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BRICS (original 5) Policy Outlook, Transitional Electricity Production Technologies, Social Impact and Funding Models.

PhD Research Thesis

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Submitted to:

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the School of Chemical and Metallurgical Engineering at the University of the Witwatersrand

Declaration

I, Rajesh Ramluckun, declare that the thesis entitled: Just Energy Transition for South Africa: BRICS (original 5) Policy Outlook, Transitional Electricity Production Technologies, Social Impact and Funding Models is my own work and that all sources I have used or quoted have been indicated and acknowledged by means of references.

Signature: *Rajesh Ramluckun*

Date: 26th August 2025

Acknowledgement

Parts of this thesis was published in a peer-reviewed journal authored by the candidate. Specifically, chapter 3 which deals with the energy policies and parts of chapter 5 and 6 that deal with the impact on BRICS countries and the funding thereof. The title of the paper published is *"A Review of the Energy Policies of the BRICS Countries: The Possibility of Adopting a Just Energy Transition for South Africa."* An Open Access Journal by MDPI, Sustainability 2024, Volume 16, Issue 2, 703.

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Dedication

I dedicate this doctoral study to my loving and supportive wife Dharmita Ramluckun for being supportive and encouraging me to complete this study. To my children Arshia, Kiara, Viveka and Taresh you are the guiding light that kept me going through all the challenges and the laughter that lifted me in the most difficult moments. This journey with all its trials and triumphs, is as much yours my beloved wife and children as it is mine. This achievement would be a constant reminder to, me that with perseverance, love and self believe, anything and everything is possible.

Lastly, but most important of all I thank our Sri Sai, Sri Rama, Sri Vishnu, Sri Hanuman, Sri Shiva, Sri Ganesha and Maha Lakshmi Mata for the divine inspiration, knowledge and strength to complete this spiritual journey.

Abstract

This thesis investigates the Just Energy Transition within the BRICS countries (Brazil, Russia, India, China, and South Africa), with a particular focus on energy policy, technological innovations, social impact, and green finance. As the world transitions towards sustainable energy, it is critical to ensure that this shift is equitable, especially for emerging economies where energy access, social equity, and economic stability are central concerns. This research examines the energy policies of BRICS nations, assessing their effectiveness in fostering inclusive, sustainable development while addressing the environmental and social dimensions of the energy transition. It also explores the role of technology and green finance in enabling the transition to cleaner energy systems, particularly in the context of developing economies. Using a comparative case study approach, the thesis highlights the lessons learned from BRICS countries' experiences in implementing just energy transitions, focusing on best practices and challenges faced. Special attention is given to South Africa, where energy poverty, socio-economic inequalities, and dependence on coal have created significant barriers to a just transition. Drawing on the experiences of other BRICS nations, this research provides targeted recommendations for South Africa, emphasizing the need for tailored energy policies, social inclusion strategies, and investment in green finance to ensure a just and sustainable energy future. The findings contribute to the broader discourse on just energy transitions, offering insights for policymakers, industry leaders, and international stakeholders seeking to balance sustainability with equity in emerging economies.

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Abbreviations

ATS	Accelerated Transition Scenario
ACT	Accelerating Coal Transition
ACOE	African Centre of Excellence
AfDB	African Development Bank
AFI	Alliance for Financial Inclusion
AC	Alternating Current
APS	Announced Pledges Scenario
BESS	Battery Energy Storage Systems
BATR	Biennial Assessment Technical Report
BCG	Boston Consulting Group
BRICS	Brazil Russia India China and South Africa
ABDI	Brazilian Industrial Development Agency
BUSA	Business Unity South Africa
CCS	Carbon Capture and Sequestration
CCUS	Carbon Capture Usage and Sequestration
CO_2	Carbon Dioxide
CEA	Central Electricity Authority
CFB	Circulating Fluidised-bed boiler
CFBC	Circulating Fluidized Bed Combustion
CIF	Climate Investment Funds
CPP	Climate Prosperity Plans
CVF	Climate Vulnerable Forum
CCGT	Combined Cycle Gas Turbine
CAGR	Compound Annual Growth Rate
COP	Conference of Parties
CSIR	Council for Scientific and Industrial Research
°C	Degree Celsius
DEFF	Department of Environmental, Forestry and Fisheries
DMRE	Department of Mineral Resources and Energy
DPE	Department of Public Enterprises
DC	Direct Current
EMS	Energy Management Systems
ERCP	Energy Research Cooperation Platform
ERCP	Energy Research Cooperation Platform

ERI RAS	Energy Research Institute of the Russian Academy of Sciences
ESR	Energy Strategy of Russia
ETI	Energy Transition Index
ESG	Environmental Social Governance
EGD	European Green Deal
EU	European Union
FWG	Finance Working Group
FSDR	Financing for Sustainable Development Report
Gt	Gigaton
GW	Gigawatt
GS	Global Shield
GST	Global Stocktake
GCRI	GlobalData Country Risk Index
GCF	Green Climate Fund
GJAIN	Green Jobs Assessment Institution Network
GT	Green Transformation
GHG	Greenhouse Gases
GDP	Gross Domestic Product
G7	Group of Seven
G20	Group of Twenty
HRSG	Heat Recovery Steam Generator
HELE	High Efficiency Low Emissions
HFC	Hydrofluorocarbon
H_2	Hydrogen
iGST	Independent Global Stocktake
IPP	Independent Power Producer
ITT	Independent Think Tank
IRA	Inflation Reduction Act
IHCG	InsuResilience High-Level Consultative Group
IRP	Integrated Resource Plan
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IEA	International Energy Agency
IFC	International Finance Corporation
ILO	International Labour Organisation

IRENA	International Renewables Energy Agency
JET	Just Energy Transition
JET IP	Just Energy Transition Investment Plan
JETP	Just Energy Transition Partnership
JTF	Just Transition Framework
KPI	Key Performance Indicator
kV	Kilovolt
kWh	Kilowatt-hour
LDC	Least Developed Countries
LCC	Life Cycle Cost
LED	Light Emitting Diode
LNG	Liquid Natural Gas
LIC	Low Income Countries
LEDS	Low-Emissions Development Strategy
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MPa	Megapascals
Mtoe	Megatons of oil equivalent
MW	Megawatt
CH_4	Methane
MSME	Micro, Small and Medium Enterprises
MCFC	Molten Carbonate Fuel Cells
MDB	Multilateral Development Bank
NAP	National Adaptation Plans
NBI	National Business Initiative
NCEH	National Centre for Environmental Health
NDP	National Development Plan
NEP	National Electricity Plan
NIS	National Integrated System
NPC	National Planning Commission
NDC	Nationally Determined Contributions
NDB	New Development Bank
NEV	New Energy Vehicle
NOx	Nitrogen Oxide
N_2O	Nitrous Oxide
ONE	Office of Nuclear Energy

OCGT	Open Cycle Gas Turbine
OECD	Organisation of Economic Cooperation and Development
PM	Particulate Matter
%	Percentage
PFC	Perfluorochemical
PAFC	Phosphoric Acid Fuel Cells
PV	Photovoltaic
PEMFC	Polymer Electrolyte Membrane Fuel Cells
PCC	Presidential Climate Commission
PCFTT	Presidential Climate Finance Task Team
PA	Primary Air
PSP	Private Sector Participation
PPP	Public and Private Partnerships
PF	Pulverized Fuel
SEBI	Securities and Exchange Board of India
SIDS	Small Island Developing States
SPD	Social Partner Dialogue
SPV	Solar Photovoltaics
SOFC	Solid Oxide Fuel Cells
SA	South Africa
SAERRP	South African Economic Reconstruction and Recovery Plan
SANT	South African National Treasury
SA JET-IP	South Africa's Just Energy Transition-Investment Plan
SPV	Special Purpose Vehicle
m^2	Square metre
SCF	Standing Committee on Finance
SO_2	Sulphur Dioxide
SD&L	Supplier Development and Localisation
SDG	Sustainable Development Goals
TW	Terawatt
UV	Ultraviolet
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly

US	United States
$	United States Dollar
USA	United States of America
U	Uranium
V20	Vulnerable 20
WB	World Bank
WEF	World Economic Forum
WEO	World Economic Outlook
WTODDA	World Trade Organization's Doha Development Agenda
WWF	World Wildlife Fund

CHAPTER 1 INTRODUCTION

1.1 Chapter introduction and motivation of research topic

The Just Energy Transition (JET) objectives and the impact of failing to transform in line with these objectives, should be common knowledge to all living in this world since the consequences of failure would be incalculable. The impact would be more catastrophic than the pandemics and natural disasters that mankind and the world has ever experienced. The nations of the world cannot afford to continue producing greenhouse gases; and compliance with the Paris Agreement is paramount to prevent climate change (European Environment Agency, 2024).

In the earth's composition of gases, there are numerous gases that are termed or referred to as "Greenhouse Gases" (GHG). What essentially occurs is that these GHG permit sunlight to enter the atmosphere, but unfortunately some of the sunlight or solar energy is reradiated from the surface of the earth as infrared radiation (Hirsch et al., 2017). The GHG absorb and capture the heat in the atmosphere instead of allowing the energy to disperse (Zhong et al., 2013; Intergovernmental Panel on Climate Change, 2021). Instead of this energy being radiated back into space, it is retained in the earth's atmosphere, resulting in temperatures rising over time rather than reaching the equilibrium of zero change in temperature. The majority of these gases (carbon dioxide, methane, water vapour, sulphur and nitrous oxides) occur naturally, but there has been an exponential increase of approximately thirty percent (30%) due to anthropogenic activities over the last hundred and fifty years (World Meteorological Organization, 2024). In the last twenty to twenty-five years, about 75% of anthropogenic emissions originated from burning fuels containing hydrocarbons and contributed directly to this exponential increase. This continuous incineration is contributing to the growth of GHG's and particularly CO_2. This disrupted the Earth's gaseous equilibrium, contributing to excessive strain on natural carbon sinks thereby diminishing their effectiveness, which in turn altered the overall carbon balance and led to rising CO_2 levels (Gruber et al., 2019).

The relative contributions of gas species to the global GHG emissions is illustrated in Figure 1. It is clear that the largest contributor of atmospheric GHG is the thermally generated CO_2 for energy requirements.

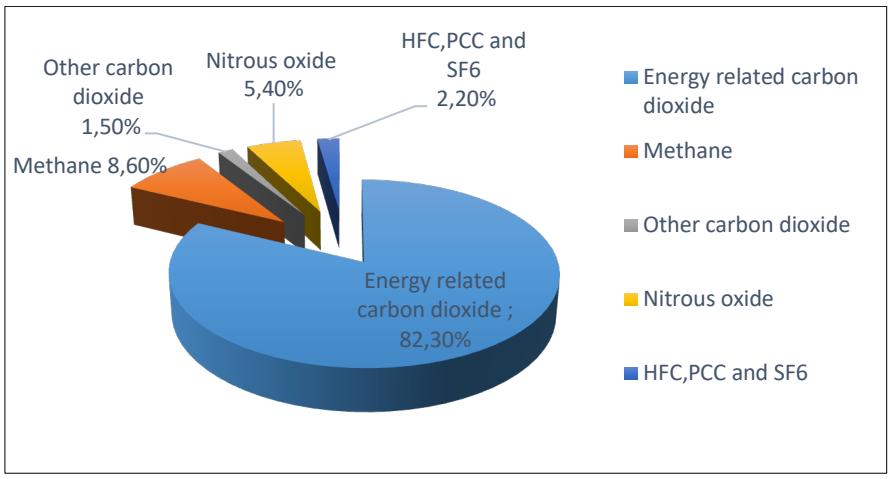


Figure 1: The relative contribution to GHG Emissions by gas species (Our World in Data,2024).

Human activities, their relative contribution worldwide to CO_2 emissions into the atmosphere and sources of the emissions have been exhaustively confirmed by many sources from various locations worldwide are shown in Figure 2 and Figure 3. This data is reflected in percentages, but the correlation and trends remain identical even with the COVID-19 pandemic which reduced normal human activities, resulting in improved air quality. However, the contributors' share in percentages remained surprisingly identical, which is extremely alarming. The CO_2 increase is a byproduct of an increased anthropogenic action that is not in equilibrium with the corresponding carbon sinks.

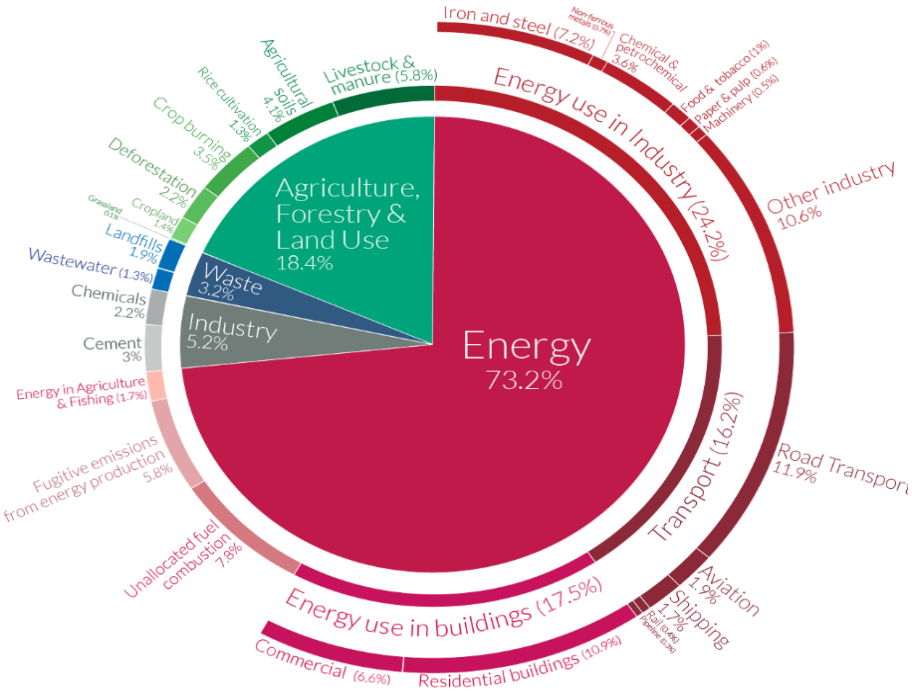


Figure 2: Activity-based CO_2 emissions (Our World in Data, 2020).

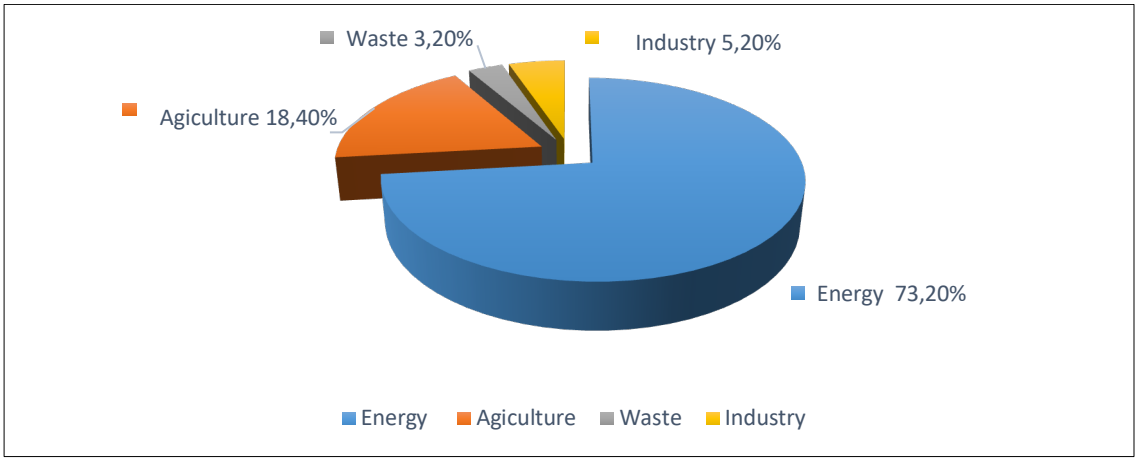


Figure 3: Global activity-based CO_2 emissions (Our World in Data, 2020).

The Keeling Curve depicted in Figure 4 represents the overall increase in atmospheric CO_2 since 1958 in the Pacific Ocean area called Mauna Loa, Hawaii. The red line shows the trending of CO_2 levels in the atmosphere while the grey line shows the annual fluctuations in northern hemisphere carbon emissions during season changes because of spring "green up". In a global contrast, South Africa is ranked the 15th in terms of annual CO_2 emissions (Worldometers, 2024). South Africa contributed 1.3 percent of the total global CO_2 emissions (International Energy Association, 2023).

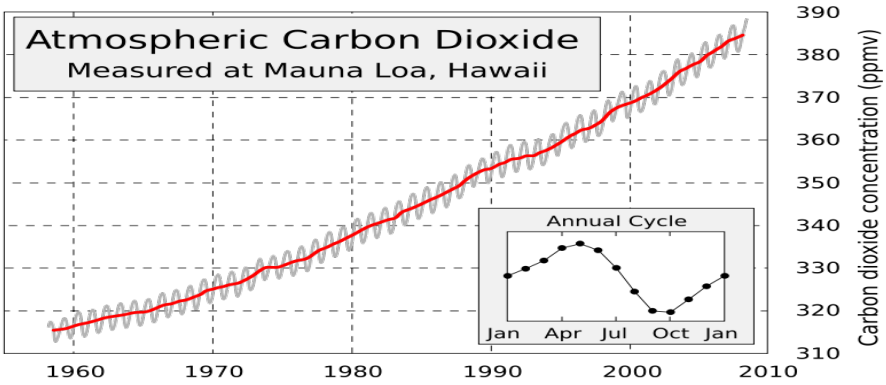


Figure 4: The Keeling Curve (Scripps Institute of Oceanography)

Africa contributes the least to the global CO_2 emissions, however South Africa on a per capita basis is the leading CO_2 producer on the continent as shown in Figure 5 and Figure 6 (Carbon Dioxide Information Analysis Centre, 2008).

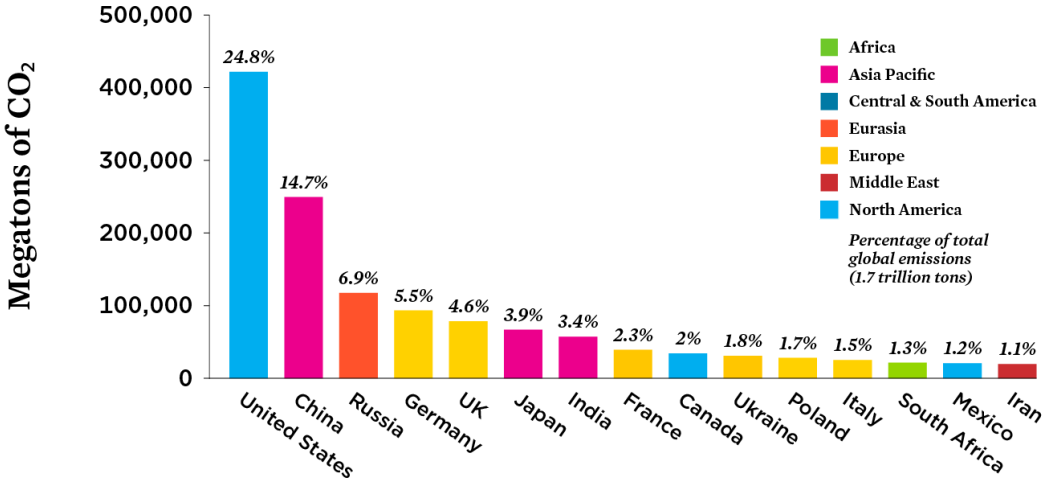


Figure 5: CO_2 emission by country (Our World in Data, 2023)

It is evident from data acquired over decades that severe climate change is imminent, and there is a necessity to urgently lower the global GHG emissions which is approximately 50 billion tons annually. The statistics extracted from the global emissions segment issued by *"Climate Watch and the World Resources Institute",* is illustrative of the main contributors of CO_2 emissions, being energy (electricity, heat and transport) which contributes 73.2%, direct use in industrial processes which contributes 5.2%, waste which contributes 3.2%, agriculture, forestry and land use which contributes 18.4% (Ritchie et al., 2017).

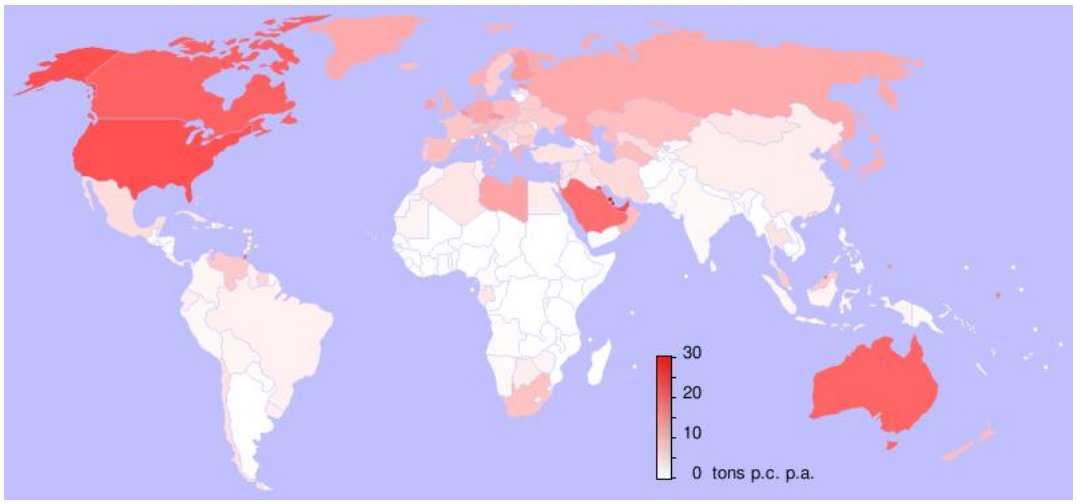


Figure 6: CO_2 emission per capita per year (Our World in Data, 2023).

South Africa, as an emerging economy, was initially not obligated to reduce carbon emissions under the Kyoto Protocol due to its classification as a non-Annex I country. Nevertheless, it ratified the protocol in 2002 and actively participated in its mechanisms, particularly the Clean Development Mechanism (CDM), which enabled industrialized nations to invest in emission-

reduction projects in developing countries like South Africa (Ritchie et al., 2017; Hirsch et al., 2017). Although not legally bound, South Africa recognized the urgency of climate action and began aligning its national policies with global efforts to curb GHG emissions. The energy sector dominated by coal-fired electricity generation has historically been the largest contributor to GHG emissions, accounting for over 80% of total CO_2 emissions between years 2000 and 2022 (Mail & Guardian, 2025; UNFCCC National Inventory Report, 2023). In year 2022 alone, the energy sector was responsible for 92.3% of South Africa's carbon dioxide emissions, primarily from coal combustion for electricity production (Mail & Guardian, 2025). To address this, the government developed the Integrated Resource Plan (IRP) as a strategic framework for electricity generation. The IRP 2019, published by the Department of Energy, aimed to diversify the energy mix by 2030, reducing coal's dominance and increasing the share of renewables such as wind and solar (Department of Energy, 2019). It projected coal to supply 43% of electricity, with wind and solar contributing 22.5% and 10.5%, respectively.

The Draft IRP 2023, released in January 2024, builds on this by introducing a two-horizon approach:

- Horizon 1 (from year 2024 to year 2030) focuses on resolving immediate energy shortages and improving Eskom's performance.
- Horizon 2 (from year 2031 to year 2050) emphasizes long-term decarbonization, with increased deployment of renewables, battery storage, and gas infrastructure (Department of Minerals and Energy (DMRE), 2024; Energy Group, 2024).

Despite these efforts, coal remains entrenched in the energy system, and the transition is challenged by aging infrastructure, grid constraints, and economic pressures. Nonetheless, South Africa's commitment to the Paris Agreement and its Nationally Determined Contributions (NDCs) aim to peak emissions between year 2020 and year 2025 and reach net-zero by year 2050. This emphasizes its progressive responsibility in global climate governance (Climate Transparency, 2020).

Furthermore, it is explicitly focusing on the reduction of the use of fossil fuels for electrical power production by mandating the use of cleaner coal technologies through the application of more stringent emissions legislation. The South African administration *(Department of Public Enterprises (DPE), Department of Mineral Resources and Energy (DMRE) and Department of Environmental, Forestry and Fisheries (DEFF))* had discussions in the year 2008 with interested stakeholders and requested that all imminent "fossil fuel-fired" electricity generation plants should consider Carbon Capture and Sequestration (CCS) embedded in the design of the

plant or at least be CCS ready (Surridge, 2008). The SA government policy aspires to be the driving force to substantially reduce CO_2 emissions, with the envisaged aim of total carbon capture sequestration (CCS) (Ritchie et al., 2017). This initiated the process to investigate viable options for renewable energy sources (solar, wind, Battery Energy Storage Systems (BESS), nuclear, hydrogen), High Efficiency Low Emissions (HELE) technologies (biomass, supercritical boilers, technologies (Ritchie et al., 2017). Economics will essentially influence the rate at which Circulating Fluidized Bed Combustion (CFBC) and gas technologies will be implemented. Biomimicry within BRICS could be a useful means to aid the reduction in GHG's in the future. In the South African situation at present, great inadequacies persist with the workforce and crucial counteractive measures are essential in complying with the International Labour Organisation (ILO policy, 2015) and plans to encourage ecological conducive energy resources with the appropriate technologies for sole or a combination of renewable resources. Additionally, an enormous need exists to bridge the deficiency that exists in the typical financing practice against the "green funding" practices (Naidoo, 2019). Explicit and clear energy strategic plans apart from the IRP, 2019 and the draft 2023 are lacking; nevertheless there are several collective initiatives with the South African administrative sectors, (Labour, Environment, Mineral Council of South Africa, Department of Trade, Industry and Competition), Eskom, Sasol, Council for Scientific and Industrial Research (CSIR), National Business Initiative (NBI), Business Unity South Africa (BUSA), private and public segments in appraising and paving the path for the transition (DMRE,2024). This should be done through studies on social economic impact such as Transition Pathways (TP) independent initiative/ investigation which encompasses all aspects of the JET by Boston Consulting Group (BCG) with stakeholder reviews (BCG, 2022; NBI, 2022; DMRE, 2024; Climate Transparency, 2023). These engagements will be referenced in the International Labour Organization's (ILO) guidelines, 2015 for just transition towards environmentally sustainable economies and societies for all in South Africa.

The values promoted by the ILO emphasize the importance of strong community consensus on the goals and pathways toward sustainability. Meaningful social dialogue should be a core element of any official agenda for developing and implementing strategies at all levels. Inclusive, sustained, and evidence-based dialogue should take place with all relevant stakeholders. Policies must uphold, promote, and implement fundamental workplace values and rights. They should also recognize and address the gendered dimensions of ecological challenges and opportunities. Respecting and applying gender-sensitive policies is essential to achieving equitable outcomes (ILO, 2015).

Clear and coherent policy frameworks spanning economic, environmental, social, educational, and employment domains are crucial for fostering an enabling environment that facilitates the transition toward environmental sustainability. By aligning efforts across these interconnected sectors, such policies empower organizations, workers, stakeholders, and local communities to actively participate in shaping more resilient economies and inclusive societies. This integrated approach not only strengthens institutional capacity but also reinforces the shared responsibility required to achieve sustainable development outcomes (ILO, 2015).

Comprehensible and coherent policies must deliver a Just Transition (JT) agenda that supports the creation of new employment opportunities. This includes anticipating impacts on jobs, ensuring adequate and sustainable social protection for employment losses, promoting skills development, and fostering inclusive social dialogue. These elements must be implemented through a shared commitment to collaboration and negotiation. It is important to recognize that no universal framework for transition exists; rather, policies and strategic plans must be tailored to the specific circumstances of each nation including its level of development, economic sectors, and the size and nature of its organisations. In pursuing sustainable development, global cooperation among countries is essential (Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All, ILO, 2015). Incremental changes to the economy will be insufficient to address large-scale climate challenges, given the mounting pressures that current human development places on natural systems such as land, food, water, and air alongside technological disruption from the Fourth Industrial Revolution and widening social inequalities (Naidoo, 2019).

The JET imperatives as per simple definition will be the basis of this research with a focus on BRICS energy and economic context. JET is a change process to achieve net zero CO_2 emissions in the energy segment through the deployment of technologies synergistically and harmoniously changing the landscape of energy sources through socially amicable approaches for sustainable employment of the workforce. Hence addressing all objectives of transitioning to net zero CO_2 emissions and managing the "Just" component of the social impact and the JET execution.

1.2 Literature Review

The Just Energy Transition (JET) is a step into making a significant, favourable impact on reducing greenhouse gases (GHG's) and adherence to the stance taken by BRICS countries including South Africa, COP22 and Paris Climate Agreements in the realisation of the overall

target towards sustaining the global warming under 2°C by year 2100 and zero carbon emissions by 2050 (Ritchie et al., 2017).

Figure 7 illustrates five scenarios of the past, present and the future of the CO_2 and GHG emissions. The graphical representation shows an array of probable upcoming situations of worldwide GHG production (Climate Action Tracker, 2020). The green line shows where we are at present. The first scenario depicted in a shade of pink, is where no climate policies are in place. The projected future emissions may produce a predicted 4.1 to 4.8°C increase in temperature by the year 2100 (in relation to pre-industrial temperatures).

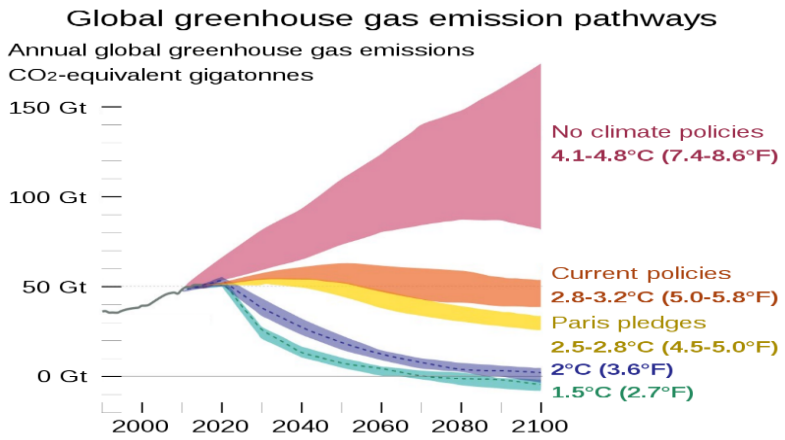


Figure 7: Global GHG emissions with climate policies and pledges (Ritchie et al., 2017).

