x (1 – K)}> x**

- X- represents the amount to be determined that must not be less than zero.
- E- represents the total fuel combustion-related greenhouse gas emissions expressed as a CO_2 equivalent.
- S- represents the sequestrated emissions certified by the Department of Environmental Affairs.
- C- represents the aggregate sections 7,10,11,12and13 allowable emissions allowances that vary per industry.
- D- petrol and diesel emissions expressed as a CO_2 equivalent.
- M- represents the aggregate sections 7,12, and 13 allowable emissions allowances that vary per industry.
- P- represents total industrial process-related greenhouse gas emissions expressed as a CO_2 equivalent.
- J- represents the aggregate sections 8,10, 11,12, and 13 allowable emissions allowances that vary per industry.
- F- represents total fugitive greenhouse gas emissions expressed as a CO_2 equivalent.
- K- represents the aggregate sections 7,9,10,11,12, and 13 allowable emissions allowances that vary per industry.
- R – represents the tax rate of ZAR 120 (2019 rate) per tonne of CO_2.

Table 2-2 illustrates the specific allowable emissions for a mine that is referred to in the above carbon tax formula.

Table 2-2: Carbon mission allowances

Carbon Tax Act	**Allowance**	**Mining sector emission allowances**
Section 7	Fossil fuel combustion	60%
Section 8	Industrial process emissions	0
Section 9	Fugitive emissions	0
Section 10	Trade exposure	10%
Section 11	Performance allowance	5%
Section 12	Carbon budget allowance	5%
Section 13	Offset allowance	10%
Total Allowances *		90%

*The emissions allowances are subject to section 14 of the Carbon Tax Act that limit the allowances with an aggregate of 100% to 95%. This limitation is not applicable to the mining sector, with aggregate allowances of only 90%.

Source: own compilation based on the Second Schedule of the Carbon Tax Act.

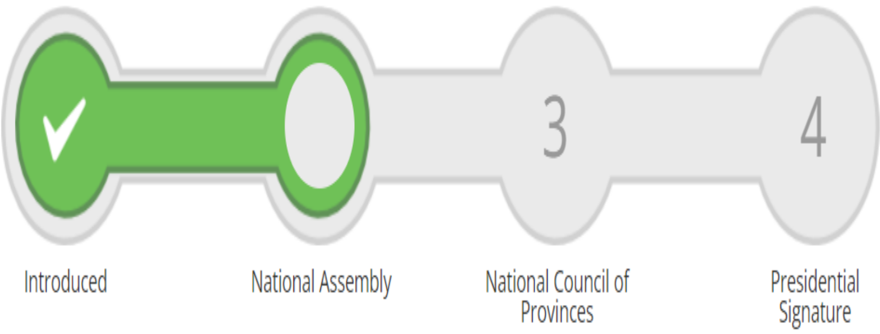
2.5.6.7. Proposed changes to the carbon tax regime

Effective from 1 January 2023, the carbon tax rate was proposed to be ZAR 159 (USD 8.37[13]) per tonne of CO_2 equivalent (South Africa 2023:53). The first phase of the carbon tax regime initially planned to end on 31 December 2022, was extended by three years to 31 December 2025 (South Africa 2022:47). The first phase support mechanisms and incentives will be extended to 31 December 2025 (South Africa 2022:48). There is uncertainty about the carbon pricing policy trajectory in the second phase, beginning January 2026 (Minerals Council South Africa 2022:5) due to the limited communication about the carbon policy direction. There is some expectation that Scope 2 emissions will also form part of the tax base (Minerals Council South Africa 2022:5) and that the removal of the relief measure added to avoid electricity costs increases from carbon tax. This would result in South African mining entities paying more in carbon prices and electricity costs should they not decarbonise their operations. Increased operating costs would also result in lower profits and possible losses, depending on the magnitude of carbon tax rate charged.

Mandatory carbon budgeting was scheduled to become effective January 2023, ending the current voluntary carbon budgeting system, which provided entities with a 5% tax-free allowance for subscribing to the system (South Africa 2022:48; South Africa 2021:8). It has been proposed that emission exceeding the mandatory budget attract a higher carbon tax of ZAR 640 (USD 33.68[14]) per tonne CO_2 equivalent (South Africa 2022:48). The climate change bill will legislate the carbon budgeting system (South Africa 2021:11). The climate change bill as depicted in Figure 2-2, is currently with the National Assembly, which is conducting public participations hearings on the matter, and once signed into law will mandate prescribed entity participation in the carbon budgeting system.

[13] Translated at ZAR 19 to USD 1.
[14] Translated at ZAR 19 to USD 1.

Figure 2-2: Status of Climate Bill in South Africa



Under consideration by the National Assembly.

Bill history

NATIONAL ASSEMBLY

Minister of Forestry, Fisheries and the Environment

18 February 2022	Bill introduced by Minister of Forestry, Fisheries and the Environment

Forestry, Fisheries and the Environment

11 March 2022	Climate Change Bill: Minister & DFFE briefing; SAWS & SANParks Quarter 1 and 2 2021/22 Performance
13 May 2022	Climate Change Bill: Workshop, with Minister
07 September 2022	**Climate Change Bill: public hearings; National Resource Management and Working on Fire Programme: DFFE briefing; Deputy Minister** public participation
20 September 2022	**Climate Change Bill: public hearings** public participation
28 October 2022	**Climate Change Bill: public hearings; COP 27 prep** public participation
09 May 2023	**Climate Change Bill: public hearings** public participation
16 May 2023	**Climate Change Bill: public hearings** public participation

Source: Parliamentary monitoring group (n.d.)

2.5.6.8. *Mandatory carbon budgeting design considerations*

South Africa (2021:11) proposes that mandatory carbon budgets on Scope 1 emissions apply to the following emission sources:

- stationary combustion;
- civil aviation;
- domestic navigation;
- fugitive emissions; and
- industrial processes and product use.

All other Scope 1 emission sources will fall under voluntary carbon budgets and if elected will form part of the carbon budgeting accounting system of the country (South Africa 2021:11). Scope 2 and 3 emissions can voluntarily be elected to form part of the carbon budgeting system, however, will not form part of the overall carbon budgeting system of the country (South Africa 2021:11). South Africa (2021:11) proposed that mandatory carbon budgets be allocated at the company level, tailored to a particular activity being undertaken. Where multiple companies in a similar industry are performing the same activities, a sectoral threshold of 30 kilo tonnes (kt) per annum CO_2 threshold may apply. The overarching intention of the carbon budgets is to regulate emissions for activities and for companies to report on mitigation strategies that will reduce emissions for their business processes in South Africa (2021:8-11).

The proposed mandatory budgets change the South Africa environmental policy from market-based instruments, into a combination of market-based and command and control instruments. The higher carbon tax charge amounts to penalties discharged where emissions exceed prescribed limits under regulatory instruments. Command and control instruments are effective environmental regulations to mandate pollution reduction regardless of the cost of pollution abatement (Gupta 2020:5).

2.5.6.9. Carbon pricing policy impediments

Evaluation of South Africa's carbon pricing policy has identified the policy impediments that limit the ability to encourage investment in decarbonisation technologies. Insufficient carbon tax rates, excessive free emission allowances, and continued support of fossil fuels constitute impediments identified in the South African carbon pricing regime.

2.5.6.9.1. Insufficient rate

Carbon tax is a form of Pigouvian tax, internalising the external cost by requiring polluters to pay for CO_2 equivalent emitted in the atmosphere (Ball 2018:134). The OECD (2010:98) asserts in this regard that a well-designed Pigouvian tax equates the cost of pollution to the cost abating the pollution. In December 2017, 59 commentators to the Second Draft Carbon Tax Bill argued that the recommended tax rate of ZAR120 is insufficient and ineffective to persuade entities in reducing emission levels (Nong 2020:2). Nong (2020:1) evaluated South Africa carbon price and found that at R120 (USD 6.32),[15] it would only result in emission reduction levels by 12.25% to 15.6%, which comes in below the Paris Agreement targets. It is argued that such carbon prices are too low to have a substantial impact on the country's emission levels, economy, and the economic transformation (Winkler & Marquard, 2019).

Many scholars have argued that low carbon tax rates have resulted in the ineffectiveness of the policy instrument to mitigate climate change (Baranzini et al 2017:12; Boyce 2018:54; Haites 2018:961; Rosenbloom et al 2020:8665;). Rosenbloom et al (2020:8665) asserts that two-thirds of the existing carbon prices are below USD 20 (ZAR 380[16]) per carbon tonne equivalent of CO_2, and that, at these prices, this is ineffective in encouraging the decarbonisation of operations. South Africa's carbon price of ZAR 134[17] (USD 7.05)[18] is lower than USD 20 and based on the argument of Rosenbloom et al, set too low to effect significant decarbonisation of carbon-intensive operations. This argument may hold true for

[15] Translated at ZAR 19 to USD 1,
[16] Ibid.
[17] Price effective 1 January 2021 to 31 December 2021
[18] Translated at ZAR 19 to USD 1.

South Africa, which introduced carbon tax in 2019, yet has since experienced an increase of 8.4 million tonnes of CO_2 emissions in that year (BP 2020:13). Carbon dioxide emissions stem from consumption of oil, gas, and coal for combustion-related activities (BP 2020:13). This increase in CO_2 emissions may signal an ineffective carbon price, where the continued increase in emissions will further exacerbate climate change.

South Africa's discussion paper on a carbon tax intended to introduce carbon tax rate of ZAR 75 (USD 3.95[19]) per tonne of CO_2, with progressive increases up to ZAR 200 (USD 10.52[20]) per tonne CO_2 (at 2005 prices) (South Africa 2010:55). The assumption in this regard was that these prices would be sufficient to effect the behavioural changes necessary to reach emissions-reduction targets and encourage the adoption of renewable energy technologies (South Africa 2010:55). In the year 2021, values applying compounded inflation of 140.7%[21] (Crause n.d.), equates to a carbon tax of ZAR 481.36 (USD 25.33).[22] World Bank (2017b:50) suggests that to achieve the Paris agreement emission reduction targets by 2030, requires higher carbon prices ranging from between USD 40 to 80 in 2020 and USD 50 to 100 thereafter. Scholars concur that higher carbon prices are required to limit temperature rise below 2°C above the level pre-dating the first industrial revolution (Tvinnereim & Mehling 2018:185; VanderWolk 2021:4). Tvinnereim and Mehling (2018:185) added that carbon pricing alone will not result in the attainment of Paris agreement goals; deep decarbonization will require a policy mix of climate mitigating strategies.

South Africa's carbon price of ZAR 134 (USD 7.05[23]) per tonne of CO_2, coupled with aggregate tax-free emission allowances of 90% in the mining sector, renders the effective price per tonne of CO_2 of ZAR13.40 (USD 0.71).[24] This price is significantly lower than the estimated ZAR 481.36 (USD 25.33),[25] at which it is estimated a behavioural change would be affected. It can therefore be deduced that the current carbon pricing policy is ineffective in influencing any real change in behaviour towards low carbon operations. Boyce (2018:53)

[19] Translated at ZAR 19 to USD 1.
[20] Translated at ZAR 19 to USD 1.
[21] Compounded inflation for period between 1 January 2005 to 30 April 2021, with an average yearly Consumer Price Index (CPI) 5.6% increase derived from Crause inflation calculator.
[22] Translated at ZAR 19 to USD 1.
[23] Ibid.
[24] Ibid.
[25] Ibid.

states that, for entities to be incentivised to transition to green technologies, the investment cost of green technologies must be lower than the carbon price. A price that discourages investment in green technologies further exacerbates climate change complexities, as polluters would just pay a minimal price to continue polluting.

South Africa (2022:49) proposed a gradual increase of the carbon price by at least USD 1 (ZAR 19) each year until it reaches USD 20 (ZAR 380) per tonne of CO_2 equivalent by 2026. The government plans more substantial carbon price increases in the second phase to USD 30 (ZAR 570[26]) by 2030. Significantly higher carbon prices are proposed thereafter, up to a price of USD 120 (ZAR 2 280) by 2050. These proposed increases are aligned with international standards, with the World Bank's High-Level Commission recommending carbon prices ranging between USD 40 (ZAR 760)[27] to USD 80 (ZAR 1 520)[28] per tonne by 2025, and USD 50 (ZAR 920), to USD 100 (ZAR 1 900), by 2030 (South Africa 2022:49).

2.5.6.9.2. Allowances to exempt emissions from carbon tax.

Baranzini et al (2017:12) found that carbon tax and emission trading schemes to be ineffective due to the generous tax-free emission allowances. Van Heerden et al (2016:728) assert that for South Africa to achieve their ambitious Paris pledge, the generous emissions allowances need to be removed in favour of the current carbon tax system. Van Heerden et al, (2016:726) found that, for South Africa to cumulatively reduce 52.5% from the baseline 2016 by the year 2035, emissions allowances ought to be ceased in the year 2022, where the revenue is recycled through a renewable electricity generation subsidy.

South Africa (2022:49) recommends the reduction of the basic tax-free allowances from 1 January 2026 to 31 December 2030 to enhance the price signals under the carbon tax. From 01 January 2026, the government plans to increase the carbon offset allowance by 5% to promote investment in carbon offset projects. These and additional recommendations will be considered as part of the second phase's examination, which will inform future budget releases (South Africa 2022:49).

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[26] Translated at ZAR 19 to USD 1.
[27] Ibid.
[28] Ibid.

2.5.6.9.3. Fossil Fuel Subsidies

Boyce (2018:54) links the low carbon prices to the vested interests of political influence on the continued use of fossil fuels. Boyce (2018:54) further argues that this influence is evident in the continuation of fossil fuel subsidies, contradicting the objectives of a carbon pricing. South Africa is one such country that continues to, both directly and indirectly, subsidise the production of fossil fuels to the value of 0.7 percent of GDP or 2.4 percent of South Africa's general government revenue (IISD 2019:4). Skovgaard and Van Asselt (2019:9) affirmed that the government’s continued support of fossil fuel subsidies is counterproductive when transitioning to a low-carbon economy. Skovgaard and Van Asselt (2019:9) suggests that these fossil fuel subsidies could be reformed into renewable energy subsidies, however, note that additional research needs to be undertaken to assess the fossil fuel subsidy reform and fit in the low-carbon transition.

2.5.7. Impact of carbon tax on mining in South Africa

Ulrich, Trench and Hagemann (2022:14) evaluated the impact of introducing a carbon tax of USD 50 (ZAR 950) and USD 100 (ZAR 1 900) per CO_2 equivalent on the production costs of a gold mine in South Africa. Ulrich et al (2022:14) found that a USD 50 (ZAR 950)[29] and USD 100 (ZAR1 900)[30] increased production costs by USD137.7 (ZAR 2 616)[31] and USD 275.4 (ZAR 5232)[32] per ounce, respectively. Carbon pricing has a significant negative impact on mining production costs and competitiveness (Ulrich et al 2022:1). Ulrich et al (2022:14) suggests that carbon pricing affects the cost competitiveness of entities in low-emission countries. Countries with carbon low-emission energy have a competitive edge over those that rely on fossil fuels to generate electricity Ulrich et al (2022:14). The mining industry has been identified as an industry that carbon tax has had adverse impacts either production costs or competitiveness (Ulrich et al 2022:1).

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[29] Translated at ZAR 19 to USD 1.
[30] Ibid.
[31] Ibid.
[32] Ibid.

2.6. CONCLUSION

This chapter reviewed the literature as it relates to the environmental policy instruments, and South African carbon tax policy. The review established that the current South African carbon price is ineffective to effect real behavioural change to a low carbon economy. The ineffectiveness has been linked to low carbon tax rates, generous tax-free CO_2 emissions and continued support of fossil fuels production through fossil fuel subsidies.

The introductory South Africa carbon price of ZAR 120 (USD 6.32) was found to be insufficient to aid South Africa in achieving Paris Agreement targets. Nong (2020:1) found that the introductory carbon price of ZAR 120 (USD 6.32) would only result in emission reduction levels of around 12.25% to 15.6%, which is below Paris Agreement targets (Nong 2020:1). The carbon tax rate has since increased from ZAR 120 (USD 6.32) in 2019 to ZAR 159 (USD 8.37) in 2023, per tonne of CO_2 equivalent. The South African carbon price of ZAR 159 (USD 8.37) is significantly lower than the estimated ZAR 481.36 (USD 25.33)[33] rate that would affect the industry's behavioural change. Entities can only be incentivised to transition to green technologies, when the investment cost of green technologies is lower than the carbon price. It can therefore be deduced that the South African carbon price is ineffective in influencing any real change in behaviour towards low carbon operations.

The generous tax-free carbon emission allowances and continued fossil fuel subsidies further reduce the effectiveness of the carbon pricing in South Africa. A mining entity with a voluntary carbon budget can obtain a total tax-free emission allowance of 90%, resulting in an effective price of ZAR 15.90 (USD 0.87) per tonne of CO_2 equivalent in 2022. This further exacerbates the insufficient carbon price problem. South Africa needs to cease tax-free carbon emission allowances in the year 2022 in order to cumulatively reduce 52.5% of emissions from the baseline by the year 2035 (Van Heerden et al 2016:726). South Africa further weakens the carbon pricing policy with the continued subsidies of fossil fuel production. South Africa subsidises the production of fossil fuels to the value of 2.4% of the country's general government revenue (IISD 2019:4). The government's continued support

[33] Translated at ZAR 19 to USD 1.

of fossil fuel through subsidies is counterproductive when transitioning to a low-carbon economy (Skovgaard & Van Asselt 2019:9).

Transitioning to a low-carbon economy has to balance the environmental requirements with the economical impact. The low carbon price and high tax-free emission allowances were measures put in place to cushion the negative impact of introducing a carbon tax (South Africa 2018:4). Based on the proposed tax policy changes the South African government is signalling for higher carbon prices in future. This signalling strategy may persuade entities to start investing in carbon reducing technologies before the carbon tax exceeds the cost of investment in the long-term. Communicating intended future prices reduces the carbon tax price uncertainty, that may lead to investors investing immediately rather than delay until more information is collected where uncertainty existed.

Another proposed change to the carbon pricing policy, is the introduction of mandatory carbon budgets. The Minister of environmental affairs has been entrusted with responsibility of setting mandatory carbon budgets to entities conducting activities releasing the greenhouse gases that exacerbate climate change. The allocation of the carbon budgets should consider socio-economic impact, as well as the best practicable mitigation options available. The climate change bill requires the Minister to quantify these carbon budgets a year after the enactment of the Bill. The climate change Bill was introduced in February 2022 and is currently still under consideration. Findings of limited regulatory oversight, lack of funding for regulatory agencies, and political involvement in extractive activities pose a significant threat to the effectiveness of carbon budgets (Esterhuyse et al 2019:13; Oshionebo 2017:36-37). This threat should be minimised in the final design and quantification of carbon budgets.

Chapter 3 compares international carbon pricing systems, that South Africa can draw lessons from to improve the country’s carbon pricing system.

CHAPTER 3

INTERNATIONAL CARBON PRICING SYSTEMS

3.1. INTRODUCTION

Countries have successfully implemented measures to enhance their carbon pricing systems, which led to reduced CO_2 emissions and thereby offering suitable policies to benchmark. This chapter will review the international carbon pricing to establish countries that are suitable jurisdictions for the comparative selection. A comparative framework will be compiled based on the international and South African pricing systems to draw lessons for the future development or advancement of South Africa’s carbon pricing policies.

This chapter is laid out as follows: Comparative tax research approaches are discussed in section 3.2. Section 3.3 details the rationale used to select countries for the comparative carbon tax analysis. Section 3.4 review the carbon tax regimes in place in the EU, Switzerland, The UK, and Canada. Section 3.5 presents the conclusion to the chapter detailing the lessons for the future advancement of South Africa’s carbon pricing policies.

3.2. COMPARATIVE TAX RESEARCH

Comparative law research is generally conducted through grouping countries into legal families, traditions, and cultures (Duve 2018:15). Thuronyi and Brooks (2016:2) define comparative tax law as the examination of patterns, and differences in tax policies of different counties that address similar problems. Classification into different legal families provides insight to the roots of the legal system in a particular country (Thuronyi and Brooks 2016:20). Even where rules differ, they will be rooted in the same legal heritage and therefore to understand the rules, the legal heritage would first have to be understood (Thuronyi and Brooks 2016:20). Classification into legal families aids in building a methodological framework to compare legal systems (Duve 2018:15). Legal families are beneficial in a comparative study, where a deep understanding to the tax systems is sought (Thuronyi and Brooks 2016:20). Legal family groupings would be beneficial to this study, which aims to obtain deep understanding of international carbon pricing systems, to draw lessons for South Africa’s carbon pricing policy.

Furthermore, lessons need to also be drawn from countries that have advanced their progress on tackling climate change. Despite different legal families, South Africa can extract lessons on how to accelerate their decarbonisation efforts. These fiscal policy instruments can then be adapted for the South African context. The comparative countries in this study were selected based on the combination of legal family and with policies that address the carbon pricing shortcomings identified in Chapter 2.

3.3. SELECTION AND RATIONALE FOR CHOICE OF COUNTRIES

In Chapter 2, it was found that South Africa carbon tax rate is too low for the required decarbonisation, in line with Paris Agreement targets. The first criteria to select countries with a carbon price equal and exceeding USD 40 (ZAR 760) that is in the range of effective carbon prices. This resulted in the selection of the countries listed in Table 3-1:

Table 3-1: Countries with a carbon tax exceeding USD 40

Country	**Price USD Per CO_2 tonne in 2022**
Finland	85
France	49
Ireland	45
Liechtenstein	130
Luxembourg	43
Netherlands	46
Norway	88
Sweden	130
Switzerland	130
Uruguay	137
Canada	40
United Kingdom	103
Canada	40
South Africa	7

Source: World Bank Carbon Pricing Dashboard 2022 (No date).

This criterion was further stratified to select countries with a carbon price exceeding USD 40 (ZAR 760) and by 2021 had reduced their country emissions by at least 20% from both baseline years 1990 and 2005. This resulted in the selection of the countries listed in Table 3-2.

Table 3-2: Countries that reduced emissions by at least 20% in both 1990 and 2005

Country	Year	
	2005	1990
Finland	-33%	-32%
France	-26%	-22%
Liechtenstein	-26%	-22%
Luxembourg	-31%	-28%
Sweden	-31%	-33%
Switzerland	-26%	-22%
United KIngdom	-40%	-43%
South Africa	+2%	+39%

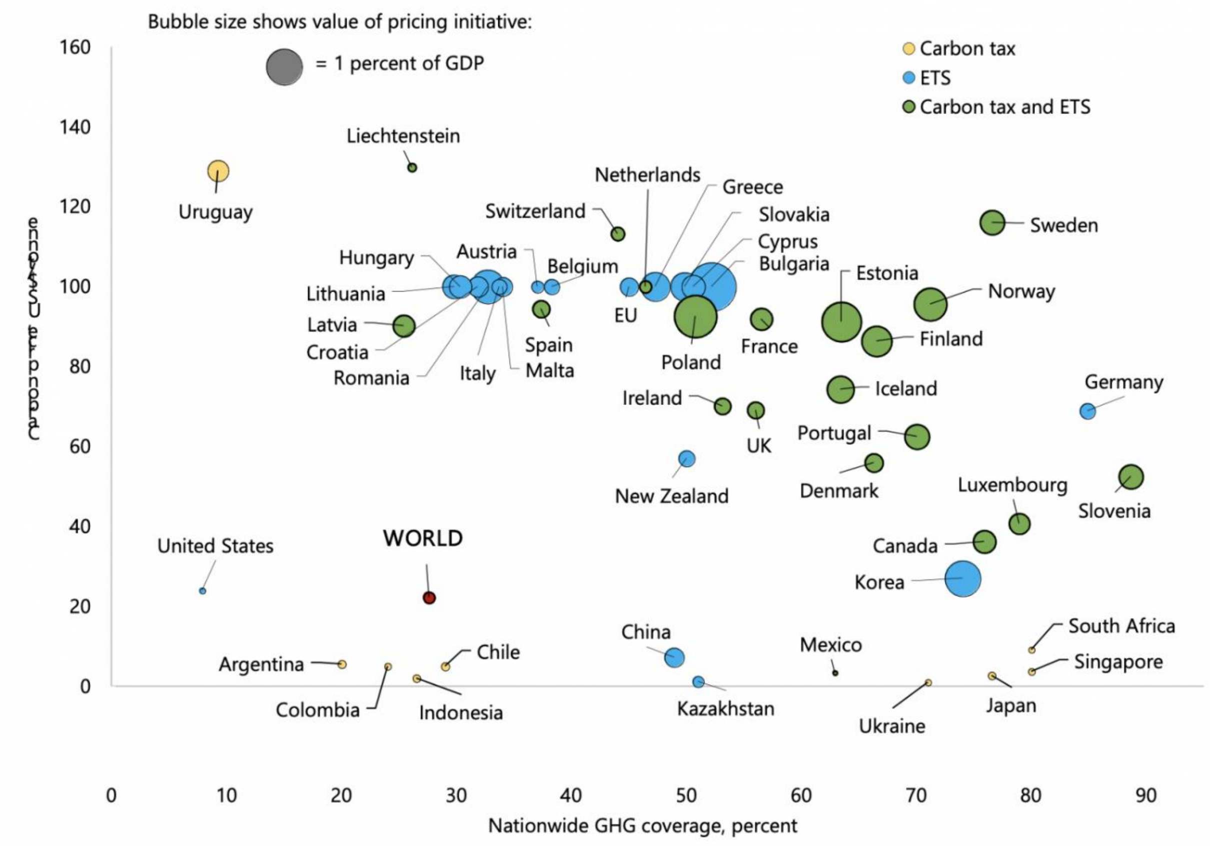
Source: Crippa, Guizzardi, Banja, Solazzo, Muntean, Schaaf E, Pagani, Monforti-Ferrario, Olivier, Quadrelli, Grassi, Rossi, Oom, Branco, San-Miguel & Vignati (2022).

Finland, France, Liechtenstein, and Luxembourg participate in the European Union (EU) ETS that covers the power and energy intensive industries. Their domestic carbon taxes are centred heating fuels and transportation, with insignificant application to the energy-intensive mining industry. Therefore, these countries will be group together under EU ETS to focus on the policy instrument aimed at energy intensive industries. The EU ETS, Switzerland, and the UK have carbon emission trading systems that would not be feasible in South Africa, due to being limited participants in the power and energy intensive industries. The ETS policy instruments are evaluated for design mechanism just prior to trade and the price of each tonne of CO_2 equivalent. The trade aspect can be adapted into a penalty levied that would be more suitable for the South African context. Canada is introduced to draw lessons on how an emissions cap instrument can be designed to have a levy instead of trading among participants, as adopted by the EU ETS.

3.4. REVIEW OF THE CARBON TAX REGIMES OF THE SELECTED COUNTRIES

Globally the adoption of carbon taxes and emissions trading systems (ETS) has gained momentum with countries exploring and implementing various carbon pricing mechanisms. Figure 3-1 highlights international carbon pricing and ETS regimes adopted in 2022 (Parry, Zhunussova & Black 2022).

Figure 3-1: International carbon pricing regimes, 2022



Source: (Parry, Zhunussova & Black, 2022).

3.4.1. European Union Emissions Trading System

The EU ETS commenced in the year 2005 and has been the main climate policy instrument of decarbonising the European Union (Teixidó, Verde & Nicolli 2019:1; Verde, Galdi, Alloisio & Borghesi 2021:302). The EU ETS operates on a cap-and-trade system on CO_2 emissions from energy intensive industries, aircrafts, and electricity-generating operations (Joltreau & Sommerfeld 2019:453; Teixidó et al 2019:1; Verde et al 2021:304). The EU ETS participants must have combustion installations, with a fuel-to-energy conversion capacity of 20 MW to be regulated under the EU ETS (Joltreau & Sommerfeld 2019:453). The entities' GHG emissions are capped for EU ETS participants and allowances are created granting participants to emit prescribed levels of CO_2 equivalent emissions (European Union 2015:16).

Some entities receive free emission allowances to reduce the adverse effects on their competitiveness, and most of the emission allowances are sold on auction or amongst EU ETS participants (European Union 2015:16). The auction price of each tonne of CO_2 ranged between EUR 69.19 (ZAR 1 383.80[34]) and EUR 86.76 (1 735.20) during the period from October to December 2022 (European Energy Exchange 2022:5). The free allowances were allocated to power and industry entities as a total of the allocated emissions to the sectors, as listed in Table 3-3 (European Union 2015:24; Joltreau & Sommerfeld 2019:454).

Table 3-3: EU ETS free emission allowances

Share of free allowances allocated to each sector	**2016**	**2017**	**2018**	**2019**	**2020**
Electricity	0%	0%	0%	0%	0%
Industry sectors	58.60%	51.40%	44.20%	37.10%	30%
Industry sectors with carbon leakage risk	100%	100%	100%	100%	100%

Source: European Commission (2022:12).

Free emission allowances are determined based on performance benchmarks of the top 10% of efficient entities in the industrial sector (European Commission 2022:12). These free emission allowance decline each year to incentivise adoption of decarbonisation measures (European Commission 2022:12; Verde et al 2021:304). The overall cap on the CO_2 emissions also declines yearly to aid in reaching the emission reduction target set (Teixidó et al 2019:1; European Union 2015:16). The goal is to have reduced GHG emissions by 43% from the year 2005 emissions during the 2021 to 2030 period (Teixidó et al 2019:1).

Installation covered under EU ETS reduced emissions by approximately 35% between 2005 and 2021(European Commission n.d.). Entities who emit above their acquired, and free emission allowances must pay a penalty of EUR 100 per tonne of CO_2 equivalent emitted. This rate is higher than the average auctioned emissions price signalling entities to purchase tradeable emissions allowances. This will keep the CO_2 emissions within the total threshold allocated, thereby aligning with the decarbonisation strategy.

[34]Translated at ZAR 20 to EUR 1

3.4.2. Switzerland Carbon Tax Regime

Switzerland aims to halve its emissions by 2030 when compared to the emission levels in 1990 and reach net zero by 2050 (The Federal Council 2021:18). Switzerland has a Federal Act on the Reduction of CO_2 Emissions (CO_2 Act) that regulates climate policy, setting targets, instruments, and implementation responsibilities (The Federal Council 2021:18). The Switzerland climate policies have three instruments to regulate the reduction of greenhouse gasses in the country (Hintermann & Žarković 2021:290). A CO_2 levy, emissions trading system and command and control instrument that incentivise medium sized entities with a subsidy for emitting below the threshold (Hintermann & Žarković 2021:290).

3.4.2.1. Carbon dioxide levy

Article 29 of the Carbon Act levies a carbon tax on the production, extraction, and importation of thermal fuels. Thermal fuels are fossil fuels used in thermal facilities or combined heat and power plants to produce heat, light, and electricity. Coal, natural gas, oil, diesel, and biomass are commonly used as thermal fuels in boilers to produce heat, light, and electricity. The carbon tax levied on thermal fuels is CHF 120 (ZAR 2520[35]) per tonne of CO_2 in the year 2022 (Federal Office for the Environment n.d.). The carbon levy is intended to encourage the reduced use of fossil energy and accelerate the transition to green energy (The Federal Council 2021:18). The accelerated transition to green energy is essential to reach the net-zero target and can be achieved by imposing a higher cost for fossil fuel use in comparison to green energy sources.

3.4.2.2. Swiss ETS

Article 16 of CO_2 Act obligated entities with high GHG emissions to form part of the Swiss ETS. Entities that are GHG intensive with a combustion capacity exceeding 20 MW must participate in the Swiss ETS. Entities with lower than 20 MW combustion levels can opt to voluntarily participate in the Swiss ETS (Galdi, Verde, Alloisio, Borghesi, Füssler, Jamieson, Schäppi, Wimberger, Zhou 2020:49; Hintermann & Žarković 2021:294). Article 17 CO_2 Act

[35] Translated at ZAR21 to CHF 1.

exempt entities participating in the Swiss ETS from the carbon levy, by refunding the carbon levy paid on thermal fuels. Like all other ETS programmes, some carbon emission allowances are granted for free and some are auctioned among the ETS participants. The clearing price per tonne of CO_2 was EUR 86 in March 2023 (Federal Office for the Environment n.d.). The free carbon emission allocation follows similar benchmarks to the EU ETS from the year 2022 (International Carbon Action Partnership n.d.). The Swiss ETS is also linked to the EU ETS, in that participants can use allowances from the EU ETS in the Swiss ETS system and vice versa (Verde et al 2021:31).

3.4.3. Command and control with subsidy

Entities that will have their competitiveness adversely affected by the imposing of the carbon levy may be exempted from paying the CO_2 levy (Hintermann & Žarković 2021:292; The Federal Council 2021:19). The exemption is subject to these entities pledging to the Swiss Confederation on emissions reduction plan (The Federal Council 2021:19). If the reduction targets are approved, then it is formalised to an entity carbon budget (Hintermann & Žarković 2021:293). The carbon levy and emission reduction obligations aim to contribute to a reduction in avoidable emissions from process heat generation (The Federal Council 2021:19). Only emission reduction plans that can recoup the implementation costs through savings over a period of four years are considered (Hintermann & Žarković 2021:293; The Federal Council 2021:19). The period is extended to eight years for the real estate industry measures (The Federal Council 2021:19). Article 320 of the CO_2 Act imposes a penalty of CHF 125 (ZAR 2 625)[36] per tonne of CO_2 equivalent more than reduction obligation emissions. Where entities exceed the reduction plan targets, the surplus emission reduced can be sold for CHF 100 (ZAR 2 100)[37] per tonne of CO_2 equivalent (Hintermann & Žarković 2021:293). It was found that entities subject to emission reduction regulations had greater emission reduction measures than entities paying a carbon levy, with a reduction in emission levels of 11.7% between the years 2012 and 2018 (Hintermann & Žarković 2021:294). These results should, however, be interpreted with caution as some of the carbon emission

[36] Translated at ZAR21 to CHF 1.
[37] Ibid.

reductions were likely to occur in the ordinary course of operation (Hintermann & Žarković 2021:294).

3.4.4. The UK Carbon Pricing Policy

The UK has a legal obligation to meet national GHG emission targets through their domestic legislation the Climate Change Act 2008 (Leroutier 2022:3). Section 4 of the Climate Change Act 2008 mandates the UK government to set carbon budgets of the maximum emissions that can be emitted in UK over a five-year period. Section 5 of the Climate Change Act 2008 further mandates that the carbon budgets be in line with the national targets set. Section 1 of the Climate Change Act 2008 sets a target that the baseline emissions of 1990 must be reduced by 34% by 2020 and 100% by the year 2050. The UK has numerous decarbonisation measures to promote energy efficiency, renewable energy heat incentives, regulations on new car emissions and emissions trading system (United Kingdom 2011:21; United Kingdom 2022:9-11). The carbon pricing policy central to achieving the targets is the emissions trading scheme, supplementary carbon tax and levy on extensive energy use.

The UK subscribed to the EU ETS system until the end of 2020, before establishing their own ETS system. The EU ETS governed emissions from the electricity generation and energy intensive industries in EU member states. The UK introduced a carbon price support system in 2013 to supplement EU ETS rates that were ineffective to affect the desired level of decarbonisation in the electricity generation sector (Abrell, Kosch & Rausch 2022:1; Gugler, Haxhimusa & Liebensteiner 2023:2; Leroutier 2022:1; Richardson-Barlow, Pimm, Taylor & Gale 2022:6). The EU ETS rates were very low, at a price of GBP5 (ZAR 120[38]) per tonne of CO_2 in 2013 prior to the introduction of carbon price support (Richardson-Barlow et al 2022:6). The carbon price support would be levied at the desired carbon price less than the EU ETS carbon price (Leroutier 2022:1). The carbon price support increase from GBP5 (ZAR120) per tonne of CO_2 in 2013 to GBP 17 (ZAR 408[39]) per tonne of CO_2 in 2017 (Leroutier 2022:1).

[38] Translated at ZAR24 to GBP 1.
[39] Ibid.

The introduction of the carbon price support has been instrumental in decarbonising the UK power sector (Leroutier 2022:1; Richardson-Barlow et al 2022:6). Electricity generation from coal declined from 40% to 7% and electricity generation GHG emissions declined by 57%, respectively (Leroutier 2022:1). Gugler et al (2023: 1) presented findings that the introduction of the carbon price support decreased CO_2 emissions in the UK power industry. Gugler et al (2023: 1) estimated that the introduction of the carbon price support and related price increases between year 2014 and 2015 reduced electricity-related CO_2 emissions by 26% within the three years.

Post Brexit, the UK introduced its own form of ETS system like the EU ETS in 2021 (Barnes 2021:19; Richardson-Barlow et al 2022:6). Energy intensive industries and power generating entities with a thermal input exceeding 20 MW must comply with the United Kingdom emission trading systems (UK ETS) (Barnes 2021:19; Richardson-Barlow et al 2022:6 2022:6). Emission credits are both auctioned and allocated freely to some industries (Abdul-Salam, Kemp & Phimister 2022:2). Carbon pricing negatively affects competitiveness of entities as it increases the product cost of goods. Competitor entities that do not have similar carbon pricing measures imposed on them have lower costs, increasing their competitiveness in a market. In response to reduced competitive edge of some industries in the international market, free emission allowances are granted to the industries to reduce the negative effects carbon pricing has on their competitiveness (Richardson-Barlow et al 2022:6; Abdul-Salam et al 2022:2). Free emissions are also granted to industries due to the perceived highest risk of relocating investment and production to jurisdictions without carbon pricing policies (Abdul-Salam et al 2022:2).

The first auction in 2021 retailed at GBP 44 (ZAR 1 056[40]) per tonne CO_2 emission (Richardson-Barlow et al, 2022:6). The carbon price for the year beginning 1 January 2023 is reported to be GBP 83.03 (ZAR 1 992.72) (Government UK 2022). The UK also imposes a climate change levy to non-domestic users of electricity, gas, and solid fuels (Barnes 2021:19). Energy intensive entities would have pledged to reduce energy use through the Climate Change Agreement with the government can pay a reduced climate change levy.

[40] Translated at ZAR24 to GBP 1.

The discount rates range between 77% to 92% depending on the fossil fuel used to generate electricity as listed in Table 3-4.

Table 3-4: Electricity discounts in the UK

	2020	2021	2022	2023
Electricity per kilowatt	GBP 0.00811	GBP 0.00775	GBP 0.00775	GBP 0.00775
Gas per kilowatt	GBP 0.00406	GBP 0.00465	GBP 0.00568	GBP 0.00672
Liquefied petroleum gas per kilogram	GBP 0.02175	GBP 0.02175	GBP 0.02175	GBP 0.02175
Other taxable commodities per kilogram	GBP 0.03174	GBP 0.0364	GBP 0.04449	GBP 0.05258

Source: Government UK B (n.d.).

3.4.5. Canada Carbon Tax Regime

Prior to introducing a national carbon tax in 2019, provinces and territories in Canada were not mandated to implement carbon policies. Only four provinces, accounting for 80% of greenhouse gas emissions, had implemented a carbon pricing scheme before the implementation of the national carbon tax (Gilder & Stiles 2019:271-272). In 2019, Canada introduced a national carbon tax system, for provinces and territories that did not implement a carbon pricing system, or their carbon pricing policies fell short of the national carbon tax requirements (Gilder & Stiles 2019:271 & 273; Lin & Bui 2019:1, Kiss & Popovics 2021:8). The introduction of a national carbon tax policy was in recognition of the challenge of meeting the NDC targets without assistance from all the provinces and territories (Gilder & Stiles 2019:271 & 273; Lin & Bui 2019:1).

This national carbon pricing system was met with some criticism from the public over the socio-economic costs, political feasibility, and constitutional authority of imposing such a scheme (Lin & Bui 2019:1). The constitution in Canada prevents the national government from directly regulating energy resources of provinces and territories (Gilder & Stiles 2019:273). Provincial and federal governments have power over the environment and taxation; however, provinces own the natural resources and regulate the use with their borders whereas the federal government regulates across the province and international movement of goods (Criqui, Jaccard & Sterner 2019:10). A compromise to the overlap in federal and provincial legislative requirements was determined to suspend national carbon if the provinces implemented their own systems. The carbon policies in the provinces would need to be sufficient in order to reduce their proportional share of CO_2 emissions to be exempt from applying the federal carbon tax systems (Gilder & Stiles 2019:273).

Carbon pricing is the key strategy to achieve the federal government's plan to reduce GHG emissions by 30% below 2005 levels (Lin & Bui 2019:2). In 2019, the federal government introduced a carbon tax on fossil fuels of CAD10 (USD13, ZAR110) per tonne of CO_2 applicable to provinces and territories that do not have programmes that achieve as a minimum the federal carbon tax (Geroe 2019:8; Environment and Climate Change Canada 2017:6; Gilder and Stiles 2019:274). The carbon tax would rise to CAD30 (USD 23, ZAR 330) per tonne of CO_2 in 2020 and CAD 50 (USD 40, ZAR 550) per tonne of CO_2 in 2022 (Geroe 2019:8; Environment and Climate Change Canada 2017:6; Gilder and Stiles 2019:274). Provinces and territories not meeting the federal carbon pricing threshold are required to adopt the backstop carbon levy (Geroe 2019:8; Lin and Bui 2019:3). The backstop has two aspects a point-of-sale carbon levy on fossil fuels used and an output-based pricing system for industries that emit above the prescribed threshold (Gilder and Stiles 2019:274; Geroe 2019:8; Environment and Climate Change Canada 2017:5). Smaller facilities with emission below the threshold can voluntarily opt into the backstop (Gilder & Stiles 2019:274; Environment and Climate Change Canada 2017:5).

A carbon levy is imposed on all fossil fuels used in a jurisdiction (Environment and Climate Change Canada 2017:7). All fossil fuels used in a jurisdiction include both imported or fuel produced in a jurisdiction subject to the backstop carbon levy. The following fuels are exempt from the backstop carbon levy (Environment and Climate Change Canada 2017:12):

a) fuel used at a facility whose CO_2 emissions are accounted for under the output-based pricing system;
b) gasoline and diesel fuel used by registered farmers in certain farming activities;
c) fuel exported or removed from a backstop jurisdiction;
d) fuel used as international ships' stores, and in certain circumstances; and
e) fuel used in the manufacturing and petrochemical process in a manner that does not release heat.

The out-put based standard aspect prescribes the emissions intensity for products and operational activities (Environment and Climate Change Canada 2017:18). The out-put based system applies to industrial facilities emitting equal or more than 50 kilo tonnes (kt) CO_2 equivalent per year (Environment and Climate Change Canada 2017:17). The prescribed standards are based on the top performer in the activity of product type category to facilitate reduced emission intensity (Environment and Climate Change Canada 2017:18). A surplus credit is issued for every carbon emission below the prescribed threshold, that can be used to offset CO_2 emissions in the years an entity exceeds the threshold. Where entities exceed allocated emissions there can pay the carbon federal levy, offset emissions with either carbon offsets, or surplus credits to comply with environmental requirements (Environment and Climate Change Canada 2017:19).

These options allow for flexibility in achieving lower compliance cost for an entity's operation. Allowing the use of carbon offsets will extend the carbon price signal to all economic sectors not yet subject to direct carbon pricing and allowing the use of surplus credits will incentivise regulated facilities to reduce their emissions intensity as much as possible, regardless of the emissions-intensity standards that are applicable to them (Environment and Climate Change Canada 2017:19). Canada's total GHG emissions reduced by 8.9% from 738 to 672 mega tonnes of CO_2 emissions equivalent over the 2019 and 2020 period (Environment and Climate Change Canada 2022:5).

3.5. CONCLUSION

This comparative analysis provided key lessons that can be incorporated into the South African carbon pricing policy. The overarching principle in all the carbon pricing models is there needs to be emissions caps for power generation and energy intensive industries. The emissions cap needs to be determined in collaboration with scientific experts and in line with the emission reduction pledges made. Mining industries are prone to carbon leakage and policies need to cushion against the adverse effects carbon pricing has on the competitiveness. South Africa provides approximately a 90% free emission allowances on the actual emission levels, whereas the comparative countries assign pre-determined level of emissions. There pre-determined free carbon emission allocations are fixed and when an entity needs to emit more, they must purchase addition emission credits. This ensures that the overall cap on CO_2 emissions is maintained, and that there is control over overall country emissions levels. The emission levels are also reduced every year to ensure that the carbon emission levels remain in the emission reduction trajectory.

In stances where the decarbonisation was not in line with targets, an additional levy was added to ETS prices to accelerate the decarbonisation in the UK power generation sector. The UK further adds an additional electricity levy to non-domestic electricity usage. The further levy on fossil fuel generated electricity aims to incentivise the transition to renewable energy options. If these measures are implemented in South Africa, the additional levy for emissions from power generation would increase electricity costs. Increased electricity costs may persuade mines to use renewable energy, however, will have an adverse effect on South African households. An additional levy on non-domestic use of electricity may be a more suitable option to persuade mining in South Africa to adopt renewable energy and avoid adverse impacts on households in South Africa. This can also be a measure of introducing a carbon tax on scope two emissions arising from the use of fossil fuel generated electricity.

Another aspect that South Africa can explore is the introduction of subsidies payable to entities that have exceeded prescribed carbon emission targets. The subsidy can encourage accelerated decarbonising measures as it can be used to partly fund decarbonisation technologies. The subsidy can alleviate funding pressures of investing in decarbonising technologies. The subsidy and carbon price levels that would incentivise investment in decarbonising technologies would need to be modelled for the South African context. These measures can be integrated into the current revenue collection system and would therefore comply with the need for ease of administration.

Tax policy certainty is crucial for investment decisions. The timing and the amounts can directly impact whether entities invest in decarbonising technologies. The comparative countries communicate emission targets and the limit trajectory five years in advance. The longer-term view of the policy trajectory results in efficient decision-making, rather than waiting it out where there is uncertainty of the policy. The second phase of the South African carbon pricing system uncertainties detailed in Chapter 2, that can be improved by providing policy direction. Clearer policy direction can result in efficient investment decision-making in carbon reducing technologies.

Chapter 4 reviews a range of technological options that exist to decarbonise the South African mining sector.

CHAPTER 4

CARBON DIOXIDE MITIGATING TECHNOLOGIES

4.1. INTRODUCTION

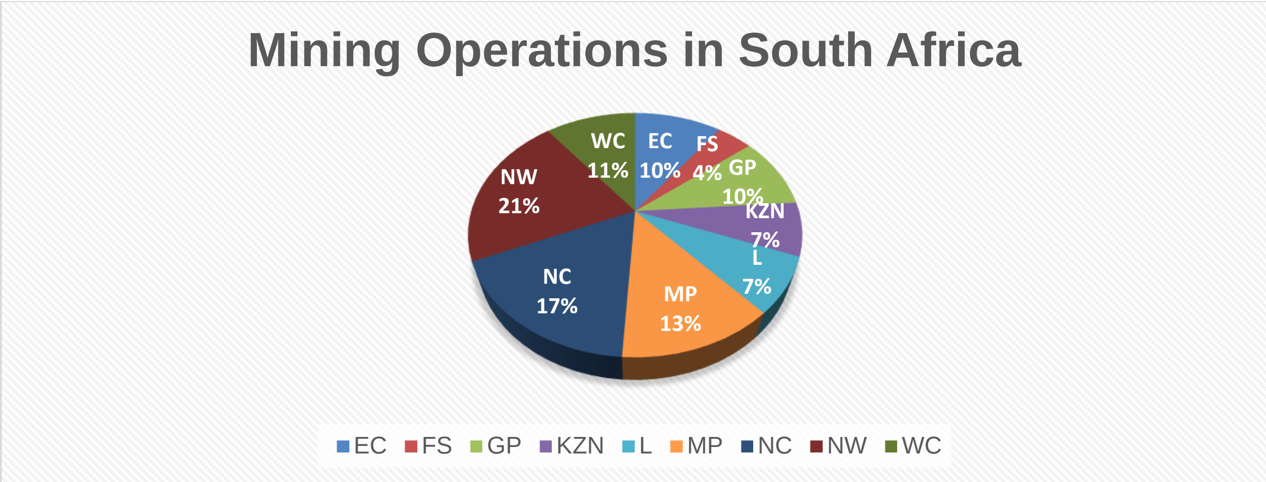
A range of technological options exist in the mining sector for decarbonisation. Mining entities can implement energy efficiency technologies, renewable energy and carbon capture and storage to decarbonise their operations. Integrating renewable energy options into mining operations require critical consideration on the availability of renewable energy generation capacity. This chapter describes CO_2 emissions mitigating technologies available to the mining sector of South Africa and the related costs thereof. The most viable CO_2 emissions mitigating technology is selected for the investment decision analysis in Chapter 6.

This chapter is laid out as follows: South African mining landscape is discussed in section 4.2. Section 4.3 Identifies the technologies available to decarbonise the mining of South Africa. Section 4.4 presents the conclusion to the chapter detailing the most feasible decarbonising technology option that can be currently integrated into mining operations.

4.2. THE SOUTH AFRICAN MINING LANDSCAPE

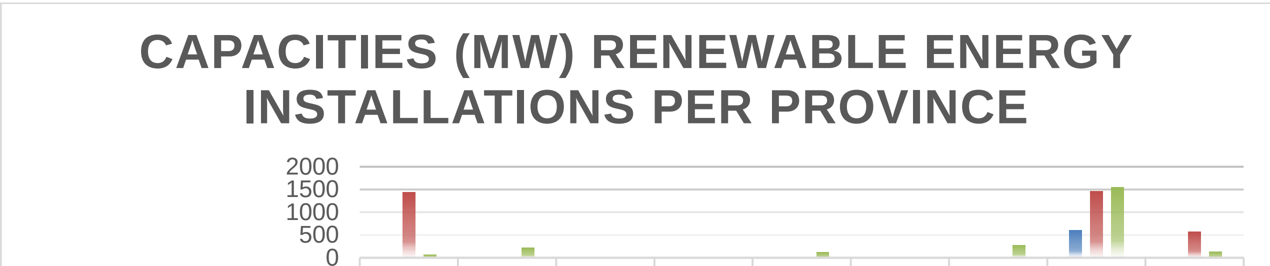
Zharan and Bongaerts (2017:162) state that mining operations around the world began to integrate renewable energy in their operations as a sustainable mining and cost reduction measure. The locations of mines inform the type of renewable energy that can be integrated in mining operations based on the availability in the area. The main mining activity is situated in non-coastal areas. Coastal areas have been found to have significant wind energy potential, with more significant wind energy potential found in Eastern and Western Cape (Akinbami, Oke & Bodunrin 2021:5084). Mining entities in the coastal areas can exploit the abundance of the resource to integrate in their operations. Currently, as depicted in Table 4-1, wind energy adoption is in the Eastern, Northern, and Western Cape. The location for 55% of mines, as depicted in Figure 4-1, is in non-coastal areas which may not be suitable for wind energy integration to the mining operations.

Figure 4-1: Mining operations by province



Source: Author's compilation from Department of Mineral Resources and Energy data (A).

Table 4-1: Renewable energy adoption by province



	Eastern Cape	Free State	Gauteng	Kwazulu Natal	Limpopo	Mpumalanga	North West	Northern Cape	Western Cape
Concentrated Solar Power								600	
Onshore Wind Power	1 440							1 459	567
Photovoltaic Power	70	219			118		280	1 551	134

Concentrated Solar Power   Onshore Wind Power   Photovoltaic Power

Source: Author's compilation from Department of Mineral Resources and Energy data (B).