The second scenario in orange, being the current climate policies, shows projected global warming of 3.1 to 3.7°C by 2100 with reference to existing applied climate change policies, global promises and commitments. The third scenario in yellow, where all countries accomplish their present objectives and pledges defined inside the Paris Climate Agreement, shows the assessed mean global warming by year 2100, to be 2.6 to 3.2°C. The fourth scenario in blue goes far over the total goal of the Paris Climate Agreement to limit global warming effectively under 2°C, and there is an array of emissions paths that would be suited to restricting the mean global warming to 2°C by 2100 (Ritchie, 2017). This would necessitate a substantial, urgent intensification of activities of the existing initiatives within the Paris Climate Change Agreement.

The fifth scenario in turquoise would be to cap mean global warming at 1.5°C by 2100, nevertheless a highly imperative and swift drop in worldwide GHG emissions would be required with stricter penalties for violations of non-compliance may have to be enforced

(Ritchie, 2017). The term "low carbon development" originated from the United Nations Framework Convention on Climate Change (UNFCCC) is demarcated briefly as policies, tactics and activities that separate development from GHG emissions, resulting to minute emission development. Low CO_2 expansion strategies were developed in a portion of the *Copenhagen Accord* (2009) and were decisively fixed in the UNFCCC course at COP16 in Cancun (2010) (Zinecker et al., 2018). Although vindication in the UNFCCC or climate policy framework usually has an implication of concrete short- or medium-term emission decrease, the term *"low carbon development"* is wider and further strictly associated to development (Zinecker et al., 2018).

The G20 Hamburg Climate and Energy Action Plan for Growth, as established in the German presidency in 2017, posits a long-term low GHG emission plan to be an exclusive prospect for nationwide, country explicit methods, controlling shorter term development and policy creation in pertinent areas, mainstreaming climate action with initiatives to boost comprehensive economic progress and execution of the Addis Ababa Agenda 2030. Investment flows and technological innovation can be incentivized, respectively. The plan will be a "living" document and not a "one-size-fits-all" resolution (G20, 2017).

Labelling the Paris Agreement as radical changes is referenced on the rate of destruction and forthcoming resource requirements that technological progress will have on the planet. Although the economic system has attracted positive changes in development, its expanding global influence has an adverse influence on the social, biological, and geological practices of the planet (Mathews, 2015; Dearing et al, 2009). Specifically, industrialised growth is resource-intensive and related to excessive carbon emissions which is the major cause of climate change (Intergovernmental Panel on Climate Change, 2014, Crutzen, 2000, Mathews, 2015). In this context, Mathews (2015) argues that the essence of industrial development is the cause of major problems as it is driven by "*fossil energies allowing for unlimited enjoyment, non-satiety and resource spoliation, finance divorced from ecological realities*".

The interregnum from existing to new systems must consider the destabilisation of the existing systems as they break down and the nurturing of new alternative systems, both of which have social consequences (Voβ et al, 2009, Mathews, 2015, Naidoo, 2019). World Bank economists predict that with the present systems, approximately hundred million people will live in poverty over the next 15 years (World Bank, 2016). Some positive indications of the co-existence of the old and new development paths are emerging. Mathews (2015) studies shows that nations such as China, India and Brazil show signs of greening their industrial development paths to

mitigate social, economic, and ecological impacts through green job creation, local manufacturing, wellbeing, and green finance initiatives. Rwanda, Ethiopia, and Colombia have included green growth into their national development plans and have special governance and financing arrangements to promote implementation (Naidoo, 2019).

Depending on how green transformations pan out at a country level, different types of finance may be necessary. Combinations of Public and Private Partnerships (PPP) that can supply longer term and more patient capital as well as provide capital for immediate short-term opportunities will require further evaluation (Spratt, 2014). New technologies and innovations may require venture capital and private equity providers. Public finance can support green transformations through technical assistance, direct investment through its development agencies and participation with private finance (Mazzucato, 2013). The social impact of the transition of curbing global warming is as crucial to the technologies that will be utilised as the special purpose vehicle for a "Just Transition" and will be partially assessed and taken into consideration as transformation into a zero carbon emitter proceeds. The task of addressing climate change is far more challenging. Due to the adverse influences of climate change and the drive to clean renewable energy sources, this will inadvertently lead to job losses as the coal mining activities and fossil fuel power plants are extremely labour intensive compared to renewable energy fuel sources and power plants (Zinecker et al., 2018). There are differences in opinion and robust discussions with great emotions at times, depending on the side of the direct workforce affected versus the promised unverified sustainability of job creation that would evolve for the future.

A study by Semelane, 2018 is indicative of growing and fostering the role of renewable resources to close the capacity deficiency caused by the decommissioning of coal power plants as they approach their economically and environmentally feasible lifespan. In the short term, socio-economic trials will arise, as the change necessitates a reorganisation not limited to the power segment, but inclusive of employment. Considering the "coal segment" is a significant source of labour in the country, one must be cognisant of the effect of the move towards *"low carbon"* electricity on jobs and the financial health of South Africa; and it is vital to warrant a "Just Transition" entirely for individuals working in the area, as is positioning the evolution with the power segment reorganisation framework outlined in the IRP 2019 (Semelane et al., 2018).The draft South Africa Integrated Resource Plan (IRP) 2023 reflects a significant shift in the landscape regarding the decommissioning of coal-fired power plants. With increasing pressure to transition to cleaner energy sources, the plan outlines accelerated timelines for phasing out coal, driven by both environmental commitments and the need for energy

diversification. This shift is influenced by a growing emphasis on renewable energy investments and the urgency to address climate change, reshaping the energy mix and paving the way for sustainable development in the country.

Similar research and evaluations on BRICS member countries' emissions and social impacts profile conducted by Burton in year 2019, reiterates and confirms the requirement for these aspects to be analysed more deeply in this paper. Subjugated by "energy emissions" total (80%) and coal-correlated burning emissions due to the country's dependency on the source for energy comprising of coal contributing to 49% of main energy source for BRICS countries in year 2019 (Climate Transparency, 2019; Burton et al., 2019). In the South African context, coal is used to generate 92% of electrical power; and approximately 25% of liquid fuels used emanate from processing coal into synthetic fuels at Sasol's Secunda plant (Department of Energy (DOE), 2015). The rest is castoff wholly in the production iron and steel, cement and process heat and a minute part is utilised in the residential and commercial areas. South Africa is reliant on coal for essential energy amongst the G20 countries, emphasizing mutually the energy and socio-economic trials of mitigation (Climate Transparency, 2019; Burton et al., 2019).

South Africa (SA) like the rest of the BRICS members, faces severe economic development challenges and addressing these are critical to ensure a successful approach to the country's JET. In the year 2023, the "narrow unemployment" in SA was 32% and the "broad unemployment" (inclusive of suppressed employment searchers) is 38% (StatsSA, 2023). Equally they are growing, whilst youth joblessness was approximately 50%. In Mpumalanga, the province which is the hub of coal mining and coal fired power plants, has joblessness rates which are greater than the domestic mean at 35% and 44% on the "narrow and broad" indicators respectively (StatsSA, 2019). More than 50% of the population lives in poverty, whilst 25% live in extreme poverty, meaning these communities cannot afford their essential nutritional requirements (StatsSA, 2017). The educational structure is collapsing, corresponding with an assessment where 80% of South African grade 4 children cannot read for "meaning" in whichever (do you mean chosen or English as First or Second Language?) language (Burton et al., 2019). Various studies have emphasised the disparity between the composition of the economy (capital), energy concentration and the necessity for a labour-intensive growth path that lessens emissions, encourages employment, and promotes wellbeing (NPC, 2011; Marquard et al., 2019; Altieri et al., 2015).

The sensitivity (do you mean volatility of the economy/ economic rating?) that portrays the country's financial status implies that any economic development plans that jeopardises employment should be thoroughly evaluated. Therefore, advancement in JET should foster and warrant wider socio-economic growth in the country. (you are implying that JET is the silver bullet that will address poor economic policy, financial mismanagement, and structural inequality in the SA society. It needs government to make significant commitments and action towards eliminating crime, corruption, culture of non-payment and high labour costs. JET will not be the only way the economy recovers.)

Addressing the main restraints (corruption, political favours) to progress in the economy will therefore be a fundamental element of JET policy for the country (Burton, 2019). There are numerous technologies for renewable energy fuel sources (solar, wind and nuclear, wave, tides, geothermal), gas, HELE technology and CO_2 capture and sequestration, are sought-after technologies that will pave the way to a reducing CO_2 to nett zero CO_2 emissions by 2050 (Ciolkosz, 2023).

Renewable energy is energy harvested from renewable sources which are naturally regenerated, including carbon unbiassed sources reminiscent of sunlight, wind, rain, tides, waves, nuclear and geothermal heat (Ciolkosz, 2023).

HELE technologies are technologies developed to improve the efficiency of coal-fired electricity generation plants, therefore reducing CO_2 and GHG discharges, including non-GHG discharges for example, Nitrogen Oxide (NOx), Sulphur Dioxide (SO_2) and Particulate Matter (PM).

An insightful summary of coal Benson boilers are tabulated in Table 1. It is apparent that from Sub-critical to Advanced Ultra-supercritical, the efficiencies range is from 38% to 50%, CO_2 intensity range is from 880 g CO_2/kWh to 670-740 g CO_2/kWh; coal consumption range is from 380 g/kWh to 290-320 g /kWh; and steam temperature range is from 550°C to 700°C (Lockwood, 2011).

Table 1: Efficiencies of "coal- fired" electricity generation plants (Lockwood, 2011).

HELE	Efficiency rate	CO_2 Intensity	Coal Consumption	Steam Temperature
Advanced Ultra-Supercrtical	45-50%	670-740gCO_2/KWh	290-320g/KWh	700^oC
Ultra-Supercritical	Up to 45%	740-800gCO_2/KWh	320-340g/KWh	600^oC
Superctritical	Up to 42%	800-880gCO_2/KWh	340-380g/KWh	Approx.550- 600^oC
Subcritical	Up to 38%	>880gCO_2/KWh	>380g/KWh	<550^oC

The transition to HELE technology explained in Table 1 emphasises the technical benefits of HELE coal technologies. It is quantified in terms of efficiency and emissions reduction which are not just environmental metrics - HELE are cornerstones of a socially responsible energy transition, as envisioned by global climate and labour frameworks.

As an example, the benefit of a 400 GW coal-fired electrical power production plant from Sub-critical to HELE coal technologies would equate to approximately 6 billion tonnes of CO_2 cumulative reduction over a 25-year period if it is implemented ~~used~~ (Lockwood, 2011). The sustainability of jobs is in line with the *"International Labour Organisations guideline on Just Transition and Compliance to the Paris Climate Change Agreement, COP22, the Copenhagen Accord (2009), United Nations Framework Convention on Climate Change (UNFCCC) and Addis Ababa Agenda 2030"* which gave rise to the term Just Energy Transition (JET).

What is Just Energy Transition (JET)?

A Just Energy Transition (JET) is a formulated conceptual process to enable practices in energy creation and utilisation with the objective to lessen adverse social effects on employees and societies (De Vivero et al., 2019); and is inclusive of vested interests in elevated-carbon arenas that will gradually reduce and morph into sustainable prospects to withstand and expand employment in the low-carbon development segments of the future. The emphasis is to make sure that the economic gains of the change are equitably split and harmoniously integrated with human resource and environment sustainability (De Vivero et al., 2019). Employment is a crucial constituent of this evolution and energy transformations frequently include a redesigning of economies and employment marketplaces, while specific segments will experience contraction and others a rise in employment. The ILO predicts that the interregnum towards sustainability in the energy segment will initiate approximately 18million additional employment opportunities worldwide by the year 2030 related to business-as-usual activities (International Renewable Energy Agency (IRENA), 2023). Currently, these job opportunities

have been randomly allocated. The International Renewables Energy Agency (IRENA) reported that approximately, 14million new employment opportunities in the renewable energy segment globally were created in 2023. The locality of the newfound employment will be contingent on current qualified benefits of areas, as well as reserved programs (IRENA, 2023).

CO_2 capture and sequestration (CCS) technologies are being researched and investigated globally. In general terms, CCS is an integrated process that involves the capture of CO_2 from coal fired power plants, compressed and transported to a storage site, with monitoring of permanent sequestration in deep geological formations. CO_2 capture and transportation technologies are being investigated internationally however the type and capacity of the available geological storage is very country-specific and depends on local geology (Juodaityte, 2011). The "*Atlas on Geological Storage of Carbon Dioxide in South Africa*" estimates that the offshore basins might present the biggest potential storage capability. Unfortunately, they are far removed from the main CO_2 sources of South Africa and specifically South Africa's power utility company, Eskom, has an inland coal-fleet. The onshore formations were found unsuitable for CO_2 storage and no single large viable storage site was identified (Juodaityte, 2011).

Photosynthetic conversion of CO_2 into microalgal biomass is currently considered globally as a possible alternative sequestration option. Microalgal CO_2 sequestration is the technology that is based on the consumption of fossil fuel-fired power plant flue gas as a carbon source to enhance microalgal growth rates and biomass production (Juodaityte, 2011). Microalgal sequestration fits under the broader group of emerging CCS technologies that investigates the reuse or beneficial utilization of CO_2. Microalgal biomass could be an important feedstock for other industries such as bioenergy, agriculture and biotechnology (Juodaityte, 2011). The CO_2 captured from coal power plants, flue gas or from the atmosphere can produce synthetic fuels through a chemical reaction between CO_2 and hydrogen (H_2) (Juodaityte, 2011).

Assessment of JET skills, socioeconomics (including probable job losses and gains), and BRICS energy policies would benefit and support the development of an executable policy for South African JET. The JET funding models will be investigated to allow for sustainable development to comply with the aims of the Paris Agreement and COP22 considering economically viable investment prospects to cater for all South Africans (low to high income earners).

1.3 Problem statement

South Africa is ranked as the 7th major global supplier of coal, a resource integral not only to its domestic electricity generation but also to a range of industries (Lawrence, 2020). Despite coal being the main fuel source, it supports several other industrial processes such as the steel production, cement production, paper and aluminium industries, chemical and pharmacological industries, "coal gas and coal liquid" as conveyance fuel and plant fertiliser as shown in Figure 8 (Malumbazo, 2020). Currently, coal dominates the country's energy mix, mirroring trends across other BRICS nations. However, global imperatives to achieve net zero carbon emissions by 2050 have catalysed a shift toward renewable energy sources, posing significant socio-economic and infrastructural challenges for coal-dependent economies (Harlsey et al., 2020).

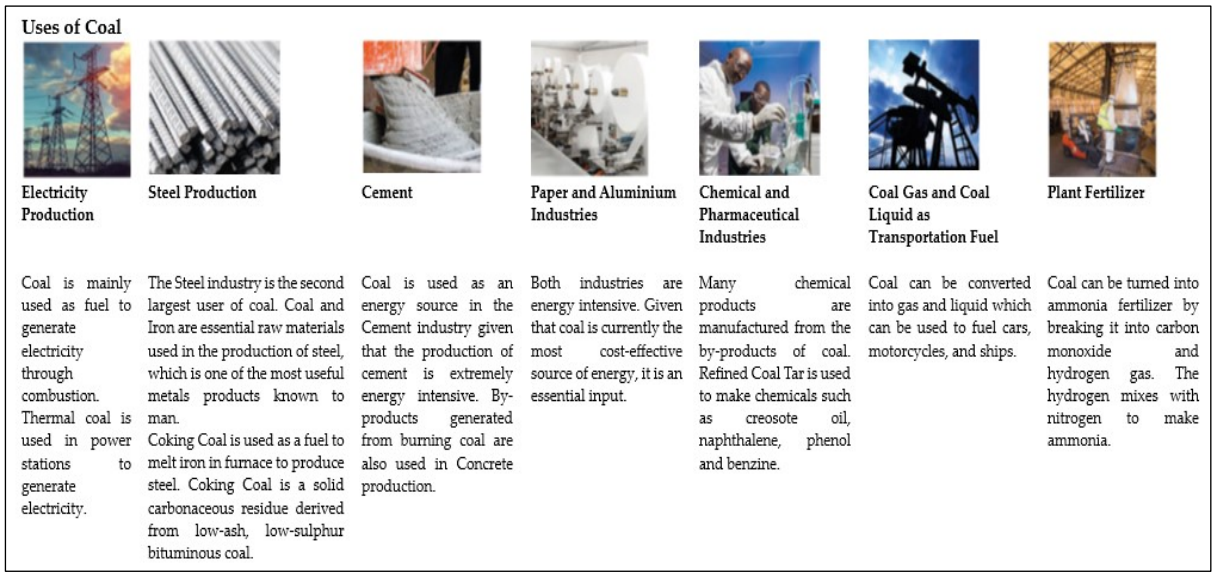


Figure 8: Uses of Coal (Malumbazo, 2020).

The transition away from coal is projected to result in extensive occupational displacement, particularly in regions where coal mining and fossil-fuel power generation form their economic backbone (Solomons, 2017). South Africa's aging fleet of coal-fired power plants, many of which are nearing their end-of-life phase, further underscores the urgency of developing a strategic energy transition plan. Yet, there is currently no comprehensive policy that synthesizes the technical, economic, and social dimensions of this transition within a Just Energy Transition (JET) framework.

A critical research gap is detected surrounding the alignment of JET-related skills development, socio-economic trade-offs (including probable job losses and gains), and the strategic energy policies of BRICS nations. Moreover, existing energy policies do not adequately incorporate

alternative financing models such as Public-Private Participation Partnerships (PPPs) or community equity-based crowdfunding initiatives that could facilitate inclusive and sustainable energy transformation.

This study seeks to address these gaps by assessing the interplay between JET skill requirements, socio-economic impacts, and comparative BRICS energy strategies to inform an executable and contextually grounded policy framework for South Africa's energy transition. By integrating environmental sustainability with economic resilience and social equity, the research aims to contribute to a pragmatic and scalable model of energy reform.

Besides, the ambition to realise the goal of near zero CO_2 emissions by year 2050 is a desperate attempt to prevent global warming and climate change. The conservation of coal resources to realistically and urgently change the global image is illustrated in Figure 8 which depicts the present energy resources where 56% is coal, 14% hydro, 10% wind, 8% solar, 7% gas, 3% biomass and 2% nuclear. It is evident that coal is required for future sustainability of numerous vital businesses OR It is clear that coal remains essential for the continued sustainability of many critical industries. The pharmacological trade is included and is disregarded because of the negligible quantities of coal usage in contrast to the great quantities used in the energy area (CEA, JMK Research). Power plants in South Figure 9 illustrates the South African composition of the energy mix reflective of similar source of fuels yet most reliant on coal versus other sources (Harlsey et al., 2020).

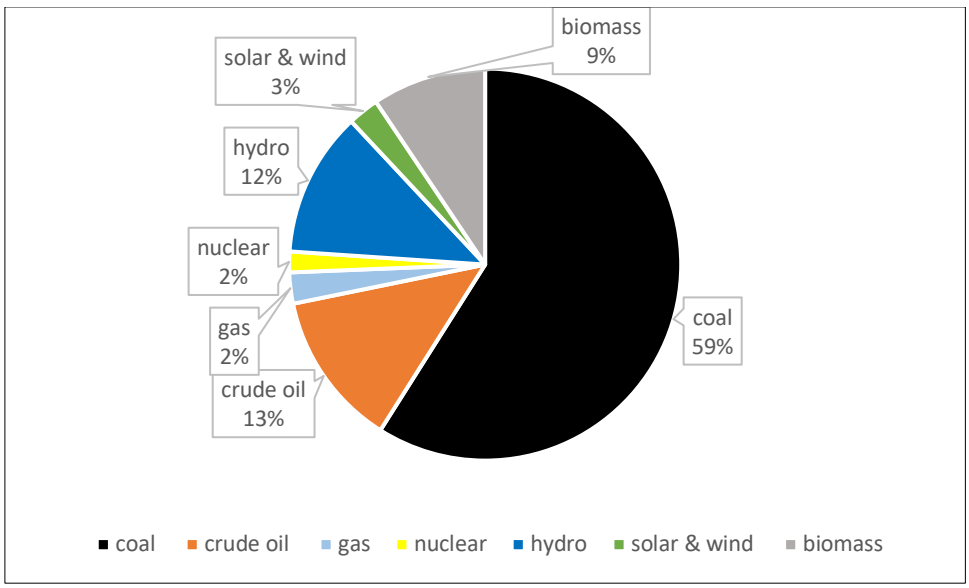


Figure 9: Power plants fuel sources in South Africa (Adapted from DoE Energy Balances (Aggregate), 2012).

In SA of the coal-fired power plants are in their mid to end-of-life phase as shown in Figure 10.

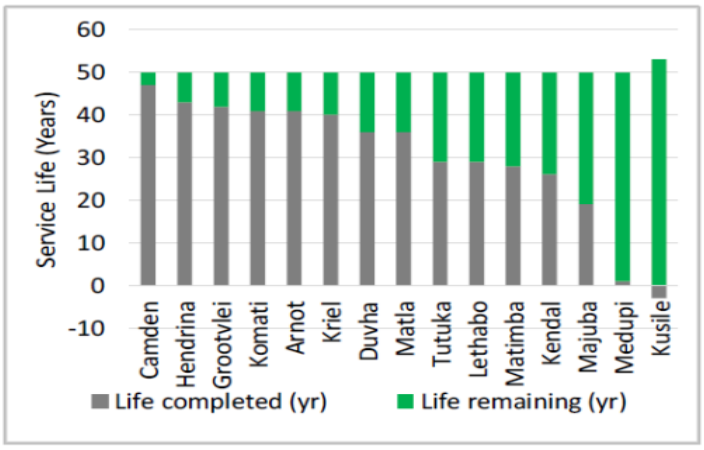


Figure 10: SA's fossil fuel power stations economical life (Juodaityte, 2011).

This coincides favourably with ~~to~~ the country's transition into substitute reduced hydrocarbon energy sources. Legislation~~s~~ and policies requiring energy transformation demand attention as there is no evidence of a policy encompassing South Africa's energy transition. Traditionally or historical approaches of funding methodology for the power utility business must change to alleviate the massive financial drain on government and investigate ground-breaking financial models with Public-Private Participation Partnerships (PPP) models. These models require development into models that the local groups and residents are able to contribute to and be able to have a shareholding into the prospective natural replenishable resources of "greener" power generating plants. With this participation or funding initiative that is similar to a trust or "crowdfunding", the loss of employment impacts can be alleviated by this shared equity opportunity (Harlsey et al., 2020).

1.4 Research questions

1.4.1 What will be the most effective strategy for South Africa to meet the Just Energy Transition (JET) transformation efficiently?

1.4.2 What energy resources and technologies are available to ensure near zero carbonisation or zero CO_2 emissions for South African power producing plants?

1.4.3 How can future South African energy initiatives and power plants be funded?

1.4.4 Are the Paris Climate Change Agreement, COP22 and global warming initiatives achievable for South Africa and if not, what~~'s~~ are the consequences and remedial actions?

1.4.5 Will unemployment rates increase due to the impacts of JET and how will South Africa manage and reduce the negative social impacts?

1.5 Aims and objectives

The aim of the research study is to evaluate and assess the appropriate technologies, policies and funding models as special purpose vehicles to ensure compliance to the Paris Climate Change Agreement for South Africa and aid the world initiatives to prevent global warming.

The objectives of the study would be the following:

- Explicitly elaborating on the consequences of not achieving the targeted zero carbon emissions or net zero.
- How to formalise a JET policy for South Africa.
- Efforts to reduce the social impact of JET.
- Reduction of greenhouse gases (GHG) with various energy resources usage for future.
- Create a symbiotic relationship between social impact, technology and the environment to achieve a JET commitment.

1.6 Hypothesis

The Just Energy Transition (JET) is an essential and inevitable pathway for South Africa to reduce and eliminate greenhouse gas (GHG) emissions, with a targeted outcome of zero carbonisation by 2050.

1.7 Research methodology

The methodology to be applied in this research study will follow international guidelines for JET, which have been applied in BRICS countries. Quantitative and qualitative research methodology will be conducted to test the hypothesis which requires assessment by a detailed statistical and logical analysis of technologies, social impacts, policies and funding models related to JET in BRICS. Quantitative analysis includes how energy transition technologies would affect the existing level of employment (both direct and indirect jobs). Qualitative analysis includes the quality of employment which will be created by the energy transition technologies; thus, these are the issues that cannot be easily quantified. The following sub-sections are the impact studies that will be considered in the JET strategies to be conducted in this research study.

1.7.1 Social Impact Study

Social impact studies will be conducted by assessing the health and wellness of the human population specifically within the BRICS member countries. The effects of transforming to renewable energies will be assessed with the anticipated reduction in job opportunities correlated with the present technologies where more job opportunities are expected as opposed to the dire climate change consequences. In other words, the conservation of the planet might require sacrifice: erosion of employment opportunities in coal-mining, coal-fired power stations and other industry but with the luxury of clean ambient air quality. Human lifespans and quality of life (financial, health and wellness), requires assessment of the transition to reduce GHG with expected vast resistance and emotions in support or against.

1.7.2 Technology Screening and Selection

Present technologies or industries ~~that~~ are contributing the most to GHG and thus the biggest impact on global warming resulting in climate change. Alternate energy sources and technologies that are currently available or emerging technologies to be evaluated with criteria to be compiled that would aid the transition into decarbonisation in the energy producing sectors for electricity production. It would be necessary to study a combination of technologies; where mitigation technologies are deployed where the fuels used might produce CO_2 and other GHG. CO_2 capture and storage or sequestration measures would be evaluated, and the opportunities of synthetic fuels and other positive uses could be explored.

1.7.3 Policy Development

To guide and recommend inputs into a strategic policy; where the socio-economic benefits, economic growth benefits through localisation (design, manufacture, and construction), environmental legislation, the Paris and COP22 Agreements on climate change, technology assessments, selection and implementation, would ramp. up CO_2 and other GHG reduction studies for consideration. BRICS policies will serve as points of reference and benchmarks; hence detailed analysis and applicability would be prioritised to enable the JET effectively and efficiently. It must be noted that numerous supporting policies will enable the JET and ultimate transformation strategy of South Africa.

1.7.4 Funding Models

A study of the funding available from financial institutions including their requirements, cost and affordability of finance, terms and conditions of finance, sovereign guarantees, and acceptance especially for developing states and magnitude of funds available must be

conducted. The analysis and understanding of the types of funding that can be accessed requires adherence to the Addis Abba Agenda and Article 2.1.c of the Paris Climate Agreement; which are crucial to acknowledge as they signify a consolidated and agreed stance amid nations that put economics and monetary schemes at the head of the Sustainable Development Goals (SDG) Agenda and worldwide climate change mitigation (Naidoo, 2019). Comprehension of the academic connections amongst monetary schemes and transformation plans by analysing by what means monetary schemes respond through transformation plans and advance policy visions intended for specific monetary schemes and transformation plans or processes (Naidoo, 2019).

The UN's 2019 Financing for Sustainable Development (FSD) article encourages nations to create investment structures to incorporate sustainable progress in harmony through the Addis Ababa Agenda 2030 (UN, 2019b). The article emphasises the essential significance that funding policies cannot be divided, and every mitigation to funding encounters should focus on the wider change context. It advocates that nations ought to link their workforce marketplace policies, social protection schemes, competition policies, fiscal segment directive and strategies, and trade policies with the novel certainties of advancement (particularly points of social disparity) (Naidoo,2019). The Green Climate Fund (GCF), Direct Funding Institutions (DFI), Public-Private Partnerships (PPP), Private Sector Participation (PSP) and Green Bonds (GB) would be dissected and investigated to formalise usable finance Special Purpose Vehicles (SPV) for the SA situation. The study would be cognitive of the correlation linking financial systems, climate, and sustainable development with the concept of CO_2 incentive credits which might lead to affordable finance.

1.8. Outcomes

The benefits of this thesis would be the following:

1.8.1 Providing an understanding of the need for JET and what will be the result of "doing nothing" versus the compliance to many crucial agreements on global warming prevention and the ultimate decrease of CO_2 and GHG.

1.8.2 Technology scan, technology selection in the electricity production industry and how can we turn the trend of GHG and CO_2 into a beneficial cycle to the environment and humanity.

1.8.3 Policy inputs for South Africa and the enabling strategies to guide and warrant transformation towards the aim of net-zero CO_2 emissions by year 2050 in an amicable logical and consensual manner with socialism, technologies, financial and government.

1.8.4 Special purpose vehicles to improve and sustain health, wellness with eradication of poverty.

1.9 Format of thesis

This thesis is divided into eight chapters which include:

Chapter 1 Introduction: Introduction, background of the study and motivation, hypothesis, aims and objectives.

Chapter 2: Methodology

Chapter 3: JET Policy of the BRICS countries.

Chapter 4: Energy Technologies.

Chapter 5: JET Funding for the BRICS countries.

Chapter 6: Social impact

Chapter 7: Conclusion

Chapter 8: Recommendations and Limitations

CHAPTER 2: METHODOLOGY

This chapter outlines the research methodology employed to explore the concept of Just Energy Transition (JET) in the context of BRICS countries (Brazil, Russia, India, China, and South Africa). The study investigates the policy, technology, social impact and funding mechanisms of the BRICS member countries, as well as the JET processes in these countries, considering the justice dimensions that pertain to the distribution of benefits and burdens, the inclusivity of various stakeholders, and the equitable access to energy. The research follows a qualitative and quantitative approach, underpinned by a systematic literature review sourced primarily from academic articles, policy documents, government reports, and web-based literature.

2.1 Research Design

The research adopts a mixed methods design, integrating both qualitative and quantitative approaches to build a comprehensive understanding of how the energy transition is unfolding across BRICS countries, and the extent to which justice concerns are being addressed. Given the multi-dimensional nature of the Just Energy Transition (JET) concept, the study employs comparative analysis to evaluate and contrast the progress, policy frameworks, challenges, and opportunities unique to each BRICS nation.

2.2 Research Questions

The primary research questions guiding this thesis are:

- What will be the most effective strategy for South Africa to meet the Just Energy Transition (JET) transformation efficiently?
- What energy resources and technologies are available to ensure near zero carbonisation or zero CO_2 emissions for South African power producing plants?
- How can future South African energy initiatives and power plants be funded?
- Is the Paris Climate Change agreement, COP22 and global warming initiatives achievable for South Africa and if not what's the consequences and remedial actions will be required?
- Will unemployment rates increase due to the impacts of JET and how will South Africa manage and reduce the negative social impacts?

2.3 Data Collection

The study utilises data derived from a comprehensive analysis of relevant literature. The focus is placed on sources available online and through academic databases. The sources were selected through the following criteria:

- Academic Databases: Peer-reviewed journals, books, and conference papers focusing on energy policy, sustainable development, and the Just Energy Transition.
- Policy Reports and Official Documents: Reports by international organizations like the International Energy Agency (IEA), United Nations Framework Convention on Climate Change (UNFCCC), and national government reports from BRICS countries.
- Web-based Literature: Reputable websites such as think tanks, governmental agencies, energy research institutes, and environmental NGOs that publish reports on energy transition in the BRICS countries.

The sources included in the review were published up until year 2025 to ensure the relevance and timeliness of the findings. To ensure the quality and credibility of the sources, documents from well-established authors and reputable institutions were included in the review.

2.4 Data Analysis

The data analysis for this research follows a thematic analysis approach, which is well-suited to the exploratory and comparative nature of the study. Given the complexity of Just Energy Transition (JET) and the diversity of the BRICS countries, thematic analysis enables the identification of patterns and narratives across policy documents and literature. This method allows for a nuanced understanding of how justice dimensions are embedded in energy transition strategies, making it an appropriate choice for synthesizing qualitative data and drawing cross-country comparisons.

Thematic analysis is particularly well-suited to this research for several reasons:

- Exploratory nature of the research topic: JET is a complex, multidimensional concept encompassing policy, social justice, economics, and environmental interests. Thematic analysis allows for flexible exploration of these dimensions across diverse national contexts.
- Cross-Country Comparative Framework: BRICS countries differ drastically in their energy policies, socio-economic conditions, and governance structures. Thematic analysis supports comparison by identifying repetitive themes and country specific nuances.

- Document based data: the study depends on qualitative data from policy documents, reports, and academic literature. Thematic analysis is perfect for integrating insights from such documented sources, enabling the researcher to extract meaning systematically.

- Focus on justice dimensions: justice in energy transition involves subjective and value-loaded interpretations (e.g., equity, inclusion, fairness). Thematic analysis assists in uncovering essential narratives that quantitative methods might skip.

The steps of the data analysis process include:

- Familiarization with the data by assessing selected documents to identify relevant information pertaining to the energy transition and justice dimensions in BRICS countries.
- Theme development: Grouping the codes into broader themes related to the energy transition (e.g., policy frameworks, socio-economic impacts, stakeholder participation, challenges to implementation).
- Interpretation: Interpreting the themes to address the research questions, making comparisons between the BRICS countries, and drawing conclusions about how each country is advancing a Just Energy Transition.

The analysis includes a cross-country comparison to highlight similarities and differences in the strategies, policies, and outcomes of the energy transition process in the BRICS nations. Thematic analysis allows the researcher to delve into the qualitative aspects of the transition, such as public participation, the role of marginalized communities, and policy effectiveness.

2.5 Ethical Considerations

Although this research primarily uses publicly available secondary data, ethical considerations still apply. The following measures were taken to ensure the ethical integrity of the research:

- Proper Citation and Referencing: All data sources, including reports, articles, and web-based literature, were correctly cited and referenced to acknowledge the original authors and institutions.
- Transparency: the methodology, data collection process, and analysis steps were transparently described to allow for reproducibility of the study.
- Data Integrity: only credible and verifiable data sources were used to avoid bias or misinformation.

2.6 Limitations

While the study benefits from the rich data available through a literature review, there are several limitations:

- Dependence on Secondary Data: The study does not involve first-hand data collection such as interviews or surveys, limiting the ability to capture the perspectives of stakeholders on the ground.
- Potential Bias in Web Sources: Web-based literature can sometimes reflect the biases of the organizations that publish them. Efforts were made to select a wide range of reputable sources to minimize this bias.

2.7 Conclusion

This methodology chapter outlines the qualitative approach adopted for analysing the Just Energy Transition in BRICS countries. Through a systematic review of existing literature and secondary data, the study provides an in-depth understanding of the various justice aspects involved in the energy transition processes within these countries. The thematic analysis will allow for a comprehensive exploration of the topic, contributing to policy recommendations and future research in the area of energy transition in emerging economies.

CHAPTER 3: JET POLICIES OF THE BRICS COUNTRIES.

3.1 Introduction

To formulate and implement a Just Energy Transition (JET), it is essential to align with national government initiatives, the International Labour Organization's (ILO, 2015) JET guidelines, and comply with key global agreements such as the Paris Climate Agreement, COP22, the Copenhagen Accord (2009), the UNFCCC, and the Addis Ababa Agenda 2030. Equally important is assessing the strategies, progress, and lessons learned from other countries on their path toward zero carbonisation.

This chapter focuses on the JET policies of the BRICS member countries, with the aim of recognising valuable lessons and possible adoption of some of the key energy policy aspects utilized in other countries for benchmarking for the South African context. It considers the present stage of JET in South Africa while being cognisant of the energy-source mix supporting the electricity sector, together with the lifespan and condition of power plants.

3.1.1 Overview and objectives of the BRICS alliance

At BRICS inception in 2006, four BRIC affiliate nations comprising of Brazil, Russia, India, and China formed the initial bloc. However, in year 2010 South Africa was invited to join BRIC, leading to the transformation of the group into BRICS (Morazán et al., 2012). South Africa officially joined the group in December 2010 to "promote peace, security, economic development, and cooperation" among these nations (BRICS-JSP, 2018).

The key intent of the partnership was to extensively improve the socio-economic topography of the five member nations consisting of a population of greater than billion. This equates to 40% of the world's inhabitants and around 25% of the international "Gross Domestic Product" (GDP). Owing to the geographic and demographic proportions, BRICS markets are meaningfully influencing worldwide development, specifically in "Low Income Countries (LIC)" (Morazan et al., 2012). In addition, BRICS is promoting stability in trade and investment, and acting as a buffer to global recession when the global market is in financial crisis (International Monetary Fund 2011a:8).

- The objectives of the BRICS alliance are as follows (Darnal et al., 2023; International Monetary Fund 2011a:8"; Morazan et al., 2012; World Bank, 2021):
    - "Commitment towards reforming international financial institutions."

- "A greater voice for the emerging and developing economies for better representation in financial institutions."
- "To work with the international community to keep the multilateral trading systems stable and improve the international trade and investment environment."
- "To be part of the World Trade Organization's Doha Development Agenda (WTODDA) and the achievement of the Millennium Development Goals (MDG) through sustainable development, the Rio Declaration, the Agenda for the 21st Century and multilateral environmental agreements."
- "Coordination and cooperation among BRICS states in the field of energy efficiency."
- "Focus on climate change and socio-economic development initiatives."
- "To provide humanitarian assistance and reduce natural disaster risks (includes addressing issues like global food security)."
- "Cooperation among the BRICS countries in science and education and engagement in fundamental research and advanced technological development."
- "This promises democratic and diplomatic cooperation, mutual respect, coordinated action and collective decision-making (discourages terrorism)".

The BRICS member countries do not have a generic energy policy since it would be too restrictive considering that the circumstances in each country are different. However, with the main objective of economic growth and sustainability, BRICS member countries have embedded and adopted the pledge to comply with the Paris Climate Change Agreement and the ILO (2015) guidelines in their countries' energy policies to ensure economic growth in an environmentally responsible manner.

The progress and effectiveness of the BRICS countries energy policies together with the BRICS alliance objectives can be directly measured from the "Energy Transition Index" (ETI) ratings and the JET standings issued by the "World Economic Forum" (WEF). The ETI benchmarks nations on the performance of their energy scheme, in addition to their willingness to change to a secure, sustainable, reasonably priced, and dependable energy future. "ETI 2024" scores on a scale from 0 to 100 consistently for all countries. The BRICS affiliates JET standings and ETI grades respectively are Brazil (66), Russia (57), India (55.3), China (64.1) and South Africa (52.4) (WEF, 2024). These grades and standings are a specific reference to evaluate the strength and elasticity of the JET. For a strong revolution, the interregnum of JET must sustain the forward change drive to realise dependable, cost-effective and self-sustaining

energy systems despite the harsh conditions of the COVID-19 pandemic encountered globally (WEF, 2021).

3.2 Energy Policies of BRICS

Nationally Determined Contributions (NDC's) are the country's pledge to decrease nationwide GHG emissions and adjust to the effects of climate-change (United Nations Framework Convention on Climate Change (UNFCCC), 2015). NDC's are pivotal for the Paris Climate Change Agreement and the accomplishment of these long-term targets of zero CO_2 emissions. It is a requirement of the Paris Climate Change Agreement that individual countries or parties articulate, correspond, and encourage succeeding NDCs that the country plans to accomplish. Parties should follow national internal alleviation procedures, focused on realising the goals of their NDC's (UNFCCC, 2015). NDCs combined, assess if the planet reaches the long-term aims (GHG reduction) of the Paris Climate Change Agreement. There is urgency to tackle quick GHG reduction objectives in alignment with appropriate practices and accessible technologies; the target being an equilibrium between anthropogenetic emissions by sinks of GHGs from the year 2050 to year 2100. It is acknowledged that the reduction of emissions for developing countries, will require additional time.

The critical development priorities for many developing countries however are to lower emissions executed on impartiality and from the perspective of sustainable advancement to eliminate poverty (ILO, 2022). The frequency of NDC submissions to the UNFCCC secretariat, is every five years. This is to ensure compliance, and Paris Climate Change Agreement objectives are accurately measured and achieved (ILO, 2022). BRICS member countries' NDC reviews are conducted to assess the efforts made on "climate-change" and goals aimed at the ultimate net-zero CO_2 emissions in BRICS countries. The aim is to identify policies and measures implemented to influence "green employment". Policies on social protection, organizational expansion, occupational safety and health, communication, skills, education and training should take cognisance of the ILO Guidelines for a Just Transition (ILO, 2022).

All BRICS member countries have pledged their commitment to net-zero targets and in their NDC submissions as further confirmation (Brazil by 2060, Russia by 2060, India by 2070, China by 2060, and South Africa by 2050). Brazil and Russia submitted their updated NDCs in 2020, China and South Africa submitted theirs in 2021, while India submitted its first NDC in 2016 (ILO, 2015). A common observation from the BRICS member counties NDCs' is the social elements which are vaguely referenced.

Apart from South Africa, none of the other BRICS member countries addressed “Just Transition” as part of the Just Energy Transition (JET) and heat stress aspects. However, the Russian NDC mentions the term "fairness" and cognisant of social impacts of climate-change and JET (International Labour Organisation (ILO), 2022). India refers to jobs and power eradication, whilst bearing in mind diverse groups' specific weaknesses to climate-change. China's NDC highlighted few employment repercussions of climate-change with a requirement to foster equitable, reasonable, cooperative, and a win-win global climate policy (Tian et al., 2020). All the BRICS member countries' NDCs have considered to an extent education, training, and skilling but specific details are missing especially with respect to reskilling and upskilling nationwide workforces, however South Africa has revealed, in a detailed assessment of the financial and environmental aspects, where the financial development was integrated together with the environmental emissions and resource use. The study recommendation was to separate economic expansion and development from CO_2 emissions and resource usage (Tian et al.,2020)

In summary, based on the assessment, Brazil appears to lead among BRICS countries in implementing the Paris Climate Change Agreement. The nation has made notable progress in curbing deforestation within the Amazon, advancing renewable energy initiatives, and setting ambitious targets for Greenhouse Gas (GHG) emissions reduction. However, the overall progress can vary, with each country facing unique challenges and priorities in addressing climate change. The Nationally Determined Contributions (NDCs) play a crucial role in the implementation of the Paris Climate Change Agreement. NDCs present each country’s commitment to reduce greenhouse gas emissions and adapt to climate change effects. For the BRICS nations, the submissions reflect a blend of ambitions toward achieving net-zero emissions, with varied timelines for Brazil, Russia, and China aiming for 2060, South Africa by 2050, and India by 2070. While these commitments are vital, the NDCs often lack specificity regarding social dimensions and the JET framework, which emphasizes equitable workforce transitions in the face of climate change. Notably, South Africa is more explicit in addressing these social aspects, while others, such as Russia and India, mention fairness and job considerations but do not delve deeply into necessary support measures. The overall analysis suggests that, despite some recognition of education and reskilling, BRICS countries need to enhance the integration of social protection policies and align economic growth with sustainable practices to effectively meet their climate goals.

The following section will delve deep into the energy policy of each BRICS member country with the intention to gain appreciation for the policy intent, assessment and an understanding of the country's commitment to comply with the Paris Agreement.

3.2.1 India's Energy Policy

India's fiscal development in the year 2022, was 7% with an expected GDP of 5.6% from the years 2023 to 2024. Currently, India is rated 59 from 152 nations in the GlobalData Country Risk Index (GCRI) on macroeconomics (GCRI, 2022). As a positive spin off from the existing regulation of the Securities and Exchange Board of India (SEBI), the country's equity marketplace is outstanding and appealing because of significant attempts toward economic regulation and liberalization. The World Bank (WB) indicated that India's country's equity of the resident associations registered as a component of GDP improved from 81% of GDP in year 2019 to 97% of GDP in year 2020, surpassing China's GDP of 84% which was exceptional for India (Macroeconomic Outlook Report: India, 2023).

The current energy mix of India is comprised of 46% coal, 25% petroleum (and other liquid fuels), 20% biomass and waste, 6% natural gas, 1% nuclear, 1% hydroelectric and 1% other sources of renewable energy as depicted in Figure 11 (IEA, 2021).

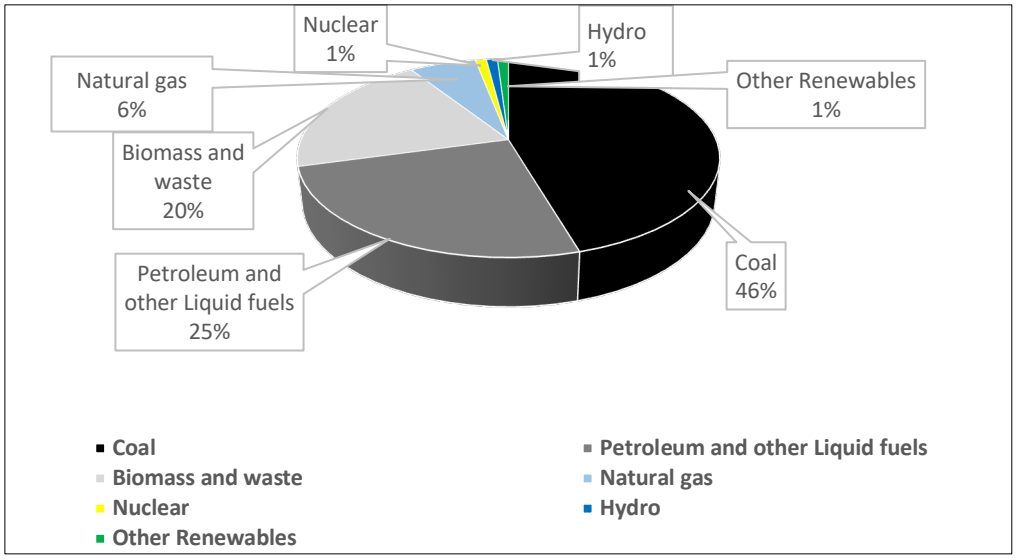


Figure 11: India's current Energy mix (IEA, 2021).

The "social impact" on the country's residents is very crucial since it impacts directly on health and wellness. The energy policy describes the requirement for health and wellness as a fundamental theme. To transform harmoniously with respect to the quality of life of their

inhabitants, specifically the low-income, countryside societies. These countryside societies have almost 700 million inhabitants that are forced to utilise biomass resources to prepare their meals (IEA, 2021). The Indian government's Prime Minister, Narendra Modi, declared the nation is devoted to zero CO_2 emissions by year 2070 at the COP 26 summit convened in Glasgow in year 2021 (COP26, 2021).

The country's new National Electricity Plan (NEP) from the Central Electricity Authority (CEA) is in draft and was published for communal participation. It has an assessment of the detailed electricity capacity expansion plans for 2032 (NEP-India, 2022), and in particular, the predicted expansion of new power-generating plants, where the largest contribution will be from green energy sources by approximately 40% - from 623 GW to 866 GW by 2032. The bulk of the increase of 214 GW is planned to be from renewable energy sources with approximately 69% contribution from Solar Photovoltaics (SPV). An additional 10 GW is expected from an offshore wind power plant by 2032. The total renewable energy, therefore, is expected to contribute 60% (approximately, 516 MW) of the total electricity supply by 2032. Hydropower contribution of 69 GW is expected to increase from 1% to 7% by 2032 as depicted in Figure 12.

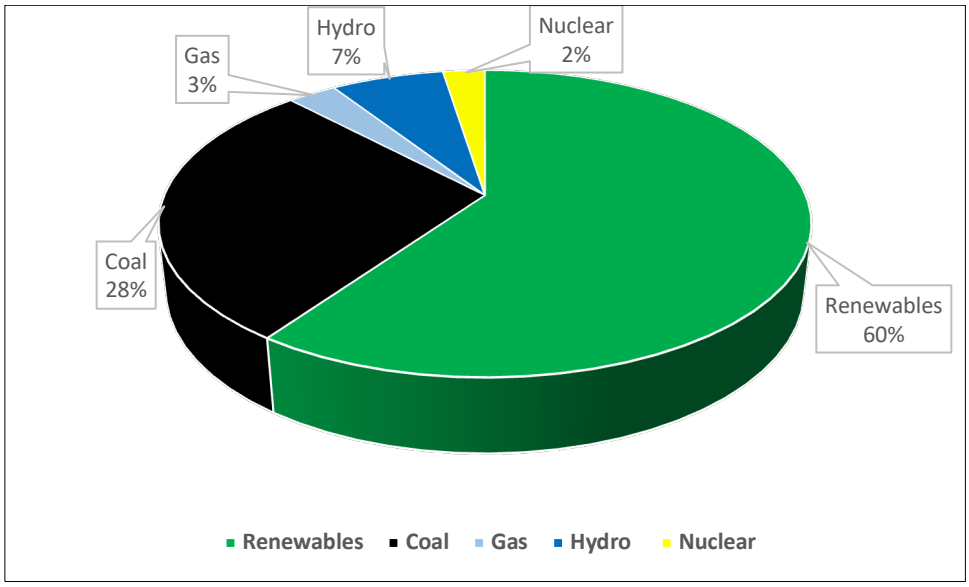


Figure 12: India's envisioned 2032 Energy mix (NEP, 2022).

Nuclear power plant capacity is expected to increase to 22.5 GW, contributing 2.5% of the electricity pool; while the contribution of fossil fuel electricity production is forecast to decline by 2032, from 46% to 28%. In addition, gas power plants installed capacity is projected to decrease from 6% to 3% by 2032. (Powel et al., 2022).

The Indian government has expressed the apprehensions and challenges of the emerging countries at the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom, 2021 (COP26, 2021). The concerns and challenges were related to the move of climate finance and affordable climate mitigation expertise which have become more significant for execution. The aims on climate finance by developed countries cannot continue in the same manner as they were at the time of the Paris Climate Change Agreement in 2015 due to their unfair economic advantages in comparison to developing countries. Climate finance should be tracked in the similar manner as the UNFCCC monitors the advancement in climate action to ensure fairness to developing countries.

India reiterated the country's commitment to assist in eradicating global warming by achieving the following just energy transition objectives/goals:

- "Reach 500 GW non-fossil energy capacity by 2030."
- "50% of its energy requirements from renewable energy by 2030."
- "Reduction of total projected carbon emissions by one billion tonnes from now to 2030."
- "Reduction of the carbon intensity of the economy by 45% by 2030, with reference to 2005 levels."
- "Achieving the target of net zero emissions by 2070."

The unavailability of affordable electricity results in poor air quality which negatively impacts the health of the communities and the environment. This was exacerbated by the COVID-19 pandemic and financially constrained electricity generation. The distribution utility companies in India caused Indian cities to have one of the poorest qualities of air globally in the year 2021 (Kaur et al., 2021). The country with its population of one billion, is the globe's third biggest electricity consumer which remains fuelled by 77% fossil fuel (coal 46%, petroleum and other fossil fuels 25%) power plants (IEA, India Outlook, 2021). India is also rapidly evolving into the globe's greatest populated nation by urban expansion with the growth size corresponding to a city of the magnitude of Los Angeles. This will lead to a dramatic rise in demand for electrical energy over the next twenty years which is equivalent to the capacity of the size of the European Union (EU) in addition to India's present network. However, in compliance to the energy policy, India has approved a budget and committed to transition towards 50% of renewable energy by 2030 (Agrawal et al., 2020).

India's successes in the energy transition are most commendable even with the COVID-19 pandemic in year 2020. This is due to the drive to electrify the entire country with the

implementation of a more efficient lighting technology known as Light Emitting Diode (LED) for many residential customers. India has adopted a strategy of planned implementation where 38% of the total energy market is from renewable energy sources with emphasis on solar energy technologies (Mani et al, 2020). The urgency spearheading the international reaction to climate related change is a fundamental priority which India has committed to. The plan is to achieve this commitment through a massive 50% renewable electricity capacity expansion by 2030. This will be achieved through improving energy efficiency and the transport framework, expanding local coal production, and easing dependence on coal importation. India is seen as a huge participant in the world's energy ecosystem with energy consumption that increased two times the energy demand from the year 2000. Commendable success of electrification connections to meet demands for approximately 900 million citizens was achieved in 2019 (IEA, 2021).

In summary, India's economic landscape in 2022 shows promising growth, with a fiscal development of 7% and an anticipated GDP increase of 5.6% for years 2023 and 2024. The country's commitment to transitioning to renewable energy is reflected in its ambitious National Electricity Plan, which aims for renewable sources to contribute 60% of electricity supply by 2032, significantly reducing reliance on fossil fuels. However, challenges persist, particularly in social equity and health impacts linked to energy access, especially for the 700 million rural residents relying on biomass. India's commitment to achieving net-zero emissions by 2070 and its goals for substantial renewable capacity expansion underscore its proactive stance in addressing climate change. Despite facing hurdles like poor air quality and high fossil fuel dependency, India is making strides in energy efficiency and electrification, aiming to align its growth with sustainable practices and improve quality of life for its citizens.

Industrialisation and urbanisation initiatives in India are increasing the burden of its energy sector and pressure is on the government to change or provide effective empowering policies to warrant the energy demand which is met in synergy with the Paris Climate Change Agreement. New power plants (renewable energy and fossil fuels) must comply with the net zero carbon emission agreements to ensure affordability and reliability of electricity to the communities. The Indian government is focused on the health and wellness of the population and therefore, understands the impacts and consequences of carbon emissions thereon. Therefore, the Indian government is committed to switch from fossil fuels to greener, renewable fuel sources to power and sustain India's economic growth in harmony with the environment (Aklin, et al., 2015). The global COVID-19 pandemic has delayed some of the progress to energy transition to reduce GHG. However, the pandemic resulted in slow

economic growth of 35% in comparison with forecasted economic growth of 50% between year 2019 and 2030 which might have led to the delay to transform to green fuels (Aklin, et al., 2015).

Over the past two decades, the power generation mix for India's sustainable development plan of cost efficient and more affordable renewable energy of 450 GW by 2030 is on target (IEA, 2021). Currently, India's electricity grid and its fossil fuel power plants meet most of India's needs, supplemented by hydroelectric and gas power plants to support the grid stability more especially during power swing conditions (Chandran, 2018). This ensures the quality of power supply of voltage, frequency and reactive power control to sustain and protect the power system from failure. Battery energy storage systems are ideal to render interim leeway or resilience that India requires to meet the country's solar driven midday electricity maximum production; and its earlier evening maximum load requirements of which planned capacity is 140 GW. (BESS IEA, 2021). This highlights the country's commitment to enhancing energy reliability and sustainability as it transitions to a more renewable-centric power grid.

India's NDC was tendered to UNFCCC in the year 2016, and India did not present an update of the year 2030 target. However, it's projected to overachieve the target with current policies (Climate Action Tracker, 2020). During COP26 in Glasgow in year 2021, India presented a net-zero target by year 2070. In addition, like the other BRICS member countries, the NDCs do not categorically refer to "just transition" which encompasses decent employment, conditions of work, Occupation Health and Safety (OHS), social protection, or social dialogue. However, the NDC mentions, climate and social fairness specifically with regards to improving rural population's livelihoods. This placed the emphasis on the disadvantaged sector of the population (ILO, 2022). Likewise, the NDCs contained some organisation initiatives that concentrated on resource efficiency, waste management, contamination handling and the public employment initiative of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The MGNREGA might assist as an excellent model of how community work initiatives may integrate with environmental aims. The MGNREGA's objective is to aid social protection and economic defence to eradicate poverty in rural communities, supporting drought-proofing, flood management, and enabling disadvantaged societies. The MGNREGA states that every countryside home is entitled to 100 days of work per annum. The NDC for India does mention the requirement to provide funds for education and enhancement of expertise across areas as well as *"establishing a more intensive state centric knowledge"* on various attributes of renewable energy. Funding in research and development institutes for

"pre-competitive research" is also integrated into India's NDC which is vital to reach the zero CO_2 mark in compliance to the Paris Climate Change Agreement (ILO-WSP, 2017).

In summary, India's energy policy demonstrates a strong commitment to transitioning toward a sustainable energy future, aiming for a significant increase in renewable energy capacity and a substantial reduction in carbon emissions by 2030. The ambitious targets, including achieving 500 GW of non-fossil energy capacity, and sourcing 50% of energy needs from renewable energy, indicate a strategic approach to balancing economic growth with environmental responsibilities. However, challenges such as a high reliance on fossil fuels, infrastructure development, and social equity in energy access must be addressed for these goals to be achievable. With continued investment in technology, improved energy efficiency, and effective policy implementation, India has the potential to meet its ambitious targets and pave the way for a cleaner energy landscape. The success of this transition will largely depend on governmental support, international collaboration, and financial investments in renewable infrastructure.

3.2.2 China's Energy Policy

The real GDP growth was 4.5% in year 2022 and it is predicted to be 4.8% in year 2023, while consumption (use of goods and services) was 6.5% in year 2022 (Macroeconomic Outlook Report: China, 2024). As of 2024, real GDP growth in China is projected to be around 5.2%, reflecting a slight recovery from previous years. Consumption growth remains strong, estimated at approximately 7% for 2023, driven by increased consumer spending and economic stabilization efforts. The continued focus on domestic consumption and investment suggests a positive outlook for the economy moving forward (Macroeconomic Outlook Report: China, 2024). The World Bank's business ranking of China in year 2022 was 31 out of 190 countries. China's electrical and electronic trade magnitude is predicted to expand at a Compound Annual Growth Rate (CAGR) of 11.6% from year 2021 to 2025, to a targeted monetary amount of $3.3 trillion in year 2025 (Macroeconomic Outlook Report: China, 2024).

The current energy mix of China comprises of 52% coal, 3% solar, 2% biomass, 10% natural gas, 3% nuclear, 8% hydro, 4% wind and 18% oil as shown in Figure 13.

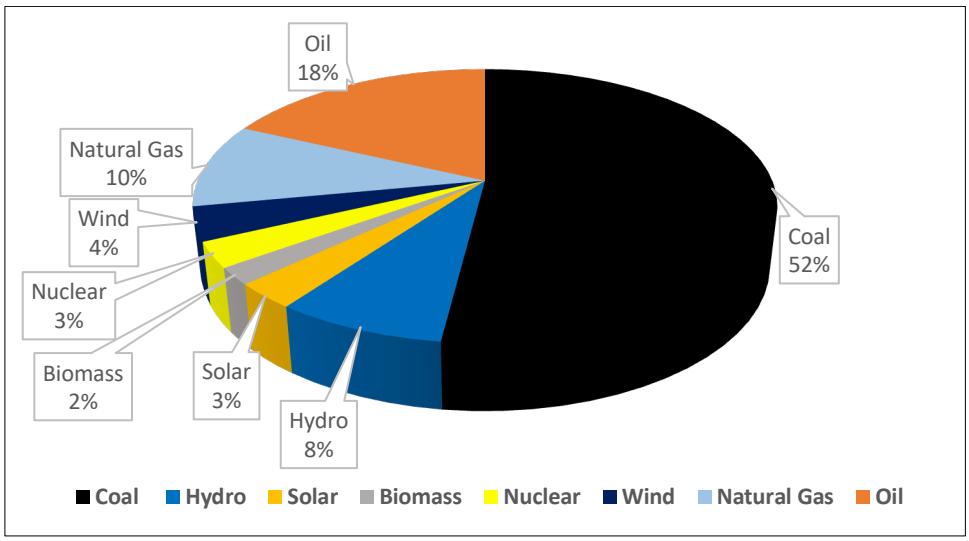


Figure 13: China's current Energy mix (IEA, 2021).

China's planned nett-zero transition by 2060 would result in 3% coal, 23% solar, 5% biomass, 3% natural gas, 19% nuclear, 15% hydro, 24% wind and 8% oil by 2060 as depicted in Figure 14.