4.3. TECHNOLOGIES AVAILABLE TO MITIGATE CO_2 EMISSIONS IN MINES

Igogo, Awuah-Offei, Newman, Lowder and Engel-Cox (2021:1) assert that mining entities could complement, replace, or lessen the effects of using fossil fuels by using energy efficiency, renewable energy, and carbon capture utilization and storage. Substantial reduction of fossil fuels use, the world require the combined use of renewable energy sources and carbon capture utilization and storage (Igogo et al 2021:1). Oyewo, Aghahosseini, Ram, Lohrmann, and Breyer (2019:563) discovered empirical evidence that a 100% renewable energy integration is the most cost-efficient, least GHG emissions and optimal job stimulating option for the South African energy system by 2050. Naicker and Thopil (2019:637) evaluated renewable technology options in South Africa based on technological feasibility and found solar photovoltaic (PV) and wind technology to be favourable options due to the technological advancements. Votteler and Brent (2016:21) further found PV, onshore wind, and geothermal technologies to be viable renewable technology solutions that can be integrated into mining operations, in declining order of suitability. Investors predominantly support PV and wind technologies, due to technological advancements, financing support and lower risk associated with the technologies (Naicker and Thopil 2019: 647). Solar PV appears to be the most supported renewable energy technology, with 91% of global renewable technology integration (Votteler and Brent 2016:8).

Renewable technology integration is not without its challenges. Mining operations use a substantial amount of electricity on a consistent basis, which makes incorporating fluctuating renewable energy challenging (Igogo et al 2021:8, Votteler and Brent 2016:1). The intermittent supply of electricity from Solar PV and wind would require hybrid use with current sources of electricity (Votteler and Brent 2016:21). Mines frequently utilise hybrid systems to mitigate unpredictability in energy supply, with systems powered by on-site diesel generators (Igogo et al 2021:8). The use of diesel fossil fuel in a support capacity would also contribute to the emission of GHG. However, this would be to a lesser extent than when the mining operations are fully powered by fossil fuel generated electricity, lessening the advancement of climate change.

There is an opportunity for mining operations in South Africa to integrate renewable energy to contribute to their long-term profitability. This amid uncertain previous and anticipated future economic conditions of uncertain electrical supply and continued above inflation increases of electricity (Votteler and Brent 2016:21). The integration of renewable energy sources creates a triple dividend for mining operations by increasing independence from unreliable electricity supply, lowering electricity costs, and lower CO_2 emissions (Votteler and Brent 2016:21). Amid these electricity supply risks, mining entities have begun to increase their investment in renewable energy to generate 5116 MW from the existing National Energy Regulator of South Africa registered 295 MW (Minerals Council South

Africa 2022). This is done to safeguard against productivity loss incurred during load shedding, which threatens the sustainability of mining operations (South Africa 2023:23) Energy efficiency is integral to climate change mitigation strategies over the short and medium term (Katta et al 2020:1; Sugiyama et al 2014:397). Due to the varied technology options a mining entity can implement in the varied resource production processes, energy efficient technologies will not be evaluated in this study. Focus will instead be placed on renewable energy options that can be integrated in any mining operation.

4.3.1. Renewable energy

4.3.1.1. Solar energy

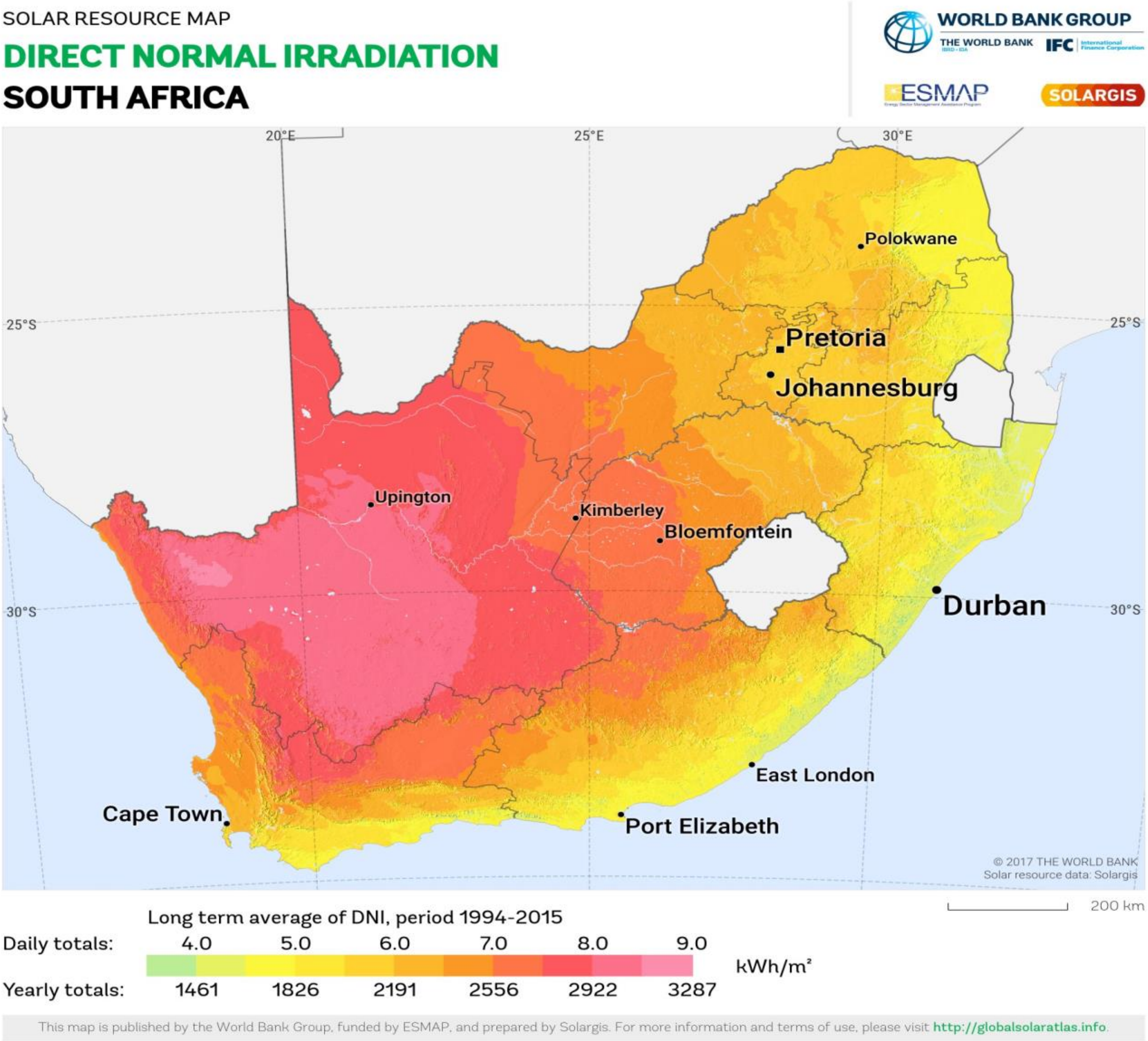
Solar energy can be used to generate electricity. The use of solar energy to generate electricity can be done directly through the use of PV cells or indirectly through concentrated solar power (CSP) technology (Ahmadi, Ghazvini, Sadeghzadeh, Alhuyi Nazari, Kumar, Naeimi & Ming 2018:340; Hayat, Ali, Monyake, Alagha & Ahmed 2019:1049; Kumar, Hasanuzzaman & Rahim 2019:889; Mutombo & Numbi 2019:876; Shahabuddin, Alim, Alam, Mofijur, Ahmed & Perkins 2021:1). PV cells are devices used to directly convert energy of the sun directly into usable electricity through the photoelectric effect (Akinbami, et al 2021:5086). The photoelectric effect occurs when light shines on PV cells causing the movement of electrodes in the cells that generates electric voltage (Hayat et al 2019:1049; Akinbamiet al 2021:5086). Solar photovoltaic power has a poor degree of conversion efficiency; studies show that about 15% to 20% of solar radiations is converted into electricity, depending on the PV technology (Kumar et al 2019:889; Nasrin, Hasanuzzaman & Rahim 2018:1115). This inefficiency led to the development of concentrated photovoltaics or CSP as more efficient solar alternatives to solar PV technology (Felsberger, Buchroithner, Gerl & Wegleiter 2020:1).

CSP technology utilises mirrors and lenses to collect the warmth of the sun’s rays through collectors to heat high temperature transfer fluid that heats the water supply system. The heated water supply system then produces steam that is transferred to a turbine or steam generator to produce electricity (Ahmandi et al 2018:341; Felsberger, Buchroithner, Gerl & Wegleiter 2020:1; Hayat et al 2019:1045; Shahabuddin et al 2021:1). CSP technology can generate electricity in the absence of the sun by integrating energy storage systems to store extra thermal energy to be used in periods of sunlight unavailability (Ahmandi et al 2018:341). Ahmandi et al (2018:341) state that the ability to generate electricity when there is no sun constitutes the main advantage of CSP technology over other solar power technologies. Concentrated solar power has also been found to achieve more efficient conversion of the sun's rays to energy of 42.1% (Felsberger et al 2020:1), in comparison to the solar PV conversion rate of 15% to 20% (Kumar et al 2019:889).

4.3.1.2. Availability in South Africa

The abundance of solar power makes it is the most viable renewable energy source (Adenle 2020:1; Shahabuddin et al 2021:1; Shahsavari & Akbari 2018:279). South Africa has a substantial solar energy potential, with varying irradiation levels in the different regions (Akinbami et al 2021: 5085; Aliyu, Modu & Tan 2018:2506; Simpson, Badenhorst, Jewitt, Berchner & Davies 2019:6;). The main potential energy sources are concentrated solar power (43 275 TWh/year), solar PV (42 243 TWh/year), and wind (41 195 TWh/year) in South Africa (Adenle 2020:1). The Northern Cape region in South Africa has a total surface area of high solar radiation potential of 194,000 km^2 (Aliyu et al 2018:2506) and was found to have the most substantial DNI (direct normal irradiation) of over 3 200 kWh/m2 (Akinbami et al 2021: 5086; Ting & Byrne 2020:11). The DNI represents the quantity of solar radiation received by a surface on Earth. DNI solar energy must have an annual average of at least 2000 kWh/m2/yr to be used to produce electricity (Mutombo & Numbi 2019:877). The higher the DNI, the greater the potential of energy production from solar. The highest DNI potential is depicted in red in Figure 4-2 highlighting areas in South Africa with the greatest solar energy production potential. The areas in yellow in Figure 4-2 also have good potential of solar energy production as it is within the 2000 kWh/m2/yr threshold to produce electricity.

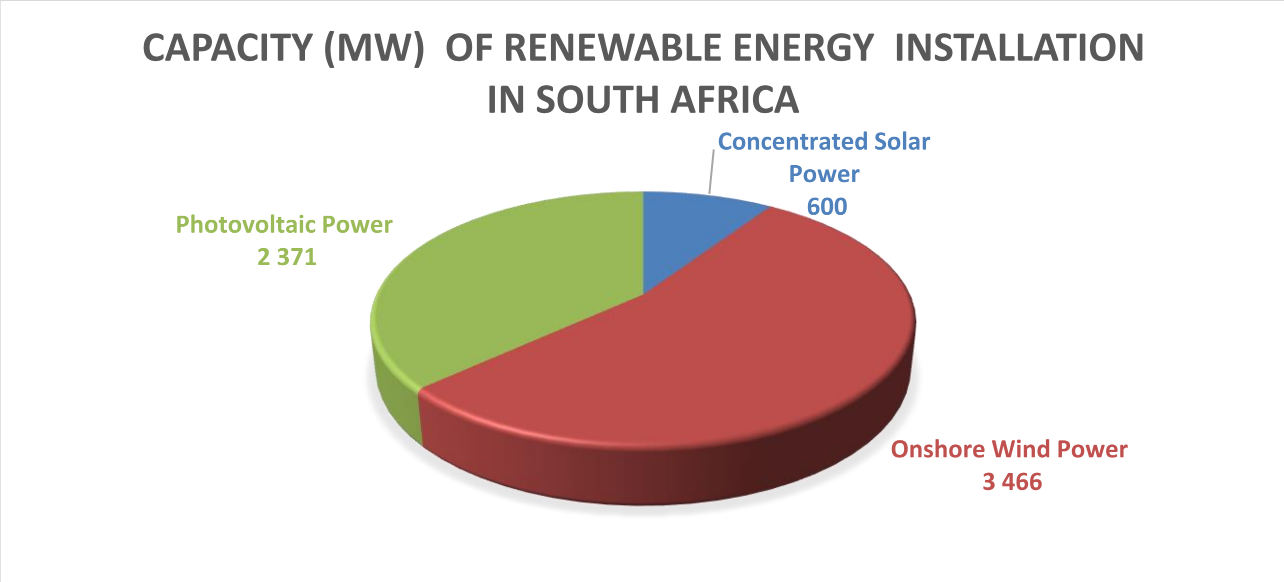
Figure 4-2: Direct normal irradiation in South Africa



Source: World Bank (2020).

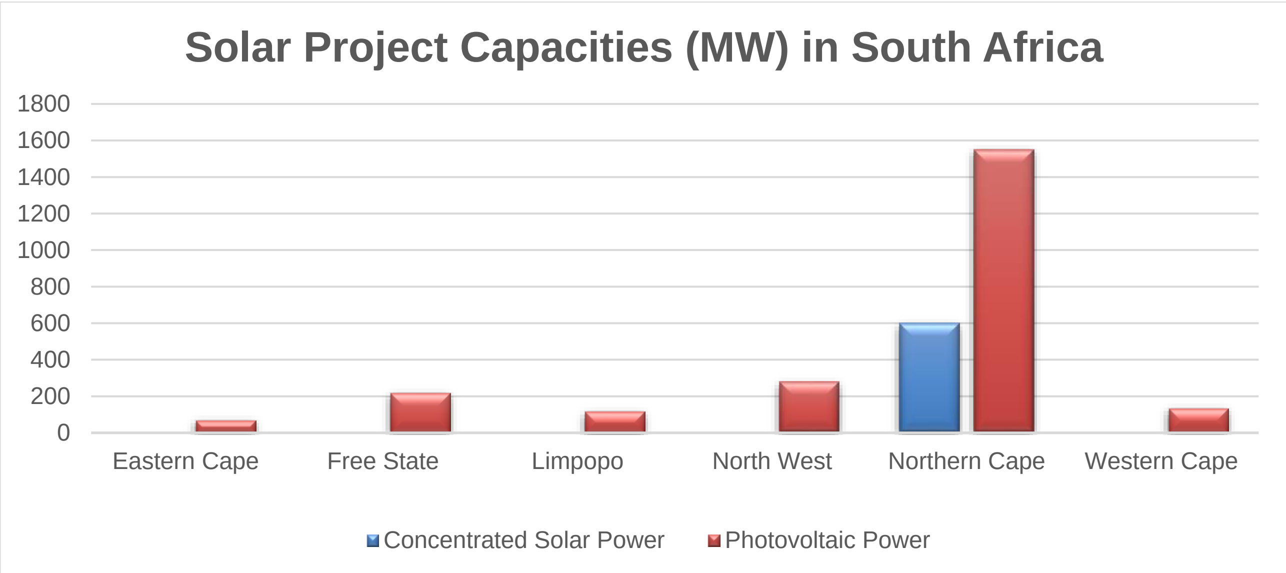
Figure- 4-3 highlights the solar energy plants installed in South Africa. Figure 4-4 further illustrates the solar plants installed by province, that conforms to the solar resource map in Figure 4-2 of the most substantial adoption being in the Northern Cape, the area with the most DNI.

Figure 4-3: Solar project installations in South Africa



Source: Author's compilation from Department of Mineral Resources and Energy data (B).

Figure 4-4: Solar project installations per province in South Africa



Source: Author's compilation from Department of Mineral Resources and Energy data (B).

4.3.1.3. Benefits

Solar is the fastest growing renewable energy source and International Energy Agency (IEA) estimates solar to supply approximately 22% of the world's electricity by 2050 (Shafiee, Alghamdi, Sansom, Hart & Encinas-Oropesa 2020:1). Solar systems are environmentally friendly technologies for electricity production, with no adverse effects on the environment (Mutombo & Numbi 2019:876; Nasrin et al 2018:1115). Solar energy technologies aid in reducing reliance on fossil fuels, resulting in climate change mitigation by reducing CO_2 emissions, and thereby contributing to the achievement of SDG 13 targets (Adenle 2020:11). Adenle (2020:11) found that the installation of solar water heating technology adoption in South African households and commercial establishments has the potential to reduce 186.4 Mt CO_2[41] and 297.7 Mt CO_2 emissions were reduced for moderate and accelerated SWH scenarios. The moderate and accelerated scenarios assumes that 50% and 80% of the energy heating needs will be heated by solar at the current energy mix.

Each square meter of concentrator surface in CSP systems saves 200-300 kg of CO_2 per year, depending on its location on the Earth (Shahsavari & Akbari 2018:279). Solar PV systems can save 0.53 kg CO_2 emission for each kilowatt-hour of electricity generated. Utilisation of solar PV systems can reduce between 69 to 100 million tonnes of CO_2, 126 000 to 184 000 tonnes of sulphur dioxide and 68 000 to 99 000 tonnes of nitrogen oxides by 2030. The reduced emissions of nitrogen oxides and sulphur dioxide will reduce the advancement of many serious diseases. Heart and Asthma attacks will reduce by between 490 to 720 and 320 to 470 each year (Shahsavari & Akbari 2018:279). This would alleviate some pressure from the overburdened health system in South African and reroute resources to assist more vulnerable members of our society.

Integration of solar PV can also aid vulnerable communities in isolated rural locations where grid extensions are neither economically feasible nor technically feasible (Shahsavari & Akbari 2018:275). Solar energy systems are the most cost-effective option for mini-grid and off-grid electrification in rural or remote areas, as well as grid expansion in some cases of centralised grid supply with excellent renewable resources (Shahsavari & Akbari 2018:278). Technical advancement over the years has resulted in substantial reduction the cost of solar technologies (Hayat et al 2018:1066; Kost, Mayer, Thomsen, Hartmann, Senkpiel, Philipps, Nold, Lude, Saad, Schmid & Schlegl 2013:2; Solaun & Cerdá 2019:11). Solar modules cost USD27 000 per kilowatt (KW) in 1980 and significantly decreased to USD3500 per KW in 2017 (Hayat et al 2018:1066). This makes solar PV an excellent alternative in isolated areas with limited resources, and reduces the affordability barriers as the costs decrease.

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[41] Metric tonnes of carbon dioxide equivalent or MT CO_2 is the unit of measurement representing an amount of a GHG whose atmospheric impact has been standardised to that of one unit mass of carbon dioxide.

4.3.1.4. Drawbacks

Climate change is an inherent risk to the adoption of solar energy sources (Solaun & Cerdá 2019:11), where Solaun and Cerdá (2019:11) find that output of light energy from the Sun varies with seasonal changes, with winter experiencing a higher output from the light energy than in summer for South Africa. This creates barriers of solar power integration into mining operations from unreliability of power supply due to intermittency. Mining operations require continuous power supply due to operating all hours of each day and irregular solar power generation creates a supply security risk (Nasirov & Agostini 2018:197). This then necessitates that solar power generation be supplemented with fossil fuel technologies, due to the inability to cater for baseload electricity requirements (Naicker & Thopil 2019:647; Nasirov & Agostini 2018:197). Energy storage mechanisms may be implemented to mitigate the intermittency risk.

Solar PV produced power has a very poor conversion efficiency of approximately 15% to 20% of solar radiations being able to be converted into electricity (Kumar et al 2019:889). Solar PV is not sufficient to meet baseload electricity requirements, and often needs to be supplemented by fossil fuel generated electricity (Naicker & Thopil 2019:647). Adoption of the technologies may also be constrained by the inability of the current grid infrastructure to support their expansion due to diffusion levels (Naicker & Thopil 2019:647). Sustainable expansion of the technology would require substantial land for a big PV power plant that is often not available (Nasrin et al 2018:1115).

The financing cost has been identified as a hurdle of adopting solar technology (Adenle 2020:11; Solaun & Cerdá 2019:11). Solar technology has a higher levelised cost of producing electricity when compared to other renewable energy sources like hydropower and wind (Hayat et al 2018:1066). Solar technologies, particularly solar PV products, have significant capital, investment, installation, and operational expenses (Adenle 2020:11; Nasrin et al 2018:1115). The lengthy payback periods reduce the economic feasible for mining projects with a relatively short or uncertain mine life (Nasirov & Agostini 2018:197). This is because of payback period exceeding the remaining mine life, that would render the mining operation unable to recover the investment cost when the mine ceases to operate. The barrier of significant investment cost in large solar projects can be reduced by smaller installations with less capital expenditures than hydro or wind, which could lessen the impacts of climate change (Solaun & Cerdá 2019:11).

Adenle (2020:12) finds technical issues to present one of the factors affecting uptake of solar technologies in Ghana, Kenya and South Africa. Adenle (2020:12) attributes the technical issues to limited knowledge and skills, poor installation and maintenance, and unreliable and low-quality components in African countries. Nasirov and Agostini (2018:197) assert that majority of mining operations lack the electrical engineering skills compatible with solar technologies adversely affecting the adoption of solar technology. The electrical engineering skill set in mines in currently suitable for conventional fossil fuel electricity generation. Investment in additional training and recruitment of engineers skilled in solar power is required to advance the adoption of solar power. The slow adoption of solar technologies in South African mining operations is also attributable to slower technological advancements in the CSP technologies (Naicker & Thopil 2019:647; Nasirov & Agostini 2018:197). Battery storage technology's lack of technical, and financial viability is a major barrier to the application of solar technology in South African mining (Nasirov & Agostini 2018:197).

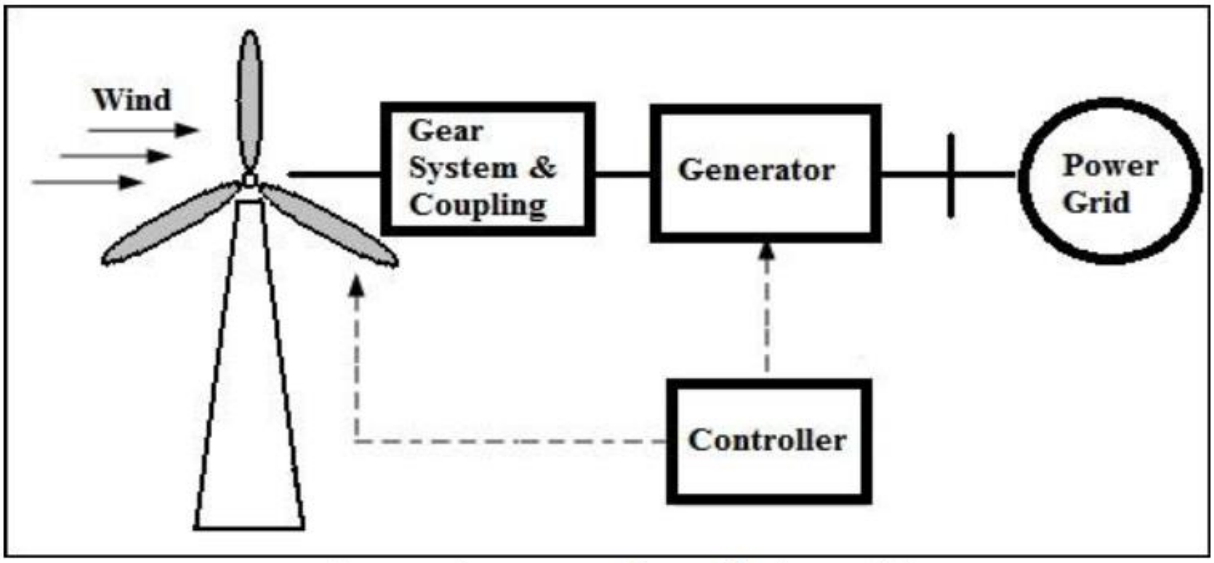
4.3.2. Wind energy

Wind energy involves the conversion of the kinematic energy of moving air into electrical energy. A rotating wind turbine converts air kinematic energy into mechanical energy (Mutombo & Numbi 2019:877; Saifullah, Karim & Karim 2016:6). As wind passes over the wind turbines a turn force is exerted to move the wind turbine blades. The moving turbine blades turn a shaft in the nacelle[42] (Saifullah et al 2016:6). A nacelle horizontal structure containing a gearbox, generator and power electronic devices that are connected to the blades (Hossain & Ali 2015:482). The generator's rotation speed is accelerated by the gearbox, and the generator uses magnetic fields to transform the rotational energy into electrical energy (Saifullah et al 2016:6). Power production occurs at wind speeds of approximately four metres per second (Hossain & Ali 2015:482), and this power output passes through a transformer that coverts the electricity generated into appropriate voltage

[42] A structure covering the gearbox and other components connect to the wind blades.

for usage (Saifullah et al 2016:6). Figure 4-5 graphically illustrates how the wind system works and described in the test above.

Figure 4-5: Wind energy system



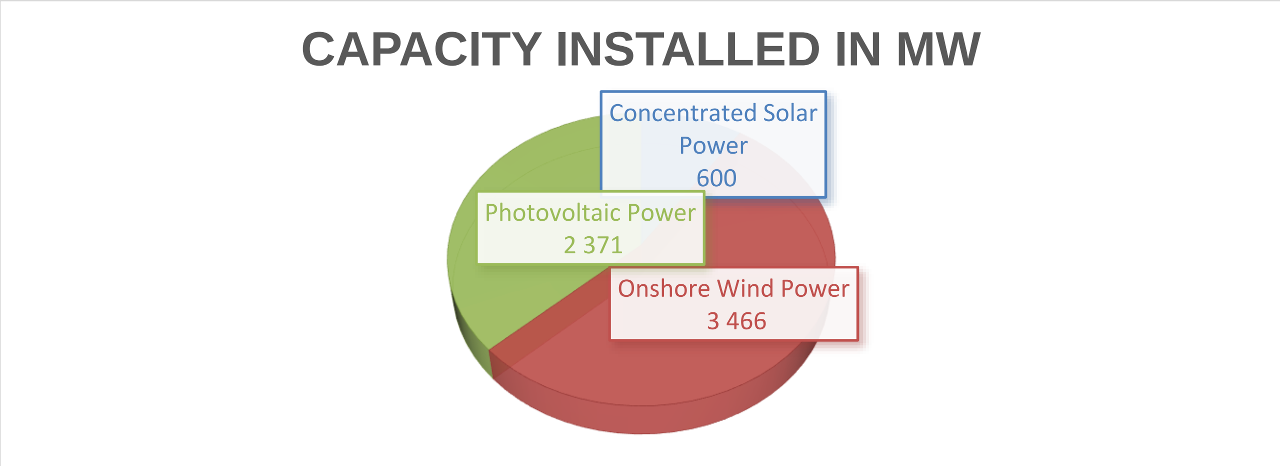
Source: Saifullah et al (2016:6).