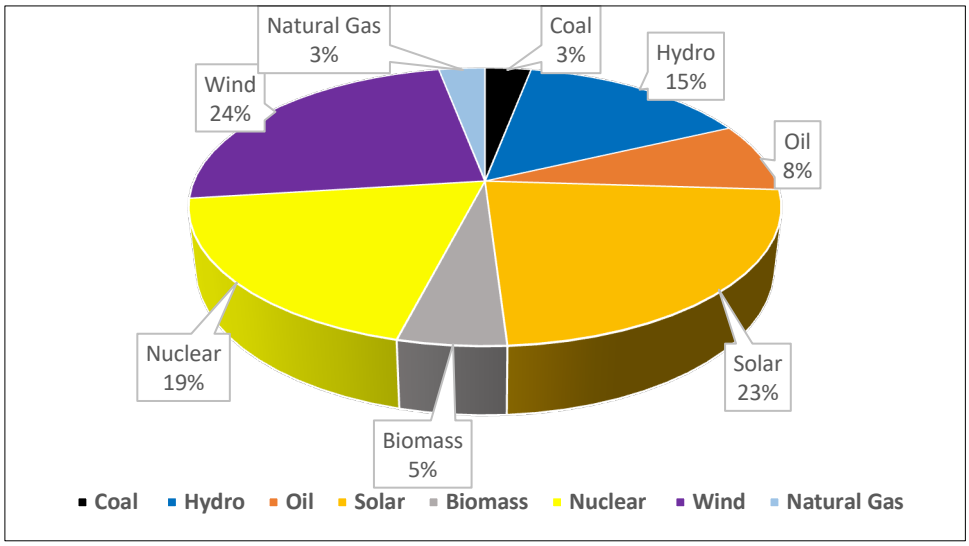


Figure 14: China's envisioned Energy mix by 2060 (IEA).

With the Accelerated Transition Scenario (ATS) and the Announced Pledges Scenario (APS) China has been adding nuclear (70 GW) (20 new reactors) and solar (110 GW) capacity to cater for the requirements of 33 million homes. China is a large player in the world energy markets since it is the world's biggest energy user since 2009 (Finamore, 2010). The country has acknowledged the crucial role it has to play to curb global warming and ultimately climate change.

The country is ranked first on the globe's carbon emissions ranking and is one of the globe's leading energy user and CO_2 producer which makes up 33% of the world's CO_2 discharge (IEA, 2021). Therefore, the success of its energy transition to nett zero carbon emissions will be a key success factor to prevent global warming from exceeding temperatures of 1.5 °C increase (IEA, 2021). The power producing plants are the origin of approximately 90% of the country's GHG, highlighting that the energy plans are imperative for carbon neutrality (Chang et al., 2016). China believes in collaborative engagements with the IEA and other countries in the common vision of eliminating carbon emissions. The spin-off from achieving nett zero carbonisation is envisaged to foster China's sustainable economic and environmental development goals yet cultivating prosperity in improving technology leadership resulting in sustainable economic growth led by innovation (Genin et al., 2020). One of the most noteworthy achievements and contributions globally, is that China produces 70% of electric vehicle battery demand. The rapid rate of solar plant deployment has hedged or counterbalanced the reduction of the environmental impact of being the second largest consumer of oil globally. It must also be noted that China is the biggest supplier of steel and cement which makes up more than 50% of the global demands. The impact is that the carbon emissions generated by these plants are astronomical and are deemed to be more than the European Union's carbon emissions (Chang et al., 2016).

The major contributors to the country's CO_2 emissions are the electricity utility area where 48% of CO_2 production originates from energy production and industrial activities, 36% from industry (steel and cement), 8% from transport and 5% from the infrastructure (buildings). China's five-year plan, called Modern Energy System (MES), aims to reduce energy intensity by 13.5% (from 65% to 51.5%). This plan is expected to lower CO2 intensity by about 18% and increase the share of renewable energy in total consumption to 20% by 2025 (Chen, 2018).

It is imperative for China to achieve these short-term policy targets, as it will show the IEA and global authorities that the country's CO_2 emissions from coal was on target in year 2020 of achieving 15.9% non-fossil fuels and that a modest decline will be reached by the year 2030. China's pledge in 2021, at the United Nations General Assembly (UNGA) reiterates the country's determination to end the construction of coal-fired power generation plants in solidarity for a greener economy. In association with the economic growth forecast, it is predicted that the energy demand will not increase at the same rate as the economy due to efficiency gains of energy transition to cleaner fuel sources resulting in improved air quality (Chang et al., 2016). The future energy mix of China will be dominated by solar and hydrogen

of at least 60% of the total energy requirements by the year 2045. The emphasise will be to reduce the dependency on fossil fuels especially coal by 80%, oil by 60% and natural gas by more than 45% by 2060 (Chang et al., 2016). This will be achieved by interim measures of Carbon Capture Utilisation and Storage (CCUS) to moderate the CO_2 emissions more rapidly (Chen, 2018). China is in favourable financial position to fund the transition to clean energy and infrastructure with a committed budget of $640 billion to the year 2030 and $900 billion from the year 2031 to the year 2060 (IEA, 2021). In comparison, the annual energy investment share of the country's Gross Domestic Product (GDP) was at a mean of 2.5% from the year 2016 to 2020 which will substantially decline to approximately 1.1% by the year 2060 (Chen, 2018).

China encourages all sectors to contribute to the reduction of carbon emissions and participate in the electrification of road transport (cars, buses, motorbikes, and trucks), rail (metrolight, high speed trains between cities), shipping and aviation to use low carbon fuels that will result in efficiency gains. This will be achieved by the reduced use of fuel for the exact amount of energy required. In addition, another target is to shrink the carbon emissions in the building segment by approximately 95% of the current emissions by the year 2060 through electrification, solar powered climate control (air conditioning), and innovative energy reduction concepts in building designs to make buildings less energy intensive (IEA, 2021). Fast-tracked progress before the year 2030 would be beneficial in the reduction of emissions that may be experienced beyond the year 2030, with socio-economic rewards past those connected to managing climate change. Synchronising the intensity of the emissions' maximum, as well as the percentage of emissions reduction at the instance that the maximum is attained, are paramount for the success of China's ultimate objectives of zero CO_2 emissions. China is in the fortunate position that it has the technical knowledge, economic strength and sound policy to accomplish the efficient green energy transition by the year 2030 (Hasanbeigi et al., 2019).

Lately, China initiated an emissions trading scheme as well as their electricity market improvements which are illustrations of the country's commitment towards zero CO_2 emissions. By 2030, carbon emissions from electricity producing power plants are projected to reach about 2 GT, roughly one-fifth lower than the ATS. Collective investment in the ATS mirrors that of the APS, and funding requirements are not a constraint for China (Chang et al., 2016). Prosperity in some regions in China have not realised the gains from the economic expansion, however, renewable energy sources supply, value chain and developing green technologies will enhance the country's economic growth (Chang et al., 2016).

The energy transition is welcomed and supported by labour as it is thought to have the potential to increase the employment rate. The labour market is envisioned to be approximately 3.6 million by the year 2030, matched to the 2.3million employment envisioned to be lost in the fossil fuel resource and power plant segments. Employment growth may increase significantly if China can be successful in securing part of the increasing renewable energy requirements of countries that are not skilled in these emerging technologies. The advantage of increasing the range of the country's nett zero CO_2 goal to include all GHG would result in the energy segment reaching a nett-zero CO_2 emissions much earlier than the year 2060 (Genin et al., 2020). This will cater for the other CO_2 emitting industries that are not easily dispensed with. The government acknowledges that accelerated success in reducing carbon emissions through to the year 2030 is critical. Solar PV and wind energy of approximately 1.4 TW which equates to approximately a fifth larger than the year 2050 APS, fostering the compliance to the Paris Agreement (IEA, 2021).

Should the current intensive CO_2 emissions structure in the country continue to run in a similar manner, it would result in 175 Gt of CO_2 production by the year 2060, corresponding with 33% of the world's emissions budget left over that may curb the planet's temperature increase to 1.5 °C. If cleaner energy plants are not developed on time, the consequences would be disastrous in the subsequent phase of heavy industry funding in the country with unfavourable increased carbon emissions. In the APS, 40% of the country's electricity generation carbon emissions reductions by year 2060 is dependent on technologies that are currently being prototyped or in testing and under demonstration phases that should accessible as scheduled to replace present fossil fuel generation. It is envisaged that this would eradicate CO_2 emitted from the country's heavy industry (iron, steel, coal, etc.) which is the equivalent of approximately 15% of the projected world's CO_2 financial allocation; and has a probability of 50% to restrain the average planetary rise in temperature to 1.5°C (Hasanbeigi et al., 2019).

China submitted the updated NDC in year 2020 to the UNFCCC. The NDC includes the country's viewpoint and objectives on managing "climate-change", and favourable outcomes were obtained in the application of NDC. Newly discovered actions are to be executed in line with the revised NDC objectives including the country's aim to encourage global collaboration on climate change. Similarly, China aims to have CO_2 emissions peak prior to year 2030 and reach CO_2 objectivity prior to year 2060 (ILO, 2022). The NDC makes repeated reference to socio-economic transitions, unfortunately not supported with occupational health and safety, acceptable jobs or social conversation. The "Just transition" of JET pledges were not explicitly

stated in the NDC, however international cooperation on climate change was alluded to. The NDC states that *"China is committed to promoting the establishment of a fair, reasonable, cooperative, and win-win global climate governance system and the global transition to green, low-carbon, climate-resilient and sustainable development"* (Tian et al., 2020). Training and education are covered appropriately in the NDC although it does not adequately cover the requirement for skilled labour for a decarbonised economy. The strategy or plan to reskill current employees that are at risk because of their jobs becoming redundant from JET is not clear. China's requirement to enhance the skills of its professional workforce, particularly in green (renewable energy) sectors, is addressed through educational standards (Tian et al., 2020).

In summary, my assessment of China's energy plans for JET focuses on balancing economic growth with environmental sustainability. The country aims to reduce carbon emissions while ensuring energy access for all, particularly in underserved regions. Efforts include expanding renewable energy capacity, improving energy efficiency, and investing in green technologies. However, challenges remain, such as managing job transitions in traditional energy sectors and ensuring equitable distribution of resources. Overall, China's strategy emphasizes a pragmatic approach to achieving its climate goals while maintaining social stability.

3.2.3 Russia's Energy Policy

In the year 2022, the real GDP growth was 2.1% and it is predicted to be 1.2% in year 2023 (Korsunskaya, 2023). Unemployment is at a record low of 3.5% and forecasted to remain low till year 2026 with the challenge of the Russia-Ukraine war. Russia's current account surplus is declining rapidly to approximately 73% in the first quarter of 2023. However, increased oil and gas exports were at record highs in year 2022. The Russian ministry reduced its forecast by 50% for the current account surplus in year 2023 to $87 billion from $158billion and reduced the trade balance prediction from $228 billion to $152 billion (Korsunskaya, 2023).

Prior to the Russia-Ukraine war, Russia, like numerous resource-rich (oil, coal and gas) and electricity exporting countries, had begun JET; however, this progress slowed due to challenges to its implementation, such as the country's financial status, which is highly dependent on hydrocarbon export income. From the year 2000, Russia has controlled the rise in energy resource exports substantially between year 2000 to 2005 where exports increased by 56%; providing rapid economic growth and reinforcing Russia's stance in the global arena as an energy superpower (Henderson et al., 2017). The worldwide economic recession in 2008 led to the export of energy resources to decline rapidly. After the recession, from years 2011 to

2014 inflated oil costs as a result of poor international trade demand and declining "petrodollar" income adversely impacted GDP, with oil priced at $110 per barrel. Income from oil and gas global sales decreased from high prices of the year 2008 to year 2012, compounded by decreasing prices of hydrocarbons. However, in 2017, hydrocarbons contributed 25% to GDP and 39% to Russian planned income; where 65% was from export revenue and 25% was from total funding in the Russian economy (Mitrova et al., 2019). Global renewable energy objectives and therefore transition towards nett-zero CO_2 emissions might render a significant decrease of hydrocarbon export revenues in Russia together with the unintended consequences of the Russia-Ukraine war.

In the primary energy consumption, production of electricity is mainly from gas which accounts for 47%, coal accounts for 16%, hydro accounts for 17%, nuclear accounts for 18%, oil and renewable energy accounts for 1% each as depicted in Figure 15. The country's tactical behaviour with respect to JET is paramount for Russia and the planet. Numerous constituents of macroeconomics, institutional frameworks in the power production industry, climate change and technology plans or policies exist which defines the country's strategy towards the energy transition (IEA, Coal, 2018).

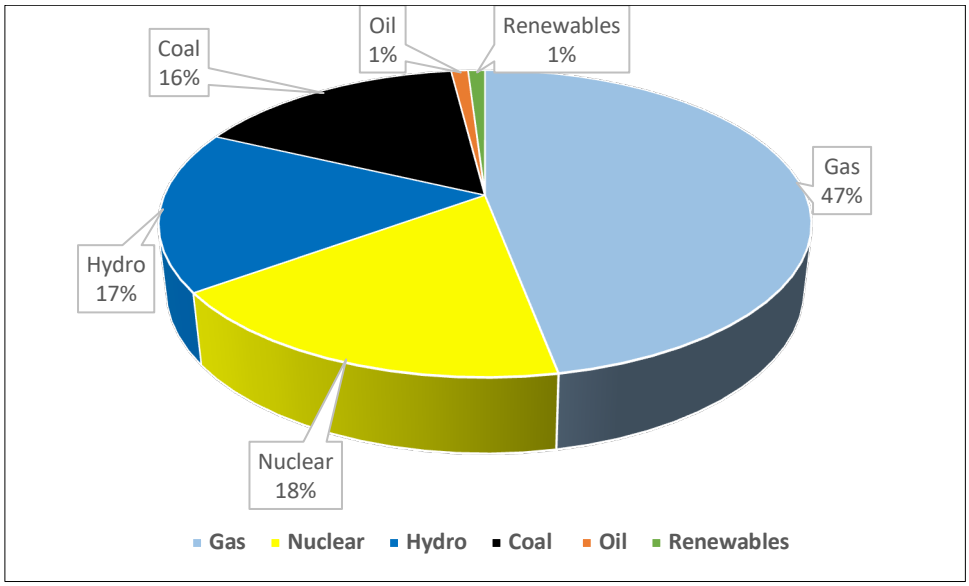


Figure 15: Russian Energy current mix (IEA, Coal, 2018).

Figure 16 illustrates the envisaged energy mix by 2030 with successful execution of the Energy Strategy of Russia (ESR, 2010) whereby gas is envisioned to contribute 36%, coal 5%, hydro 8%, nuclear 4%, oil 39% and renewable energy 8%, respectively (IEA, Coal, 2018).

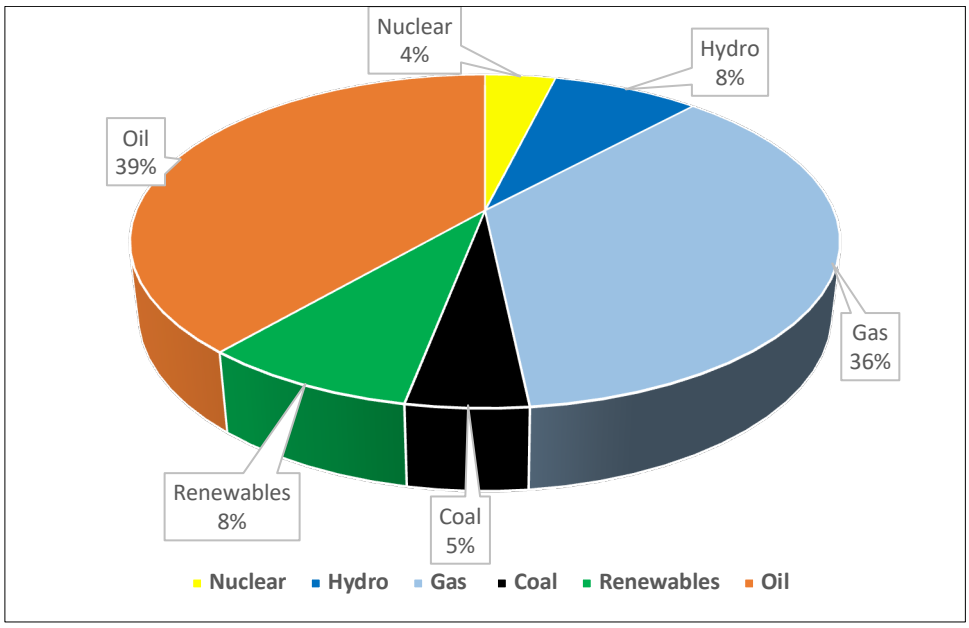


Figure 16: Russia's envisioned Energy mix by 2030(IEA, Coal, 2018).

Russia ranked 4th on the world emissions rankings and is ranked as the fourth-largest primary energy consumer globally. Russia's climate change related policies are under ongoing review to improve and bring about opportunities to bridge the gaps and develop the required strategies for climate-energy interface effectiveness (Mitrova et al., 2019). Russia is committed to the UNFCCC and the Kyoto Protocol. It had set a CO_2 aspiration of 5% below the 1990 intensity for the first pledge cycle between 2008 and 2012 which was achieved in year 2012. Furthermore, the country supplies 10% of the globe's energy fuel sources, 5% of the international electricity usage and 16% of foreign commercial dealing in energy (Mitrova et al., 2019). Currently, Russia is classified as the largest supplier of power fuels ranked first in gas, second in oil, and third in coal (IEA, Coal, 2018). Cognisant of this fact, the country's planned intent with JET is mutually beneficial for national and international outcomes. This status presents a unique opportunity for the country to leverage its resources while pursuing JET. The planned intent of JET in Russia aims to balance economic growth with environmental sustainability. By investing in renewable energy and improving energy efficiency, Russia can enhance its energy security and diversify its economy. This transition is mutually beneficial: domestically, it can create jobs in new green sectors and reduce reliance on fossil fuels (IEA, Coal, 2018) and internationally, it positions Russia as a proactive participant in global climate efforts; potentially opening new markets for its energy exports and strengthening diplomatic ties. Moreover, embracing JET allows Russia to align with global trends towards decarbonization, potentially leading to increased foreign investments and technology transfer in renewable sectors. This alignment could enhance Russia's competitiveness in a changing

energy landscape, ensuring that it remains a key player while addressing climate change concerns. Thus, the integration of JET not only supports national goals but also contributes to global sustainability efforts, creating a win-win scenario for both Russia and the international community (IEA, Coal, 2018).

The 2022 Russia-Ukraine war has unfortunately negatively affected the global energy transition with financial and trade sanctions imposed on Russia by the “European Union (EU) countries, United Kingdom (UK) and United States of America (USA)”. President, Putin has halted the supply of coal, oil and gas to countries that were dependent on these supplies because of the sanctions imposed on Russia. This has resulted in an energy crisis mostly for the EU countries while the USA is using its own oil resources to dampen the crisis and thereby, prevent the increase of energy costs. Other countries were left with no choice but to refurbish and recommission their fossil fuel power plants to curb the energy crisis impacts. This crisis has fortunately resulted in a positive spin-off, with short-term contingency plans to soften the energy crisis impact. This has further resulted in governments rapidly initiating longer-term energy action strategies. The USA's "Inflation Reduction Act" (IRA), the EU's "Fit for 55" package and REPowerEU initiative, Japan's "Green Transformation" (GT) program, Korea's plans to increase the share of nuclear and other renewable sources in its energy mix, and the renewable energy goals of India and China, alongside South Africa's decision to delay the decommissioning of its coal power plants until 2030 (WEO, 2022).

Internationally the “energy sector” is experiencing a drastic switch due to a change in the requirements of hydrocarbons within the next 20 years (Henderson et al., 2017). The Energy Research Institute of the Russian Academy of Sciences (ERI RAS, 2019) projects that with the unavoidable reshaping of the intercontinental trade, and declining requirements for the country’s hydrocarbons, the foreign revenue from oil and gas to the Russian GDP will be reduced by 18% between year 2015 to 2040 (Henderson et al., 2017). The consequence of climate change mitigating plans would unfortunately, adversely impact the country’s financial stature. A decrease of economic growth results in growth-less national energy needs, fixed sales cost and a decline in capital available for latest technology implementation (Henderson et al., 2017).

The institutional design of Russia's energy sector has advanced through a centralized approach. This involves a single, complex set of five-year development plans that tier the various energy industries, including transportation, export, storage, and centralized distribution (Henderson et al., 2017. Even with the numerous market transformations in the 1990s, the institutional

framework of the country's energy segment is still currently categorized by high business concentration and an absence of marketplace instruments (Henderson et al., 2017. Decentralization as a model encounters fierce opposition from government and influential business participants. The long evolution of the Russian electricity sector has eventually transformed as having many privately owned and state-owned companies (Henderson et al., 2017. State owned companies are in the majority (approximately 70%), in electricity production and in the power network. The Russian government owns the high voltage power network of 220 kV and above, which Russia defined as transmission network, as well as most of the electricity distribution networks. Approximately 60% of the country's electricity is produced from combustion of fuel sources (ERI RAS, 2019). It is apparent that the climate agenda, and the campaign for decarbonisation, are not yet a critical aspect of Russia's energy policy. Certainly, the Paris Climate Change Agreement is stated only once in the draft version of the Russian Energy Strategy up to year 2035; a vital paper describing Russia's tactical imperatives in this vital industry, and that was tendered to the administration by the Energy Ministry in 2015. Russia signed the Paris Climate Change Agreement in the year 2016 which included the development (by year 2020) of a plan of socio-economic advancement with a reduction of GHG emissions up to 2050. To remedy the adverse impacts of the country's fuel and energy development for the enactment of this compact, an enormously biased methodology is required to take supplementary governing actions to counter "climate-change" (Mitrova et al., 2019).

In Russia, the reluctance toward decarbonization is influenced by several factors (Mitrova et al., 2019):

- "Economic Dependence on Fossil Fuels: The Russian economy heavily relies on oil and gas exports, making a transition to cleaner energy sources economically challenging."
- "Energy Security Concerns: There is a strong emphasis on maintaining energy security, with concerns that decarbonization could jeopardize energy supply and stability."
- "Lack of Infrastructure: The existing infrastructure is primarily built for fossil fuels, and transitioning to renewable energy requires significant investment in new technologies and systems."
- "Political Will and Policy Framework: There is insufficient political support for aggressive climate policies, partly due to the influence of the fossil fuel industry on government decisions."
- "Public Perception and Awareness: Limited public awareness and understanding of the benefits of decarbonization can hinder momentum for change."

- "International Market Dynamics: Global demand for fossil fuels continues to drive production, discouraging rapid shifts to alternative energy sources."
- "Technological Barriers: A lack of domestic technological development in renewable energy limits the capacity for a quick transition."
- "Global Climate Agreements: Skepticism towards international climate agreements and their implications for economic competitiveness may also contribute to their reluctance."

Disbelief regarding the anthropogenic composition of "climate-change" is evident as the Russian Academy of Sciences (RAS) and several government administrators publicly voice their misgivings concerning the actual notion of anthropogenically-driven climate change (Stafell et al., 2018). Russia has in effect rapidly reduced GHG emissions after the economic recession and economic reforms implemented in the 1990s.

From the year 1998 to year 2008, GHG emissions increased up to 16%, which is a significantly decreased rate than anticipated. Since the year 2017, the country's power segment has decreased its carbon footprint (in terms of g/CO_2 per kWh) compared to countries such as Poland, Germany, Australia, China, India, Kazakhstan, the Arab countries of the Persian Gulf, the USA, Chile, and South Africa (Melnikove et al., 2019). This is because of approximately 35% of electricity being generated from nuclear electricity generation plants and huge hydropower plants with minimal CO_2 emissions (Mitrova et al., 2019). Gas power plants contribute to 48% of the electricity capacity of Russia, enabling the energy transition from a fuel mix of petroleum and fossil-fuelled power plants (the portion of gas substitution into fossil-fuelled electricity generation grew from 69% to 74% from year 2006 to year 2017). The Paris Climate Change Agreement, the Addis Ababa Agenda 2030 and the UNFCCC affect the country's projections for fossil fuel exportations (coal and natural gas exportations substantially affected by the zero-carbon emissions agreement globally by year 2050).

The short-term exports are affected by the Russia-Ukraine war with export and financial sanctions instituted against Russia. Russia is confronted by the threat of marketplace impediments for exports of its energy-intensive products. This impacts the energy cost negatively with huge socio-economic implications for the Russian population. Knowledge of this information confirms the cause of Russia's isolation from the global decarbonisation trend for many years (Mitrova et al., 2019).

Despite these challenges, Russia is on course to develop supportive regulations and achievement campaigns to comply with and honour the Presidential Decree 752 of September

2013 on GHG emissions decrease, demanding the administration to enable GHG emissions to be reduced to the levels of no more than 75% of the year 1990 emissions levels. Russia is proactive in regular climate change impact analysis on the Russian ecosystems and economy. Analysis shows that global warming may result in few favourable effects on the country's financial status with larger agricultural growth requirements and declined need for heating with some conceivable adverse effects that will arise during harsh weather conditions and permafrost liquefying, impacting on the energy architecture (Grushevenko et al., 2018).

On the academic front, Russia is pursuing aggressive and ambitious energy plans to improve energy efficiency, driven by a growing awareness of energy conservation among scholars and experts. This focus has been highlighted in various studies, such as by Ratner et al. (2021), who emphasize the importance of sustainable practices. Additionally, researchers like Ivanov (2020) and Petrov (2019) have examined the potential benefits of energy efficiency in reducing costs and emissions. These scholarly contributions underscore a collective recognition of the need for enhanced energy strategies in Russia.

The studies also showed that social obstacles impede the transition towards an energy-efficient economy in the urban small business area. This is due to disregard for recent energy-efficient technologies, and from social hierarchical behaviour in large corporations creating social barriers. To defeat these hurdles, organisations are required to introduce positive dynamics and internal educational plans to introduce Energy Management Systems (EMS) (Ratner et al., 2021). Increasing the contribution of renewable energy and revamping the energy industry demonstrates that Russia is a responsible nation. The quantity of electricity needed to yield a unit of Gross Domestic Product (GDP) (in buying capability equivalent terms) is, currently more than 200% higher than the International Energy Agency (IEA) average, which reemphasises the major inefficiencies that must be remedied. Russia has a mammoth capability for energy efficiency with a specialised prospective of approximately 260 m tonnes of oil equivalent (Mtoe) (Ratner et al., 2021). The capability for this to materialise in the future years will configure the country's energy equity, influence the upstream electricity production, thermal industry funding requirements, industrial edge and the availability of energy fuels for international commerce. Advancement in energy efficiency, is conducive to relieving the effects of high energy prices for the citizens. Energy efficiency can encourage a move towards "cost-reflective pricing" by inviting funding into revamping generation, transmission, and distribution to reduce prices to end users (Mitrova et al., 2019).

Having signed the Paris Climate Change Agreement in September 2019, the administration must act to create additional approaches for coal and other fossil fuels. Nevertheless, the administration must furthermore warrant a Just Energy Transition (JET), considering Russia's fossil fuel-producing zones and the widespread outcomes of transformations for coal mining and exportation (Mitrova et al., 2019). The JET programme would improve comprehension of energy changes in Russia. In its existing level, it will examine local economic divergence in Russia's main coal area, Kuzbass, evaluate the outlook of coal in the power and heat sector, and investigate how to reduce the social price of coal changes in Russia.

Russian submitted an amendment of its NDC in year 2020 to the UNFCCC, announcing their objective to restrict the GHG emissions to 70% relative to year 1990 amounts by 2030. The NDC considers the maximum possible permeable capacity of the forests, ecosystems and contingent to feasible and fair socio-economic growth of Russia (NDC-Russia, 2020). Referenced in the NDC, Russia's implementation initiatives are concentrated on economic action to foster GHG decrease, raising energy efficiency in all areas and developing the use of non-fuel and renewable energy sources. Further mitigations focus at enhancing the condition of natural sinks and storing of GHG (NDC-Russia, 2020). It is reflected in the NDC that Russia will furthermore revise its GHG emission standards in synergy with global standards aimed at measuring the carbon footprint of what it produces. The NDC does not specifically mention "just transition" in Just Energy Transition (JET), however there are numerous references that summarises the quintessence of "just transition." It is noted that there is no specific reference to the value of jobs, employment creation, Occupational Health and Safety (OHS), social shield, or social discussion (NDC-Russia, 2020). The NDC has not mentioned training, retraining and education of their labour force for the JET.

In summary, the assessment of Russia is that their JET faces significant challenges, primarily due to its heavy reliance on fossil fuels and the economic structure centred around oil and gas exports. Russia's economy is heavily reliant on oil and natural gas, making the transition away from fossil fuels economically risky and necessitating significant policy and investment changes. Although the country has substantial renewable energy potential, particularly in hydro, wind, and solar, actual development remains limited due to low investment in renewable energy compared to fossil fuels. Efforts have been made to promote renewable energy and efficiency but are often overshadowed by fossil fuel interests, and the government's commitment to a just transition is unclear amidst geopolitical challenges. Additionally, social equity issues, such as job creation in emerging sectors and support for communities dependent

on fossil fuels, have not been prioritized. Geopolitical tensions and sanctions further complicate Russia's access to international markets and technologies needed for a greener economy.

Achieving JET in Russia is challenging but feasible, requiring strong political commitment to diversify the economy and significant investment in renewable energy infrastructure. A comprehensive strategy that addresses economic, social, and environmental needs is essential.

3.2.4 Brazil's Energy Policy

In the year 2022, The real GDP growth was 1.2% and it is predicted to be 1.6% in year 2023, while consumption (use of goods and services) was 3.2% in year 2022 (Macroeconomic Outlook Report: Brazil, 2023). The World Bank's conducting business ranking of Brazil in year 2022 is 91 out of 190 countries. There was a significant increase in international tourism in Brazil (107.5% in 2021) despite the Covid-19 pandemic and is predicted to grow by 61.5% in year 2022 to 2023 (Macroeconomic Outlook Report: Brazil, 2023).