4.3.2.1. Availability in South Africa

South Africa has significant potential for solar and wind power generation (Simpson et al 2019:6), having substantial wind energy potential in the Sub-Saharan Africa with wind speeds between 7.29 to 9.70 m/s recorded in Cape Alguhas (Aliyu, Modu & Tan 2018:2506). The wind atlases confirm that coastal regions of Africa have the most substantial wind potential (Nwaigwe 2022:4530). Western and Eastern Cape coastal regions were found to have significant wind energy potential with average annual speed of over 4 m/s at 10 meters above the ground level (Akinbami et al 2021:5084). The Drakensburg foothills and Kwazulu-Natal regions were found to have moderate wind energy potential (Akinbami et al 2021:5084). South Africa has a total wind power potential of 6,700 GW, which is comparable to the country's solar power potential (Nwaigwe 2022:4530; Jain & Jain 2017:725). Despite the substantial wind potential, ESKOM only generates 0.05% of electricity from wind energy from the Klipheuwel demonstration plant and the Darling wind farm (Aliyu, Modu & Tan, 2018:2506).

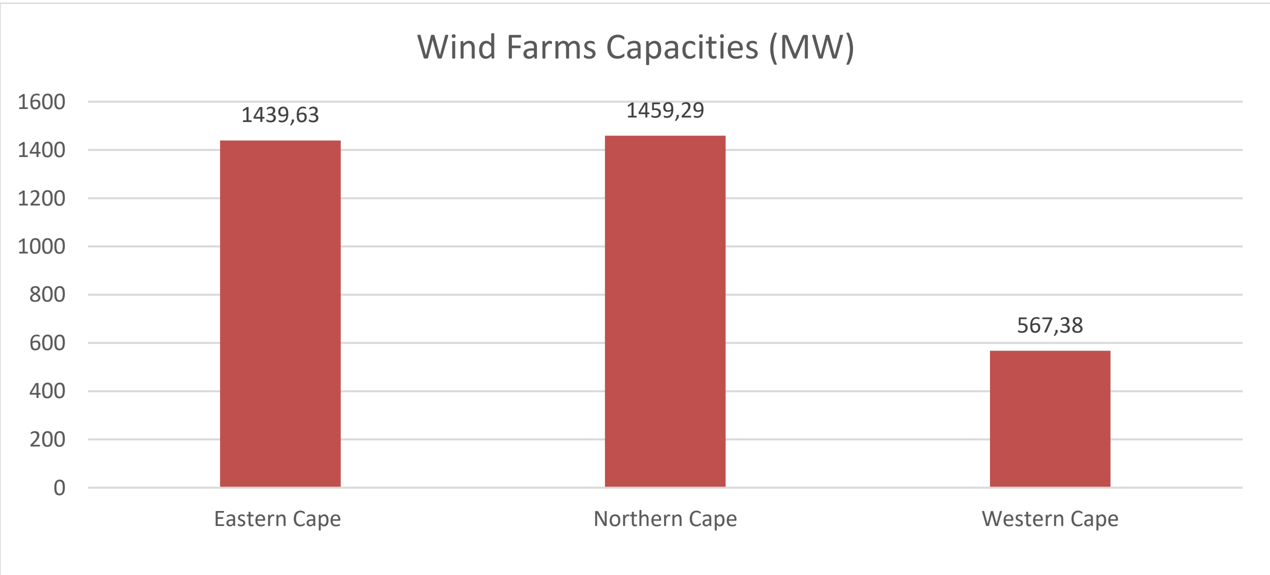
The current wind energy adoption as depicted in Figure 4-6 and Figure 4-7 depicted current wind energy adoption of 3,466 MW adoption, which is significantly less than the overall wind energy potential of 6,700 GW in South Africa. There is substantial room to expand the wind energy adoption as decarbonisation measures and move away from fossil fuels.

Figure 4-6: Renewable energy in South Africa



Source: Author's compilation from Department of Mineral Resources and Energy data (B).

Figure 4-7: Current wind farms in South Africa



Source: Author's compilation from Department of Mineral Resources and Energy data (B).

4.3.2.2. Advantages

Wind energy is an environmentally friendly energy source that it is widely available, clean, and emits no greenhouse gases (Mutombo and Numbi 2019:877; Sayed, Wilberforce, Elsaid, Rabaia, Abdelkareem, Chae & Olabi 2021:5). Gaseous emissions such as sulphur and nitrogen oxide released during the burning of fossil fuel cause adverse health conditions such as asthma that are significantly reduced with the use of environmentally friendly energy sources (Sayed et al 2021:5). Wind energy technologies aid in reducing reliance on fossil fuels, and thereby contributing to the mitigation of climate change from the reduced use of fossil fuels. Wind energy systems use less water when compared to fossil fuel power plants allowing for better usage of the limited resource (Sayed et al 2021:5). Wind energy harnesses approximately 50% to 60% of the wind passing through the turbines into electricity (Harrison solar n.d; Word Economic Forum 2022). This level of efficiency is higher than 15% to 20% of solar and 42% of CSP, making it the most efficient renewable energy.

4.3.2.3. Disadvantages

Wind speeds have a significant impact on output, where even minor changes can have a significant impact on electricity generation (Solaun & Cerdá 2019:3). Varied wind speeds may lead to voltage fluctuations leading to excess of low supply of electricity that disrupt the power grid resulting in costly repairs of the grid (Akinbami et al 2021: 5085). Mining operations require continuous power supply due to operating all hours of each day and intermittency from varied wind speeds may create an electricity supply risk. The intermittency of renewable resources is an inherent electricity supply risk that that restricts the sole use of wind energy (Votteler & Brent 2016:5).

Wind farms have been reported to cause noise pollution from the movement of the wind through wind turbine blades (Akinbami et al 2021:5085; Msigwaa, Ighalob & Yap 2022:5; Sayed et al, 2021:6). Big turbines have been found to cause noises at frequencies of 100 Hz with fast windspeeds causing hearing issues for human life near these wind farms (Akinbami et al 2021:5085; Sayed et al 2021:6). Installation of wind power projects is recommended to be installed far away from residential areas so as to mitigate the adverse noise effects of wind power projects (Sayed et al 2021:6). The installation of wind farms in remote arears creates further difficulties of connecting the wind energy to the grid (Akinbami et al 2021: 5085).

In the construction phase plants are removed, adversely affecting the local climate. Further excavations for the foundation of the wind turbines and connection of transmission lines to the electricity grid damage the soil in the area (Sayed et al 2021:7; Msigwaa et al 2022:7). Wind turbines have also been associated with the death of birds colliding with the wind turbine blades (Akinbami et al 2021:5084; Sayed et al 2021:7; Msigwaa et al 2022:5) adversely affecting the ecosystem in the area. South Africa was found to have a bird mortality rate of 2.9 birds per wind turbine per year. killing 130 species of birds between the years 2014 to 2018 at the 20 wind farms investigated (Msigwaa et al, 2022:5). The ecology is therefore adversely affected by death of birds caused by the wind turbines.

4.3.3. Carbon capture and storage

4.3.3.1. How it works

Raza, Gholami, Rezaee, Rasouli, and Rabiei (2019:336) describes CCS as a process of capturing CO_2 from industrial sites and transporting it through pipelines to an identified site for permanent storage. CCS technology can either store CO_2 onsite deep underground or transported offsite to an identified storage facility. The storage process is a means of isolating harmful emissions from the atmosphere (Ko, Zigan & Liu 2021:2), mitigating the advancement of climate change. CCS has gained significant attention in recent years, as it captures up to 90% of the CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes (Ko, Zigan & Liu 2021:2). CCS technology can aid in attainting carbon emission reduction to reduce the advancement of global warming (Malischek, Baylin-Stern & McCulloch 2019:17; Selosse & Ricci 2017:32; Viebahn, Vallentin & Höller 2015:14380; Wilberforce, Olabi, Sayed, Elsaid & Abdelkareem 2021:2).

The UNFCCC (2000:76-78) argues that fossil fuels cannot exist in a sustainable energy system without the use of this CCS. The use of carbon capture, utilisation and storage can reduce substantial emissions consistent with the Paris Agreement climate pledges at the least cost (Malischek et al 2019:17). Haszeldine et al (2018:1) proposes the combined use CCS and negative emissions technology to aid in the achievement of net-zero CO_2

emissions. CCS would reduce current GHG emission rates, and negative emissions technology would retrieve CO_2 already emitted in the atmosphere (Haszeldine et al 2018:2). Limiting and retrieving CO_2 emissions would reduce the advancement of climate change by reducing GHG emissions in the atmosphere.

4.3.3.2. Carbon capture and storage in South Africa

South African has identified CCS as a climate change mitigating option that could aid the attainment of emission reduction targets (Surridge, Kamrajh, Melamane, Mosia, Phakula, & Tshivhase 2021:1). The technology is still in an exploratory stage in South Africa, with bodies like the South African Centre for Carbon Capture and Storage, a division of the South African National Energy Development Institute (SANEDI), having been incorporated to investigate the viability of this technology in South Africa. A Pilot Carbon Storage Project to evaluate the viability of geological storage and monitoring for between 10 000 and 50 000 tonnes of CO_2, was planned to be completed between 2017 and 2021 (Beck, Kulichenko-Lotzb & Surridge 2017:5637). However, challenges of CCS development in South Africa include the slow progress of the development of CCS as a clean development mechanism, delays in implementing the CCS Roadmap and the unsatisfactory progress of the Technical Assistance Project for the Development of CCS in South Africa (Ko, Zigan & Liu 2021:3). The road map indicated that they expected commercialisation of CCS in 2025, however, due to the delays the timelines need to be updated. Due to the infancy of the technological development of CCU in South Africa restricts the availability of the technology to be exploited by the mining sector in decarbonising their operations. Globally there has been small scale adoption of CCS projects as depicted in Table 4-2, and it is expected to increase with the technologic advancements and commercialisation of the technology.

Table 4-2: Global carbon capture projects

Country	Capture[43] (Mt CO_2/yr)	CCU[44] (Mt CO_2/yr)	Full chain[45] (Mt CO_2/yr)	Grand Total
Australia			4	4
Belgium		0.125		0.125
Brazil			8.7	8.7
Canada	1.6	0.438	2.2	4.238
Hungary			0.16	0.16
Iceland			0.004	0.004
Japan	0.18		0.1	0.28
Netherlands		0.4		0.4
Norway			1.7	1.7
People's Republic of China			2.15	2.15
Qatar			2.1	2.1
Saudi Arabia			0.8	0.8
United Arab Emirates			0.8	0.8
United States			20.4969	20.4969
Grand Total	**1.78**	**0.963**	**43.2109**	**45.9539**

Source: International Energy Agency (2023).

4.4. CONCLUSION

Solar PV has been found to have higher technical maturity in comparison to wind and CSP technology (Naicker & Thopil 2019:645). Solar PV has been found to be a more viable integration in mining operations over wind and CSP (Votteler & Brent 2016:21). This is due to advanced technical maturity and lower levelised cost in comparison to wind and CSP technologies. The lower efficiency rate of solar PV in comparison to CSP and wind appears to not have reduced investment prospects in the technology as currently the leader in global integration. Globally, solar PV is the most supported renewable energy technology with 91% of global renewable technology integration (Votteler & Brent 2016:8). The substantial decline in the cost of solar PV modules further makes this technology attractive for investors. There has been great investor support in the funding of solar PV and wind energy projects.

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[43] Captured CO_2 emissions, with no storage or use.
[44] Captured CO_2 emissions that will be used by external parties.
[45] Captured CO_2 emissions that will be used internally.

Wind energy harnesses approximately 50% to 60% of the wind passing through the turbines into electricity (Harrison solar n.d.; Word Economic Forum 2022). This level of efficiency is higher than 15% to 20% of solar and 42% of CSP, making it the most efficient source of renewable energy. However, the higher costs, noise pollution and need for substantiable land space makes this technology unsuitable for mining operations. The wind turbines make excessive noise that is not suitable for installation near residential areas. Mining areas normally have small mining communities living near the mines, and therefore, wind energy integration near such communities would cause hearing issues for people in the community. Solar PV can be attached to existing builds and infrastructure, while wind energy technology always requires substantial land space to install the wind turbines. Current adoption of wind energy has been in coastal areas that have greater wind speeds than inland areas that would be suitable for 45% of mining operations in South Africa.

CSP technology is currently not viable, due to the limited technological knowledge, higher levelised costs than that of wind and solar PV. CSP technology will be more relevant in future with increased technological and knowledge development due to the benefits of technological scalability and diminished intermittency, in comparison to other technologies (Naicker & Thopil 2019:647). Thus, the basis of the investment decision in Chapter 6 will focus on 30MW solar PV generation capacity.

The next chapter follows with a discussion on research methodology adopted in this study.

CHAPTER 5

METHODOLOGY

5.1. INTRODUCTION

The study stems from the Pigouvian theory of corrective taxes. To reduce negative externalities[46] of market activities, the participants must bear the cost of the negative externalities. Carbon tax is a form of Pigouvian tax, internalising the external cost by requiring polluters to pay for CO_2 equivalent emitted in the atmosphere (Ball 2018:134). A well-designed Pigouvian tax equates the cost of pollution with the cost of abating the pollution (OECD 2010:98). This study explores whether the cost of abating GHG emissions through solar PV equates or is greater than the South African carbon tax. Embedded in this theory is the adequacy of the carbon tax design considerations to correct the negative externalities of pollution.

Prior chapters conducted a systematic literature review from literary sources that address the role of carbon pricing in mitigating climate change, international comparative carbon pricing review and exploring mitigating options available. Paula and Criado (2020:1) describe literature review as a synthesis of literature available to strengthen foundational knowledge on a specific subject matter. The choice of conducting a systematic literature review was to identify substantive empirical evidence on carbon pricing as a climate change policy, and the use of a systematic method aims to reduce bias to achieve reliable results (Snyder 2019:334). This chapter discuss the research methodology adopted in this study.
Research and data collection methods are discussed in section 5.2. Section 5.3 presents the conclusion to the chapter, with a summary of the research method, data collection and analysis adopted in this study.

[46] Cost or benefit incurred by a producer but not paid for or received by that producer.

5.2. RESEARCH METHODOLOGY

Taxation is a phenomenon that can be studied through varied lenses and attracts research from different disciplines such as law, accounting, economics, and other disciplines (McKerchar 2008:7). Tax research can be conducted as doctrinal or non-doctrinal research. Doctrinal research mainly involves the analysis and synthesis of legislation, court judgements, and commentary (McKerchar 2008:19). Non-doctrinal approach is research is research about legislation and makes use of other methodologies used in fields such as economics, accountancy, political and social sciences (McKerchar 2008:19). This study is non-doctrinal research adopting a qualitative documentary review (Ahmed, 2010) of South Africa's carbon pricing policy regime, practises in comparative jurisdictions and CO_2 mitigating technologies available to decarbonise mining entities. In qualitative research, a variety of data sources are gathered and reviewed to create insightful analyses of complicated problems (Leedy & Ormrod 2001:269; Williams 2007:70). Qualitative analysis is conducted to gain an understanding of how carbon pricing can encourage entities to adopt decarbonising measures in their operations. Furthermore, a NPV simulation is conducted to further support the overall qualitative inquiry.

The use of numbers in qualitative research does not automatically result in research being mixed in its methods (Maxwell 2010:480). Mixed methods involve the collection and analysis of data from both the qualitative and quantitative approaches in one study (Williams 2007:70). Quantitative research collects numerical data for statistical and mathematical modelling analysis to support or disprove a phenomenon (Williams 2007:66). Numerical data can be used as a supplement to a larger process approach to the research and maintain its legitimacy as a qualitative research strategy (Maxwell 2010:480). An investment decision simulation is conducted to enumerate and support the literature findings that low carbon prices do not incentivise investment in carbon reducing technologies such as solar PV. The study does not conduct any statistical or mathematical modelling, and therefore does not have a quantitative methodological approach to it. The numerical costing data collected in this study is used to complement the overall qualitative review inquiry in this study. The absence of the quantitative aspects therefore renders this study purely qualitative, and not a mixed method study.

The qualitative nature of the study is further underlined by the use of an interpretive philosophical paradigm. Mixed methods studies follow pragmatism, while quantitative studies are positivist or post-positivist. The documentary review and the accompanying discernment of the meaning of the review is done through interpretivism.

5.2.1. RESEARCH DESIGN: DOCUMENTARY REVIEW

Secondary data employs evidence generated by another party for a different main objective, and then brings that data into play in order to interpret the data for a different set of objectives (Johnston 2014:619). To use existing data to answer research questions, secondary data review requires the application of theoretical knowledge and conceptual expertise (Johnston 2014:620). Using secondary data in this manner is a documentary review, the selected design for this study (Ahmed 2010). The documentary review of this study was supported through the use of ATLAS.ti,™ Version 8 (hereafter ATLAS). The computer-aided qualitative data analysis software tool, ATLAS provides several features and capabilities to help with reviewing and analysing data as argued by Smit (2002) in a seminal piece for South African contexts. Smit indicates that ATLAS enables a themed approach to the review which was evident in the previous chapters. ATLAS therefore enabled the documentary review. The programme was used to identify carbon pricing themes and information that answer the research objectives. Costing data of Solar PV technologies was sourced reports from International Energy Agency, academic journals, and JSE listed mining entities annual reports. For the documentary review to be within scope, the researcher drew a sample which is discussed below.

The documentary review sample is purposefully selected to answer the research questions being examined (Zhang & Wildemuth 2005: 2). This study applies purposive sampling as sample is selected based on the attributes they possess (Etikan, Musa, & Alkassim 2016:2). Purposive sampling allows the sample to be selected on their relevance to the research objectives (Campbell, Greenwood, Prior, Shearer, Walkem, Young, Bywaters & Walker 2020:653). The sample purposively select reports disclosed costs of renewable energy investments, in order fulfil the research objective of performing a cost benefit analysis. The reported CO_2 emissions and costs will enable a recalculation of carbon tax to compare to the cost and benefits associated with investing in carbon mitigating technologies.

From the sample, the contents were harnessed in order to write the chapters that constituted a review of the literature. The process is declared in Table 5-1 below.

Table 5-1: Global carbon capture projects

Sources of documentary data	Research Objective	Chapter
• Legislation - Income Tax Act No. 58 of 1962 and Carbon Tax Act No.15 of 2019 • Explanatory memorandum on the carbon tax bill National Treasury Reports • Explanatory Memorandum on the Draft Taxation Laws Amendment Bill • Budget Speech • Department of Environmental Affairs and Tourism reports • Davis Tax Committee reports • OECD reports • Journal articles and other literature • Energy transition policy papers	Review the existing carbon tax policy and its role in decarbonising mining operations in South Africa.	2
• Journal Articles • Carbon pricing and emissions data from international government online websites and reports • Energy Transition policy papers Policy papers • Carbon Tax legislation in the comparative jurisdictions • World Bank CO_2 emissions reports	Compare international carbon pricing models in relation to varying carbon price levels and the reciprocal reductions in CO_2 emissions.	3
• Department of Mineral Resources and Energy data • International Energy Agency reports	Explore the CO_2 emissions mitigating technologies available to decarbonise mining operations in South Africa.	4
• Journal Articles • JSE listed mining entity integrated reports • Costing data from an academic thesis	Conduct CBA of existing carbon prices against the investment cost of available CO_2 emissions mitigating technologies, using NPV analysis.	6

5.2.2. Data Collection

After declaring its sample, the study gathered secondary data available from the sampled literature (Johnston 2014:619) on the role of carbon pricing in mitigating climate change,

CO_2 emissions mitigating technologies available, and the effective carbon prices modelled by other scholars. To gather the data, the researcher used the following key word searches:

- Carbon tax
- Emissions trading schemes
- Decarbonising mines
- Renewable energy in South Africa
- South African carbon tax
- Cost benefit analysis
- Pigou taxes
- Environmental taxes
- Carbon pricing policies
- Carbon tax and decarbonisation
- Global carbon taxes
- Climate change
- Command and control policies
- Climate change mitigation
- Effective carbon tax
- Carbon capture and storage in South Africa

Table 5-1 information was gleaned in a data collection strategy through conducting in-depth internet and library searches using the University of South Africa library, the University of Cape Town library, and research databases and search engines like EBSCO-Host, Google Scholar, and Connected Papers. The searches were restricted to recent journal publications, although older articles that offered helpful definitions of terms and information on carbon pricing policy were also used. Finding papers that addressed the research objectives became the focus of the searches. There were no studies that were found in the search that matched the current study.

5.2.3. Data analysis

Data analysis involves documentary review of literature to identify themes of the impact of carbon pricing on decarbonisation efforts, costing data, and decarbonising technologies available in South Africa. ATLAS.ti is used as a supportive tool highlight carbon pricing themes. Furthermore, costing data collected was collated on to Microsoft Excel spreadsheet, and NPV simulation conducted using the Microsoft Excel NPV functionality. The detail on how the costing inputs is selected is further detailed in Chapter 6.

5.2.4. Methodological integrity

Qualitative research must be thoroughly documented, systematised, and disclose methods of analysis in sufficient detail to enable credibility analysis and that data analysis was carried out in a precise, consistent, and exhaustive manner (Nowell, Norris, White, & Moules 2017:1). Lincoln and Guba (1985) improved the idea of trustworthiness by introducing characteristics of credibility, transferability, dependability, and confirmability to the traditional quantitative assessment criteria of validity and reliability (Nowell et al 2017:3). The trustworthiness criteria of the study are applied below:

5.2.4.1. Credibility

In quantitative research, credibility is taken to be synonymous with internal validity and truth value (Korstjens & Moser 2018:121). The truthfulness in this study can be supported by extensive use of varied secondary data sources to corroborate the findings. All claims are adequately supported by citing the appropriate author of the claim.

5.2.4.2. Transferability

An inquiry's potential to be used broadly is referred to as transferability (Nowell et al 2017:3). The study can be inferred to a broader investment decision study. The benefits of any investments would have to exceed the costs in order to encourage investments prospects. The exception to this rule is for non-profit or altruistic investment prospects.

5.2.4.3. Dependable

Research is dependable when it can be guarantee that the study process is rational, traceable, and well-documented (Tobin & Begley 2004:392). The study has been conducted in a rational manner, is well-documented, with all inputs easily traceable.

5.2.4.4. Confirmability

Confirmability demonstrates that the data and interpretations of the findings are drawn from the data itself, and not merely from the inquirer's imagination (Tobin & Begley 2004:392). The findings of the study are solely based on the results of the data analysed in the study.

5.2.5. Ethical considerations

The study primarily evaluates secondary data and literature that already exists; therefore, the work of others will be adequately referenced and cited as such. The objective choice in data inputs for the NPV investment decision will be systematically substantiated, and will not therefore be subjected to bias. Ethical clearance approval was obtained from the University Ethics Committee [Ethics Approval 2022_CAS_008_RAM].The Turnitin software application was used to check all of the study's chapters, where the total similarity percentage is found to be within acceptable bounds.

Ethics approval
2022_CAS_008_RAM

5.3. CONCLUSION

This study presents non-doctrinal research, adopting qualitative methodology complemented with a simulation built on the qualitative review. This study conducts a qualitative review of South Africa's carbon pricing policy regime and practices in comparative jurisdictions, as well as CO_2 mitigating technologies available to decarbonise mining entities. This review is conducted through a collection and analysis of secondary data from scholarly articles, books, legislation, and government publications. The qualitative review is conducted to identify themes and conclude on the role of carbon pricing in encouraging decarbonisation detailed in chapters 2 to 4. Subsequent to the literature review, the study conducts an investment decisions analysis to further support the findings in literature review. An investment decision simulation is conducted in order to further support the literature findings that low carbon prices do not incentivise investment in carbon reducing technologies such as solar PV.

The next chapter follows with the investment decision analysis of integrating 30MW solar PV into a mining operation. Chapter 6 reviews the impact of carbon taxation on investment decisions and evaluate whether the carbon tax in South Africa incentivises mining entities to invest in solar renewable energy.

CHAPTER 6

INVESTMENT DECISION ANALYSIS

6.1. INTRODUCTION

This chapter evaluates the impact of carbon taxation on investment decisions and evaluate whether the carbon tax in South Africa incentivises mining entities to invest in solar renewable energy. The shift from fossil fuel to renewable energy options arises from investment decision process (Zharan & Bongaerts 2017:162; Haites 2018:956). The investment decisions will be evaluated using NPV, a capital budgeting tool used to evaluate the viability of prospective investment projects. The investment evaluation is conducted under CBA, defined as an analytical investment assessment of the costs and benefits that stem from an investment decision (Sofia et al 2020:1). Mining entities will invest in solar projects when the cash inflows exceed the cash outflow over the investment period.

This chapter is laid out as follows. Investment decision rules are discussed in section 6.2. Section 6.3 details the impact of carbon tax on investment decisions. The investment decision analysis is discussed in Section 6.4. The NPV simulations are discussed in section 6.5. Section 6.6 presents the conclusion to the chapter detailing the findings on suitable decarbonising technologies, and the results of NPV simulations.