Brazil is the tenth biggest producer of electricity globally and the eighth leading world user of energy (Wills et al., 2018). Brazil is one of the countries with the greenest energy mix with the use of renewable energy: hydro, wind, solar, bioenergy and fossil fuel power plants which contribute 46% of the country's energy requirements (Wills et al., 2019). After China and Canada, Brazil is the third largest hydroelectricity producer at a global level. Brazil's hydroelectric sector almost has an unlimited potential which has not been fully exploited given that the country has the capacity to construct numerous hydroelectric power plants (Karpavicius, 2021). In Brazil, 77% of the country's electricity is generated from hydropower, despite hydropower representing only 12% of the total energy resources available (Karpavicius, 2021). This heavy reliance on hydropower makes Brazil vulnerable to power supply shortages during drought years, as seen during the severe droughts of 2001 and 2002, which led to an energy supply crisis. The energy resource mix is depicted in Figure 17 where oil accounts for 36%, biomass accounts for 32%, hydro accounts for 12%, gas accounts for 11%, coal accounts for 5%, nuclear accounts for 2%, and other renewable energy (wind, solar, etc.) accounts for 2%.

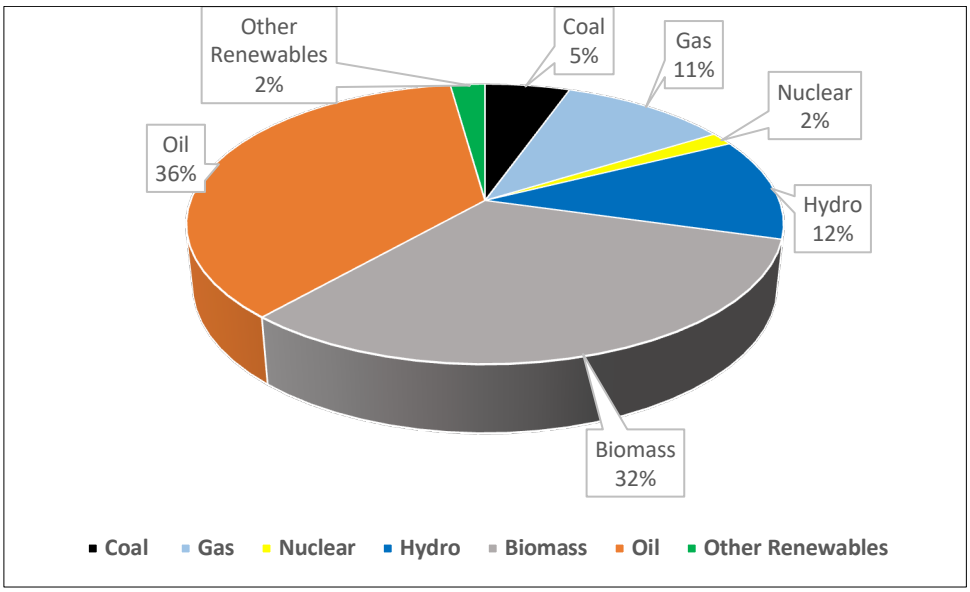


Figure 17: Brazil's current energy resource mix (Wills et al., 2019).

Brazil ranks as the fifth largest country in the world by land area and is the second largest among the top ten economies in terms of GDP (Sewalk, 2015). Brazil is a major ally in commerce and at times a competitor of the USA, with respect to energy fuels (e.g., petroleum and ethanol). Brazil has become an energy exporter which produces more energy than it consumes after 35 years of policy development to promote domestic energy resources (hydro, fossil fuels, biomass, gas, wind, nuclear, and solar) (Sewalk, 2015). Brazil shipped $5.8 billion of oil and $567 million of ethanol in year 2011 in comparison to the United States which is a net importer of oil, but Brazil exported refined oil products worth $4.5 billion and $791 million of ethanol which is highly commendable (Sewalk, 2015).

Brazil's energy security was significantly challenged throughout its history. Major energy sources were inadequate, ethanol fuel for cars (in the beginning of the 1990's), and droughts resulted in reduced hydropower (in the beginning of 2000's), and expectations that the provincial energy from Bolivia and Argentina for natural gas would improve energy security (Sewalk, 2015). Bolivia's choice to nationalize oil and gas sites surprised Brazil, and was a major setback, particularly as Brazil did not interpret the country as a dominion. The nationalization specifically shocked Petrobras, which was Brazil's oil company that had approximately $1 billion of financial stake in Bolivia (Sewalk, 2015). Argentina added to the crisis by implementing policies that restricted the country's capability to achieve its natural gas foreign commerce agreements. Depending on providers for a reliable energy source was identified as risk to Brazil however, by adopting better enabling strategies to encourage energy

production and diversification (Sewalk, 2015), Brazil has succeeded in achieving momentous growth by energy security advancements.

Argentina had nationalized its energy resources as it recognised European and American organisations as wings of EU and U.S. dominion. Brazil, as one of the colonies, did not anticipate that an associate Latin country would annex it's partnership, since Brazil did not deem the country as a dominion with the likes of the United Kingdom, Spain and Portugal (Sewalk, 2015). An incentivised reduced borrowing rate and funding plans, together with fair prices was established through electric power bidding initiatives resulting in the wind power industry expanding substantially in the country (Sewalk, 2015).

Solar, for distributed generation is becoming an effective energy source. The vast use of flexible fuel cars renders ethanol a widely used fuel. There's a blend mandate of 27.5% on the gasoline including the opportunity of operating on 100% ethanol coupled with biodiesel blending plans in the year 2018 (Wills et al., 2019). Natural gas is a huge alternative and can be a transition fossil fuel towards the nett zero decarbonization in 2050 with a focus to decrease the usage of fossil fuels. The "Climate Transparency Policy Paper: Energy Transition in Brazil" provides the generic energy plan of the country and determines initiatives, gaps, and prospects to GHG emission alleviation objectives, providing policies and legislation to sustain a vigorous evolution of the energy segment (Wills et al., 2019). Brazil's renewable energy resources make up 46% of entire primary energy resource and 85% of electricity generation. Currently, the non-renewable energy sources comprise of approximately 57% of full primary energy supply and 32.7% is utilised in the transport industry (Wills et al., 2019). Brazilian energy intensity has been constant from the year 1990 which is at below 4 TJ / million US$. Brazil's entire GHG production is approximately 1.6 billion tons of CO_2 and ranked 12^{th} on the world emission rankings (Grattan, 2022). Hence, to redirect Brazil towards the desired trend followed by other G20 countries, government reviewed and revised the economic policies to produce and export products with more value addition for economic and social reasons, with embedded energy efficiencies (Wills et al., 2019). Brazil's total GHG emissions are around 1.6 billion tons of CO_2 and ranked 12^{th} on the world emission rankings (Grattan, 2021).

The energy sector reform in 2004 brought the figures of the free and regulated market, which was important for the expansion and planning of new sources, especially for distributed generation, and a greater incentive in energy efficiency programs such as PROCEL is necessary, given the low investment verified in EE in recent years. Regarding the energy sector, the Brazilian NDC is a bit conservative, as most of the GHG emissions reduction will come

from the reduction in deforestation and agriculture. For the year 2030, it is sufficient, but for the long-term goal, a low-carbon strategy should be developed as energy is key for economic development. In summary, renewable energies in Brazil are progressing rapidly and the energy transition will take place predictably, along with the nation's technological and financial progression (Wills et al., 2019).

The power segment investments in renewable energy were made from year 2000 to 2013 due to the structural reform in the energy sector. This led to change in Energy Policy which was more focused on the production of electricity by the IPPs and thus an increased usage of renewable energy from 48% to 51%. Wind power was the majority investment in the power sector between the year 2014 and 2016. Solar energy investments augmented considerably to approximately 35% of overall funding in the power segment by the year 2016 (Wills et al., 2019).

Funding authorized and approved for year 2021 included fourteen Solar Photovoltaic (SPV), eight wind farms, two hydropower and one biomass fired thermo-power plants, increasing a further 880 MW capacity into the National Integrated System (NIS) (Ambiente Energia, 2018). Figure 18 shows that the future energy mix would improve to greener energy mix with the additional capital injection by the Brazilian government executing their energy transition strategy.

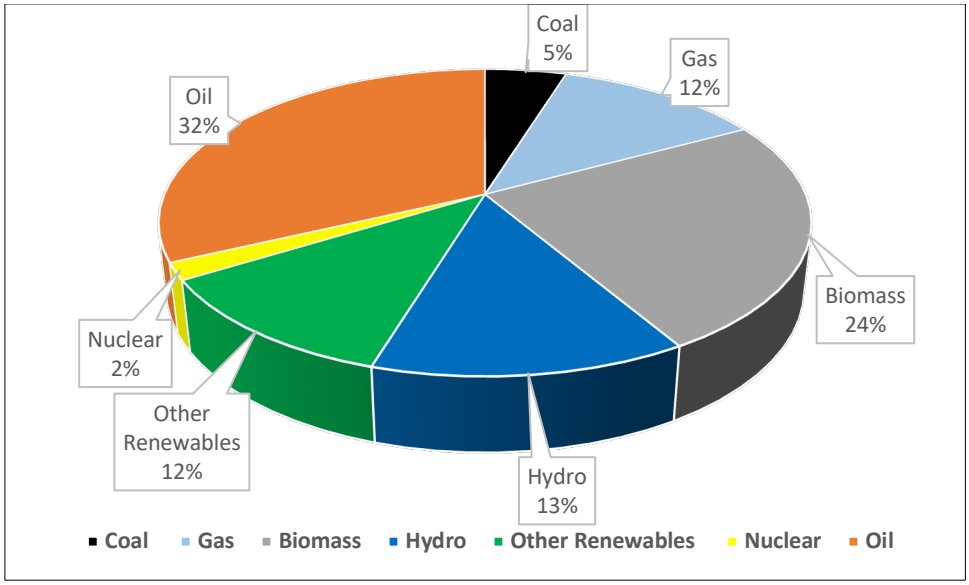


Figure 18: Brazil's envisioned energy resource mix by 2030 (Ambiente Energia, 2018).

A total of R$ 4.5 billion in investment and 4,040 direct employment opportunities are projected to be created which is positive and in compliance to the ILO, 2015. Wind power emerged as a substitute for the expansion of the electricity sector after the energy crisis of year 2001 and is currently ranked ninth in international capacity (13 GW), with an average capacity factor of 40%, representing 8% of Brazil's electricity sector in terms of connected electrical power capacity. The total potential in the country is approximately 300 GW (Ambiente Energia, 2018). It's forecasted to expand, from the Ministry of Mines and Energy, to 125% by year 2026 when the predicted target of 28.6% wind power of the total capacity of the power pool in Brazil will be installed.

It's estimated by the Brazilian Industrial Development Agency (ABDI) that by year 2026 the wind power sector would generate around 200 000 new direct and indirect employment opportunities (ABDI and ABEEólica, 2018). The wind energy value chain has been growing due to the incentives offered by the government (tax exemption, long-term financing, etc.). Recently, Brazil considerably advanced their industrial structure of the wind power segment to assemble the wind turbines and the fabrication of numerous modules (towers, blades, subcomponents of the hub and nacelle) locally, with reduced quantity of imported components compared to previous years (Ambiente Energia, 2018). The ILO, 2015 specified that if suitable policies are implemented, the evolution of the world economy to a greener and extra viable model ought to craft 620 000 additional employment opportunities in Brazil, which adequately supersedes the possible 180 000 employment opportunities that may be reduced due to decarbonisation (ILO, 2015).

Funding in renewable energy resources, linked with incentive plans (tax reductions and attractiveness in financing) in addition to decreasing GHG discharges, can yield a large quantity of jobs (Drummond, 2016). In the wind power segment only, 150 000 direct jobs were created in the year 2016, at present totalling 13 GW, or 8.6% of the nationwide electricity segment (ABDI, 2014). The "Light for All" program is conspicuous with achievement in pursuing the standardisation of access to electricity in rural areas, prioritizing traditional populations and regions of great poverty. Started in 2003, it helped more than 16 million of the population in 2016 (Drummond, 2016). An investment of $250 million in year 2019 was intended to connect approximately, 96,000 additional electrical connections in 17 states (Agência Brazil, 2018).

Numerous strategies were compiled in Brazil aimed at diversifying the Brazilian energy mix, with Proalcool and Proinfa programs as its chief indicators (Agência Brazil, 2018). These

programs permitted the triumph of the country's biofuels and wind energy segment respectively. Public funding and incentives of substitute energy sources were crucial in the progression and in establishing the nation's wind energy value chain. Currently, replicating strategies would be imperative for the increased progression of the solar energy value chain, integrated through major funding in research and development. Brazil with the "Light for All" program, has been fulfilling its social objectives (Agência Brazil, 2018).

Brazil revised the country's NDC in year 2020 which reiterates Brazil's firm pledge to lower the complete GHG production by 37% by 2025 and by 43% in year 2030 with reference to year 2005 emissions. This would set Brazil up to achieve climate neutrality (net-zero emissions) by year 2060 as per the NDC. A further update was made in the form of a submission letter to comply with nett-zero CO_2 emissions by the year 2050 (UNFCCC, 2021).
This change was due to the sizable decrease in deforestation, specifically in the Amazon Forest, between year 2005 and year 2015. The main contributor to CO_2 emissions is from "slash and burn" correlated with the land clearing activities in the growth of the agriculture (INPE, 2020). The area specifically steering deforestation and farming happened to be the single area that had GDP increase in year 2020 (AGRO, 2021).

By assisting and supporting them in adapting to the effects of environmental degradation affecting their livelihoods, Brazil is also protecting the indigenous population's rights, primarily those that are dependent on the natural environment (ILO, 2018). By securing rights of these indigenous people, it may furthermore influence them to become ambassadors to promote JET as they frequently care for large quantities of natural reserves (Oelz et al., 2017). Another great benefit in securing land rights, is it provides the population that cares for the reserves with the means to pay for the environmental service incentives. This is a symbiotic relationship, permitting them to take part in preservation initiatives and rewarded by money transfers in return (ILO, 2018) Brazil has referenced in the NDC the Brazilian constitution, *"paying due attention to the special needs of women and indigenous people"* (NDC-Brazil, 2020). Another focus area is skilling and reskilling of labour. Decrease in government funds for training, environment, science and technology are additional hindrances to stifle renewable energy skills (ILO, 2018). To develop the greener economy would require major commitment and engagement from the public sector to promote the change to an easier achievable level as comprehensive procedures will not occur freely via marketplace powers in isolation (ILO, 2018).

In summary, Brazil has made significant strides in its just energy transition initiatives by prioritizing the expansion of renewable energy sources, particularly wind and solar power. The country has enacted policies aimed at diversifying its energy mix, reducing greenhouse gas emissions, and promoting sustainable development. Notably, Brazil is a global leader in renewable energy, with a strong hydropower sector complemented by increasing investments in wind and solar. The government has introduced various policies to encourage renewable energy projects, including auctions for new energy sources and financial support mechanisms. Additionally, there are ongoing efforts to ensure that vulnerable communities benefit from this transition through job creation in renewable sectors and improved access to affordable energy. Brazil is also actively engaged in international climate discussions and forming partnerships to further its energy transition. While challenges such as regulatory issues and infrastructure needs persist, the country's commitment to a just energy transition is clear through its ambitious goals and ongoing initiatives.

3.2.5 History of Energy Policy in South Africa (SA)

3.2.5.1 SA'S Social and Economic Context in comparison with the BRICS partners.

South Africa makes up 1% of the world's land area with a population of 60million people which is 1.9% of the total BRICS member countries population as shown in Table 2. The BRICS member countries constitute up to 30% of the world territory. South Africa's GDP growth rate of 2.1% is in comparison with an average GDP growth rate of 3.32% of the BRICS member countries. In the year 2023, the real GDP growth was 0.6% and it is predicted to be 1.3% in year 2024 (GlobalData, 2024). South Africa is endowed with various natural mineral resources (gold, diamonds, coal, et al.) with the mining industry being one of the largest employers, providing the country with huge export revenue while supporting the local labour force.

Table 2: BRICS countries size, population and GDP (World Bank Data, Trading Economics, IMF, ABSA Quarterly Perspectives, GlobalData, 2024).

Country	Area of Country (1000 sq.km)	Population (million person)	Life Expectancy in years	Gross Domestic Product (GDP) growth rate % (2024)
Brazil	8516	208	76	1.2%
Russia	17125	147	71.9	2.1%
India	3287	1269	68.7	6.7%
China	9600	1386	76.3	4.5%
South Africa	1221	60	64	2.1%

3.2.5.2 Current Energy Mix in South Africa

South Africa is the 7th biggest producer of coal with most of the coal used to fuel the fossil fuel power stations locally or internationally at power plants (Lawrence, 2020). Coal although used vastly as a fuel source, it also contributes to many other industrial processes such as steel production, cement processing, paper and aluminium industries, chemical and pharmaceutical activities, coal to liquid for petroleum production and as fertiliser in the agricultural sector as (Figure 19) (Malumbazo, 2020).

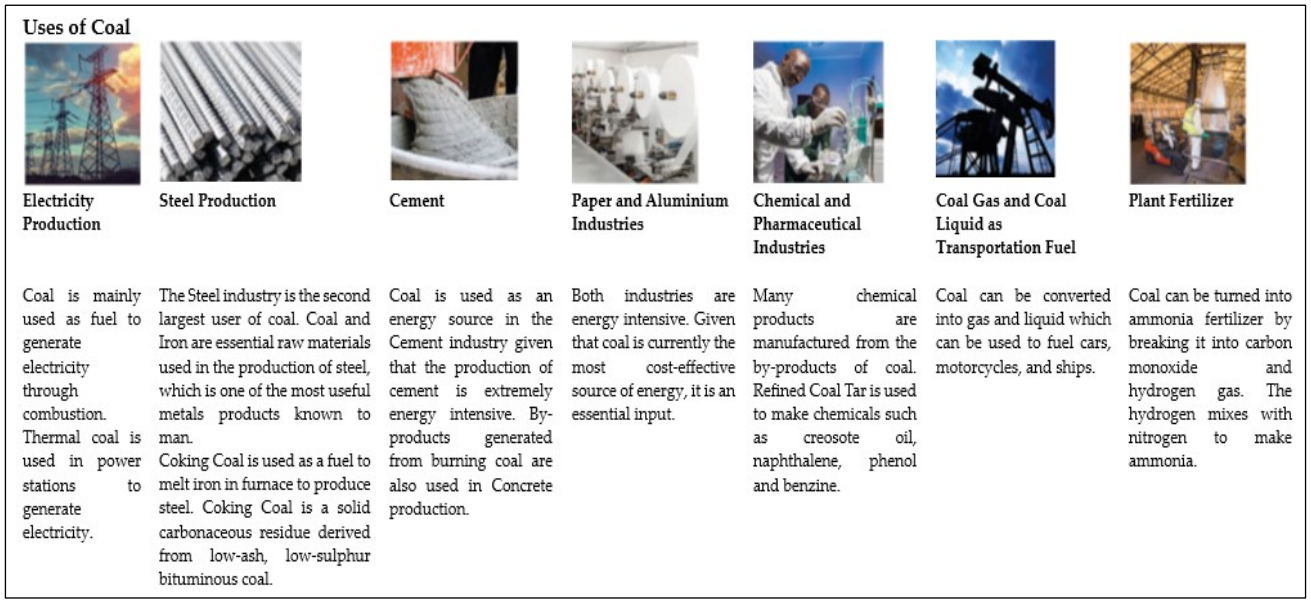


Figure 19: Uses of Coal (Malumbazo, 2020).

South Africa's coal transactions of ZAR 82 billion made it the country's third most valuable mineral export, preceded by platinum (ZAR 370 billion) and gold (ZAR 92 billion), contributing significantly to the nation's foreign income (Statista, 2024). Cognizant of this fact, the coal mining labour force is extremely concerned about the future reduction in coal usage for electricity generation and its replacement with cleaner and greener fuel sources, as this has a direct correlation with potential job losses due to reduced coal mining activity. If not managed sensitively and with appropriate engagements with labour, the initiatives towards decarbonisation and most initiatives of JET will be derailed (Lawrence, 2020).

Figure 20 depicts the present energy resources where 56% is coal, 14% hydro, 10% wind, 8% solar, 7% gas, 3% biomass and 2% nuclear. It is apparent that coal is extensively used, and drastic, urgent plans needs to be in place towards decarbonisation (CEA, JMK Research).

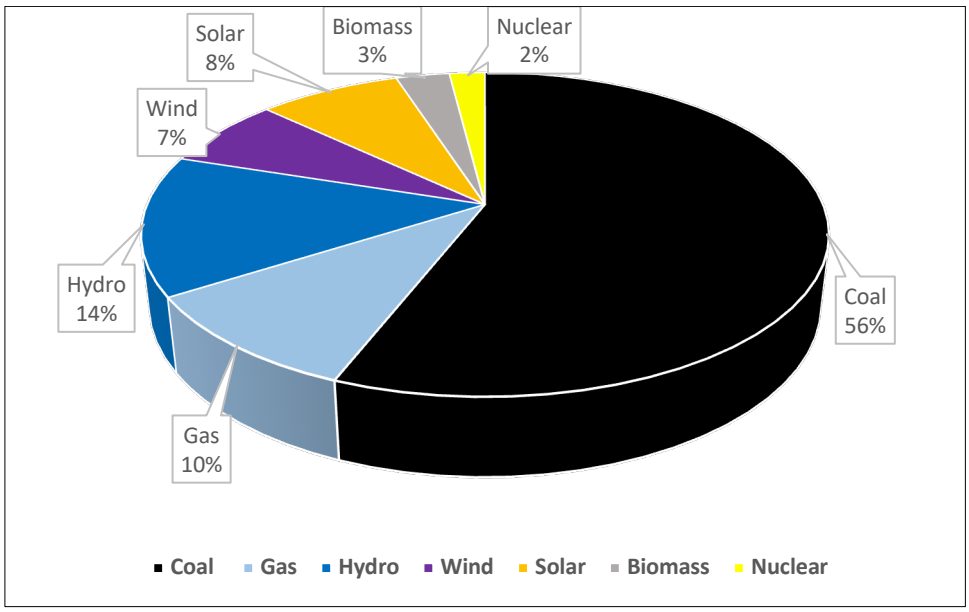


Figure 20: Power plants fuel sources (CEA, JMK Research)

In South Africa most of the fossil fuel power stations are in their mid to end-of-life phase as shown in Figure 21.

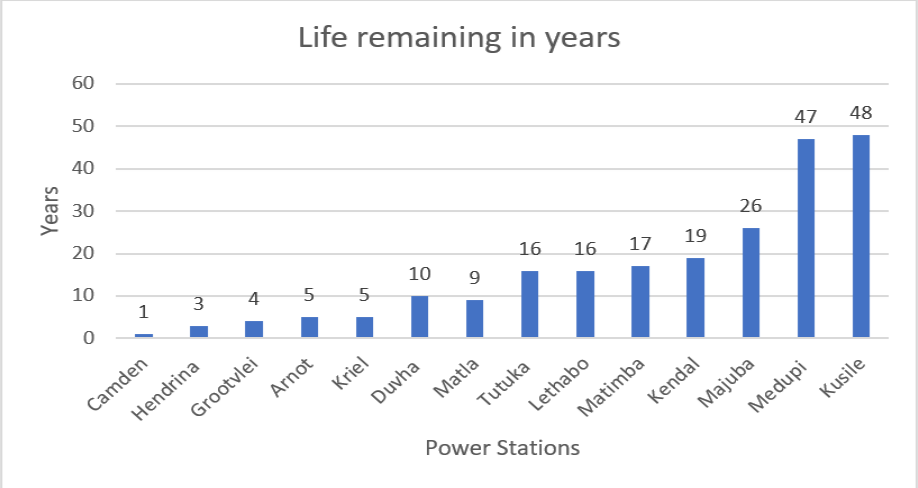


Figure 21: South Africa's fossil fuel power stations economical life (Juodaityte, 2011).

The decommissioning plan for South Africa's power plants as the shown in Table 3 coincides favourably with the country's just energy transition into alternative lower carbon fuel sources.

Table 3: South Africa's fossil fuel power plant decommissioning planned (IRP, 2019).

Power Station	**Decommissioning Date**	**Capacity (MW)**
Arnot	2021 – 2029	2232

Camden	2021 – 2024	1481
Duvha	2030 – 2034	2875
Hendrina	2021 – 2027	1638
Kendal	2038 – 2043	3840
Kriel	2026 – 2029	2850
Lethabo	2035 – 2040	3558
Majuba	2046 - 2050	3843
Matimba	2037 – 2041	3690
Matla	2029 - 2033	3450
Tutuka	2035 - 2040	3510
Total	2021 - 2050	32967

Policies and legislations incumbent to just energy transition requires attention as there is no evidence of a policy encompassing South Africa's energy transition. Traditional or historical approaches of funding methodology for the power utility business must change to accommodate the huge burden on the state, and investigate innovative investment models with public and private participation partnerships models. Therefore, there is a huge necessity in bridging the gap that exists in the conventional funding methodology versus the green funding imperatives (Naidoo, 2019) These models require development to allow the local communities and citizens to be able to contribute and be able to have a shareholding in future renewable energy projects. With this participation or funding initiative like a trust or "crowdfunding", the loss of employment impacts can be alleviated by these shared equity opportunities.

In year 2008, the Climate Investment Fund (CIF) was introduced with the objective of promoting global cooperation on climate change issues and supporting the contingency strategies and adaptation initiatives of countries. The CIF announced the launch of the Accelerating Coal Transition (ACT) program in April 2021. ACT would be the catalyst in speeding up the transition from fossil fuels, predominantly coal in a consistent and sequential approach with governance, human resources, and infrastructure which is the three pillars of the program.

The CIF issued a call for Expressions of Interest (EOI) to which South Africa issued a response in June 2021. It was favourably received in August 2021 with a proposal to concentrate on decarbonisation of the electrical energy sector in the context of its JET initiative. The CIF announced that South Africa's proposal was selected for the preparation of approximately $500 million in funding by the government in cooperation with the World Bank (WB) and the

African Development Bank (AfDB) in October 2021 (PCC, 2021) commenced. The business plan, developed by South Africa in cooperation with the CIF's Multilateral Development Bank (MDB) partners, WB, AfDB and the International Finance Corporation (IFC), supports the government's proposals. It also identifies potential areas for MDB investment and technical assistance and includes the potential of mobilizing complementary, bilateral, multilateral co-financing, and private sources.

3.2.5.3 Insight into the Just Energy Transition in South Africa

South Africa, as a developing country, initially did not commit to reducing carbon emissions. However, the Kyoto protocol and subsequent post-Kyoto protocol and other international initiatives aimed at the reduction of GHG's, to which South Africa voluntarily committed to, have had an influence on government with regards to the energy policy (Ritchie et al., 2017 and Hirsch et al., 2017). This is in the form of mandating the use of significantly more renewable energy sources as seen in the Integrated Resource Plan (IRP 2010, 2019 and draft 2023) as well as more specifically addressing fossil fuel use for electricity generation.

The South African government (Department of Public Enterprises (DPE), Department of Mineral Resources and Energy (DMRE) and Department of Environmental, Forestry and Fisheries (DEFF)) took a stance in 2008 that all future fossil fuel-fired power plants will only be licensed if they are Carbon Capture and Sequestration (CCS) compliant. This is the future directive from the government policy statement that South Africa is on a drive to substantially reduce CO_2 emissions with the envisaged aim of total Carbon Capture and Sequestration (CCS) (Ritchie et al., 2017). This initiated the process of South Africa investigating viable options of renewable energy sources (solar, wind, Battery Energy Storage Systems (BESS), nuclear, hydrogen), High Efficiency Low Emissions (HELE) technologies (biomass, supercritical boilers technologies) (Ritchie et al., 2017). The economics will influence the rate of these technologies being implemented. The above shows the seriousness and the commitment of South Africa towards the nett-zero 2050 Decarbonisation imperative. Biomimicry globally could be a useful means to aid with the reduction of the CO_2 emissions in the future.

In the South African context, there are significant shortcomings in labour conditions that require urgent remedial action. This action should comply with the International Labour Organisation's (ILO) 2015 policy and support environmentally friendly fuel sources and the adoption of technologies that utilise one or more renewable energy sources. Presently, the policies are not clear but there are various collaborative initiatives with South African government departments, (Presidential Climate Commission (PCC), labour, environment,

mineral council of South Africa, trade, industry and competition), Eskom, Sasol, Council for Scientific and Industrial Research (CSIR), National Business Initiative (NBI), Business Unity South Africa (BUSA), private and public sectors in evaluating and paving the way to and bridging the gap for JET. This is conducted through studies of social economic impact, Transition Pathways independent initiative investigation which encompasses all aspects of the Just Energy Transition by Boston Consulting Group (BCG) with stakeholder reviews. The PCC was initiated in the country for oversight to the country's JET. The PCC report provides confirmation that the South African government is pursuing JET with conviction, but time will tell if the transition will indeed be a "just" one.

The PCC completed South Africa's Just Energy Transition Investment Plan (JET-IP) in 2022. The JET framework focused on ensuring a just and equitable transition to nett-zero CO_2 emissions in South Africa by year 2050, with prescripts on mitigating actions that social partners would undertake over the short, medium, and long term. The JET plans provide the required reference guidelines to various planning and policy setting processes ensuring the JET framework gains synergy across all JET planning countrywide. The PCC commissioned numerous research studies with integrated public consultations to support the development of the JET plan in year 2021. The studies and consultations aided in exposing fundamental challenges for JET in South Africa, paving the path for the development of the JET framework that is practical, time synchronised, executable and matched with the requirements of all social partners (PCC, 2021). The PCC report is the findings of the assessments and consultations, emphasizing critical considerations for the development of the JET framework. The information derived and extracted from each related study was used to develop a vision and establish policies to support a just and equitable transition, supporting sustainable livelihoods, financing a just energy transition, improving water security and creating good governance structures to manage it (PCC, 2021).

These engagements will be referenced to the ILO guidelines, 2015 for Just Transition Towards Environmentally Sustainable Economies and Humanities for all in South Africa (ILO. 2015). The ILO principles have an emphasis on solid social confluence on the aim and passageways to energy sustainability. Therefore, social dialogue must be an integral part of the institutional framework for policy-making and implementation at all levels. Adequate, informed and ongoing consultation should take place with all relevant stakeholders. Policies must conform, stimulate, and realize necessary values and rights which are critical to energy sustainability. Comprehensible policies across the economic, environmental, social, education/training and labour groups are essential to deliver an empowering environment for enterprises, labour,

financiers, and users to embrace and drive the evolution to environmentally sustainable and comprehensive economies and humanities (ILO, 2015). These coherent policies also need to provide just transition frameworks for all to promote the creation of more decent jobs. Not only decent jobs but anticipating impacts on employment, adequate and sustainable social protection for job losses and displacement, skills development and social dialogue, including the effective exercise of the right to organize and bargain collectively. It should be noted that there is no "one size fits all" approach towards a just energy transition framework. Policies and programmes need to be designed in line with the specific conditions of countries' economic status, including their stages of development, economic sectors and types and sizes of enterprises. In implementing sustainable development strategies, it is important to foster international cooperation among countries (ILO, 2015). The incremental shifts in the economy will not be adequate to change and solve the large-scale climate challenges; considering increasing demands that anthropogenic existing development will have on ecological systems (land, food, water, air), the fourth industrial revolution and a significant increase on levels of social inequality (Naidoo, 2019).

South Africa's NDC was submitted to the UNFCCC in year 2021with a pledge of nett-zero CO_2 emissions target by year 2050 (Climate Action Tracker, 2020). Additionally, the revised NDC caters for the country's economy inclusive of *"farming, forestry, other land uses, energy, industrial practices, product usage, waste, and five (CO_2, CH_4, N_2O, HFCs and PFCs)"* gas management (NDC-SA, 2021). South Africa can be commended for being the single BRICS member to categorically refer to and mention JET in the country's NDC (NDC-SA, 2021). The NDC refers to "Just Transition" as follows (NDC-SA, 2021):

- "In South Africa, a just transition is core to shifting our development pathway to increased sustainability, fostering climate resilient and low GHG emissions development, while providing a better life for all."
- "A just transition means leaving no-one behind. It requires procedural equity to lead to equitable outcomes. A just transition is at the core of implementing climate action in South Africa, as detailed in both the mitigation and adaptation goals presented below. As South Africa indicated at the UN Secretary General's Climate Action Summit in 2019, as part of ensuring a just transition we will need to put measures in place that plan for workforce reskilling and job absorption, social protection and livelihood creation, incentivising new green sectors of our economy, diversifying coal dependent regional economies, and developing labour and social plans as and when ageing coal-fired power plants and associated coal production infrastructure are decommissioned. Similar measures will be necessary to adapt to the impacts of climate change."

- "The just transition will also need international cooperation and requires solidary and concrete support. Ensuring that no one is left behind as we move from a high GHG emission, low employment energy development pathway to a low emission, climate-resilient and job-rich pathway, is central to our national work on development and climate change."

The NDC included the function or duty of the PCC. The PCC conducted major discussions in two years to develop the year *"2050 Vision and Pathways for a Just Transition"* included in the JET to decarbonisation and economy and labour force that would be resilient to the transition (PCC, 2021). South Africa will implement the *"2050 Vision and Pathways for a Just Transition"* to minimise the temperature rise of 1.5 °C in compliance with the Paris Climate Change Agreement. At this stage stakeholder engagements on JET have taken place predominately at national level organised by the PCC and the National Planning Commission (NPC) (ILO, 2022). The NPC has played a vital role with regards to the Just Energy Transition (JET) policy development.

The NPC completed a multi-stakeholder Social Partner Dialogue (SPD) for JET in year 2019. The objective of the SPD was aimed at a comprehensible national strategy, which may be sufficiently funded and put in motion. The SPD has progressed to outline potential transition pathways in line with the ILO's framework on the "just transition" (NPC, 2019). The pathways relate to energy, land use and water. The Mpumalanga and Free State Provinces of South Africa were prioritised as geographical locations for first "Just Transition" implementation. Mpumalanga has energy, water and land interconnected as the province has 80% of the fossil fuel power generation plants in the country. Hence, the JET immediately impacts Mpumalanga province and warrants that all three sectors are at work in parallel. Free State province will concentrate on water, land and to a lesser extent, the gold mines (NPC, 2019).

3.2.5.4 Performance of JET Support Structures for South Africa

South Africa has established a multi-layered governance and implementation framework to support its JET goals as part of the country's institutional support structures as follows (JET-IP, 2024):

- "JET Inter-Ministerial Committee (IMC): Reconstituted by the President, it includes ten (10) cabinet ministers and is chaired by the Minister of Energy and Electricity."
- "JET Project Management Unit (PMU): Located in the presidency, it oversees coordination, Monitoring, Evaluation, and Learning (MEL) systems."

- "JET Funding Platform: A digital enabler to match JET projects with available grants, launched in October 2024."
- "JET Grants Register (JET- GR): Tracks funding allocations and disbursements."

Coordination among stakeholders in South Africa is structured around six key portfolios, each led by a relevant institution as tabulated in Table 4.

Table 4: Portfolio of Stakeholders and Lead Institutions in South Africa

Portfolio	**Lead Institution(s)**
Electricity	Eskom and National Transmission Company of South Africa (NTCSA)
Municipalities	South African Local Government Association (SALGA)
Mpumalanga Transition	Mpumalanga Green Cluster Agency (MGCA)
New Energy Vehicles (NEVs)	Industrial Development Corporation (IDC)
Green Hydrogen (GH2)	Industrial Development Corporation (IDC)
Skills Development	Department of Higher Education and Training (DHET) & Human Resources Development Council (HRDC)

These structures aim to ensure alignment between funders, policymakers, industry, and civil society, though challenges remain in execution and integration (JET-IP, 2024).

Performance and Gaps:

While foundational structures are in place, several performance concerns and gaps have been identified (The Presidency South Africa, 2023):

- "Monitoring and Evaluation (M&E): a MEL framework exists, but its effectiveness in tracking real-world outcomes is still being tested."
- "Stakeholder Engagement: Feedback mechanisms are active, but coordination across sectors — especially local municipalities and civil society — needs strengthening."
- "Funding Disbursement: Although $13.8 billion has been pledged internationally, the actual flow and impact of funds on ground-level projects remain unclear."
- "Skills and Capacity: The Skills Portfolio is active, but there are concerns about readiness and capacity in coal-affected communities."

Recommendations for Improvement

To enhance performance and coordination, the following steps are recommended (JET-IP, 2024; The Presidency South Africa, 2023):

- “Strengthen Local Implementation: Empower municipalities with technical and financial support.”
- “Improve Transparency: Regular public reporting on progress, funding, and outcomes.”
- “Enhance Stakeholder Integration: Create more inclusive forums for civil society and industry input.”
- “Accelerate Capacity Building: Focus on reskilling workers in coal-dependent regions.”

3.3 Developed countries versus BRICS countries JET adaptation related to Policy

Developed nations have embedded JET principles within national climate policies. The European Green Deal (EGD) of year 2019 commits to achieving nett-zero emissions by 2050, with distinctive measures corresponding to the Just Transition Mechanism (JTM) to support regions and workers impacted by the transition (European Commission, 2022). In the United States, the Inflation Reduction Act (IRA) of year 2022 includes provisions for clean energy jobs, tax credits, and equity-focused investments (United States Congress, 2022). In Germany, JET policies are integrated with national energy strategies to phase out coal, ensuring that workers are reskilled, and coal regions are supported (ILO, 2021).

In BRICS nations, energy transitions are closely synchronised to development objectives. In India, the focus is on energy security and affordable access rather than a comprehensive just transition (Ahluwalia, 2021). South Africa has formulated a JET framework, particularly in the Just Energy Transition Partnership (JETP), with support from international funds like the World Bank (The Presidency South Africa, 2021). The BRICS nations have less coordinated policies or a fragmented policy approach covering the JET concerning social equity and labour transition.

3.4 South Africa in Consolidation with International Structures

To consolidate South Africa’s JET position internationally especially with BRICS and other global partners, several strategic pathways and collaborative mechanisms are emerging.

3.4.1 Consolidation with BRICS Countries

South Africa can strengthen its JET alignment with BRICS through the following approaches (Ramluckun et al, 2024):

- “Policy Benchmarking: A comparative review of BRICS energy policies shows similar reliance on fossil fuels and shared challenges in transitioning to renewables. South Africa

can adopt best practices from Brazil's bioenergy sector, China's solar expansion, and India's grid reforms."

- "Future research suggests the feasibility of a consolidated BRICS JET policy, with embedded shared renewable energy resources and components to encourage collective transition to net-zero emissions."
- "NDC Alignment: All BRICS countries have submitted Nationally Determined Contributions (NDCs) under the Paris Agreement. South Africa stands out as the only BRICS member to explicitly reference a "just transition" in its NDC."

3.5 Conclusion

A comparative study of the energy policies of the BRICS member countries has shown varying energy mixes, and the future prediction of BRICS members NDCs' being different. The BRICS member countries utilize their country's unique natural resources for electricity generation which results in different energy mixes. The BRICS member countries face the same challenges and uncertainties which the JET brings, however, South Africa is a small-scale reflection in many respects of India, and China as a developing nation with social and environmental responsibilities for a Just Energy Transition. Russia shares some similarities with its energy mix of fossil fuels being coal and natural gas.

South Africa can replicate the hybrid or tailored energy policies of the BRICS member countries in accordance with the South African landscape of energy sources readily available with the common objective of decarbonisation. The financial situation in South Africa is rather constrained compared with the BRICS countries but could be offset by the similar funding requirements to decommission and build new power plants. South Africa could apply and enter into negotiations for green finance and green bonds with the motivation of compliance with ILO 2015 and the Paris Agreement (ILO, 2015).

South Africa (SA), being part of BRICS, has the BRICS intergovernmental leverage to advance in the JET. SA was fortunate to be nominated as the chair of BRICS from January 2023. While the world is emerging from the adverse social and financial conditions of COVID-19, there is a war between Russia and Ukraine that has exacerbated the already-challenged global economy. This has resulted in a cascading effect on the bare necessities of energy and food, and has been exacerbated by trade and economic sanctions by the UN, the USA and the EU on Russia. Russia is a crucial leader in the BRICS alliance and is the third-largest oil producer, second-largest natural gas producer and top producer of steel and wheat globally.

As with any scarcity, prices are higher as demand outstrips supply, and this has had an unprecedented effect on food and energy. To mitigate this adverse impact, especially that of the energy crisis in South Africa (SA) where regular loadshedding occurs, the country has developed the "South African Economic Reconstruction and Recovery Plan" (SAERRP). The objective of this plan is to aid the energy or electricity sector to mitigate the challenges facing the country, to attain short to long term investment and eradicate the energy crisis, which is aligned to the country's NDC. SA, being a member and chair of the BRICS alliance, requested support in January 2023 through President Cyril Ramaphosa in its goal to alleviate the current and future energy crisis and the country's economic rehabilitation (Sooklal, 2023). Coincidentally, the 2023 BRICS theme is "Partnership for Mutually Accelerated Growth, Sustainable Development, and Inclusive Multilateralism" (Sooklal, 2023). BRICS member countries are fortunate in that they have vast natural resources and technology and are in a suitable financial position to assist member countries.

The benefits of being complementary amongst its member countries was a pivotal point in the BRICS alliance at inception. BRICS has a framework in the form of a roadmap to achieve member countries' objectives. The BRICS Energy Research Cooperation Platform (ERCP) was initiated to attract and merge cooperation between subject matter specialists, organisations, and research institutes to manage and expedite the similar ambitions of the BRICS in formulating and encouraging innovation in technology and governance (Sooklal, 2023). So far, the progress of the first phase has been exceptional, with eight completed studies (renewable energy development, smart grids, energy efficiency, sustainable energy access, energy storage solutions, hydrogen economy, climate resilience and investment financing models) presented at the BRICS Ministers of Energy meetings. These studies aim to foster cooperation and shared solutions for sustainable energy transitions among the member countries.

Research on energy security is currently being executed by Russia, which is essentially the beginning of the second phase of the roadmap. The last phase is focused on building complementary beneficial cooperation, sharing best practices, using advanced BRICS technologies, trade, and funding opportunities in individual BRICS member countries' economies (SAERRP, 2023). There are vast economic and trade relations within the BRICS countries. Within the coal export market in South Africa, India acquires approximately 50% of the total coal exported annually by South Africa, and China has recently engaged in negotiations with SA for coal as well. The trade in oil and gas has been strengthened between Russia, China, India, and Brazil in 2022, as has the renewable energy trade with South Africa (Sooklal, 2023). There has been interest shown by China and India in the clean coal

technologies of SA. ROSATOM, the Russian State Atomic Energy Corporation, agreed with SA to build a hydropower plant in the Mpumalanga province of South Africa. This would be the first step in a venture with Russia in SA to meet the JET priorities of net-zero CO_2 emissions, job creation, and stimulation of the economy and a start in resolving the country's electricity challenges with renewable energy (Sooklal). The BRICS Energy and Green Economy Working Group's objective is to develop tangible deliverables for the JET. Currently, BRICS is engaging with the possibility of developing a BRICS African Centre of Excellence (ACOE) to further progress on the JET. The function of the ACOE would be to provide subject matter experts to research technological, social, economic, and environmental components of the JET. It is acknowledged by the South African National Treasury (SANT) that there are funds available to the tune of $12 trillion globally for green energy projects from various green-funding financial institutions. Developing countries, in particular, would be able to obtain this funding per Article 2.1(c) of the Paris Climate Change Agreement, although developing countries are seen as higher risk. BRICS can also assist SA with obtaining these investments, despite policy impediments identified by South African regulatory bodies.

In conclusion it is essential to respond to the research question pertinent to this chapter "What will be the most effective strategy for SA to meet the Just Energy Transition (JET) transformation efficiently?"

To achieve a just energy transition, South Africa can implement several strategies. First, it should diversify its energy sources by accelerating the integration of renewable energy like solar, wind, and biomass to reduce reliance on coal. Developing clear policies and regulatory frameworks will incentivize investments in renewable energy and improve energy efficiency. Additionally, enhancing grid infrastructure and energy storage solutions is crucial for reliability. Engaging local communities in decision-making will ensure their needs are met, while skills development programs can transition workers from fossil fuel industries to renewable energy jobs. Financial mechanisms such as green bonds and public-private partnerships can attract investments, and energy access initiatives should aim to provide affordable energy to underserved communities. Supporting research and innovation in clean technologies, alongside regional cooperation with neighbouring countries, will further strengthen South Africa's energy transition efforts. By implementing these strategies, South Africa can foster a just energy transition that balances economic growth, environmental sustainability, and social equity.

CHAPTER 4: ENERGY TECHNOLOGIES

4.1 Introduction

This chapter focusses on the technologies available to generate electricity in the BRICS member countries using both renewable and non-renewable sources of energy. Technology description, comparison and possible technology selection including the risk of stranded assets will therefore be addressed.

The migration from carbon emitting power plants to the ultimate nett-zero power plants is a challenging activity globally. It therefore, requires a careful assessment of viable technologies necessary to utilise renewable energy fuel sources while meeting the electricity needs of individual BRICS members. Successful technologies would factor in the various agreements ("International Labour Organisations (ILO,2015) Guideline on Just Energy Transition" and compliance to the Paris Climate Change Agreement, COP22, the Copenhagen accord (2009), United Nations Framework Convention on Climate Change (UNFCCC) Addis Ababa Agenda 2030") to meet national and global electricity demands. BRICS, as explained comprehensively in Chapter 2 has and will continue with the efforts to decarbonise with relevant policies, "know-how" and appropriate technologies to lead the energy transition, knowing that BRICS countries have 40% of coal, 25% of natural gas and 80% of oil globally (BRICS Academic Review (BAR), 2023).

The BRICS countries have established a policy stipulating that future fossil fuel-fired power plants will only be licensed if they comply with Carbon Capture and Sequestration (CCS) standards. This directive, agreed upon by the South African government, aims to significantly reduce CO_2 emissions with the ultimate goal of achieving full Carbon Capture and Sequestration (Ritchie et al., 2017). Consequently, South Africa has begun exploring viable renewable energy options, including solar, wind, battery energy storage systems (BESS), nuclear, and hydrogen, as well as high-efficiency low-emission (HELE) technologies like biomass and supercritical boilers (Ritchie et al., 2017).

4.2 The Risk of Stranded Assets in the BRICS Countries

BRICS member countries are heavily dependent on fossil fuel-fired power plants. The required energy technologies, fossil fuel production and consumption impact, are known as "Path Dependence", namely, the inclination for former resolutions and interventions to self-reinforce, thereby decreasing the prospects for alternatives to surface (Intergovernmental Panel on Climate Change, 2014). Path dependency is critically important when considering JET in the BRICS countries, as most are countries that are net exporters or importers of various fossil

fuels. BRICS countries' economy, labour market and infrastructure in fossil fuel will therefore be significantly impacted by JET (International Institute for Sustainable Development (IISD), 2019).

It is appropriate to note the stranded assets of each BRICS country. Brazil's stranded asset is the oil infrastructure and offshore exploration projects. Despite Brazil's electricity mix being dominated by hydropower and bioenergy, it remains a major crude oil exporter, especially from pre-salt offshore fields. As global demand for oil declines, these high cost, capital intensive projects risk becoming uneconomical (von Kursk et al., 2025). The stranded asset risk is that Petrobras' expansion plans could face financial losses if climate-aligned policies are implemented.

India's stranded asset is the coal-fired power plants and coal mining operations as India has a large fleet of coal plants, many of which are already "stressed" or underperforming due to rising renewables and financial distress in distribution companies. The imminent risk of stranded assets is that 40 GW of coal capacity is considered non-performing, with potential cascading effects on banks and investors (International Institute for Sustainable Development (IISD), 2019).

In Russia the stranded asset is natural gas pipelines and Arctic oil infrastructure. The economy is extremely dependent on fossil fuel exports, especially natural gas and oil. Infrastructure of pipelines to Europe (e.g., Nord Stream) and Arctic drilling platforms are susceptible to demand changes, restrictions, and climate regulations. Stranded assets risk of approximately $2 trillion in hydrocarbon assets could be stranded by 2036 if nett-zero targets are met globally (Cordel, 2021).

China's stranded asset is new coal power plants and coal mining infrastructure. Although leading in renewables, the country continues to build coal power plants. The majority of the power plants and mining investments will not recover the capital outlay costs incurred as a result of decreased usage and adherence to climate change imperatives. Stranded asset risk is approximately $550 billion in coal assets due to decreased usage (Wang et al.,2022).

South Africa's stranded asset is coal-fired power stations and related infrastructure. South Africa is extremely reliant on coal-fired power plants with aging plants and newly commissioned Medupi and Kusile power plants that are facing rising costs, environmental pressure, and declining competitiveness with compliance to the Paris Climate Change

Agreement of decarbonisation by 2050. The stranded asset risk of transforming without a well-defined strategy is what may lead to state owned assets, unemployment rate increases, and higher financial burdens (Mbatia et al., 2023).

GDP will increase for China and India from JET, as they are large energy importers; while with moderate GDP increases are expected for Brazil, Russia, and South Africa as result of their energy efficiency improvements and reduced costs of energy (Pimpalkhute, 2020). JET unfortunately also results in financial losses especially those positioned towards exports for the fossil-fuel producing sectors of the economy. In an assessed case study conducted by the "Independent Think Tank" (ITT) on stranded fossil fuel assets in India, it deduced that the key drivers for stranding fossil fuel assets encompassed the improved cost competitiveness of renewable energy, pollution, climate and environmental regulations as well as the need to phase out government support to fossil fuels (Worrall et al., 2018). The risks associated with stranded assets can vary based on assumptions on global climate goals, future fossil fuel prices, potentially triggering a domino effect across the financial and other sectors of the economy. The study illustrated that the Indian government was counteracting a few of the drivers of asset-stranding by delaying the pass-through of market signals and the costs of environmental and wider climate impacts to coal power project developers and investors. The study also pointed out similar patterns of government interventions to the coal power value chain in China and South Africa. Eventually, the researchers declared that it will be critical for governments in these countries to sensibly manage their interventions in the power sector to avoid fossil fuel subsidies and support a wider commitment to energy access and a transition to low carbon energy sources (ILO, 2022).

4.3 Non-renewable energies

A non-renewable energy resource is defined as a natural resource that cannot be easily replaced by natural means at a rate effective to keep pace with its consumption. Coal is a typical form of a non-renewable energy resource (Dhir, 2024). Essentially there are three key categories of non-renewable energy sources (1) oil, (2) natural gas and (3) coal. These three are jointly classified as fossil fuels as these sources originate from fossilised matter over millions of years. These non-renewable energy resources are rich in carbon and when burnt, CO_2 gas will be emitted. The EU has subsequently reclassified nuclear and gas as sustainable however judges are labelling the move "greenwashing." This was further explained by the EU commissioner that the organisation was not guilty of "greenwashing", as gas and nuclear were considered as "transitional" energy sources in their taxonomy (Strauss, 2022). Gas and nuclear energy are viewed as "transitional" energy sources due to their lower carbon emissions compared to coal

and oil, making them more environmentally friendly. They provide reliable baseload power, essential for balancing the intermittent nature of renewable energy like wind and solar. Both technologies are mature and can be deployed at scale, allowing for a quicker transition. Existing infrastructure can often accommodate gas and integrate nuclear power, facilitating a smoother shift. Additionally, gas plants can adjust output to support renewable integration, and investments in these energy sources offer a bridge to a low-carbon future while maintaining energy security (Strauss, 2022). Globally, the installed non-renewable energy capacity is approximately 7933GW, of which BRICS is 3808 GW (Fernandez, 2023).

Although oil is a fossil fuel, the study has excluded it from further investigation in the BRICS countries as the share was negligible in comparison with coal and gas, where the contribution is 0.1% in China, 3.4% in Brazil, 1.7% in India, 1.44% in Russia and 0% in South Africa in electricity production (Energy Information Administration (EIA), 2024).

4.3.1 Coal

Coal's chemical composition is a majority carbon, hydrogen, sulphur, oxygen, and nitrogen (Blander, 2010). Coal is black combustible sedimentary rock, formed as rock strata called coal seams. Coal is a fossil fuel formed from dead plant matter decayed into peat and is converted into coal by the heat and pressure of deep burial over millions of years.

Coal is the resource that powered the industrial revolution due its availability and low cost but had adverse environmental and human health impacts. Globally, coal currently supplies approximately 25% of the primary energy and approximately 35% of electricity (16.8% consumed by the BRICS) (Gasparotto, 2021). Micro and nanoparticles inhalation of coal in coal mines or coal-fired power stations presents risk to human health as coal has many other constituents including sulphur, nitrogen, organometallic compounds, and minerals, that contribute to the formation of highly toxic secondary compounds that may come in contact with the atmosphere (Gasparotto, 2021). The continuous inhalation of these hazardous substances triggers many diseases such respiratory and cardiovascular disease, systemic inflammation, and neurodegeneration and contributes significantly to extremely high CO_2 and GHG emissions (Gasparotto, 2021).

The coal-fired power generating technologies comprises of subcritical, supercritical, ultra-supercritical and "Circulating Fluidised-bed boiler" (CFB). The common technology used for the subcritical, supercritical and ultra-supercritical boiler is the "Pulverized Fuel" (PF) coal combustion technology apart from the CFB. PF is a crushed coal or ground into powder

fineness form with the use of coal mills (Ansolabehere, 2007). The PF is then blown into the boiler furnace with a "Primary Air" (PA) fan which spontaneously ignites the coal particles. The main objective of PF technology is to enable combustion of low-quality coal. The heat generated, heats the water into high pressure steam to drive the electrical power generator (Ansolabehere, 2007). The subcritical, supercritical, and ultra-supercritical versions of PF coal combustion technology are distinguished by steam pressure within the boiler. In a subcritical boiler plant, steam pressure is below 22 MPa, and the temperature is below 550^{o} C. Subcritical boilers have efficiencies of approximately 35%. In supercritical boilers, the pressure of the boiler is 24 MPa and temperatures of 565^{o} C. With this higher pressure and temperature, water is maintained as a fluid despite being above the atmospheric boiling point which enhances the efficiency from 37% to 40%. Ultra-supercritical boilers have pressures of 32 MPa and temperatures of 600^{o} C and efficiencies of more than 45% (Ansolabehere, 2007).

CFB coal is combusted with air in a circulating bed, and limestone could be added to act as a sorbent for sulphur dioxide (SO_2) absorption. Limestone has calcium carbonate which reacts with sulphur dioxide (SO_2). Limestone is used for desulphurisation of flue gases. CFB technology can burn a wider range of coal and biomass. An advantage of CFB technology is that it produces low nitrogen oxide ($NO_{x)}$ and captures SO_2 unlike the PF technologies where a Flue Gas Desulphurisation (FGD) plant is required for the absorption of (SO_2) at astronomical costs. CFB efficiencies are approximately 40% dependent on coal quality (Ansolabehere, 2007). Higher boiler efficiencies lead to less CO_2 being emitted during electricity generation.

4.3.2 Natural Gas

Natural gas is the lowest carbon hydrocarbon fuel originating from plants and animals that fossilised under great pressure and heat or by microorganisms called methanogens (Faramawy et al., 2016). Methane (CH_4) is the key element in natural gas. Burning methane results in CO_2 and water being produced. Natural gas is odourless, colourless, tasteless, and non-toxic, however a smelly element called mercaptan (faint rotten egg smell) is added to the natural gas to make it easier to detect leaks in gas pipelines (Deligeorgiou, 2014). Natural gas is in abundance in many regions globally, in quantities that ensure sustainability for anthropogenic energy activity for at least 250 years based on current estimates (Gas Exporting Countries Forum (GECF), 2023). From an environmental perspective, natural gas is a "greener" form of fossil fuels with significantly lower emissions of CO_2 and other GHG as illustrated in Table 4 (Environmental Protection Agency (EPA), 2013).

Table 4: Comparative emissions of natural gas, oil and coal (EPA, 2013)

Emissions from burning in LBs per 1 Billion BTU			
Pollutants	**Natural Gas**	**Oil**	**Coal**
Carbon Dioxide (CO_2)	117 000	164 000	208 000
Carbon Monoxide (CO)	40	33	208
Nitrogen Oxide (NOx)	92	448	457
Sulphur Dioxide (SO_2)	1	1122	2591
Mercury (Hg)	0	0.007	0.016

Natural gas fired power plants (combined cycle) could easily be categorised as HELE technology since the CO_2 emissions are between 50 to 60% less than that of coal CO_2 emissions; and favourable thermal efficiency for utility-scale electrical power generation of between 50% to 60% compared to coal and oil-fired plants of approximately 37% (Minchener, 2019). Natural gas caters for 25% of global electricity generation of which BRICS countries usage is approximately 4%. Delivery via pipelines from source plants to end user or can be stored in tanks and transport via road or sea transportation. Gas-fired power plants have the advantage of convenient and instantaneous switch off or on of the plant. This dispatchability provides an energy efficient way of meeting the demands of electricity consumers and used as back up for instantaneous supply of demand fluctuations or when there's a loss of other generating plant (IEA Natural Gas, 2023). Gas-Turbine technology to generate electricity from natural gas has two combinations of Open Cycle Gas Turbine (OCGT) and Combined Cycle Gas Turbine (CCGT). In an OCGT, hot gas propels a gas turbine to generate electricity as shown in Figure 22.

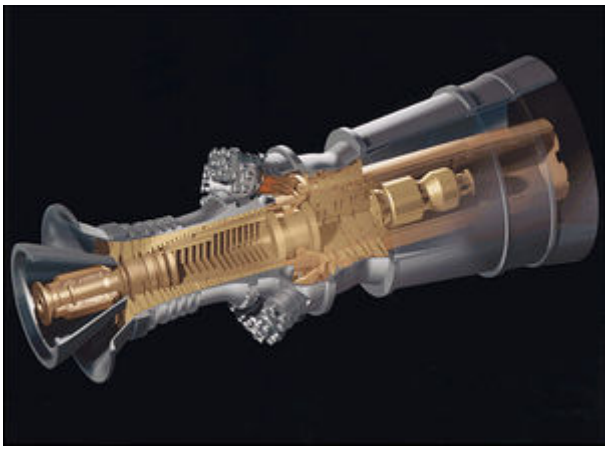


Figure 22: Open Cycle Gas Turbine (OCGT ((IEA Natural Gas, 2023).

The OCGT plant shown in Figure 23 is economical to construct with an efficiency of 30 - 40% depending on size and location of the installation.

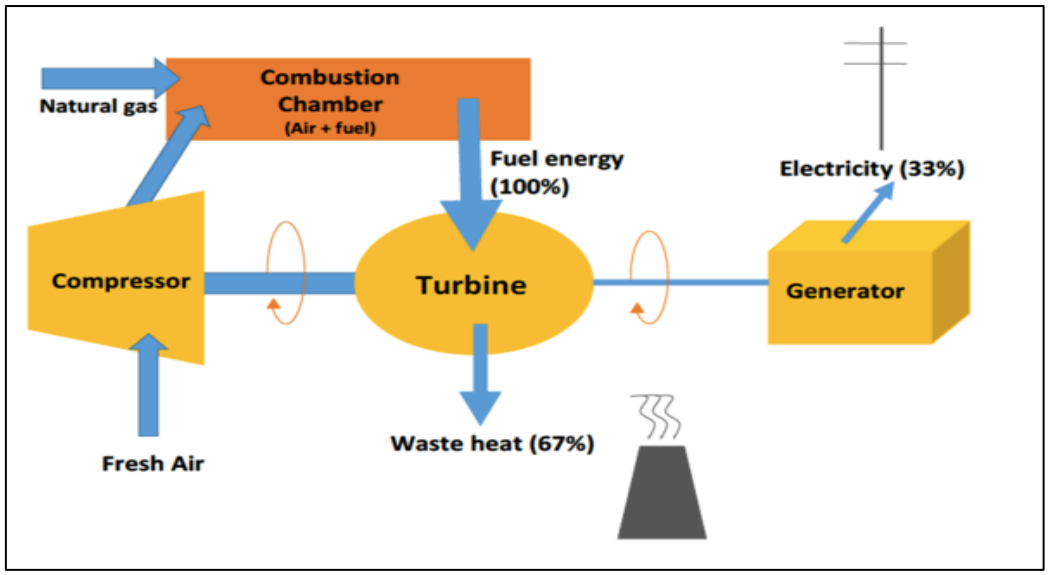


Figure 23: Schematic diagram of an OCGT plant.