6.2. INVESTMENT DECISION RULES

Investment decisions are evaluated under capital budgeting theory and evaluation techniques (Hanlon & Heitzman 2010:147). Capital budgeting tools evaluate whether resources committed to investment projects yield the desired returns (Ali, Yan, Sajjad Hussain, Irfan, Ahmad, Razzaq, Dagar & Işık 2021:3; Oke and Conteh 2020:13). Internal rate of return (IRR) and NPV are commonly used DCF techniques in capital budgeting that are to make investment decisions (Bora 2015:64; Botín 2019:67-68; Oke & Conteh 2020:15). NPV evaluates future cashflows against the cost of the investment over a period (Dobrowolski & Drozdowski 2022:354; Drury 2019:312-314; Oke & Conteh 2020:17). A positive NPV signifies the acceptance of investment due to cash inflows exceeding cash outflows over the investment period. The investment decision rules that an entity would invest in a project so long as benefits exceeded the costs (Hanlon & Heitzman 2010:147).

Raihan and Said (2021) describe cost-benefit analysis as a comparison of costs and benefits of climate change mitigation options to identify the most cost-effective solution. Investments in decarbonising technologies are long-term decisions, appraised using the net present valuation (NPV) technique. NPV evaluates all the future net cash flows linked to the investment decision (Žižlavský 2014:506) and encourages investment in projects that yield positive net cashflows from an investment. The purpose of this approach is to provide a systematic overview of the role of carbon pricing in encouraging decarbonisation of the mining sector. Applying the CBA using the NPV approach addresses empirical gaps in the existing research on whether an effective carbon price incentivises South African mines to invest in low-carbon transition technologies.

NPV method accounts for time value of money and risk through discounting cashflows (Bierman & Smidt 2012:44). The time value of money recognises that money received today is more valuable than money received in future, due to the likelihood of inflation (Bierman & Smidt 2012:12). NPV refers to the difference between the present value of all cash inflows and present value of all cash outflows from an investment (Bora 2015:63). The present value is determined by discounting cashflows, using an entity's overall cost of capital (Bierman & Smidt 2012:7; Sandahl & Sjögren 2003:52). An investment-specific cost of capital can be used when the entity risk substantially differs from the investment risk (Bierman & Smidt 2012:7). The use of the cost of capital as a discount rate represents the minimum return over the investment period (Visconti 2021:1) to cover the costs of financing.

6.3. IMPACT OF CARBON TAX ON THE INVESTMENT DECISION

Taxation represents a significant portion of mining entity expenses, and influences investment decisions (Saidu 2007:106). Reducing GHG emission involves investments in green technologies, where tax rates charged will influence investment decisions (Haites 2018:956). The tax levels imposed directly affect the return investors earn, and higher tax costs conflict with the profit-making objective (Saidu 2007:106). Mining entity decision-making will be geared towards increasing profits for shareholders. The cheaper alternative will be chosen between carbon tax and investing in green technologies to maximise shareholder wealth.

The carbon price must be higher than the price of investing in renewable energy projects for entities to immediately invest in renewable energy projects (Gong & Li 2016:271). When the carbon price is lower than that of the price of investing in renewable energy projects, entities will choose to defer the renewable energy project investment decision (Gong & Li 2016:280). when the cost of reducing pollution exceeds the carbon tax payable, then entities would rather pay the tax than invest in pollution reducing technology (Gupta 2020:12). This further solidifies the theory that for investment in green technologies to take place, the cost of carbon must be high enough to incentivise investments. Carbon taxes can promote investment in carbon reducing technologies when it is reasonably designed to encourage decarbonisation (Luo, Zhou, Song & Fan 2022:1). A well-designed Pigouvian tax equates the cost of pollution to the cost abating the pollution (OECD 2010:98) to encourage decarbonisation. Low carbon tax rates result in the ineffectiveness of carbon pricing policies (Baranzini et al, 2017:12; Boyce 2018:54; Haites 2018:961; Rosenbloom et al 2020:8665; Skovgaard & Van Asselt 2019:9).

6.4. INVESTMENT DECISION ANALYSIS

A NPV situation is conducted in order to evaluate whether the benefits of investing in a 30 megawatt (MV) solar plant exceeds the cost of carbon tax and electricity costs. The prime lending rate of 11.75% is applied as a discount rate. It is assumed that the solar plant will be financed purely from debt at the prime rate and that the useful life will be 20 years.

6.4.1. Investment cost

Solar PV costing data in Table 6-1 was collected from the below sources and increased by 6% per year from the year of investment to 2023.

Table 6-1: Solar PV costing data

Company / Source	Year of investment	Capacity	Cost of investment	Cost in 2023	Cost per MV in 2023 (ZAR)
Harmony Gold	2023	30 MW	510,150,000	510,150,000	17,005,000
Harmony Gold	2025	137 MW	1,560,000,000	1,560,000,000	11,386,861
Goldfields	2022	50 MW	715,000,000	757,900,000	15,158,000
Barnard (2020)	2019	54 MW	910,857,920	1,149,937,138	21,295,132
IEA (n.d.)	2019	1 MW	25,099,000	31,686,909	31,686,909
Statista	2021	2 MW	16,625,000	18,679,850	18,679,850
Adenle (2020)	2020	3 MW	99,750,000	118,803,846	118,803,846
Pan Africa Resources	2022	10 MW	150,000,000	159,000,000	15,900,000
Pan Africa Resources	2024	30 MW	220,000,000	220,000,000	7,333,333

Source: Author's own complication from Adele 2020; Barnard 2020; Goldfields n.d.; Harmony Gold 2021; IEA n.d.; Pan Africa Resources n.d;Statista n.d.

Adenle (2020) and IEA (n.d.) and Pan Africa Resources costing estimate for 2024, costing data were not considered, due to the costing data being significantly dispersed when evaluated against the costing data set. Costing information in Table 6-1 within the ranges of ZAR 11 million to ZAR 21.2 million were considered for the average Solar PV cost included in the NPV calculation. Table 6-2 lists the costing inputs considered in the determination of the average of solar PV per MW.

Table 6-2: Solar PV costing data considered in NPV calculation

Company / Source	Year of investment	Capacity	Cost of investment	Cost in 2023	Cost per MV in 2023
Harmony Gold	2023	30 MW	510,150,000	510,150,000	17,005,000
Harmony Gold	2025	137 MW	1,560,000,000	1,560,000,000	11,386,861
Goldfields	2022	50 MW	715,000,000	757,900,000	15,158,000
Barnard	2019	54 MW	910,857,920	1,149,937,138	21,295,132
Statista	2021	2 MW	16,625,000	18,679,850	18,679,850
Pan Africa Resources	2022	10 MW	150,000,000	159,000,000	15,900,000
Average cost per MV					**16,570,807**

Source: Author's own complication from Barnard 2020; Goldfields n.d.; Harmony Gold 2021; Pan Africa Resources n.d.; Statista n.d.

6.4.2 Electricity Saving

Mining entity annual and sustainability reports were inspected in order to find the estimated electricity costs savings that would arise from integrating solar PV renewable energy in the mining operations. Solar panels' energy production on average decreases by 0.5% annually (Forbes Home n.d.) and has been accounted for in the NPV calculation by reducing the cost saving by 0.5% for the loss in energy production. The average electricity saving per MW depicted in Table 6-3, is used in the NPV and the cost saving is increased by 6% over the investment period after consideration of the annual loss in energy production.

Table 6-3: Electricity Saving Data

Company / Source	Year of investment	Capacity	Annual Electricity Saving	Electricity saving per MW
Harmony Gold	2025	137 MW	500,000,000	3,649,635
Goldfields	2022	50 MW	123,000,000	2,460,000
Pan Africa Resources	2022	10 MW	36,000,000	3,600,000
Pan Africa Resources	2024	30 MW	100,000,000	3,333,333
Average saving per MW				**3,260,742**

Source: Author's own complication from Goldfields n.d.; Harmony Gold 2021; Pan Africa Resources n.d.

6.4.2. Taxation

An investment decision requires consideration of taxation cashflows that arise from an investment decision, where mining entities will be saving on carbon tax for emissions avoided by incorporating solar PV renewable energy in their operations. Furthermore, there will be income tax implications for maintenance costs, and saving in operational costs that are accounted for in the NPV simulation.

6.4.2.1. Carbon Tax Saving

Mining entity sustainability reports were inspected in order to find the estimated reduction in CO_2 emissions that would arise from integrating solar PV renewable energy in the mining operations. The reduction in CO_2 emissions per MV, as depicted in Table 6-4, is used in the NPV to calculate the carbon tax savings and this saving increased by 6% over the investment period.

Table 6-4: Emission Reduction Information

Company / Source	Year of investment	Capacity	Reduce CO_2 emissions per year (tonnes)	Reduced CO_2 emissions per MW (tonnes)
Harmony Gold	2023	30 MW	65,000	2,167
Harmony Gold	2025	137 MW	444,000	3,241
Goldfields	2022	50 MW	110,000	2,200
Pan Africa Resources	2022	10 MW	36,000	3,600
Pan Africa Resources	2024	30 MW	80,000	2,667
Average CO_2 emissions reduced per MW				**2,775**

Source: Author's own complication from Goldfields n.d.; Harmony Gold 2021; Pan Africa Resources n.d.

6.4.2.2. Income tax implications

6.4.2.2.1. Cost savings

Electricity costs incurred would qualify for a section 11(a) deduction from income earned by a taxpayer. The deduction reduces the income, and results in reduced tax payable. By integrating Solar PV into mining operations, these costs will not be incurred, and will not available for a tax deduction. This results in the mining entity's differential taxable income increasing by the electricity cost saving over the investment period. The increased taxable income results in additional tax payable, and this differential tax cashflow has been accounted for in the NPV over the investment period. The electricity saving has been increased by 6% over the investment period.

6.4.2.3. Maintenance costs

Naicker (2018:10) identifies the following maintenance activities listed in Table 6-5 and the frequency with which the activities ought to be conducted:

Table 6-5: Maintenance Activities

Equipment	Activity	Frequency
Inverter	Inspection and cleaning	
	Electrical connection checks	
	Functional checks	6 months
	Dust filters of inverters located in polluted environments	Monthly
PV Modules	Inspection	Monthly
	Verifications of connections	6 months
	Electrical verification	Yearly
	Cleaning	Twice per year (in winter)
Electrical JB's	Mechanical inspection, door level/catch mechanism	
	Corrosion, labelling, electrical connections, earthing	6 months
Structures	Inspection	6 months
Pyranometers	Cleaning	Weekly
SCADA System	Remote monitoring, Status of plant & sensors	Daily
Pyranometer silica-gel desiccant	Replace when desiccant changes colour to clear.	Weekly
Auxiliary Supply	Inspection and electrical connection checks	6 months
Control room containers and prefabs	Inspection and cleaning	6 months
Weather station	Verification of connection	Monthly
Transformers	Inspection	Yearly
Trackers	Functioning	Weekly

Source: Naicker (2018:10).

The nature of the maintenance activity determines which section of the Income Tax Act will be applicable to the cost thereof. Section 11(d) will be applicable to maintenance activities that result in the replacement of a component in the solar PV system. The maintenance activity must comply with the elements of a repair (South Africa 2015:3-4) and be for an asset used in the taxpayer's trade. Case law has established the meaning of repairs to be a renewable of replacement of subsidiary parts of a whole (see Flemming v KBI (1995); ITC 491, 617).[47, 48] Maintenance activities that do not constitute a repair will be deductible under section 11(a) of the Income Tax Act. Section 11(a) of the income permits deduction of expenses incurred in the production of income. Maintenance costs would qualify a trade

[47] ITC 491 (1941) 13 SATC 77

[48] ITC 617 (1946) 14. SATC 474

operational expense, as is incurred to maintain an asset that is used in the production of income. There is limited secondary data available on the maintenance costs of a solar PV system, particularly due to Solar PV installers prescribing maintenance activities based of the system installed, which would necessarily differ from mine to mine. Barnard (2020) estimates an annual maintenance cost of 0.02% of the cost of 54 MW solar system for a platinum mining entity in South Africa. This study estimates a more conservative maintenance annual cost of 1% of the cost of solar PV system, increasing by 6% over the investment period.

6.4.2.4. Solar PV investment cost

The solar PV plant cost represents cost incurred for a capital asset that will qualify for capital allowance against income earned by a taxpayer. Section 12B and the proposed section 12BA allow for capital allowances as follows.

6.4.2.4.1. Current capital allowance for solar PV plant (Section 12B)

Efforts that accelerate adoption of renewable energy by entities integrating renewable energy into their operations are permitted by Section 12B capital allowance deductible against their taxable income. The allowance is available on new and unused assets used in the production of electricity from the following renewable sources:

1. wind power;
2. solar energy;
3. hydropower to produce electricity less than 30 MW; and
4. biomass.

The allowance permits a deduction of the cost of the asset over three years, with 50% in the first year, 30% in the second year, and 20% in the third year (South Africa 2023:6).

6.4.2.4.2. Proposed capital allowance for solar PV plant (Section 12BA)

The renewable energy adoption was lower than expected, and therefore further incentives are proposed to accelerate renewable energy adoption. The South African government proposes a deduction of 125% of the cost incurred on renewable energy technology adopted (South Africa 2023:7-8). This deduction is proposed for new and unused renewable energy technologies brought into use on or after March 2023 and before 1 March 2025 (South Africa 2023:7-8). These provisions are currently only in proposal phase, and are not considered in the NPV simulations. Once promulgated into law, section 12BA allowances provide greater incentive for mining entities and tax savings from this allowance to be used as a funding mechanism for renewable energy adoption.

6.5. NPV SIMULATIONS

Mining entities can either invest in solar PV for the electricity saving, or based on the carbon tax level influencing the investment. The two variables need to be isolated and evaluated separately in order to show the impact of each variable on the investment decision. The NPV simulation is conducted under three scenarios. The first of these will examine the impact of carbon tax on the 30MW solar PV investment decision. The second simulation will evaluate the electricity costs saving on the 30MW solar PV investment decision. Lastly, both variables will be combined in the NPV to show all the cashflows associated with the 30MW solar PV investment decision.

6.5.1. Scenario 1: Carbon tax effect (Annexure 1)

The NPV in this scenario is negative ZAR 321,905,394.70, meaning that a mining entity would not invest in a 30MW solar PV plant in order to decarbonise operations due to the investment cost exceeding the carbon tax cost saving over the investment period. A sensitivity analysis is conducted so as to determine the minimum carbon price that would be charged that may encourage mining entities to invest in solar PV plants using the equivalent annual annuity method.

6.5.1.1. Equivalent Annual Annuity

The Equivalent Annual Annuity (EAA) represents the fixed annual cash flows an investment generated over its lifespan (Cai 2022:788). An entity would not invest in a project yielding a negative NPV and negative EAA. Instead, a sensitivity analysis is conducted to determine the break-even carbon price that would have to be charged for a mining entity to be indifferent to investing in solar and continuing to pay a carbon price. The EAA is divided by the annual CO_2 emissions avoided in order to be able to derive the additional carbon price charge per tonne of emissions. EAA in the NPV show that the ZAR159 carbon price would have to be increased by ZAR 509.61 per tonne of CO_2. Such an increase would lead to a break-even carbon price, where a mining entity would be indifferent from investing in solar PV technology, or from continuing to pay carbon tax for continued pollution. A one cent increase in the break-even carbon price would lead to a positive NPV, signifying that the investment ought to be adopted based on NPV rules.

6.5.2. Scenario 2: Electricity saving effect (Annexure 2)

The NPV in this scenario is a positive ZAR 352,720,743.93, signifying that a mining entity would invest in a 30MW solar PV plant purely for related savings in electricity, without a carbon tax charged on emissions. The change in NPV from scenario one highlights the importance of separately evaluating the variables in order to illustrate the individual effect of the two variables, and avoid incorrect conclusions. The savings on the high electricity costs in South Africa are significant enough for mining entities to integrate solar PV in operations, and would strengthen the energy security amid South Africa's energy supply crisis.

6.5.3. Scenario 3: Overall cashflow effect (Annexure 3)

The carbon tax and electricity savings variables were only separated in order to isolate the impact of each. A mining entity's investment decision assesses the holistic differential cashflows that arise from a decision under review. The NPV in this scenario is positive ZAR 502 299 279.73, signifying that a mining entity would likely invest in a 30MW solar PV plant due to the overall net cashflow benefits that extend from such an investment. Introducing the carbon tax saving increased the cashflow benefits from the investment. However, based on Scenario 1 where the electricity saving is removed, the carbon tax saving on its own is not sufficient to persuade mines to invest in solar PV. This shows that the carbon tax saving is merely an additional benefit, and not the main driver of the investment decision.

6.6. CONCLUSION

Tax rates charged will influence investment decisions (Haites 2018:956). Mining entities will invest in solar projects when the cash inflows exceed the cash outflow over the investment period. When evaluating acceptance of investment, cash inflows must match or exceed cash outflows over the investment period. The investment decision rules that entity would invest in a project so long as benefits exceeded the costs (Hanlon & Heitzman 2010:147). A positive NPV signifies investment acceptance due to cash inflows exceeding cash outflows over the investment period.

When reasonably designed, carbon taxes can promote investment in carbon reducing technologies (Luo, Zhou, Song & Fan 2022:1). A well-designed Pigouvian tax equates the cost of pollution to the cost abating the pollution (OECD 2010:98). The carbon price must be higher than the price of investing in renewable energy projects in order for entities to immediately invest in renewable energy projects (Gong & Li 2016:271). One of South Africa's carbon pricing impediments was that it is set too low to encourage decarbonisation. NPV Simulation 1 illustrates that the carbon tax on its own does not encourage investment in solar PV. The carbon tax rate would have to be increased by ZAR 509.61 to reach a break-even price. At break-even point, a mining entity is indifferent from investing in solar PV or continued pollution and paying a carbon tax.

An increase of ZAR 0.01 in the breakeven price would result in a positive NPV of ZAR 6316.69 per tonne of CO_2, signifying acceptance of investing in solar PV based on NPV rules. NPV simulation 2 illustrates that the saving on electricity costs without a carbon tax charged would incentivise a mining entity to invest in solar PV technology. The saving on carbon tax in NPV Simulation 3 enhances the cashflow benefits of investing in solar. The holistic cashflow benefit from investment decision analysis signifies that it would be beneficial for a mining entity to invest in 30MW solar plant. The investment will result in a triple dividend of costing savings, increasing energy security, and reducing CO_2 emissions.

The next chapter follows with the conclusion of the study and provides policy recommendations on carbon pricing in the South African mining sector. Recommendations for future research are identified.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

The climate change problem is an urgent global environmental challenge (Ginanjar & Mubarrok 2020:41; Mikhaylov, Moiseev, Aleshin & Burkhardt 2020:2897; South Africa 2004:1), where decarbonisation efforts constitute part of what is required to avoid adverse climate change effects and attendant disaster. Slowing down the advancement of climate change requires significant decarbonisation that can be achieved with mitigation strategies targeted at heavy polluting industries. The mining industry is a significant contributor of GHG emissions from their business process emissions and indirectly by consuming approximately 5% of fossil fuel generated electricity. Climate change mitigation strategies have been central to carbon pricing policies towards encouraging decarbonisation. Carbon pricing policies need to price carbon at a rate that is higher than investment in green technologies to encourage decarbonisation. The study set out to explore the adequacy of the South African carbon pricing policy and rate in encouraging decarbonisation in the mining industry.

This chapter is laid out as follows. Findings of the study are discussed in section 7.2. Section 7.3 details the policy implications of the study. Limitations of the study is discussed in Section 7.4. The significance of the study is discussed in Section 7.5. Section 7.6 recommends areas for further research. Section 7.7 presents the conclusion to the chapter summarising the findings of the study.

The study was guided by the following research objectives:

1. Review the existing carbon tax policy and its role in decarbonising mining operations in South Africa.
2. Compare international carbon pricing models in relation to varying carbon price levels and the reciprocal reductions in CO_2 emissions.
3. Explore the CO_2 emissions mitigating technologies available to decarbonise mining operations in South Africa.

4. Conduct a CBA of existing carbon price against the investment cost of available CO_2 emissions mitigating technologies using NPV analysis.
5. Make recommendations as to which CO_2 emissions mitigating technologies incentivise investment at the different carbon pricing levels.

This chapter therefore presents: a synthesis of the research findings; theoretical and policy implications of the study; limitations of the study; contributions of the study, as well as recommendations for future research.

7.2. FINDINGS OF THE STUDY

The findings of the study are discussed in relation to the individual research objectives of the study.

7.2.1. Objective 1: Review the existing carbon tax policy and its role in decarbonising mining operations in South Africa

The review found the current South African carbon price to be ineffective in effecting real behavioural change towards a low-carbon economy. This has been linked to low carbon tax rates; generous tax-free CO_2 emissions; and continued support of fossil fuels production through fossil fuel subsidies. Entities can only be incentivised to transition to green technologies in such case that the investment cost of green technologies is lower than the carbon price (Boyce 2018:53). South Africa's carbon pricing trajectory is proposed to gradually raise the carbon price to reach ZAR 380 [49](USD 20) per tonne of CO_2 equivalent by 2026 (South Africa 2022:49). International standards, with the World Bank's High-Level Commission recommend carbon prices that range between ZAR 760[50] (USD 40) and ZAR 1520[51](USD 80) per tonne by 2025. By international standards, the set trajectory of South African carbon price is set below the recommended effective carbon price trajectory. It can therefore be deduced that the South African carbon price is ineffective in influencing any real change in behaviour towards low carbon operations. The low-price argument is further

[49] Translated at ZAR19 to USD1.
[50] Ibid.
[51] Ibid.

supported by the NPV investment decision simulation that the ZAR 159 carbon price alone does not encourage mining entities to invest in Solar PV in South Africa.

7.2.2. Objective 2: Compare international carbon pricing models in relation to varying carbon price levels and the reciprocal reductions in CO2 emissions

The comparative analysis provides key lessons that can be incorporated into the South African carbon pricing policy. The overarching principle in all the carbon pricing models involves the need to institute emissions caps for power generation and energy intensive industries. The emissions cap needs to be determined in collaboration with scientific experts and ought to be in line with the emission reduction pledges made. Carbon policies in comparative countries cater for carbon leakage in determining emission caps so as to cushion the adverse effects carbon pricing has on the competitiveness. Industries prone to carbon leakage are allocated higher emissions allowances in order to cushion the adverse effects of carbon leakage. Furthermore, the emissions levels allow for a decrease per year to show the move away from business-as-usual emission levels. South Africa currently allocates approximately a 90% free emission allowances on the actual emission levels and would need to consider incorporating fixed annual emissions that reduce each year upon integration of mandatory carbon budgets in the carbon tax regime. The capped emissions levels along with pricing the CO_2 emissions to show the adverse social and environmental effects of carbon, will accelerate decarbonisation efforts.

Carbon prices in the EU, The United Kingdom, Switzerland, and Canada exceed ZAR 900 which is significantly higher than the ZAR 159 carbon price in South Africa. These prices are in line with the estimated carbon price range of ZAR 800 to ZAR 1600 per tonne of CO_2 equivalent needed in 2020 for countries to achieve Paris Agreement targets (OECD 2021). The comparative country 2023 carbon prices, with the exception of Canada, already exceed the recommend price trajectory of ZAR 1 000 to ZAR 2 000 per tonne of CO_2 by 2030 (OECD 2021) and have advanced the decarbonisation efforts. Table 7-1 provides a summary addressing the comparative jurisdictions.

Table 7-1: Summary of Comparative Tax Analysis

	South Africa	**EU ETS**	**Canada**	**Switzerland**	**The United Kingdom**
Decarbonisation policy instrument mix	Carbon tax	Emissions trading scheme.	Carbon tax Emissions cap	Emissions trading scheme Emissions cap and subsidy	Emissions trading scheme Carbon tax
Carbon prices in 2023	ZAR 159	ZAR 2000	ZAR 945	ZAR 1720	ZAR 1993 ZAR2401[52] (Power sector)
Weaknesses in SA policy and how strengthened in the comparative jurisdictions	Low carbon price Generous free emission allowances Fossil Fuel subsidies	Emissions cap with higher carbon prices to purchase emission allowances	Emissions cap and higher carbon prices to nudge decarbonisation	Emissions cap with higher carbon prices for exceeding emissions cap Carbon subsidies to reward emissions below emissions cap	Emissions cap and industry-specific higher rates for auction emission allowances Carbon tax on non-domestic use of electricity
Emission reduction	Reduced emissions by 3% from 2018 to 2021	Reduced emissions by approximately 35% between 2005 and 2021	Reduced 7% from 2018 to 2021	Capping emissions reduced in emission levels of 11.7% between the years 2012 and 2018	Carbon prices Support reduced 57% of CO_2 emissions

Source: Author's compilation of summary of comparative tax analysis in Chapter 3.

[52] Emissions Trading Auction price ZAR1993 plus CPS ZAR408.

7.2.3. Objective 3: Explore the CO_2 emissions mitigating technologies available to decarbonise mining operations in South Africa

Mining entities could decarbonise operations through energy efficiency measures, renewable energy integration, and carbon capture (Igogo, Awuah-Offei, Newman, Lowder & Engel-Cox 2021:1). Substantial reduction of fossil fuels use world require the combined use of renewable energy sources and carbon capture (Igogo et al 2021:1). Solar PV and wind technology have advanced technological feasibility in comparison to other renewable energy options adopted in South Africa (Naicker & Thopil 2019:637). Solar PV has been found to be the most viable renewable energy option to be integrated into mining operations (Votteler & Brent 2016:21). Carbon capture technology is still in an exploratory phase with feasibility of adoption evaluation in progress. The infancy of the technological development of CCU in South Africa restricts the availability of the technology to be exploited by the mining sector in decarbonising their operations.

7.2.4. Objective 4: Conduct a cost-benefit analysis of existing carbon prices against the investment cost of available CO_2 emissions mitigating technologies, using Net Present Value analysis

The carbon price must be higher than the price of investing in renewable energy projects in order for entities to immediately invest in renewable energy projects (Gong & Li 2016:271). One of South Africa's carbon pricing impediments was that it is set too low to encourage meaningful decarbonisation. NPV simulations were conducted in order to evaluate whether it is cheaper to invest in 30MW Solar PV plant, or to continue to pollute, subject to carbon tax. Mining entities can either invest in solar PV for the electricity saving, or because the carbon tax level influence the investment. The two variables need to be isolated and evaluated separately in order to show the impact of each variable on the investment decision. The NPV simulation was conducted under three scenarios. The first scenario examines the impact of carbon tax on the 30MW solar PV investment decision. Secondly, the simulation will consider the electricity costs saving on the 30MW solar PV investment decision. Lastly, both variables will be combined in the NPV to show all the cashflows associated with the 30MW solar PV investment decision.

NPV Simulation 1 illustrates that the carbon tax on its own does not encourage investment in solar PV, where the carbon tax rate would have to be increased by ZAR 509.61 to reach a break-even price. At break-even point for a mining entity is not impacted by investing in solar PV versus continued pollution with an attendant carbon tax. The second NPV simulation illustrates that the electricity costs savings are substantial, and will persuade investment in solar PV in the absence of a carbon tax imposition.

7.2.5. Objective 5: Recommend CO_2 emissions mitigating technologies that incentivise investment at the different carbon pricing levels

The carbon price of ZAR 668.62 per tonne of CO_2 would incentivise mines to invest in solar PV technology. A carbon price level of ZAR 668.62 per tonne of CO_2 will yield a positive NPV of ZAR 6 316.69 per tonne of CO_2, signifying acceptance of investing in solar PV, based on NPV rules. The suggested carbon price is only applicable to a scenario where the carbon tax impact is isolated from the electricity costs savings. The electricity cost savings alone encourage solar PV integration, without any carbon tax being levied.

7.3. POLICY IMPLICATIONS OF THE STUDY

In addition to the research objectives stated in section 7.2, the study also aimed to address the following research question:

1. What carbon pricing level incentivises mines in South Africa to invest in CO_2 emissions mitigating technologies?

The findings indicate that the answers to the question culminate to the policy implications for this study as presented below:

7.3.1. Question 1: What carbon pricing level incentivises mines in South Africa to invest in CO_2 emissions mitigating technologies?

The most feasible CO_2 reducing technology available to integrate in South African mining operations was found to be solar PV. Integrating solar PV in mining operations requires the carbon price to be higher than the price of investing in solar PV plant. The carbon price of ZAR 159 per tonne of CO_2 equivalent was found to be insufficient to incentivise Solar PV integration into mining operations. The carbon price of at least ZAR 668.62 per tonne of CO_2 would incentivise mines to invest in Solar PV technology where tax impact is isolated from the electricity costs savings. The current carbon pricing regime is not adequate to encourage decarbonisation in the mining industry.

The design of the South African carbon pricing regime needs to be overhauled to introduce policies that encourage accelerated decarbonisation efforts in energy intensive industries such as mining. Accelerating decarbonation requires policies aimed at reducing emissions in heavy polluting industries. A carbon tax on its own will not result in South Africa reaching its communicated national reduction targets. Deep decarbonisation requires a policy instrument mix and targeted sectoral policy efforts to decarbonise heavy polluting sectors. South Africa needs to develop carbon policies that are sector-specific, due to varied decarbonisation measures needed in each sector. Elsewhere, the UK has successfully levied an additional carbon price to accelerate decarbonisation in the power sector reducing coal power generation from 40% to seven percent. Furthermore, a cap on emissions needs to be introduced in order to control the emissions level. South Africa is already considering mandatory carbon budgets that will cap emission levels in South Africa. A penalty levied on exceeding the prescribed emissions threshold needs to be priced correctly and exceed the cost of abating CO_2 emissions. The carbon price of ZAR 668.62 per tonne of CO_2 would need to be charged for scope two emissions from the use of fossil fuel generated electricity.

7.4. LIMITATIONS OF THE STUDY

The study has offered a qualitative perspective on establishing the carbon pricing strategy that will encourage decarbonisation in the mining sector. The study has the following limitations:

- The carbon pricing policies and comparative jurisdiction emission levels are available at country level, and not available specifically for the mining industry. The information is aggregated with other industries, and it was not possible to evaluate the effect of the international carbon prices on mining industry specific emissions.

- This study does not model an effective carbon price that will achieve emission targets pledged under the Paris Agreement. The study will rely on the existing carbon prices.

- Investment decisions are also influenced by the strategic objectives of a business. Where the strategy is to transition to low-carbon operations, an entity may invest in CO_2 emissions mitigating technologies despite the cost exceeding the benefit. This may be done in order to enhance their corporate social responsibility profile. This study does not intend to evaluate the impact of strategic objectives on the investment decision. The evaluation will be solely from a CBA of the investment.

- Financing decisions of green technologies are omitted, and investment decisions are based solely on the economic viability of the project using discounted cashflow evaluation models. An investment is accepted when the future cash inflows exceed the cost of the investment. Once a good investment is identified, financing options are assessed. This research only assesses the investment decision.

- Energy efficiency measures are not evaluated in this study due to the varied technology options each mining entity can implement in the varied resource production processes.

7.5. SIGNIFICANCE AND CONTRIBUTION OF THIS STUDY

This research fills the knowledge and empirical gap in the unexplored trade-offs of carbon pricing relative to the investment decision into low-carbon transition technologies. Prior research focuses on the effects of carbon tax on the profitability and competitiveness of mining entities in South Africa. Minimal research has been conducted on the impact of carbon pricing on decarbonising mines in South Africa. This study makes a significant contribution to carbon pricing strategies and levels that will encourage decarbonisation of an industry that significantly contributes to climate change. Decarbonisation of an industry significantly contributing to climate change will accelerate climate change mitigation, reducing future harmful effects of climate change.

Decarbonisation requires investment in green technologies. The determination of carbon pricing level and policy strategies that will encourage investment in green technologies, informs the South African government of those carbon pricing levels that need to be implemented in order to mitigate the advancement of climate change and the related adverse effects. Determining the impact of a carbon tax on decarbonisation efforts is essential to inform a more effective carbon pricing system in the second phase of the South African carbon tax regime subsequent to 31 December 2025. The study contributes to the extant knowledge gap on the carbon tax policy strategies required to decarbonise the mining industry in South Africa, and facilitates a much-needed transition to a low carbon economy. The study further establishes the minimum carbon price that should be charged to incentivise South African mining entities to invest in Solar PV technology and reduce the reliance on fossil fuels. Reduction of fossil fuel use reduces the advancement of climate change and the adverse effects thereof.

7.6. RECOMMENDATIONS FOR FUTURE RESEARCH

Two areas of research can be expounded on in the future:

1. Firstly, South Africa can benefit from evaluating the feasibility and possible benefit of integrating a carbon subsidy policy into the carbon pricing regime.
2. Secondly, a detailed cost benefit analysis can be conducted, integrating both renewable energy and carbon capture into mining operations in order to determine the effective carbon price level that will encourage the adoption of both technologies.

7.7. CONCLUDING REMARKS

South Africa's carbon pricing policy is ineffective in encouraging decarbonisation in the mining sector. Deep decarbonisation is required in heavy polluting industries to avoid further temperature increases from the emissions of GHG that accelerate climate change. Carbon pricing policies need to be designed to adequately to encourage decarbonisation efforts in heavy polluting industries such as mining. Sector-specific carbon mitigation policies with emission caps are necessary in order to accelerate decarbonisation in the mining sector. Furthermore, the carbon price needs to be set at a level that exceeds the costs of CO_2 emissions abatement in order to persuade mining entities to decarbonise.

ANNEXURE A: NPV SIMULATION 1

Year		**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Cashflow year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment cost	(497,124,217)										
Maintenance costs		(4,971,242)	(5,269,517)	(5,585,688)	(5,920,829)	(6,276,079)	(6,652,643)	(7,051,802)	(7,474,910)	(7,923,405)	(8,398,809)
Electricity saving		-	-	-	-	-	-	-	-	-	-
Profit/loss before tax		**(4,971,242)**	**(5,269,517)**	**(5,585,688)**	**(5,920,829)**	**(6,276,079)**	**(6,652,643)**	**(7,051,802)**	**(7,474,910)**	**(7,923,405)**	**(8,398,809)**
Income tax benefit		68,454,005	41,689,831	28,352,843	1,598,624	1,694,541	1,796,214	1,903,987	2,018,226	2,139,319	2,267,678
Carbon tax saving		13,235,996	13,328,648	13,421,948	13,515,902	13,610,513	13,705,787	13,801,727	13,898,339	13,995,628	14,093,597
Total cashflow	**(497,124,217)**	**76,718,758**	**49,748,962**	**36,189,104**	**9,193,697**	**9,028,976**	**8,849,357**	**8,653,912**	**8,441,655**	**8,211,542**	**7,962,466**
Discount rate	**11.75%**										
NPV	**(321,905,394.70)**										
EAA	**42,422,719.29**										
Increase in carbon tax to break-even per tonne of CO_2	**509.61**										

Year	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**
Cashflow year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Investment cost										
Maintenance costs	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Electricity saving	-	-	-	-	-	-	-	-	-	-
Profit/loss before tax	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Income tax implications	2,403,739	2,547,964	2,700,841	2,862,892	3,034,665	3,216,745	3,409,750	3,614,335	3,831,195	4,061,067
Carbon tax saving	14,192,252	14,291,598	14,391,639	14,492,381	14,593,827	14,695,984	14,798,856	14,902,448	15,006,765	15,111,812
Total cashflow	**7,693,254**	**7,402,660**	**7,089,365**	**6,751,969**	**6,388,991**	**5,998,858**	**5,579,902**	**5,130,357**	**4,648,349**	**4,131,891**

ANNEXURE A: NPV SIMULATION 1 INCOME TAX IMPLICATIONS

Tax year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Profit/loss before tax	(4,971,242)	(5,269,517)	(5,585,688)	(5,920,829)	(6,276,079)	(6,652,643)	(7,051,802)	(7,474,910)	(7,923,405)	(8,398,809)
Section 12B allowance	(248,562,108.7)	(149,137,265.2)	(99,424,843.5)	-	-	-	-	-	-	-
Taxable income	(253,533,350.9)	(154,406,781.9)	(105,010,531.2)	(5,920,829)	(6,276,079)	(6,652,643)	(7,051,802)	(7,474,910)	(7,923,405)	(8,398,809)
Tax at 27%	(68,454,004.7)	(41,689,831.1)	(28,352,843.4)	(1,598,623.8)	(1,694,541.3)	(1,796,213.7)	(1,903,986.5)	(2,018,225.7)	(2,139,319.3)	(2,267,678.4)

Tax year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Profit/loss before tax	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Section 12B allowance	-	-	-	-	-	-	-	-	-	-
Taxable income	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Tax at 27%	**(2,403,739.2)**	**(2,547,963.5)**	**(2,700,841.3)**	**(2,862,891.8)**	**(3,034,665.3)**	**(3,216,745.2)**	**(3,409,749.9)**	**(3,614,334.9)**	**(3,831,195)**	**(4,061,066.7)**

ANNEXURE B: NPV SIMULATION 2

Year		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Cashflow year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment cost	(497,124,217)										
Maintenance costs		(4,971,242)	(5,269,517)	(5,585,688)	(5,920,829)	(6,276,079)	(6,652,643)	(7,051,802)	(7,474,910)	(7,923,405)	(8,398,809)
Electricity saving		97,822,263	103,173,141	108,816,711	114,768,985	121,046,849	127,668,112	134,651,557	142,016,997	149,785,327	157,978,585
Profit/loss before tax		**92,851,021**	**97,903,624**	**103,231,024**	**108,848,156**	**114,770,770**	**121,015,468**	**127,599,755**	**134,542,087**	**141,861,922**	**149,579,776**
Income tax implications		42,041,994	13,833,083	(1,027,669)	(29,389,002)	(30,988,108)	(32,674,176)	(34,451,934)	(36,326,364)	(38,302,719)	(40,386,539)
Carbon tax saving		-	-	-	-	-	-	-	-	-	-
Total cashflow	**(497,124,217)**	**134,893,014**	**111,736,707**	**102,203,355**	**79,459,154**	**83,782,662**	**88,341,292**	**93,147,821**	**98,215,724**	**103,559,203**	**109,193,236**
Discount rate	**11.75%**										
NPV	**352,720,743.93**										

Year	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Cashflow year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Investment cost										
Maintenance costs	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Electricity saving	166,620,013	175,734,128	185,346,785	195,485,254	206,178,297	217,456,250	229,351,107	241,896,613	255,128,357	269,083,878
Profit/loss before tax	**157,717,276**	**166,297,226**	**175,343,669**	**184,881,951**	**194,938,796**	**205,542,379**	**216,722,404**	**228,510,187**	**240,938,746**	**254,042,891**
Income tax implications	(42,583,664)	(44,900,251)	(47,342,791)	(49,918,127)	(52,633,475)	(55,496,442)	(58,515,049)	(61,697,750)	(65,053,461)	(68,591,580)
Carbon tax saving	-	-	-	-	-	-	-	-	-	-
Total cashflow	**115,133,611**	**121,396,975**	**128,000,878**	**134,963,824**	**142,305,321**	**150,045,937**	**158,207,355**	**166,812,436**	**175,885,285**	**185,451,310**

ANNEXURE B: NPV SIMULATION 2 INCOME TAX IMPLICATIONS

Tax year	1	2	3	4	5	6	7	8	9	10
Profit/loss before tax	**92,851,021**	**97,903,624**	**103,231,024**	**108,848,156**	**114,770,770**	**121,015,468**	**127,599,755**	**134,542,087**	**141,861,922**	**149,579,776**
Section 12B allowance	(248,562,108.7)	(149,137,265.2)	(99,424,843.5)	-	-	-	-	-	-	-
Taxable income	(155,711,088.1)	(51,233,641.4)	3,806,180.1	108,848,156.5	114,770,770.2	121,015,468.2	127,599,755.3	134,542,087.3	141,861,922.5	149,579,775.6
Tax at 27%	**(42,041,993.8)**	**(13,833,083.2)**	**1,027,668.6**	**29,389,002.2**	**30,988,108.0**	**32,674,176.4**	**34,451,933.9**	**36,326,363.6**	**38,302,719.1**	**40,386,539.4**

Tax year	11	12	13	14	15	16	17	18	19	20
Profit/loss before tax	**157,717,276**	**166,297,226**	**175,343,669**	**184,881,951**	**194,938,796**	**205,542,379**	**216,722,404**	**228,510,187**	**240,938,746**	**254,042,891**
Section 12B allowance	-	-	-	-	-	-	-	-	-	-
Taxable income	157,717,275.6	166,297,226.1	175,343,668.8	184,881,950.9	194,938,796.2	205,542,378.9	216,722,403.6	228,510,186.9	240,938,746.1	254,042,890.5
Tax at 27%	**42,583,664.4**	**44,900,251.0**	**47,342,790.6**	**49,918,126.8**	**52,633,475.0**	**55,496,442.3**	**58,515,049.0**	**61,697,750.5**	**65,053,461.4**	**68,591,580.4**

ANNEXURE B: NPV SIMULATION 3

Year		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Cashflow year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Investment cost	(497,124,217)										
Maintenance costs		(4,971,242)	(5,269,517)	(5,585,688)	(5,920,829)	(6,276,079)	(6,652,643)	(7,051,802)	(7,474,910)	(7,923,405)	(8,398,809)
Electricity saving		97,822,263	103,173,141	108,816,711	114,768,985	121,046,849	127,668,112	134,651,557	142,016,997	149,785,327	157,978,585
Profit/loss before tax		**92,851,021**	**97,903,624**	**103,231,024**	**108,848,156**	**114,770,770**	**121,015,468**	**127,599,755**	**134,542,087**	**141,861,922**	**149,579,776**
Income tax implications		42,041,994	13,833,083	(1,027,669)	(29,389,002)	(30,988,108)	(32,674,176)	(34,451,934)	(36,326,364)	(38,302,719)	(40,386,539)
Carbon tax saving		13,235,996	14,023,140	14,857,096	15,740,648	16,676,744	17,668,510	18,719,257	19,832,491	21,011,929	22,261,508
Total cashflow	**(497,124,217)**	**148,129,010**	**125,759,847**	**117,060,451**	**95,199,802**	**100,459,407**	**106,009,802**	**111,867,078**	**118,048,215**	**124,571,132**	**131,454,745**
Discount rate	**11.75%**										
NPV	**502,299,279.73**										

Year	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Cashflow year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Investment cost										
Maintenance costs	(8,902,738)	(9,436,902)	(10,003,116)	(10,603,303)	(11,239,501)	(11,913,871)	(12,628,703)	(13,386,426)	(14,189,611)	(15,040,988)
Electricity saving	166,620,013	175,734,128	185,346,785	195,485,254	206,178,297	217,456,250	229,351,107	241,896,613	255,128,357	269,083,878
Profit/loss before tax	**157,717,276**	**166,297,226**	**175,343,669**	**184,881,951**	**194,938,796**	**205,542,379**	**216,722,404**	**228,510,187**	**240,938,746**	**254,042,891**
Income tax implications	(42,583,664)	(44,900,251)	(47,342,791)	(49,918,127)	(52,633,475)	(55,496,442)	(58,515,049)	(61,697,750)	(65,053,461)	(68,591,580)
Carbon tax saving	23,585,400	24,988,024	26,474,062	28,048,474	29,716,517	31,483,758	33,356,097	35,339,785	37,441,442	39,668,084
Total cashflow	**138,719,012**	**146,384,999**	**154,474,940**	**163,012,299**	**172,021,838**	**181,529,695**	**191,563,452**	**202,152,221**	**213,326,726**	**225,119,394**

ANNEXURE C: NPV SIMULATION 3 INCOME TAX IMPLICATIONS

Tax year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Profit/loss before tax	**92,851,021**	**97,903,624**	**103,231,024**	**108,848,156**	**114,770,770**	**121,015,468**	**127,599,755**	**134,542,087**	**141,861,922**	**149,579,776**
Section 12B allowance	(248,562,108)	(149,137,265)	(99,424,843)	-	-	-	-	-	-	-
Taxable income	(155,711,088.1)	(51,233,641.4)	3,806,180.1	108,848,156	114,770,770	121,015,468	127,599,755	134,542,087	141,861,922	149,579,775
Tax at 27%	**(42,041,993.8)**	**(13,833,083.2)**	**1,027,668.6**	**29,389,002.2**	**30,988,108.0**	**32,674,176.4**	**34,451,933.9**	**36,326,363.6**	**38,302,719.1**	**40,386,539.4**

Tax year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Profit/loss before tax	**157,717,276**	**166,297,226**	**175,343,669**	**184,881,951**	**194,938,796**	**205,542,379**	**216,722,404**	**228,510,187**	**240,938,746**	**254,042,891**
Section 12B allowance	-	-	-	-	-	-	-	-	-	-
Taxable income	157,717,275.6	166,297,226.1	175,343,668.8	184,881,950.9	194,938,796.2	205,542,378.9	216,722,403.6	228,510,186.9	240,938,746.1	254,042,890.5
Tax at 27%	**42,583,664.4**	**44,900,251.0**	**47,342,790.6**	**49,918,126.8**	**52,633,475.0**	**55,496,442.3**	**58,515,049.0**	**61,697,750.5**	**65,053,461.4**	**68,591,580.4**

LIST OF REFERENCES

Abdul-Salam, Y, Kemp, A & Phimister, E. 2022. Energy transition in the UKCS–Modelling the effects of carbon emission charges on upstream petroleum operations. *Energy Economics*, 108:1-12. doi.org/10.1016/j.eneco.2022.105898.

Abrell, J, Kosch, M & Rausch, S. 2022. How effective is carbon pricing? —A machine learning approach to policy evaluation. *Journal of Environmental Economics and Management*, 112:1-22. doi.org/10.1016/j.jeem.2021.102589.

Adenle, AA. 2020. Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals. *Energy Policy*, 137:1-16. doi.org/10.1016/j.enpol.2019.111180.

Ahmadi, MH, Ghazvini, M, Sadeghzadeh, M, Alhuyi Nazari, M, Kumar, R, Naeimi, A & Ming, T. 2018. Solar power technology for electricity generation: A critical review. *Energy Science & Engineering*, 6(5):340-361. doi.org/10.1002/ese3.239

Ahmed, JU. 2010. Documentary research method: New dimensions. Indus Journal of Management & Social Sciences [online], 4(1):1-14.Available from: https://www.researchgate.net/profile/Jashim-Ahmed/publication/227441751_Documentary_Research_Method_New_Dimensions/links/5677ad6208aebcdda0eb20fb/Documentary-Research-Method-New-Dimensions.pdf [Accessed 16 October 2023]

AICPA, see American Institute of Certified Public Accountants

Ali, S, Yan, Q, Sajjad Hussain, M, Irfan, M, Ahmad, M, Razzaq, A, Dagar, V & Işık, C. 2021. Evaluating green technology strategies for the sustainable development of solar power projects: evidence from Pakistan. *Sustainability*, 13(23):1-29. doi.org/10.3390/su132312997.

Aliyu, AK, Modu, B & Tan, CW. 2018. A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria. *Renewable and Sustainable Energy Reviews*, 81:2502-2518. doi.org/10.1016/j.rser.2017.06.055.

Almetwally, AA, Bin-Jumah, M & Allam, AA. 2020. Ambient air pollution and its influence on human health and welfare: an overview. Environmental Science and Pollution Research, 27:24815-24830. doi.org/10.1007/s11356-020-09042-2

Akinbami, OM, Oke, SR & Bodunrin, MO. 2021. The state of renewable energy development in South Africa: An overview. *Alexandria Engineering Journal*, 60(6):5077-5093. doi.org/10.1016/j.aej.2021.03.065.

American Institute of Certified Public Accountants. 2017. *Guiding principles of good tax policy: A framework for evaluating tax proposals* [online]. United States: American Institute of Certified Public Accountants. https://www.journalofaccountancy.com/issues/2002/feb/guidingprinciplesofgoodtaxpolicy.html [17 September 2023]

Ball, J. 2018. Why carbon pricing Isn't Working: Good Idea in theory, failing in Practice. *Foreign Affairs*, 97(4):124-133. Available from https://heinonline.org/HOL/PrintRequest?collection=journals&handle=hein.journals/fora97&div=87&id=774&print=section&format=PDFsearchable&submit=Print%2FDownload [Accessed 15 June 2023].

Baranzini, A, Van den Bergh, JC, Carattini, S, Howarth, RB, Padilla, E, & Roca, J. 2017. Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. *Wiley Interdisciplinary Reviews: Climate Change*, 8(4):1-17. Doi: 10.1002/wcc.462.

Barnard, SSS. 2020. A cost-benefit analysis of implementing a solar plant in a platinum mining company. Master of Business Administration. North-West University, North-West.

Barnes, A. 2021. The challenges and prospects for carbon pricing in Europe. England: Oxford Institute for Energy Studies.

Beck, B, Kulichenko-Lotz, N & Surridge, T. 2017. World Bank CCS Program activities in South Africa – Results and Lessons Learned. *Energy Procedia*, 114:5636-5649. doi.org/10.1016/j.egypro.2017.03.1702.

Bierman Jr, H & Smidt, S. 2012. The capital budgeting decision: economic analysis of investment projects. London: Routledge.

Blackman, A. 2010. Alternative pollution control policies in developing countries. *Review of Environmental Economics and Policy*, 4(2): 234–253. doi:10.1093/reep/req005.

Bora, B. 2015. Comparison between net present value and internal rate of return. *International Journal of Research in Finance and Marketing*, 5(12):61-71. ISSN 2231-5985.

Botín, J. 2019. Managing risk in mineral investment decisions: A global focus. *Boletín Geológico y Minero*, 130 (1): 67-80. doi.org/10.21701/bolgeomin.130.1.005.

Boyce, JK. 2018. Carbon pricing: Effectiveness and equity. *Ecological Economics,* 150:52-61. doi.org/10.1016/j.ecolecon.2018.03.030.

Bowen, F, Tang, S & Panagiotopoulos, P. 2020. A classification of information-based environmental regulation: Voluntariness, compliance and beyond. *Science of the Total Environment*, 712:1-11. doi.org/10.1016/j.scitotenv.2019.135571.

BP. 2020. *Statistical review of world energy* [online]. Available from: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf [Accessed 31 July 2021].

Cai, J. 2022. International Conference on mathematical statistics and economic analysis in 2022 (MSEA 2022): Research on the Application of EAA and EAC. Atlantis Press. 787-793.

Campbell, S, Greenwood, M, Prior, S, Shearer, T, Walkem, K, Young, S, Bywaters, D & Walker, K. 2020. Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, 25(8):652-661. doi.org/10.1177/1744987120927206.

Catalano, M, Forni, L & Pezzolla, E. 2020. Climate-change adaptation: The role of fiscal policy. *Resource and Energy Economics*, 59(101111): 1-19. doi.org/10.1016/j.reseneeco.2019.07.005.

Cardona, D, De Freitas, J & Rubí-Barceló, A. 2021. Environmental policy contests: command and control versus taxes. *International Tax and Public Finance*, 28:654–684. doi.org/10.1007/s10797-020-09631-4.

Chen, X & Lin, B.2021. Towards carbon neutrality by implementing carbon emissions trading scheme: Policy evaluation in China. Energy Policy, 157:1-12. doi.org/10.1016/j.enpol.2021.112510.

Crause, R. No date. *South African inflation calculator* [online]. Available from: https://inflationcalc.co.za/?date1=2005-01-01&date2=2021-04-30&amount=200 [Accessed 30 April 2021].

Crippa M, Guizzardi D, Banja M, Solazzo E, Muntean M, Schaaf E, Pagani F, Monforti-Ferrario F, Olivier, JGJ, Quadrelli, R, Grassi, G, Rossi, S, Oom, D, Branco, A, San-Miguel, J, Vignati, E. 2022. *CO_2 emissions of all world countries - 2022 Report* [online]. Luxembourg: Publications Office of the European Union. Available from:

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC130363/co2_emissions_of_all_world_countries_online_final_2.pdf [Accessed 23 May 2023].