CCGT plants are a type of natural gas power plant used to generate electricity, comprising of a simple or open cycle gas turbine plant in combination with a second steam engine that uses the "Rankine cycle" as illustrated in Figure 24 (Breeze, 2005). The hot exhaust gases from the initial gas turbine flows to the steam engine and the heat dissipated is utilised to generate steam. This steam can then expand through another turbine, generating even more electricity and increasing the plant's overall efficiency. The efficiency of the CCGT is approximately 55%. However, the dispatch times tend to be slower than OCGT plants. The CCGT typically has an increased cost. The cost estimated for an OCGT plant the cost is approximately US$389/kW verses CCGT plants of approximately US$500/kW (Breeze, 2005).

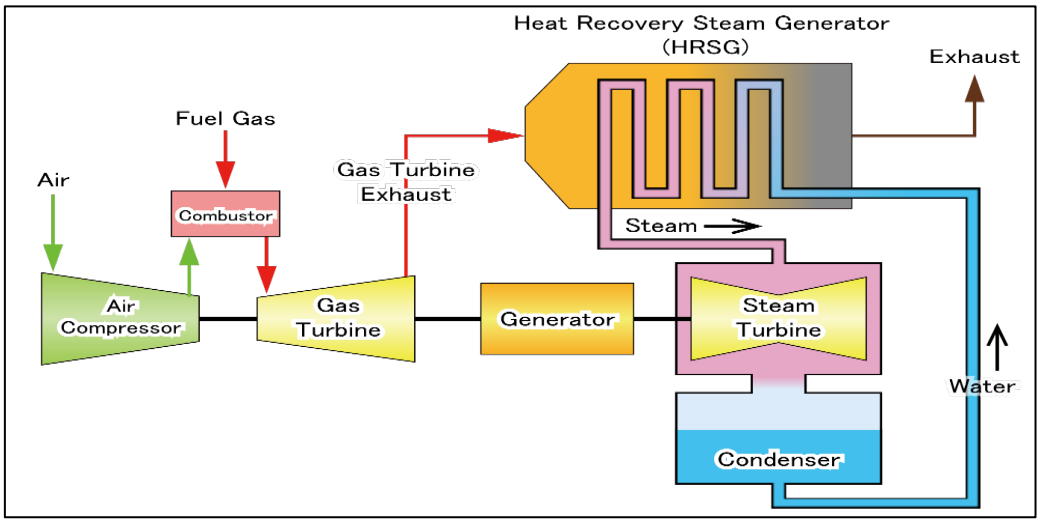


Figure 24: Schematic diagram of a CCGT plant.

Figure 24 illustrates the operation of the CCGT. The CCGT plant operates by use of a gas turbine, compressed air from the compressor, injecting fuel and igniting the mixture, which expands through the turbine causing it to rotate resulting in the generator coupled to the common shaft to turn and start electricity. The hot exhaust gases flow towards the next unit, called the "Heat Recovery Steam Generator" (HRSG). The HRSG is essentially a heat exchanger, in which the heat from the hot gases is used to heat water and generate steam. The steam flows to a steam turbine which in turn turns the common generator resulting in the production of electricity. Once the steam has passed through, it condenses and is recycled (Breeze, 2005).

4.4 Renewable energies

Since the world is going towards decarbonisation; environmentally sustainable, economically viable and affordable sources of energy are crucial to achieve this goal. A renewable energy resource is defined as a natural resource than can be replenished faster than it can be consumed. Solar, wind, hydro, tidal, geothermal and biomass are examples of renewable energies (Ellabban et al.,2014). T Globally, the installed renewable energy capacity is approximately 3400 GW which is 30% of the total installed energy capacity, while the BRICS total installed renewable energy capacity is approximately 1850 GW (Fernandez, 2023).

4.4.1 Solar Energy

The source of solar energy is the Sun. Sunlight or sunrays is a renewable source of energy which is a form of free energy available as long as there's sunshine. Solar energy is generated by nuclear fusion that occurs in the Sun. Fusion occurs when protons of hydrogen atoms

aggressively crash in the Sun's core and combine to establish a helium atom (Shaikh et al., 2017). This solar energy can be converted to power with the use of various technologies. Solar technologies transform sunlight into electrical energy through photovoltaic (PV) panels that concentrate solar radiation as shown in Figure 25. This energy can be utilized to create electricity or can be stored in batteries and thermal storage.

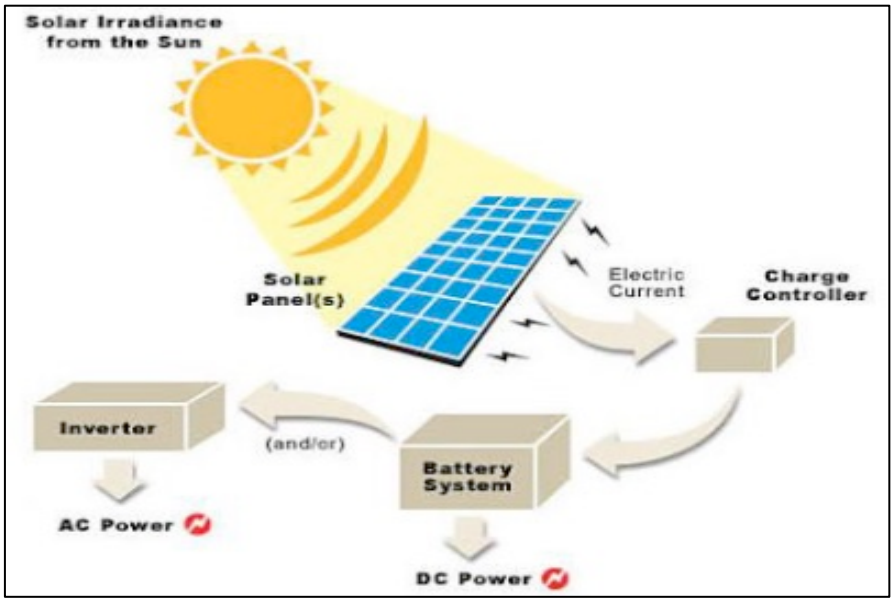


Figure 25: Production of Solar Power (Shaikh et al., 2017).

The photovoltaic solar panel is manufactured from semiconductor material as shown Figure 26.

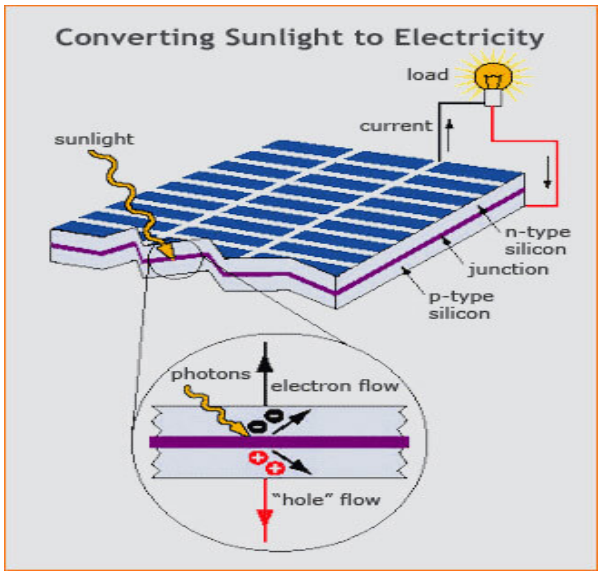


Figure 26: Longitudinal section of a typical photovoltaic solar cell (Shaikh et al., 2017).

The sun has a wide spectrum of electromagnetic waves which are the source of the energy for solar energy systems which can be categorised into ultraviolet (UV), visible and infrared light. Larger wavelengths have a smaller amount energy (for instance infrared) than shorter ones such as visible light or ultraviolet. Figure 27 shows the spectrum of sunlight as it enters Earth's atmosphere.

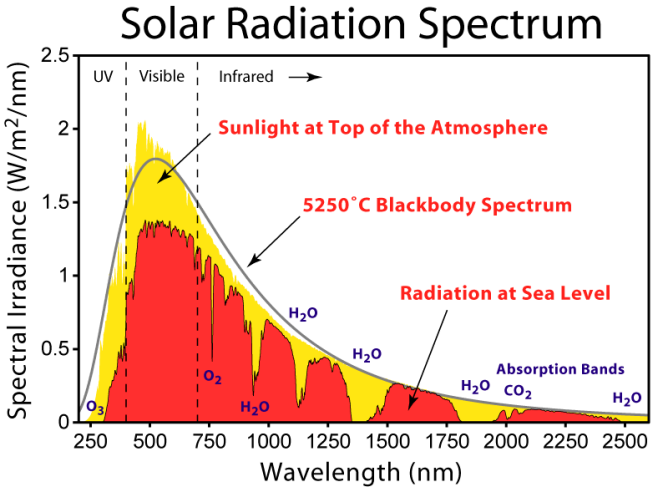


Figure 27: Solar radiation spectrum.

The peak spectral irradiance is inside the visible spectrum with significant proportions of shorter and longer wavelengths present in the visible light spectrum (Andrews et al., 2016). A fraction of this energy, (the yellow in the graph) is absorbed by the atmosphere and just the red part depicted in the diagram reaches the earth's surface. This global solar radiation (measured by a pyranometer) entering Earth is divided into direct radiation (focusable by mirrors) and diffuse radiation (unfocusable). The diffuse percentage differs noticeably with the amount of cloud in the sky on a given day which typically averages around 30%. The smooth line characterizes the spectrum of a black body, an ideal imaginary body that could absorb all electromagnetic waves (Andrews et al., 2016).

4.4.1.1 Solar Photovoltaic Power Grid System

A Solar Photovoltaic (SPV) power system consists of solar panels, inverter/s, a power conditioning unit, transformers (to enable connection to the desired voltage level) and grid connection via the conductors and switchgear as depicted in Figure 28 (Kumar et al., 2015). The solar panel converts the sun's energy to electrical energy, the invertor converts "Direct Current" (DC) to "Alternating Current" (AC). Solar PV is effective and highly efficient utilization of power that is generated from solar energy.

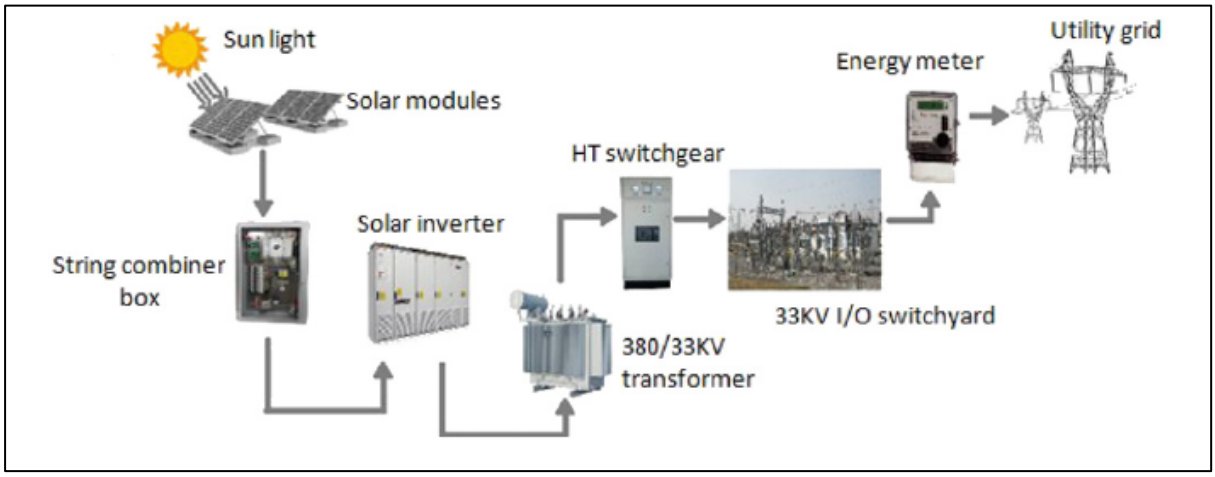


Figure 28: Typical Solar PV Schematic diagram (Kumar et al., 2015).

The Solar PV system supplies power via the utility power grid via distribution or transmission power lines. Excess power can easily be stored in batteries that would be utilised at night and/or during winter seasons. Photovoltaic (PV) solar cells are manufactured from semiconductors materials. Electrons in atoms are arranged in energy layers, called "shells or band". To conduct electricity, electrons flow is essential from the "valence to the conduction band". As shown in Figure 29, the two bands are overlapping in a metal (conductor) ensuring easier production of current through electron flow (Andrews et al., 2016). In an insulator and semi-conductor, there is an energy band gap to bridge. In the case of the insulator, it is tremendously tough to bridge the void and hence no conduction. With the semiconductor, the "valence electrons" could be liberated by exciting them (e.g., light or heat). The "valence electrons" will then be transformed into "free electrons" and rendering the "excitation" to overcome the depletion region or gap to enable electron flow. At room temperature the energy gap is 1.11 eV for Silicon (1 eV = 1.60 x 10 -19 J). The value reduces vaguely with rising temperature (Andrews et al., 2016).

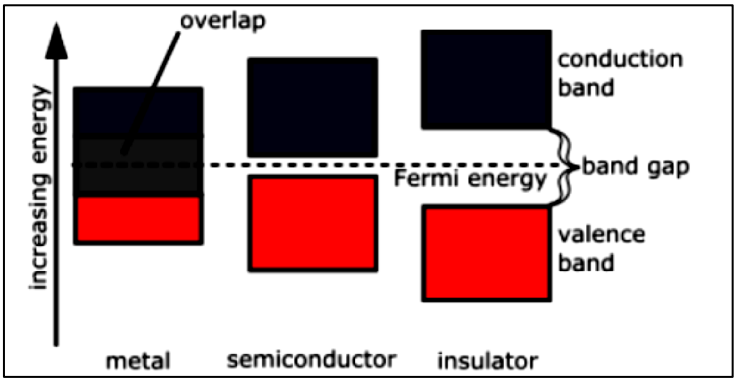


Figure 29: Conductor, Semi-Conductor, and Insulator structure.

4.4.1.2 Solar Photovoltaic footprint

Solar Photovoltaic (SPV) is a renewable energy resource and it's economically competitive globally. However, there's resistance to transition to this technology because it's a perceived that utility scale SPV would affect existing land uses or natural resources (Wyatt, 2021). However, it's normal for this resistance stemming from ignorance with all new "land uses" or development projects from communities, specifically the agricultural societies with SPV. In reality, present and planned future SPV land footprint are a negligible proportion of overall global "land uses" in comparison to other "land uses" typically less than half a percent of most country's land footprint worldwide. Societies apprehensive about solar "land use" would benefit from a demonstration of how and to what level, solar might essentially be positioned over a country's landscape. (Wyatt, 2021).

SPV advancement poses a negligible threat to the economic foundation of farming groups, as assessed by land transformation. Understanding the scope of land requirements, domestic financial consequences, and interface with regional natural resource importance linked with solar expansion could aid in alleviating these challenges. This interpretation may also assist with differentiating actual apprehensions from perceived apprehensions and place the utility scale of SPV "land use" into perspective.

Common community concerns with respect to SPV are as follows:

- "Impact on agricultural production and viability of agricultural businesses."
- "Effect on local and regional natural resources (including prime soils, surface waters, groundwater, and habitat)."
- "Change in community character, including views along roads or for the projects' neighbours."

Knowing the land constraints and the common community concerns with the construction of solar PV power plants it is imperative to provide data on the space or footprint requirements. Prospective proposals will be assessed to obtain efficient "Power-to-Land occupancy Ratio" and "Land Coverage Ratio" with same power efficiencies.

The possible options for solar PV utility scale power plants are as following:

- "Conventional solar PV installation."
- "Solar PV tree configuration."
- "Rooftop solar PV installation."
- "Agrivoltaics."

4.4.1.3 Conventional solar PV installation

Conventional Solar PV systems have shortcomings of additional land habitation and to a lesser extent community acceptance due to "conventional style" solar PV installations have firm drawbacks of additional land habitation and less encouragement amongst the public as result of less aesthetically pleasing structures. The land required is between 3 to 5 Acres/MW as seen in Figure 30.



Figure 30: Conventional Solar PV design.

4.4.1.3.1 Solar PV tree configuration

The Solar Photovoltaic (SPV) trees configuration can be used instead of conventional SPV plants (Vyas, 2022). Studies conducted on different SPV tree models deduced a significant reduction in land magnitude essential to produce the equivalent quantity of electricity compared to conventional SPV plants, (E.g., if a conventional ground mounted model needs 300m^2 area in comparison to the "Daisy" SPV tree design requires 13m^2 area for producing the exact magnitude of electricity as shown in Figure 31. From the entire land area, other vacant area may be used for numerous purposes, which could be a resolution to transition to renewable energy and can develop into the most useful in urban landscapes. The daisy, marigold, sunflower and tulip designs are configurations to obtain optimum "Power-to-Land occupancy Ratio" and "Land Coverage Ratio" with no added electricity loss in comparison to conventional land mounted SPV electrical plant produce the equivalent quantity of electricity making use minimal area of land as shown in Figure 31.

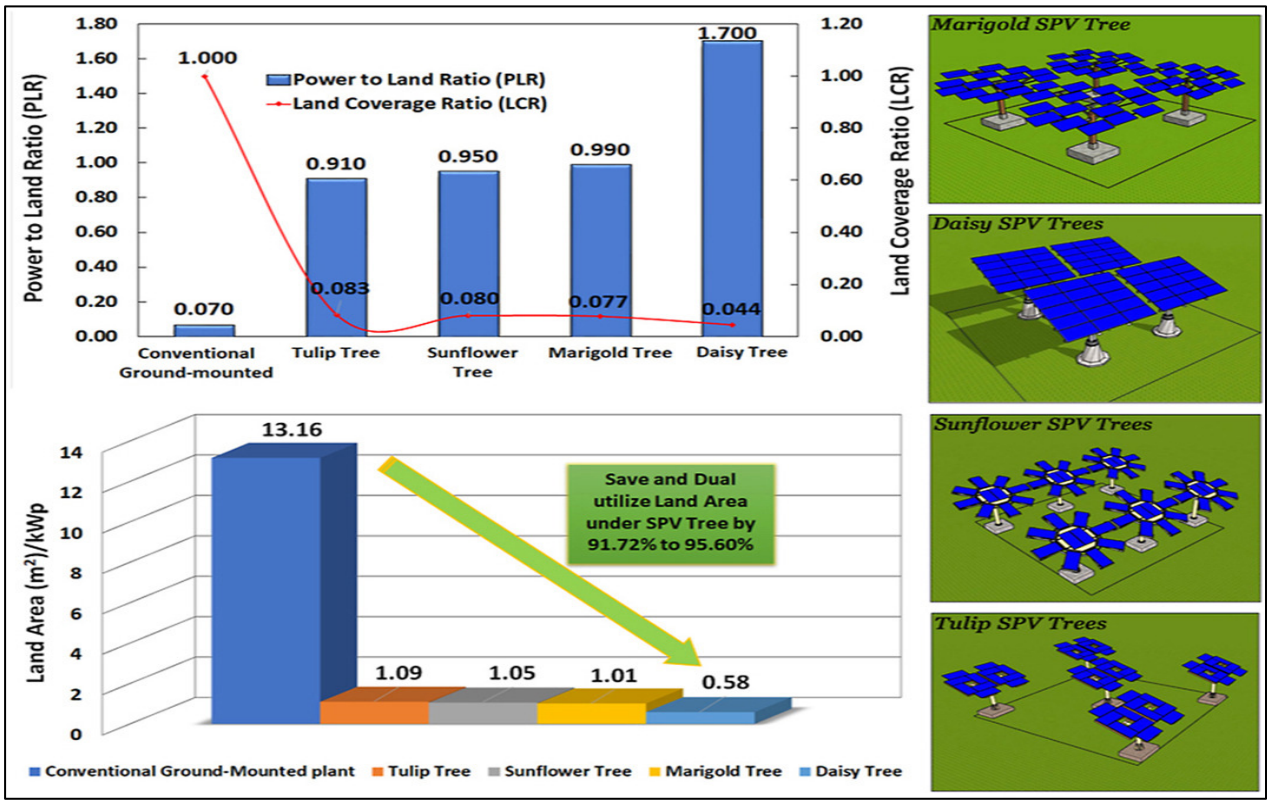


Figure 31: Power to Land Ratio of Solar PV designs.

The comparison shows that with daisy, marigold, sunflower and tulip configurations, there is a land-area ratio of 13 to 1, for marigold, sunflower and tulip configuration to the conventional SPV configuration and 22 to 1 ratio of the daisy configuration (Vyas, 2022).

4.4.1.3.2 Solar PV Rooftop configuration

A solar photovoltaic (SPV) system, mounted on the roof or integrated into the façade of a building, is an electrical installation that converts solar energy into electricity. This can be used to meet the building's own energy consumption requirements or, in certain situations, feed back into the electrical grid Rooftop solar PV systems are distributed electricity generation options, which help to meet a building's energy needs, or provide electricity within an existing distribution network. The size of the installation can vary dramatically, and is dependent on the size of the building, the amount of electricity required, the funding available for the project, and the grid operator's willingness to accept excess capacity. Core system components include PV modules, their accompanying mounting structure and an inverter. However, other components can also be incorporated into the system, depending on its size and complexity. These include string boxes, batteries, generators, transformers and meters. The layout and configuration of systems can differ, depending on the load type and the energy supply requirements (Wyatt, 2021).

4.4.1.3.3 Agrivoltaics

Agrivoltaics is a hybrid between the efficient utilisation of land to produce photovoltaic energy via solar energy plants and agricultural activities synergistically (Wyatt, 2021). This ecosystem promotes shared value with the physical land area and local communities within which the plants are located. Collaboration with agronomists, agricultural enterprises and academia have made it possible for a shared, sustainable journey for solar energy plants and agriculture to co-exist (Vyas, 2022).

4.4.2 Wind

Wind is an abundant source of energy that can be utilised to produce electricity by means of converting the kinetic energy of air in motion into electricity in an environmentally sustainable and low carbon economy (Gündoğdu et al, 2012). Wind energy uses can be dated back to 5000 B.C. to propel sail boats, sail ships, windmills to pump water and grinning grain (Woodcroft, 1851). This source of energy has increased astronomically from those early days of the discovery of the capability of wind energy. Fuelled by increased research and development and supportive JET policies that favour cost-effectiveness, the operation is straightforward: wind causes the rotor blades of a wind turbine to spin, converting kinetic energy into rotational energy, as illustrated in Figure 32. This rotational energy is transferred by a shaft to the generator sharing or coupled to the common shaft thus producing electrical energy (IRENA Wind, 2022).

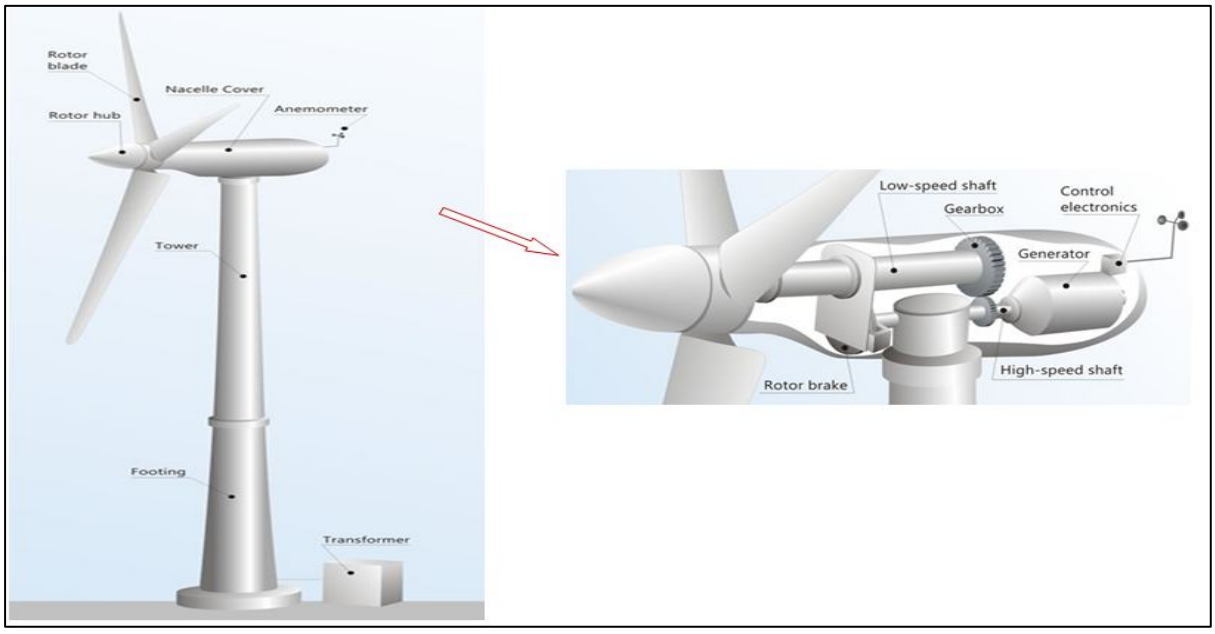


Figure 32: Wind turbine-generator unit (Manwell, 2009).

Wind turbines have various design features. The schematic diagram of a wind turbine generation system is shown in Figure 32. Some options in wind turbine topologies are as follows (Manwell, 2009).

- "Rotor axis orientation: horizontal or vertical."
- "Rotor position: upwind or downwind of tower."
- "Rotor speed: fixed or variable."
- "Hub: rigid, teetering, gimbaled or hinged blades."
- "Rigidity: still or flexible."
- "Number of blades: one, two, three or even more."
- "Power control: stall, pitch, yaw or aerodynamic surfaces."
- "Yaw control: active or free."

The generators utilised are of the salient pole synchronous machines, permanent magnet and squirrel-cage induction machines. However, the salient pole synchronous generators are most commonly used as they are best suited for the slower speeds of the turbine and more cost effective than permanent magnet units (Gündoğdu et al, 2012). The oil crises and increased concerns over resource conservation in the mid-1970s gave rise to more serious interest in wind energy (Cao et al, 2012). As a start, wind energy was a popular source to charge batteries in remote power systems, residential scale power systems, isolated or island power systems, and utility networks (Gipe, 1995). Global installed wind generation capacity onshore and offshore has increased in the last two decades from 7.5 GW to approximately 733 GW (IRENA Wind, 2022). Wind capacity onshore increased from 178 GW in 2010 to 699 GW in 2020, whereas offshore wind increased from 3.1 GW in 2010 to 34.4 GW in 2020. Wind power increased from 43.377 TWh in year 2011 and to reach 1589 TWh in year 2020 (IRENA Wind, 2022) as shown in Figure 33.

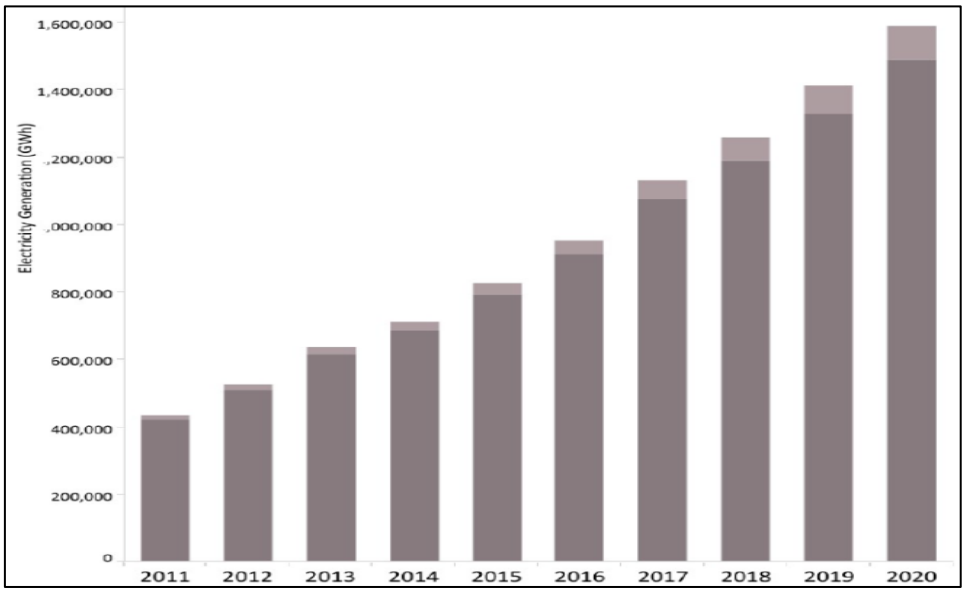


Figure 33: Global Wind Electricity Generation (IRENA Wind, 2022).

The BRICS countries electricity generation from wind energy from year 2011 to 2020 as illustrated in Figure 34 shows a progressive increase from 93.568 TWh in year 2011 to 590 TWh in year 2020.