Criqui, P, Jaccard, M & Sterner, T. 2019. Carbon taxation: A tale of three countries. *Sustainability*, 11(22):1-21. doi.org/10.3390/su11226280.

Datta, TK. 2017. Effect of green technology investment on a production-inventory system with carbon tax. *Advances in Operations Research*, 4834839:1-12. doi.org/10.1155/2017/4834839.

Davis Tax Committee. 2015. Report on a carbon tax for South Africa. Pretoria, South Africa: Davis Tax Committee.

Davis Tax Committee. 2018. Feasibility of a wealth tax in South Africa. Pretoria, South Africa: Davis Tax Committee.

Department of Mineral Resources and Energy. No Date. *Operating Mines* [online]. South Africa: Department of Mineral Resources and Energy. Available from: https://www.dmr.gov.za/mineral-policy-promotion/operating-mines [Accessed 04 April 2023].

Department of Mineral Resources and Energy. No date. Renewable energy data and information service [online]. Available from: http://redis.energy.gov.za/power-producers/ [Accessed 10 May 2023].

Dissanayake, S, Mahadevan, R & Asafu-Adjaye, J. 2020. Evaluating the efficiency of carbon emissions policies in a large emitting developing country. *Energy Policy*, 136:1-11. doi.org/10.1016/j.enpol.2019.111080.

Dobrowolski, Z, & Drozdowski, G. 2022. Does the net present value as a financial metric fit investment in green energy security? Energies, 15(1), 353-369.doi.org/10.3390/en15010353.

Dong, C, Shen, B, Chow, PS, Yang, L & Ng, CT. 2016. Sustainability investment under cap-and-trade regulation. Annals of Operations Research, 240:509-531. doi.org/10.1007/s10479-013-1514-1.

Drury, CM. 2019. *Management and Cost Accounting*. United States: Cengage Learning.

Duve, T. 2018. Legal traditions: A dialogue between comparative law and comparative legal history, *Comparative Legal History*, 6(1):15-33, doi.org/10.1080/2049677X.2018.1469271.

Environment and Climate Change Canada. 2017. Technical Paper on The Federal Carbon Pricing Backstop. Canada: Environment and Climate Change Canada.

Environment and Climate Change Canada. 2022. *Canadian Environmental Sustainability Indicators: Greenhouse gas emissions* [online]. Available at: https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/ghg-emissions/2022/ghg-emissions-en.pdf [Accessed 5 May 2023].

Etikan, I, Musa, SA & Alkassim, RS. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1):1-4. doi/org/10.11648/j.ajtas.20160501.11.

Eskom. 2021. *Emissions* [online]. Available at: https://www.eskom.co.za/dataportal/emissions/ [Accessed 12 August 2021].

Eskom. 2022. *Integrated Report* [online]. Available from: https://www.eskom.co.za/wp-content/uploads/2022/12/2022_integrated_report.pdf [Accessed 26 August 2023].

Esterhuyse, S, Vermeulen, D & Glazewski, J. 2019. Regulations to protect groundwater resources during unconventional oil and gas extraction using fracking. *Wiley Interdisciplinary Reviews*: Water, 6(6):1-19. doi.org/10.1002/wat2.1382.

European Commission. 2022. *Report from the Commission to the European parliament and the council on the Functioning of the European carbon market in 2021 pursuant to Articles 10(5) and 21(2) of Directive 2003/87/EC* [online]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0516 [Accessed 21 July 2023].

European Commission. No Date. *EU Emissions Trading System* [online]. Europe: European Commission. Available from: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en#:~:text=Installations%20covered%20by%20the%20ETS,emissions%20observing%20the%20same%20scope [Accessed 23 May 2023].

European Energy Exchange. 2022. *Auctions by the Common Auction Platform* [online]. Available from: https://climate.ec.europa.eu/system/files/2023-03/cap_report_202212_en.pdf [Accessed 20 May 2023].

European Union. 2015. *EU ETS Handbook* [online]. Available from: https://www.sallan.org/pdf-docs/ets_handbook_en.pdf [Accessed 21 July 2023].

Farjana, SH, Huda, N, Mahmud, MP & Saidur, R. 2019. A review on the impact of mining and mineral processing industries through life cycle assessment. *Journal of Cleaner Production*, 231:1200-1217.doi.org/10.1016/j.jclepro.2019.05.264.

Federal Office for the Environment. No Date. *CO_2 levy. Canada: Federal Office for the Environment* [online]. Available from: https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/co2-levy.html [Accessed 23 May 2023].

Federal Office for the Environment. No Date. *Emissions registry. Canada: Federal Office for the Environment* [online]. Available from: https://www.emissionsregistry.admin.ch/crweb/public/auction/dates.action [Accessed 23 May 2023].

Felsberger, R, Buchroithner, A, Gerl, B & Wegleiter, H. 2020. Conversion and testing of a solar thermal parabolic trough collector for CPV-T application. *Energies*, 13(22), 1-24. doi:10.3390/en13226142.

Flues, F & van Dender, K. 2020, Carbon pricing design: Effectiveness, efficiency, and feasibility: An investment perspective, Paris: OECD Taxation Working Papers. Available from: doi.org/10.1787/91ad6a1e-en [Accessed 20 July 2023].

Forbes Home. No Date. *How Long Do Solar Panels Last?* [online]. Available from: https://www.forbes.com/home-improvement/solar/how-long-do-solar-panels-last/#:~:text=Utah-,Do%20Solar%20Panels%20Degrade%20Over%20Time%3F,slight%20decrease%20over%20the%20years [Accessed 23 July 2023].

Galdi, G, Verde, SF, Isabella, A, Borghesi, S, Jürg, F, Ted, J, Bettina, S, Emily, W & Zhou, L. 2020. *Informing the carbon market policy dialogue: the emissions trading systems at a glance* [online]. Available from: https://usiena-air.unisi.it/retrieve/e0feeaab-b93f-44d2-e053-6605fe0a8db0/2020b%2c%20Verde%20et%20al_compressed.pdf [Accessed 23 July 2023].

Geroe, S. 2019. Addressing climate change through a low-cost, high-impact carbon tax. *The Journal of Environment & Development,* 28(1):3-27. doi.org/10.1177/1070496518821152.

Ghazouani, A, Xia, W, Jebli, MB & Shahzad, U. 2020. Exploring the role of carbon taxation policies on CO_2 emissions: contextual evidence from tax implementation and non-implementation European Countries. *Sustainability*, 12(20):1-16. doi.org/10.3390/su12208680.

Gilder, A & Stiles, G. 2019. Comparative Approaches to Carbon Taxation in Canada and South Africa. *Carbon & Climate Law Review*, 13(4):270-279. Available from: https://www.jstor.org/stable/10.2307/26895683 [Accessed 05 Dec 2022].

Ginanjar, WR & and Mubarrok, AZ. 2020. Civil Society and Global Governance: The Indirect Participation of Extinction Rebellion in Global Governance on Climate Change. *Journal of Contemporary Governance and Public Policy*, 1(1):41-52. doi.org/10.46507/jcgpp.v1i1.8.

Gold Fields. No date. *The South Deep Khanyisa solar plant* [online]. Available from: https://www.goldfields-southdeep.co.za/resources/the-south-deep-solar-plant [Accessed 15 July 2023].

Gong, P & Li, X. 2016. Study on the investment value and investment opportunity of renewable energies under the carbon trading system. *Chinese Journal of Population Resources and Environment*, 14(4):271-281. doi.org/10.1080/10042857.2016.1258796.

Government UK. No date. Guidance Climate Change Levy rates [online]. Available from: https://www.gov.uk/guidance/climate-change-levy-rates [Accessed 23 May 2023].

Government UK. 2021. *Changes to rates for the Climate Change Levy for 2022 to 2023 and 2023 to 2024* [online]. The United Kingdom: Government UK. Available from: https://www.gov.uk/government/publications/changes-to-rates-for-the-climate-change-levy-for-2022-to-2023-and-2023-to-2024/changes-to-rates-for-the-climate-change-levy-for-2022-to-2023-and-2023-to-2024 [Accessed 23 May 2023].

Government UK. 2022. Guidance UK ETS: Carbon prices for use in civil penalties [online]. Available from: https://www.gov.uk/government/publications/determinations-of-the-uk-ets-carbon-price/uk-ets-carbon-prices-for-use-in-civil-penalties-2023#:~:text=the%20carbon%20price%20for%20the%20scheme%20year%20beginning,January%202023%20is%20%C2%A383.03 [Accessed 23 May 2023].

Green, JF. 2021. Does carbon pricing reduce emissions? A review of ex-post analyses. *Environmental Research Letters*, 16(043004):1-17. doi.org/10.1088/1748-9326/abdae9.

Gugler, K, Haxhimusa, A & Liebensteiner, M. 2023. Carbon pricing and emissions: Causal effects of Britain's carbon tax. *Energy Economics*, 121:1-21. doi.org/10.1016/j.eneco.2023.106655.

Guo, X, Fu, L & Sun, X. 2021. Can environmental regulations promote greenhouse gas abatement in OECD countries? Command-and-control vs. market-based policies. Sustainability, 13(12):1-18. doi.org/10.3390/su13126913.

Gupta, NK. 2020. Analysing Command and Control Mechanism and Market Based Instruments for Implementation of Polluter Pays Principle in India. *GLS Law Journal*. Available from: https://www.glslawjournal.in/index.php/glslawjournal/article/view/26/35 [Accessed 20 July 2023].

Haites, E. 2018. Carbon taxes and greenhouse gas emissions trading systems: what have we learned? *Climate Policy*, 18(8):955-966. doi.org/10.1080/14693062.2018.1492897.

Halkos, GE & Kitsou, DC. 2018. Weighted location differential tax in environmental problems. *Environmental Economics and Policy Studies*, 20(1):1-15. https://doi.org/10.1007/s10018-016-0179-9.

Hanlon, M & Heitzman, S. 2010. A review of tax research. *Journal of Accounting and Economics*, 50(2-3):127-178. doi:10.1016/j.jacceco.2010.09.002.

Harmony Gold. 2021. *ESG Report 2021* [online]. Available from: https://www.har.co.za/22/download/HAR-ESG22.pdf [Accessed 24 July 2023].

Harrison Solar. No Date. *Solar vs Wind Power* [online]. Available from: https://www.harrisonssolar.co.nz/article/solar-vs-wind-power-which-renewable-energy-is-better [Accessed 23 May 2023].

Haszeldine, RS, Flude, S, Johnson, G & Scott, V. 2018. Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2119):1-23. doi.org/10.1098/rsta.2016.0447.

Hayat, MB, Ali, D, Monyake, KC, Alagha, L & Ahmed, N. 2019. Solar energy—A look into power generation, challenges, and a solar-powered future. *International Journal of Energy Research*, 43(3):1049-1067. doi.org/10.1002/er.4252.

Hazra, ND. 2022. Emission Trading Schemes (ETS) in India: An Overview. *Sustainability, Agri, Food and Environmental Research*, 11(1):1-12. doi.org/10.7770/safer-V11N1-art2634.

Heal, G & Schlenker, W. 2019. Coase, hotelling and Pigou: The incidence of a carbon tax and CO_2 emissions. *National Bureau of Economic Research*. Doi.10.3386/w26086.

Hintermann, B & Žarković, M. 2021. A carbon horse race: Abatement subsidies vs. permit trading in Switzerland. *Climate Policy*, 21(3):290-306. doi.org/10.1080/14693062.2020.1846485.

Hodgkinson, JH & Smith, MH. 2018. Climate change and sustainability as drivers for the next mining and metals boom: The need for climate-smart mining and recycling. *Resources Policy*, 101205:1-11. doi.org/10.1016/j.resourpol.2018.05.016

Hoegh-Guldberg, O, Jacob, D, Taylor, M, Bolaños, TG, Bindi, M, Brown, S, Camilloni, IA, Diedhiou, A, Djalante, R, Ebi, K, & Engelbrecht, F. 2019. The human imperative of stabilizing global climate change at 1.5 C. *Science*, 365(6459):1-11. doi.org/10.1126/science.aaw6974.

Hossain, MM & Ali, MH. 2015. Future research directions for the wind turbine generator system. *Renewable And Sustainable Energy Reviews*, 49:481-489. doi.org/10.1016/j.rser.2015.04.126.

ICC, see International Chambers of Commerce.

International Chambers of Commerce. 2022. Critical Design Features for Effective Carbon Pricing A Business Perspective. Paris, France: International Chambers of Commerce.

IEA, see International Energy Agency.

Igogo, T, Awuah-Offei, K, Newman, A, Lowder, T & Engel-Cox, J. 2021. Integrating renewable energy into mining operations: Opportunities, challenges, and enabling approaches. *Applied Energy*, 300(117375):1-13. https://doi.org/10.1016/j.apenergy.2021.117375.

IISD, see International Institute for Sustainable Development.

Immink, H, Louw, RT & Brent, AC. 2018. Tracking decarbonisation in the mining sector. *Journal of Energy in Southern Africa*, 29(1):14-23. doi.org/10.17159/2413-3051/2018/v29i1a343.

Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: New York.

International Carbon Action Partnership. No date. Swiss ETS [online]. Available from: https://icapcarbonaction.com/en/ets/swiss-ets#:~:text=3%25%20were%20placed%20in%20the,benchmarks%20as%20the%20EU%20ETS [Accessed 19 April 2023].

International Energy Agency. 2023. *CCUS Projects Database* [online]. Paris International Energy Agency. Available from: http://www.iea.org/data-and-statistics/data-product/ccus-projects-database [Accessed 24 March 2023].

International Energy Agency. No Date. *Capital costs of utility-scale solar PV in selected emerging economies* [online]. Available from: https://www.iea.org/data-and-statistics/charts/capital-costs-of-utility-scale-solar-pv-in-selected-emerging-economies [Accessed 20 July 2023].

International Institute for Sustainable Development. 2019. *Beyond Fossil Fuels: Fiscal Transition in BRICS a South African case study* [online]. Available from: https://www.iisd.org/publications/beyond-fossil-fuels-south-africa [Accessed 1 May 2021].

International Programme for climate change. 2021. A credible carbon tax trajectory for Ireland. Accessed from: https://www.oecd.org/climate-action/ipac/webbooks-practices/dynamic/ipac-case-studies/a39128a3/pdf/a-credible-carbon-tax-trajectory-for-ireland.pdf [Accessed 8 May 2023].

IPCC, see Intergovernmental Panel on Climate Change.

Jain, S & Jain, PK. 2017. The rise of renewable energy implementation in South Africa. *Energy Procedia*, 143, pp.721-726. doi.org/10.1016/j.egypro.2017.12.752.

Jaqua, D & Schaffa, D. 2021. The case for subsidizing harm: constrained and costly Pigouvian taxation with multiple externalities. *International Tax and Public Finance*, 29:1-35. doi.org/10.1007/s10797-021-09670-5.

Johnson, JMF, Franzluebbers, AJ, Weyers, SL& Reicosky, DC. 2007. Agricultural opportunities to mitigate greenhouse gas emissions. Environmental Pollution, 150(1):107-124. doi:10.1016/j.envpol.2007.06.030.

Johnston, MP. 2014. Secondary data analysis: A method of which the time has come. *Qualitative and quantitative methods in libraries*, 3(3):619-626. Available from: http://www.qqml-journal.net/index.php/qqml/article/view/169/170 [Accessed 8 September 2021].

Joltreau, E & Sommerfeld, K. 2019. Why does emissions trading under the EU Emissions Trading System (ETS) not affect firms' competitiveness? Empirical findings from the literature. *Climate policy*, 19(4):453-471. doi.org/10.1080/14693062.2018.1502145.

Katta, AK, Davis, M & Kumar, A. 2020. Assessment of greenhouse gas mitigation options for the iron, gold, and potash mining sectors. *Journal of Cleaner Production*, 245(118718):1-17. doi.org/10.1016/j.jclepro.2019.118718.

Khan, SAR, Ponce, P & Yu, Z. 2021. Technological innovation and environmental taxes toward a carbon-free economy: An empirical study in the context of COP-21. *Journal of Environmental Management*, 298:1-12. doi.org/10.1016/j.jenvman.2021.113418.

Kiprotich, BA. 2016. *Principles of taxation* [online]. Available from: https://taxjustice-and-poverty.org/fileadmin/Dateien/Taxjustice_and_Poverty/Introduction/05_Principles.pdf [Accessed 20 July 2023].

Kiss, T & Popovics, S. 2021. Evaluation on the effectiveness of energy policies–Evidence from the carbon reductions in 25 countries. *Renewable and Sustainable Energy Reviews*, 149:1-10. doi.org/10.1016/j.rser.2021.111348.

Ko, YC, Zigan, K & Liu, YL. 2021. Carbon capture and storage in South Africa: A technological innovation system with a political economy focus. T*echnological Forecasting and Social Change*, 166:1-10. doi.org/10.1016/j.techfore.2021.120633.

Köppl, A & Schratzenstaller, M. 2021. *Effects of environmental and carbon taxation: A literature review* [online]. Available from: https://www.econstor.eu/bitstream/10419/231459/1/1750203480.pdf [Accessed 20 July 2023]

Korstjens, I. and Moser, A., 2018. Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. European Journal of General Practice, 24(1):120-124. doi.org/10.1080/13814788.2017.1375092

Kost, C, Mayer, JN, Thomsen, J, Hartmann, N, Senkpiel, C, Philipps, SP, Nold, S, Lude, S, Saad, N, Schmid, J & Schlegl, T. 2013. *Levelized Cost of Electricity: PV and CPV in comparison to other technologies* [online]. Available from: https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/conference-paper/29-eupvsec-2014/Kost_7AV640.pdf [Accessed 13 September 2021].

Kotlán, I, Němec, D, Kotlánová, E, Skalka, P, Macek, R & Machová, Z. 2021. European Green Deal: Environmental Taxation and Its Sustainability in Conditions of High Levels of Corruption. *Sustainability*, 13(4):1-15. doi.org/10.3390/su13041981.

Kumar, L, Hasanuzzaman, M & Rahim, NA. 2019. Global advancement of solar thermal energy technologies for industrial process heat and its future prospects: A review.

Energy Conversion and Management, 195:885-908. doi.org/10.1016/j.enconman.2019.05.081.

Leedy, P & Ormrod, J. 2001. Practical research: Planning and design (7th ed.). United Sates: SAGE Publications.

Leroutier, M. 2022. Carbon pricing and power sector decarbonization: Evidence from the UK. *Journal of Environmental Economics and Management*, 111:1-22. doi.org/10.1016/j.jeem.2021.102580.

Levin, K, Rich, D, Bonduki, Y, Comstock, M, Tirpak, D, Mcgray, H, Noble, I, Mogelgaard, K & Waskow, D. 2015. *Designing and preparing intended nationally determined contributions (INDCs)* [online]. World Resources Institute: Washington, DC, USA. Available from: https://www.climatefinance-developmenteffectiveness.org/sites/default/files/event/CFSDforum2015/climate/Designing%20and%20Preparing%20Intended%20Nationally%20Determined%20Contributions%20(INDCs).pdf [Accessed 17 September 2021].

Li, X & Deng, G. 2022. Research on the Effect of an Environmental Protection Tax Policy on Haze Control in China—Empirical Analysis Based on Provincial Panel Data. *Sustainability*, 14(1):1-12. doi.org/10.3390/su14010041

Li, W, Gu, Y, Liu, F & Li, C. 2019. The effect of command-and-control regulation on environmental technological innovation in China: a spatial econometric approach. Environmental Science and Pollution Research, 26:34789-34800. doi.org/10.1007/s11356-018-3678-3.

Liao, Z. 2018. Environmental policy instruments, environmental innovation and the reputation of enterprises. *Journal of Cleaner Production*, 171:1111-1117. doi.org/10.1016/j.jclepro.2017.10.126.

Lin, T & Bui, L. 2019. A multi-stakeholder approach to carbon pricing in Canada. *Journal of Science Policy & Governance*, 14(1):1-10. Available from http://www.sciencepolicyjournal.org/uploads/5/4/3/4/5434385/lin___bui_jspg_02_19.pdf [Accessed 20 July 2023].

Lincoln, Y & Guba, EG. 1985. Naturalistic inquiry. Newbury Park, CA: Sage.

Lim-Camacho, L, Jeanneret, T & Hodgkinson, JH. 2019. Towards resilient, responsive, and rewarding mining: an adaptive value chains approach. *Resources Policy*, 101465:1-9. doi.org/10.1016/j.resourpol.2019.101465.

Luo, R, Zhou, L, Song, Y & Fan, T. 2022. Evaluating the impact of carbon tax policy on manufacturing and remanufacturing decisions in a closed-loop supply chain. *International Journal of Production Economics*, 245:1-24 doi.org/10.1016/j.ijpe.2022.108408.

Malischek, R, Baylin-Stern, A & McCulloch, S. 2019. *Transforming Industry through CCUS* [online]. Paris: International Energy Agency. Available from: https://www.iea.org/reports/transforming-industry-through-ccus [Accessed 30 March 2021].

Maxwell, JA. 2010. Using numbers in qualitative research. Qualitative inquiry, 16(6):475-482. doi:10.1177/1077800410364740.

McKerchar, M. 2008. Philosophical paradigms, inquiry strategies and knowledge claims: Applying the principles of research design and conduct to taxation. Available from: https://heinonline.org/HOL/Page?handle=hein.journals/ejotaxrs6&div=5&g_sent=1&casa_token=3FQG7aeqEWMAAAAA:R6CBdDYurR1SAH0NQIsryD3mgyCayI-C4fPXU2BheW2vsSvuLlk37_XQ6-DxW8EkfSvnkw6I54k&collection=journals [Accessed 20 June 2023].

McKitrick, R. 2016. A practical guide to the Economics of Carbon Pricing. *SPP Research Papers*, 9(28): 1-27.doi.org/ssrn.com/abstract=2844481.

Messere, KC & Owens, JP. 1987. International Comparisons of Tax Levels: Pitfalls and Insights”. *Economic Studies*, 8:83-119. Available from: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ef3c02d17266bd1b67210938764bcbfdbd02ca3c [Accessed 20 July 2023].

Miceikiene, A, Lideikyte, J, Savickiene, J & Cesnauske, J. 2019. The role of environmental taxes as a fiscal instrument for mitigation of environmental pollution: Lithuanian case. *European Scientific Journal*, 15(25):1-16 .doi.org/10.19044/esj.2019.v15n25p26.

Mikhaylov, A, Moiseev, N, Aleshin, K & Burkhardt, T. 2020. Global climate change and greenhouse effect. *Entrepreneurship and Sustainability Issues*, 7(4): 2897-2913. doi.org/10.9770/jesi.2020.7.4(21).

Minerals Council South Africa. 2019. *Integrated Annual Review* [online]. Available from: https://www.mineralscouncil.org.za/industry-news/publications/annual-reports [Accessed 31 July 2021].

Minerals Council South Africa. 2022. *The impact of the carbon tax on the mining sector* [online]. Available from: https://www.mineralscouncil.org.za/downloads/send/33-factsheets/847-the-impact-of-the-carbon-tax-on-the-mining-sector#:~:text=The%20indirect%20impact%20of%20the,electricity%20(from%202023%20onwards).

Modiba, DG. 2019.The Potential Effects of the Carbon Emission Tax Imposition on South African Mining Companies' Profitability and Emission Reduction. Master of Science in Engineering. University of the Witwatersrand, Johannesburg.

Moore, FC, Baldos, U, Hertel, T & Diaz, D. 2017. New science of climate change impacts on agriculture implies higher social cost of carbon. *Nature Communications*, 8(1):1-9. doi.org/10.1038/s41467-017-01792-x.

Moz-Christofoletti MA & Pereda PC. 2021. Winners and losers: the distributional impacts of a carbon tax in Brazil. Ecological Economics, 183:1-19. doi.org/10.1016/j.ecolecon.2021.106945.

Msigwa, G, Ighalo, JO & Yap, PS. 2022. Considerations on environmental, economic, and energy impacts of wind energy generation: Projections towards sustainability initiatives. *Science of the Total Environment*, 849(2022):1-12. doi.org/10.1016/j.scitotenv.2022.157755.

Mutombo, NMA & Numbi, BP. 2019. Assessment of renewable energy potential in Kwazulu-Natal province, South Africa. *Energy Reports*, 5:874-881. doi.org/10.1016/j.egyr.2019.07.003.

Naicker, K. 2018. Investigating the operations and maintenance strategy of solar photovoltaic plants in South Africa. Master of Business Administration. North-West University, North-West.

Naicker, P & Thopil, GA. 2019. A framework for sustainable utility scale renewable energy selection in South Africa. *Journal of Cleaner Production*, 224: 637-650. doi.org/10.1016/j.jclepro.2019.03.257.

Nasirov, S & Agostini, CA. 2018. Mining experts' perspectives on the determinants of solar technologies adoption in the Chilean mining industry. *Renewable and Sustainable Energy Reviews*, 95:194-202. doi.org/10.1016/j.rser.2018.07.038.

Nasrin, R, Hasanuzzaman, M & Rahim, NA. 2018. Effect of high irradiation on photovoltaic power and energy. *International Journal of Energy Research*, 42(3):1115-1131. doi.org/10.1002/er.3907.

Nichols, KL. 2005. Tax Policy and the Principles Underlying a “Good Tax”. *Maine Policy Review*, 14(1):12-15. Available from: https://digitalcommons.library.umaine.edu/mpr/vol14/iss1/5. [Accessed 20 July 2023].

Nkambule, NP & Blignaut, JN. 2012. The external costs of coal mining: the case of collieries supplying Kusile power station. *Journal of Energy in Southern Africa*, 23(4):85-93. Available from: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-447X2012000500009&lng=en&nrm=iso>. ISSN 2413-3051 [Accessed 8 August 2021].

Nong, D. 2020. Development of the electricity-environmental policy CGE model (GTAP-E-PowerS): A case of the carbon tax in South Africa. *Energy Policy*, 140(2020):1-16 doi.org/10.1016/j.enpol.2020.111375.

Nordhaus, WD. 2016. Revisiting the social cost of carbon. Proceedings of the National Academy of Sciences, 114(7):1518-1523. doi.org/10.1073/pnas.1609244114

Nowell, LS, Norris, JM, White, DE & Moules, NJ. 2017. Thematic analysis: Striving to meet the trustworthiness criteria. International journal of qualitative methods, 16(1):1-13. doi.org/10.1177/1609406917733847.

Nwaigwe, KN. 2022. Assessment of wind energy technology adoption, application and utilization: a critical review. International *Journal of Environmental Science and Technology*, 19(5):4525-4536. doi.org/10.1007/s13762-021-03402-2.

Odell, SD, Bebbingtonne, A & Frey, KE. 2018. Mining and climate change: A review and framework for analysis. *The extractive industries and society*, 5(1):201-214. doi.org/10.1016/j.exis.2017.12.004.

OECD, see Organisation for Economic Co-operation and Development.

Oke, O & Conteh, LJ. 2020. Capital Budgeting and Financial Management in Investment Decisions: An Illustrative Study. *International Journal of Business, Accounting, and Finance,* 14(2):13-26. Available from: https://search.ebscohost.com/login.aspx?direct=true&db=bsu&AN=148444455&site=ehost-live [Accessed: 18 August 2021].

Olufemi, AC, Bello, PO & Mji, A. 2018. Conflict implications of coal mining and environmental pollution in South Africa: Lessons from Niger Delta, Nigeria. *African Journal on Conflict Resolution*, 18(1):7-35. doi/pdf/10.10520/EJC-ff5423180.

Organisation for Economic Co-operation and Development. 2010. Taxation, Innovation, and the Environment. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2014. Addressing the tax challenges of the digital economy. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2017. Designing Carbon Pricing Instruments for Ambitious Climate Policy. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2021. *Environmental performance reviews Ireland 2021* [online]. Accessed from: https://doi.org/10.1787/9ef10b4f-en [Accessed 8 May 2023].

Oshionebo, E. 2017. Citizen Enforcement of Environmental Regulation in Africa's Extractive Industries. International Business and Trade Law, 17:35-57. Accessed from: https://heinonline.org/HOL/PrintRequest?collection=journals&handle=hein.journals/asperv17&div=5&id=43&print=section&format=PDFsearchable&submit=Print%2FDownload [Accessed 20 July 2023].

Oyewo, AS, Aghahosseini, A, Ram, M, Lohrmann, A and Breyer, C. 2019. Pathway towards achieving 100% renewable electricity by 2050 for South Africa. *Solar Energy*, 191:549-565. doi.org/10.1016/j.solener.2019.09.039.

Pacheco-Vega, R. 2020. Environmental regulation, governance, and policy instruments, 20 years after the stick, carrot, and sermon typology, *Journal of Environmental Policy & Planning*, 22:5: 620-635. doi.org/10.1080/1523908X.2020.1792862.

Pan African Resources. No Date. Available from: https://www.panafricanresources.com/renewable-energy-fuels-pan-africans-journey-towards-more-sustainable-mining/ [Accessed 20 July 2023].

Parliamentary Monitoring Group. No Date. Climate Change Bill (B9-2022) [online]. South Africa: Parliamentary Monitoring Group. Available from: https://pmg.org.za/bill/1065/[Accessed May 2023].

Parties to United Convention, Framework Change Climate and Durban Platform for Enhanced Action. 2015. *Paris Agreement*. Available from:

https://unfccc.int/sites/default/files/english_paris_agreement.pdf [Accessed 1 May 2021].

Partnership for Market Readiness. 2017.Carbon Tax Guide: A Handbook for Policy Makers. Washington: World Bank. Available from: http://hdl.handle.net/10986/26300 [1 May 2021].

Parry, IW, Black, S & Zhunussova, K. 2022. Carbon Taxes or Emissions Trading Systems?: Instrument Choice and Design. Staff Climate Notes, 2022(006). Washington: International Monetary Fund.

Parry, IW. 2012. How to design a carbon tax. Washington: International Monetary Fund.

Paul, J, & Criado, AR. 2020. The art of writing literature review: What do we know and what do we need to know? *International Business Review*, 29(4):1-7. doi.org/10.1016/j.ibusrev.2020.101717.

PMR, see Partnership for Market Readiness.

Pellizzari, P, & Wall, F., 2015. Simulation in management accounting and management control. Journal of Management Control, 26:95-98. doi.org/10.1007/s00187-015-0215-0

Raihan, A & Said, MNM. 2021. Cost–Benefit Analysis of Climate Change Mitigation Measures in the Forestry Sector of Peninsular Malaysia. *Earth Systems and Environment*, 5(2):1-15. doi.org/10.1007/s41748-021-00241-6.

Raza, A, Gholami, R, Rezaee, R, Rasouli, V & Rabiei, M. 2019. Significant aspects of carbon capture and storage – A review. *Petroleum*, 5(4):335-340. doi.org/10.1016/j.petlm.2018.12.007.

Richardson-Barlow, C, Pimm, AJ, Taylor, PG & Gale, WF. 2022. Policy and pricing barriers to steel industry decarbonisation: A UK case study. *Energy Policy*, 168:1-12. doi.org/10.1016/j.enpol.2022.113100.

Rogelj, J, Den Elzen, M, Höhne, N, Fransen, T, Fekete, H, Winkler, H, Schaeffer, R, Sha, F, Riahi, K & Meinshausen, M. 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 C. *Nature*, 534(7609): 631-639. doi:10.1038/nature18307.

Rosenbloom, D, Markard, J, Geels, FW & Fuenfschilling, L. 2020. Opinion: Why carbon pricing is not sufficient to mitigate climate change—and how “sustainability transition policy” can help. *Proceedings of the National Academy of Sciences*, 117(16):8664-8668. doi.org/10.1073/pnas.2004093117.

Saidu, B. 2007. How taxes, royalties, and fiscal regime stability affect mining investment: a comparison of Niger and Indonesia. *Journal of Structured Finance*, 13(3):105-112. Doi:10.3905/jsf.2007.698661.

Saifullah, A, Karim, MA & Karim, MR. 2016. Wind energy potential in Bangladesh. *American Journal of Engineering Research*, 5(7):85-94. e-ISSN: 2320-0847.

Sánchez, PÁ & Deza, VX. 2015. Environmental policy instruments and eco-innovation: an overview of recent studies. Innovar, 25(58):65-80. doi.org/10.15446/innovar.v25n58.52426.

Sandahl, G & Sjögren, S. 2003. Capital budgeting methods among Sweden's largest groups of companies. The state of the art and a comparison with earlier studies. *International Journal of Production Economics*, 84(1):51-69. doi.org/10.1016/S0925-5273(02)00379-1.

Sandelowski, M. 2001. Focus on Research Methods. Whatever Happened to Qualitative Description? Research in Nursing & Health, 23: 334-340. doi.org/10.1002/1098-240X(200008)23:4<334::AID-NUR9>3.0.CO;2-G.

Sayed, ET, Wilberforce, T, Elsaid, K, Rabaia, MKH, Abdelkareem, MA, Chae, KJ & Olabi, AG. 2021. A critical review on environmental impacts of renewable energy systems and mitigation strategies: Wind, hydro, biomass and geothermal. *Science of the Total Environment*, 766:1-15. doi.org/10.1016/j.scitotenv.2020.144505.

Selosse, S & Ricci, O. 2017. Carbon capture and storage: Lessons from a storage potential and localization analysis. *Applied Energy*, 188:32-44. doi.org/10.1016/j.apenergy.2016.11.117.

Shafiee, M, Alghamdi, A, Sansom, C, Hart, P & Encinas-Oropesa, A. 2020. A through-life cost analysis model to support investment decision-making in concentrated solar power projects. *Energies*, 13(7):1-20. doi.org/10.3390/en13071553.

Shahabuddin, M, Alim, MA, Alam, T, Mofijur, M, Ahmed, SF & Perkins, G. 2021. A critical review on the development and challenges of concentrated solar power technologies. *Sustainable Energy Technologies and Assessments*, 47:1-16. doi.org/10.1016/j.seta.2021.101434.

Shahsavari, A & Akbari, M. 2018. Potential of solar energy in developing countries for reducing energy-related emissions. *Renewable and Sustainable Energy Reviews*, 90:275-291. doi.org/10.1016/j.rser.2018.03.065.

Shome, P. 2021. Taxation history, theory, law and administration. Cham: Springer.

Simpson, GB, Badenhorst, J, Jewitt, GP, Berchner, M & Davies, E. 2019. Competition for land: The water-energy-food nexus and coal mining in Mpumalanga Province, South Africa. *Frontiers in Environmental Science*, 7(2019):1-12. doi.org/10.3389/fenvs.2019.00086.

Smit, B. 2002. Atlas.ti for qualitative data analysis. *Perspectives in education*, 20(3):65-75. https://repository.up.ac.za/bitstream/handle/2263/4813/Smit_Atlas(2002).pdf.

Skovgaard, J & van Asselt, H. 2019. The politics of fossil fuel subsidies and their reform: Implications for climate change mitigation. *Wiley Interdisciplinary Reviews: Climate Change*, 10(4):1-12. doi.org/10.1002/wcc.581.

Snyder, H. 2019. Literature review as a research methodology: An overview and guidelines. *Journal of business research*, 104:333-339. doi.org/10.1016/j.jbusres.2019.07.039.

Sofia, D, Gioiella, F, Lotrecchiano, N & Giuliano, A. 2020. Cost-benefit analysis to support decarbonization scenario for 2030: A case study in Italy. *Energy Policy*, 137(111137):1-10. doi.org/10.1016/j.enpol.2019.111137.

Solaun, K & Cerdá, E. 2019. Climate change impacts on renewable energy generation. A review of quantitative projections. *Renewable and Sustainable Energy Reviews*, 116:1-16. doi.org/10.1016/j.rser.2019.109415.

Sonter, LJ, Dade, MC, Watson, JE & Valenta RK. 2020. Renewable energy production will exacerbate mining threats to biodiversity. *Nature communications*, 11(1):1-6. doi.org/10.1038/s41467-020-17928-5.

South Africa. Department of Environmental Affairs. 2010. National climate change response green paper. Pretoria: Department of Environmental Affairs.

South Africa. Department of Environment Affairs and Tourism. 2004. *National Climate Change Response Strategy for South Africa*. Pretoria: Department of Environment Affairs and Tourism.

South Africa. Department of Environment Forestry and Fisheries. 2020. *South Africa's Low-Emission Development Strategy 2050*. Pretoria: Department of Environment Forestry and Fisheries.

South Africa. Department of Environment Forestry and Fisheries. 2021. Carbon Budget Methodology Document A Guideline to Implementing the Tiered Methodological Approach. Pretoria: Department of Environment Forestry and Fisheries.

South Africa. Department of Mineral Resources and Energy. 2002. *The Mineral and Petroleum Resources Development Act (MPRDA) Act 28 of 2002*. Pretoria: Department of Mineral Resources.

South Africa. Department of Mineral Resources and Energy. 2023. *Annual Performance Plan for 2022 – 2023* [online]. Available from: https://static.pmg.org.za/2022-23_APP_-_Master_Doc_29_March_2022_with_signatures.pdf [Accessed 19 May 2023].

South Africa. National Treasury. 2006. A framework for considering market-based instruments to support environmental fiscal reform in South Africa. Pretoria: National Treasury.

South Africa. National Treasury. 2010. *Discussion paper for public comment Reducing Greenhouse Gas Emissions: The Carbon Tax Option*. Pretoria: National Treasury.

South Africa. National Treasury. 2013a. Reducing greenhouse gas emissions and facilitating the transition to a green economy Pretoria: National Treasury.

South Africa. National Treasury. 2013b. *Notice of the date upon which section 12L of the Income Tax Act,1962 (Deduction in respect of energy efficiency savings), as inserted by Act 17 of 2009, amended by Act 7 of 2010 and substituted by Act 22 of 2012 comes into operation*. Pretoria: National Treasury.

South Africa. National Treasury. 2017. Explanatory memorandum on the carbon tax bill. Pretoria: National Treasury.

South Africa. National Treasury. 2018. Explanatory memorandum on the carbon tax bill. Pretoria: National Treasury.

South Africa. National Treasury. 2019a. *Draft explanatory memorandum on the draft income tax amendment bill*. Pretoria: National Treasury.

South Africa. National Treasury. 2019b. *Carbon Tax Act No. 15 of 2019*. Pretoria: National Treasury.

South Africa. National Treasury. 2020. *Carbon Tax Implementation in South Africa 2020: Stakeholder Consultation*. Available from: http://www.energy.gov.za/files/COAS/2020/Carbon-Offsetting-under-the-Carbon-Tax-Act.pdf [Accessed 17 September 2021].

South Africa. National Treasury. 2022. Budget 2022 Budget Review [online]. Available from: https://www.treasury.gov.za/documents/national%20budget/2022/review/FullBR.pdf [Accessed 17 September 2023].

South Africa. National Treasury. 2023a. Republic of South Africa draft explanatory memorandum on the draft taxation laws amendment bill. Pretoria: National Treasury.

South Africa. National Treasury. 2023b. Budget 2023 Budget Review [online]. Available from: https://www.treasury.gov.za/documents/national%20budget/2023/review/FullBR.pdf [Accessed 20 September 2023].

South Africa. Parliament of the Republic of South Africa. 2023c. Draft Republic of South Africa Taxation Laws Amendment Bill. Pretoria: Parliament of the Republic of South Africa.

South Africa. South African Revenue Services (SARS). 2015. Interpretation note: no. 74 (issue 2) deduction and recoupment of expenditure incurred on repairs. Pretoria: SARS.

South Africa. The South African National Energy Development Institute (SANEDI). 2016. *Carbon Capture and Storage and the Carbon Tax in South Africa*. Sandton: SANEDI.

South Africa. The South African National Energy Development Institute (SANEDI). 2018. *Annual Performance Plan*. Sandton: SANEDI.

Statista. No Date. *Average installed cost for solar photovoltaics worldwide from 2010 to 2021* [online]. Available from: https://www.statista.com/statistics/809796/global-solar-power-installation-cost-per-kilowatt/ [Accessed 20 July 2023].

Statistics South Africa, 2020. *Quarterly employment statistics* [online]. Available from: http://www.statssa.gov.za/publications/P0277/P0277December2020.pdf [Accessed 31 July 2021].

Stavins, RN. 1997. Policy Instruments for Climate Change: How Can National Governments Address a Global Problem? University of Chicago Legal Forum ,1997(10). Available at: http://chicagounbound.uchicago.edu/uclf/vol1997/iss1/10 [Accessed 7 July 2023].

Steinebach, Y. 2019. Instrument choice, implementation structures, and the effectiveness of environmental policies: A cross-national analysis. *Regulation & Governance*, 16(1): 225-242. doi:10.1111/rego.12297.

Steinebach, Y, Fernández-i-Marín, X & Aschenbrenner, C. 2021. Who puts a price on carbon, why and how? A global empirical analysis of carbon pricing policies. *Climate Policy*, 21(3):277-289. doi.org/10.1080/14693062.2020.1824890.

Sterner, T & Robinson, EJ. 2018. Selection and design of environmental policy instruments. In Handbook of environmental economics, 4:231-284. doi.org/10.1016/bs.hesenv.2018.08.002.

Sugiyama, M, Akashi, O, Wada, K, Kanudia, A, Li, J & Weyant, J. 2014. Energy efficiency potentials for global climate change mitigation. *Climatic change*, 123(3):397-411. doi.org/10.1007/s10584-013-0874-5.

Sumner, J, Bird, L & Dobos, H. 2011. Carbon taxes: a review of experience and policy design considerations. *Climate Policy*, 11(2):922-943. doi.org/10.3763/cpol.2010.0093.

Surridge, AD, Kamrajh, N, Melamane, G, Mosia, T, Phakula, D, & Tshivhase, T. 2021. CCUS Progress in South Africa. 15th *International Conference on Greenhouse Gas Control Technologies, Abu Dhabi, March 15-18.* Council for Geoscience. 1-11.

Tan, Z, Wu, Y, Gu, Y, Liu, T, Wang, W & Liu, X. 2022. An overview on implementation of environmental tax and related economic instruments in typical countries. *Journal of Cleaner Production*, 330:1-26. doi.org/10.1016/j.jclepro.2021.129688.

Tang, K, Qiu, Y & Zhou, D. 2020. Does command-and-control regulation promote green innovation performance? Evidence from China's industrial enterprises. *Science of the Total Environment*, 712:1-10. doi.org/10.1016/j.scitotenv.2019.136362.

Tang, M, Li, X, Zhang, Y, Wu, Y & Wu, B. 2020. From command-and-control to market-based environmental policies: Optimal transition timing and China's heterogeneous environmental effectiveness. *Economic Modelling*, 90:1-10. doi.org/10.1016/j.econmod.2020.04.021.

Teixidó, J, Verde, SF & Nicolli, F. 2019. The impact of the EU Emissions Trading System on low-carbon technological change: The empirical evidence. *Ecological Economics*, 164(2019):1-13. doi.org/10.1016/j.ecolecon.2019.06.002.

The Federal Council. 2021. Switzerland's Long-Term Climate Strategy. Available from: https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/fachinfo-daten/langfristige-klimastrategie-der-schweiz.pdf.download.pdf/Switzerland's%20Long-Term%20Climate%20Strategy.pdf [Accessed 23 May 2023].

The Guardian. 2019. *Resource extraction responsible for half world's carbon emissions* [online]. Available from:

https://www.theguardian.com/environment/2019/mar/12/resource-extraction-carbon-emissions-biodiversity-loss [Accessed 1 May 2021].

Thuronyi, V & Brooks, K. 2016. Comparative tax law. Netherlands: Kluwer Law International BV.

Ting, MB & Byrne, R. 2020. Eskom and the rise of renewables: Regime-resistance, crisis and the strategy of incumbency in South Africa's electricity system. *Energy Research & Social Science*, 60:1-15. doi.org/10.1016/j.erss.2019.101333.

Tobin, GA & Begley, CM. 2004. Methodological rigour within a qualitative framework. Journal of advanced nursing, 48(4):388-396. doi:10.1111/j.1365-2648.2004.03207.x

Tucker, L. 2021. *The Why and How of Sound Tax Policy. Oklahoma City: 1889 Institute* [online]. Available from: https://1889institute.org/wp-content/uploads/2021/09/1889_TaxPrinciples_PolicyPrescription-002.pdf [Accessed 18 January 2022].

Tvinnereim, E, & Mehling, M. 2018. Carbon pricing and deep decarbonisation. *Energy Policy*, 121:185-189.doi.org/10.1016/j.enpol.2018.06.020.

Tyler, E & Cloete, B. 2015. Combining price and quantity instruments: insights from South Africa. Climate Policy, 15(3):374-387. doi.org/10.1080/14693062.2014.937382.

Ulrich, S, Trench, A & Hagemann, S. 2022. Gold mining greenhouse gas emissions, abatement measures, and the impact of a carbon price. *Journal of Cleaner Production*, 340:1-15. doi.org/10.1016/j.jclepro.2022.130851.

UNFCCC, see United Nations Framework Convention on Climate Change

United Kingdom. Department of Energy & Climate Change. 2011. *The Carbon Plan: Delivering our low carbon future* [online]. London. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47613/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf [Accessed 05 May 2023].

United Kingdom. Department of Energy & Climate Change 2022. Carbon Plan. London. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47621/1358-the-carbon-plan.pdf [Accessed 05 May 2023].

United Nations Framework Convention on Climate Change. 2000. *South Africa Initial National Communication* [online]. Available from:https://www.google.com/url?client=internal-elementcse&cx=009772925632828311246:gjvsnghto1u&q=https://unfccc.int/resource/docs/natc/zafnc01.pdf&sa=U&ved=2ahUKEwjVoLqH5pTyAhURoVwKHVuWBdUQFjAAegQIBxAC&usg=AOvVaw2YMPctAmoyQJJC4MWwiLNH [Accessed 21 May 2021]..

Van der Meijdena, GC & Withagen, CA. 2019. *Limit pricing, climate policies, and imperfect substitution*. *CESifo Working Paper Series No. 6163,* 1-24. Available from: http://hdl.handle.net/10419/149493 [Accessed 25 May 2021].

VanderWolk, JP. 2021. Carbon Tax: The Global Perspective, *Bulletin for International Taxation,* 75(5). Available from: https://www.ibfd.org/shop/oecdinternational-carbon-tax-global-perspective [Accessed 5 July 2021].

Van Heerden, J, Blignaut, J, Bohlmann, H, Cartwright, A, Diederichs, N & Mander, M. 2016. The economic and environmental effects of a Carbon Tax in South Africa: A Dynamic CGE Modelling Approach. *South African Journal of Economic and Management Sciences,* 19(5):714-732. doi.org/10.17159/2222-3436/2016/v19n5a3.

Verde, SF, Galdi, G, Alloisio, I & Borghesi, S. 2021. The EU ETS and its companion policies: any insight for China's ETS? *Environment and Development Economics*, 26(3):302-320. doi.org/10.1017/S1355770X20000595.

Viebahn, P, Vallentin, D & Höller, S. 2015. Integrated Assessment of Carbon Capture and Storage in South Africa's Power Sector. *Energies*, 8(12):14380-14406. doi.org/10.3390/en81212432.

Visconti, RM, 2021. *DCF metrics and the cost of capital: ESG drivers and sustainability patterns* [online]. Available from: https://www.morovisconti.com/wp/wpcontent/uploads/2021/01/costofcapitalsustainabilityREV11.pdf [Accessed 20 July 2023].

Votteler, RG & Brent, AC. 2016. A literature review on the potential of renewable electricity sources for mining operations in South Africa. *Journal of Energy in Southern Africa*, 27(2):1-21. Available from: <http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-447X2016000200001&lng=en&nrm=iso>. ISSN 2413-3051. [Accessed on 20 July 2023].

Walter, JM. 2021. *The Political Economy of Market-based and Information-based Environmental Policies* [online]. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3892503 [Accessed 20 July 2023].

Wang, YK & Zhang, X. 2019. Firm's Imperfect Compliance and Pollution Emissions: Theory and Evidence from South Africa. *Asian Journal of Economics, Business and Accounting*, 11 (3): 1-9. doi.org/10.9734/ajeba/2019/v11i330129.

Wilberforce, T, Olabi, AG, Sayed, ET, Elsaid, K & Abdelkareem, MA. 2021. Progress in carbon capture technologies. *Science of the Total Environment*, 761:1-11. doi.org/10.1016/j.scitotenv.2020.143203.

Wills, W, La Rovere, EL, Grottera, C, Naspolini, GF, Le Treut, G, Ghersi, F, Lefèvre, J & Dubeux, CBS. 2022. Economic and social effectiveness of carbon pricing schemes to meet Brazilian NDC targets. *Climate Policy*, 22(1):48-63. doi.org/10.1080/14693062.2021.1981212.

Williams, C. 2007. Research methods. *Journal of Business & Economics Research*, 5(3):65-72. doi.org/10.19030/jber.v5i3.2532.

Winkler, H & Marquard, A. 2019. Carbon tax revenues could be harnessed to help South Africa's poor [online]. Available at: https://theconversation.com/carbon-tax-revenues-could-be-harnessed-to-help-south-africas-poor-117847 [Accessed 08 November 2023].

Wolde-Rufael, Y & Mulat-Weldemeskel, E. 2021. Do environmental taxes and environmental stringency policies reduce CO 2 emissions? Evidence from 7 emerging economies. *Environmental Science and Pollution Research*, 28(18):22392-22408. doi.org/10.1007/s11356-020-11475-8.

World Bank. 2017a. *Minerals for climate action: The mineral intensity of the clean energy transition* [online]. Available from: https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action [Accessed 5 July 2021].

World Bank. 2017b. *Report of the High-Level Commission on Carbon Prices* [online]. Available from: https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing_FullReport.pdf [Accessed 15 August 2021].

World Bank. 2020. Global Solar Atlas 2.0 [online]. Available from: https://solargis.com/maps-and-gis-data/download/south-africa [Accessed 15 September 2023].

World Bank. 2022. *Carbon Pricing Dashboard 2022* [online]. United States: World Bank. Available from: https://carbonpricingdashboard.worldbank.org/ [Accessed 20 May 2023].

World Economic Forum. 2022. *Solar wind power renewable energy climate change* [online]. Available from: https://www.weforum.org/agenda/2022/03/solar-wind-power-renewable-energy-climate-change/ [Accessed 19 May 2023].

Zhang, Y, Abbas, M & Iqbal, W. 2021. Analyzing sentiments and attitudes toward carbon taxation in Europe, USA, South Africa, Canada, and Australia. *Sustainable Production and Consumption*, 28:241-253. doi.org/10.1016/j.spc.2021.04.010.

Zhang, Y, Wang, J, Xue, Y & Yang, J. 2018. Impact of environmental regulations on green technological innovative behavior: An empirical study in China. *Journal of Cleaner Production*, 188:763-773. doi.org/10.1016/j.jclepro.2018.04.013.

Zhang, Y & Wildemuth, BM. 2005. *Qualitative analysis of content* [online]. Available from: https://www.ischool.utexas.edu/~yanz/Content_analysis.pdf [Accessed 20 June 2023].

Zharan, K & Bongaerts, JC. 2017. Decision-making on integrating renewable energy in the mining industry: A case studies analysis, a cost analysis, and SWOT analysis. *Journal of Sustainable Mining*, 16(4):162-170. doi.org/10.1016/j.jsm.2017.11.004.

Ziervogel, G, New, M, Archer van Garderen, E, Midgley, G, Taylor, A, Hamann, R, Stuart-Hill, S, Myers, J & Warburtonne, M. 2014. Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change*, 5(5):605-620. doi.org/10.1002/wcc.295.

Žižlavský, O. 2014. Net present value approach: a method for economic assessment of innovation projects. Procedia-Social and Behavioral Sciences, 156:506-512. doi.org/10.1016/j.sbspro.2014.11.230.