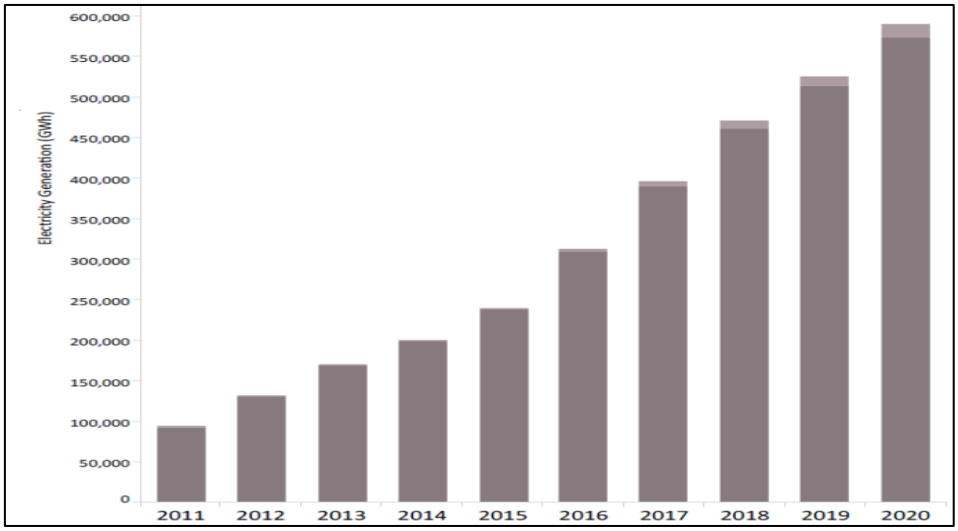


Figure 34: BRICS Wind Electricity Generation (IRENA Wind, 2022).

Wind turbines are between 20 to 40% more efficient when converting wind into electrical energy. The typical life span of a wind turbine is 20 years, with routine maintenance required every six months (Gündoğdu et al, 2012).

4.4.3 Hydrogen

Hydrogen (H_2) is a colourless, odourless, tasteless, flammable gaseous substance. H_2 is an abundant element contained in water, atmosphere, animal and vegetable matter. However, H_2 is only approximately 0.00005% of the earth's atmosphere (Helmenstine, 2019). Hydrogen energy is a means of utilising H_2 which is green fuel that when consumed in a fuel cell produces only water. Hydrogen can be produced from two main processes of electrolysis and steam reforming of natural gas (Ke et al, 2009).

Steam reforming is a thermal process for hydrogen production. The process involves high temperature between 700 to 1100 °C in which steam reacts with a hydrocarbon fuel to produce hydrogen as shown in Figure 35. Hydrocarbon fuels commonly used are natural gas, diesel, renewable liquid fuels, gasified coal, and gasified biomass. This method produces approximately 95% of all hydrogen is produced from steam reforming of natural gas (Ibrahim, 2015). Steam reforming to produce H_2 is between 70 to 85% efficient.

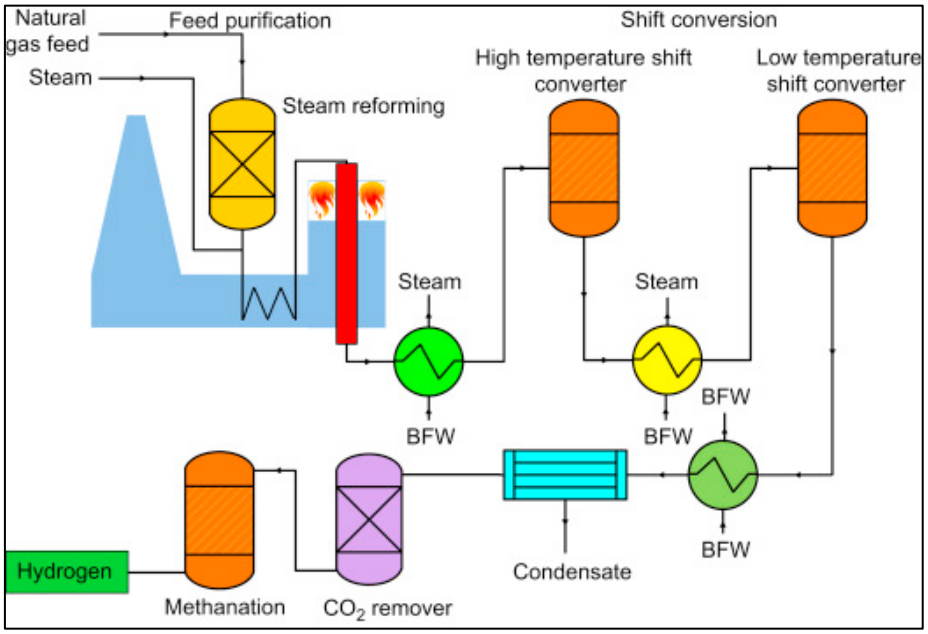


Figure 35: Typical Steam Reforming process to produce Hydrogen.

Electrolysis is the second method of producing H_2. Water is separated into oxygen and hydrogen through a process called electrolysis. Electrolytic processes take place in an electrolyser. A DC electrical power source is connected to two electrodes, or two plates made from an inert metal such as platinum or iridium that are placed in the water (Zumdahl et al, 2013). Hydrogen collects at the cathode where electrons enter the water and oxygen at the anode as shown in Figure 36. Electrolysis consists of using electricity to split water between

50 to 80 °C into hydrogen and oxygen (Kalamaras et al, 2013). Electrolysis of process of producing hydrogen is between 70 to 80% efficient.

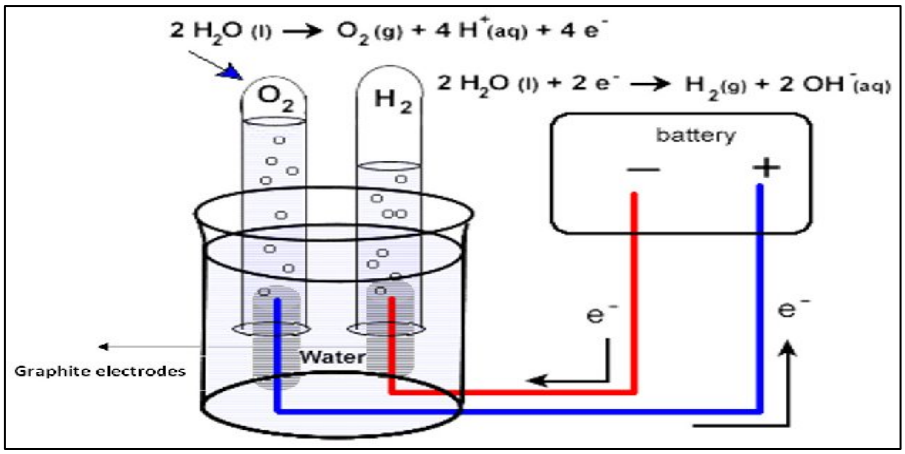


Figure 36: A schematic diagram of the electrolytic production of hydrogen gas (Kalamaras et al, 2013).

Between reforming and electrolysis methods of hydrogen production, the main difference is the primary energy consumption of electricity for electrolysis or fossil fuel for steam methane reforming. The scientific community has shown greater interest in the electrolysis process due to use of water which is the more environmentally friendly process depending on the power used for the electrolysis process. Water is also readily available resource combined with renewable energy sources would possibly reduce the cost of hydrogen production, renewable sources of energy have been targeted to allow electrolysis (Ghosh et al, 2003).

Currently, hydrogen's role in the power sector is negligible as its share of the power generation globally is approximately 0.2%. It is forecasted that there is huge potential in H_2 power plants in the future cognisant that it's a clean source with zero CO_2 emissions fostering decarbonisation in compliance to JET initiatives and well recognised by the energy sector (IEA Hydrogen, 2019). Hydrogen could be the catalyst for the rapid use renewable energy with the added characteristics of increased power system flexibility as well as storage of variable renewable energy (IEA Hydrogen, 2019). Figure 37 provides an indication of seven significant roles of hydrogen in an energy transition (enables large scale renewable energy integration and power generation, distribute energy across sectors and regions, decarbonise transportation, decarbonise industry use, decarbonise building heating and power and serve as feedstock using captured $CO_{2)}$ (Mackey, 2021).

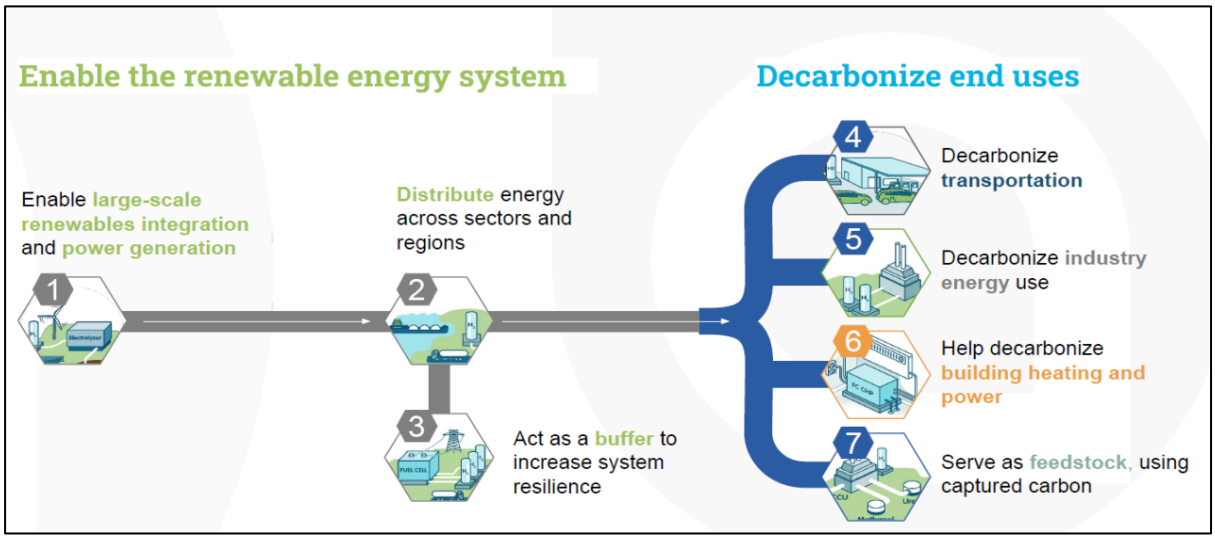


Figure 37: Role of Hydrogen in Just Energy Transition (JET) (Mackey, 2021).

Ammonia co-fired has immense potential to decrease the carbon intensity of the present conventional fossil fuel power plants. Hydrogen fired gas turbines and combined cycle gas turbines would offer flexibility in electricity production. H_2 in the form of compressed gas, ammonia or synthetic methane, hydrogen would provide long term storage option to balance seasonal variations in electricity demand or generation from renewable energy as tabulated in Table 5 (IEA Hydrogen, 2019).

Table 5: Role of Hydrogen and hydrogen-based products in power generation (IEA Hydrogen, 2019).

Power Generation Mode	**Current Role**	**Demand Perspectives**	**Future Deployment**	
			Opportunities	**Challenges**
Co-Firing Ammonia in Coal Power Plants	No deployment so far; Co-firing has been demonstrated in a commercial coal power plant in Japan	20% co-firing share in global coal power plant fleet could by 2030 lead to an ammonia demand of up to 670 Mt or a corresponding hydrogen demand of 120 MtH2	Reducing the carbon impact of existing coal-fired power plants in the near term	CO_2 mitigation costs can be low but rely on low-cost ammonia supply. Attention must be paid to NOx emissions; further NOx treatment may be needed. Only a transitional measure – still significant remaining CO_2 emissions

Flexible Power Generation	Few commercial gas turbines using hydrogen-rich gases. 363,000 fuel cell units (1,600MW)	Assuming 1% of global gas-fired power capacity would run on hydrogen by 2030, this would result in a capacity of 25GW, generating 90TWh of electricity and consuming 4.5MtH2	Supporting the integration of VRE in the power system. Some gas turbine designs are already able to run on high hydrogen shares	Availability of low-cost and low-carbon hydrogen and ammonia. Competition with other flexible generation options as well as other flexibility options (e.g. demand response, storage)
Backup and Off-Grid Power Supply	Demonstration project for the electrification of villages. Fuel cell systems in combination with storage.	With the increasing growth for telecommunications, there is also a growing need for a reliable power supply.	Fuel cell systems in combination with storage are a cost-effective and less polluting alternative to diesel generators. More robust than battery systems.	It is often a higher initial investment and needs to be compared with diesel generators.
Long-Term and Large-Scale Energy Storage	Three salt cavern storage sites for hydrogen are in the United States; And 3 more are in the United Kingdom.	In the long term, with very high VRE shares, the need for large-scale and Long-term storage for seasonal imbalances or longer periods with no VRE generation. In combination with long-distance trade, scope to take advantage of seasonal differences in Global VRE supply	Due to the high energy content of hydrogen, relatively low CAPEX cost for Storage itself. Few alternative technologies for long-term and large-scale storage. Conversion losses can be reduced if stored hydrogen or ammonia can be directly used in end-use applications.	High conversion losses. Geological availability of salt caverns for hydrogen storage is region-specific. Little experience with depleted oil and gas fields or water aquifers for hydrogen storage (e.g. contamination issues).

Classification of Hydrogen is basically categorised by the fuel source used to provide the power for H_2 production from reforming or electrolysis. Green H_2 is produced from renewable energy fuel source with electrolysis with no CO_2 emissions. Blue H_2 is produced from fossil fuels energy with the use of Carbon Capture and Sequestration (CCS) technology to capture the carbon emissions. Grey H_2 is produced by electricity generated from fossil fuels which are carbon intensive and termed "dirty" H_2 illustrated in Table 6 (IRENA, 2020).

Table 6: Hydrogen classification (IRENA, 2020).

Hydrogen Classification	**Definition**
Grey Hydrogen - Fuel Based	Natural or synthetic gas is separated into hydrogen and carbon dioxide, while the carbon is emitted into the atmosphere.

Blue Hydrogen - Fossil Fuel based utilising carbon capture and storage	Blue hydrogen is when natural gas is separated into hydrogen and carbon dioxide by Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR), but the carbon is captured and stored.
Green Hydrogen - Renewable Energy with Electrolysis	Green hydrogen is produced by water splitting via electrolysis and produces only hydrogen and oxygen. The electricity supply for the electrolysis should be from renewable energy sources.

Grey hydrogen production is currently globally dominant, and cost-effective for current applications however, grey H_2 must be phased out by year 2050 to be compliant to the Paris Agreement (Hydrogen Council, 2020). Green hydrogen production is currently marginal as demonstration projects, due to the high cost of production and hence reluctance in the energy sector (IRENA, 2020). Their reluctance is due to the lack of infrastructure dedicated to hydrogen (mainly related to the production stage of electrolysis), high production cost, energy efficiency, poor H_2 value recognition and the need to ensure sustainability (IRENA, 2020).

The H_2 conversion technologies available to convert H_2 to electricity which can be converted at the end of the hydrogen cycle as shown in Figure 38. The renewable energy as a source of electrical power provides electricity to an electrolyser that produces hydrogen that is stored in a tank and later used in either fuel cells or gas turbine to produce electricity which is supplied to the power grid (IRENA, 2020).

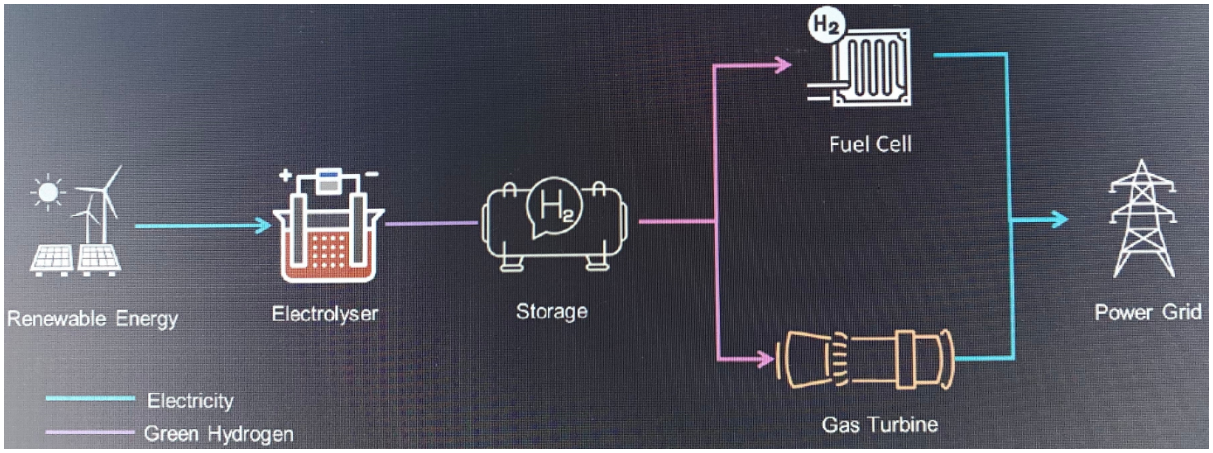


Figure 38: Hydrogen conversion to electricity (IRENA, 2020).

The two main conversion technologies:

- Hydrogen fuel cell and

- Gas fired turbine.

A Hydrogen fuel cell is basically an electrochemical device that converts the chemical energy in H_2. Fuel cells are similar to batteries, and produce electricity directly from chemical energy. A fuel cell has various technologies for power applications as described below (Goldmeer, 2018): Polymer Electrolyte Membrane Fuel Cells (PEMFCs) operate at temperatures below 100°C with a fast start-up time where pure H_2 stream is required as fuel. PEMFCs are used today as micro co-generation units, operating with natural gas or Liquid Natural Gas (LNG) in residential buildings Phosphoric Acid Fuel Cells (PAFCs), based on phosphoric acid as electrolyte, are used as power generators with electrical power outputs in the 100 to 400 kW range. Not limited to electricity generation, PAFC's produce heat at approximately 180°C, which has potential for building and water heating uses Molten Carbonate Fuel Cells (MCFCs) and Solid Oxide Fuel Cells (SOFCs) operate at temperatures between 600°C and 800°C to 1000°C respectively. MCFC's are used in the MW scale for power generation (due their low power density, resulting in a relatively large size). The produced heat can be used for heating or cooling in buildings and industrial applications. While SOFCs application are in smaller scale in the kW range, typically as micro co-generation units or for off-grid power supply.

Gas fired turbine technology uses gas turbines that run on 30% hydrogen and 70% natural gas at this time, that are coupled to a generator to produce electricity. A gas turbine that is powered by 100% hydrogen is due to be developed by 2025 (MHI, 2018).

It is evident that H_2 in the power generation sector is basically in infancy stage with small scale pilot power plants using pure H_2 as a fuel source. A few H_2 fired combined cycle gas turbine in Italy, Texas, United States of America (USA) and in Kobe, Japan piloted and not in commercial operation although in Japan it is piloted to power a small community.

4.4.4 Nuclear

Nuclear technology makes use of the energy from radioactive source like Uranium (Hardy, 1999). In the year 1789 Martin Klaproth, a German chemist discovered Uranium (U) and named the element after the planet Uranus (Hardy et al, 1999). In the year 1895 Wilhelm Röntgen developed ionising radiation by conducting an electric current through an evacuated glass tube and producing continuous X-rays. Subsequently, in the year 1896 Henri Becquerel found that Pitchblende (an ore containing Radium and Uranium) caused a photographic plate to darken due to beta radiation (electrons) and alpha particles (Helium nuclei) being emitted. A third type of radiation from pitchblende was discovered as gamma rays which was similar to

as X-rays. Marie and Pierre Curie in year 1896 gave the name "Radioactivity" to this phenomenon. In the year 1898 they isolated Polonium and Radium from the Pitchblende and the first use of Radium in medical treatments. Samuel Prescott in the year 1898 demonstrated that radiation had the ability to destroy bacteria in food. Ernest Rutherford in the year 1902 illustrated radioactivity, as a spontaneous phenomenon that emits an alpha or beta particle from the nucleus gave birth to a new element. In the year 1919 Ernest Rutherford fired alpha particles from a radium source into Nitrogen and found that nuclear rearrangement occurred resulting in the formation of Oxygen. Niels Bohr through his work lead to the understanding of the atom and the way electrons were arranged around its nucleus through to the 1940's. Frederick Soddy in the year 1911 discovered that naturally radioactive elements had a number of different isotopes called Radionuclides of identical chemistry. George de Hevesy in the same year demonstrated that such Radionuclides were invaluable as tracers as minute magnitude was readily detected with simple instruments (Hardy et al, 1999).

James Chadwick with his extensive experiments discovered the Neutron in the year 1932. Coincidentally in the same year, Cockcroft, and Walton by bombarding atoms with accelerated protons produced nuclear transformations. Irene Curie and Frederic Joliot in year 1934 discovered that some nuclear transformations created artificial radionuclides. In the year 1938, Otto Hahn and Fritz Strassmann demonstrated that the new lighter element was Barium and others which were about half the mass of Uranium and consequently discovered and demonstrated that Atomic Fission occurred. Lise Meitner, Otto Frisch, and Niels Bohr then explained Atomic Fission by alluding that the neutron was captured by the nucleus resulting in immense vibration which led to splitting the nucleus of the atom into almost equal proportions. Lise Meitner and Otto Frisch calculated the energy release from this fission to approximately 200 million electron volts. Otto Frisch qualified the calculated result experimentally in the year 1939 (Hardy et al, 1999). Unfortunately, the main objective was to harvest immense energy by splitting the atom and to produce an atomic bomb in the year 1940 and used in the Second World War. Post-war, in the 1950's the technology was research more to have more purpose for human consumption in a peaceful manner in its use in electrical power generation in nuclear power plants (IEA-OECD, 2022).

This discovery and research gave birth to nuclear power plants that are operational in 32 countries globally (WNA, 2022). With transmission grids that cross borders of countries, many more countries depend on nuclear generated power. Countries like Italy and Denmark are a typical example of this and that obtain approximately 10% of their imported electrical power from nuclear power. Nuclear technology not only provides low carbon electrical power but

also has a significant role to control the spread of disease, helps medical practitioners in their diagnosis and treatment of patients and enables human needs of space exploration. The basic operating principle of nuclear power plants is shown in Figure 39.

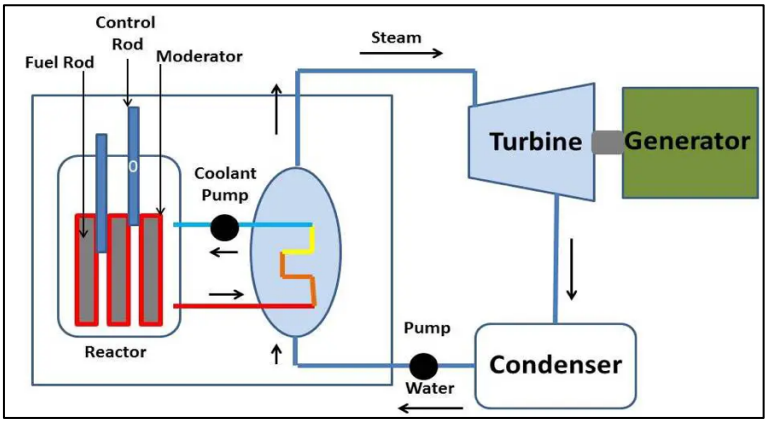


Figure 39: Nuclear Power plant (IRENA, 2020).

The function of the reactor in the nuclear plant is to house and control nuclear fission (a process where atoms are split and release energy). Uranium or the choice of the nuclear fuel for the reactors is processed into small ceramic pellets and stacked together into sealed metal tubes called fuel rods. The quantity of 200 (is commonly used) of these rods are bundled together to form a fuel assembly (ONE, 2021). The core of the reactor comprises of a few hundred assemblies, depending on power level requirements. Within the reactor, the fuel rods are immersed in water which acts as both a coolant and moderator. The moderator assists to slow down the neutrons produced by fission to sustain the chain reaction. Control rods are then inserted into the reactor core to decrease the reaction rate or removed in order to increase the reaction. The heat generated by fission is used to heat the water into steam. The steam produced then spins a steam turbine which turns an electrical generator that produces electricity (ONE, 2021). The nuclear power plants efficiencies are in the range of 33 to 37%.

Small Modular Reactors (SMRs) are improved easy to construct nuclear reactors with an generation potential of 10MW to 300 Reactor-Generator set, approximately 33% of the power producing capability of conventional nuclear plants (IAEA, 2021). Advantages of SMRs are that their design of small and modular makes it easier to construct with reduced construction periods that could built on smaller physical ground area.. Assembled SMR generating sets can be fabricated, transported, and commissioned on site, rendering cost effective and time efficient nuclear reactors. These SMR's have the benefit of deployment to cater for increasing electricity growth (IAEA, 2021). In contrast to current reactors, SMR models are usually not so intricate

like the larger traditional nuclear reactors, and safer concepts for SMRs frequently depends on inert systems and intrinsic safety properties of the reactor, of minimal power and operational pressure. No manned operations is necessary to de-energise plant, as submissive systems depend on physical occurrences, of natural circulation, convection, gravity and self-pressurization. The improved safety measures, better manages or reduces the possibility of hazardous emissions of radioactivity to the environment in the event of an incident. Refuelling is less frequent compared to traditional large units of an average of 4 to 7 years versus 1 to 2 years respectively. There are exceptions that SMR's are constructed to operate for 30 years without refuelling which is extremely favourable for continuity of electricity supply.

Carbon footprint of nuclear power is negligible of approximately 15 to 50 g CO_2/KWh of CO_2. Compared to gas powered generator of approximately 450 g CO_2/KWh and for coal fired power plants its approximately 1,050 g CO_2/KWh. Nuclear power is significantly contributing to the reductions of CO_2 emissions resulting in a positive impact on decarbonisation of the global energy system. Nuclear power plants provide approximately 30% of the world's low carbon electricity, second only to hydropower (IEA, 2021). Nuclear power plants energy helps the reduction of approximately 1.5 gigatonnes (Gt) of global emissions and 180 billion cubic metres (bcm) of global gas demand to be decreased yearly (IEA, 2021).

In the year 2021 nuclear plants supplied 2653 TWh of electricity from 2553 TWh in 2020 (WNA, 2022). The BRICS countries have a significant amount of nuclear power. China has 55 nuclear reactors with a total net capacity of 53.3 GWe which in 2021 made up 5.0% of the country's total electricity generation. Russia has 37 nuclear reactors, with a total capacity of 27.7 GWe which in 2021 made up 20.0% of the country's total electricity generation. Brazil has 2 nuclear reactors with a total capacity of 1.9 GWe in 2021which comprises of 2.4% of the country's electricity produced. India has 22 nuclear reactors with total capacity of 6.8 GW which in 2021 had 3.2% of the country's electricity generated. South Africa has 2 nuclear reactors with a total capacity of 1.9 GWe in 2021 comprised of 6% of the country's electricity On the African continent, South Africa is the only country producing electricity from nuclear (WNA, 2022).

4.4.5 Hydroelectric Power

Hydroelectric power is energy harnessed from flowing water without reducing the quantity of water. The fact that no water is lost in the process to harness this hydropower, hydroelectric is categorised as renewable energy source (IRENA-Hydro, 2022). The first use of hydropower was more than 2000 years ago by the ancient Greeks. Hydropower was used to turn the wheels

of grinders for grain. Currently hydroelectric power is the most cost-effective method of generating electricity.

The typical arrangement of a hydroelectric power plant in shown in Figure 40. The water from the storage reservoir or surge tanks flows in a penstock (penstocks are open or closed conduits that carry water to the turbines) with a gradient to provide sufficient head pressure to allow water to flow at the desire flow rate. The flowing water kinetic energy is converted into mechanical energy at the turbine shaft. The turbine drives the generator that's coupled with the turbine shaft. The electrical generator produces electricity at the desire power rating. The generators are low speed (75rpm to 300rpm) synchronous generators (IRENA-Hydro, 2022). Hydroelectric generators are air cooled with closed circuit cooling. Hydroelectric power plants consist of two basic configurations with dams and reservoirs or without. Hydroelectric power plants can run as base load power plants where there a continuous flow of water or with a large reservoir can store water over short or long periods of time to meet peak power system demands. The hydropower plant can also be configured into smaller dams for more flexibility like time of use (night or day), seasonal storage or pumped storage reversible plants. For the pumped storage hydroelectric power plants, the power from the power network is used to power the generator in the motor mode spinning the water turbine in the opposite direction and functions as water pump. This enable the power system operator from using surplus spinning reserves of the power network to pump water into these dams or reservoirs and this power can be utilised when there's peak demand or shortage of generation capacity (IRENA-Hydro, 2022).

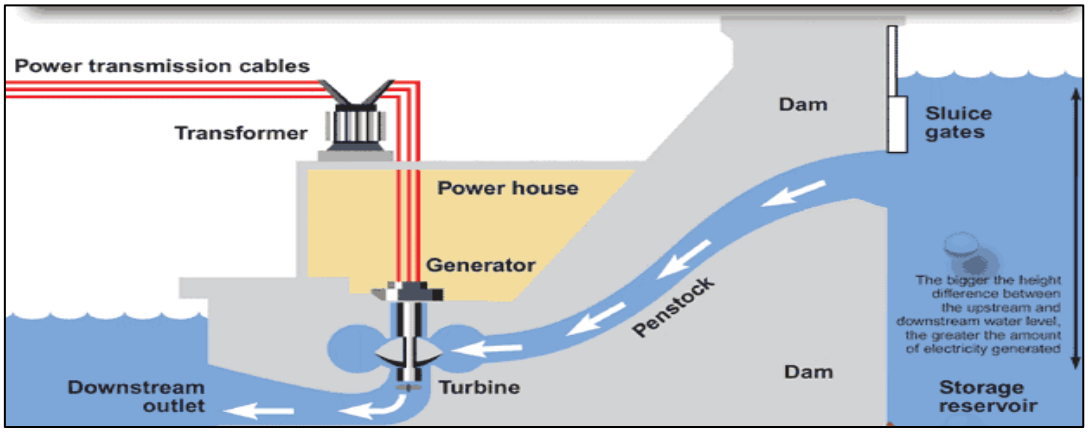


Figure 40: Typical Hydroelectric Power Plant (IRENA, 2022).

Installed hydroelectric power generation capacity in the world has increased in the last decade from 953 GW to approximately 1230 GW (IRENA-Hydro, 2022). Hydroelectric power > and

EU have supported innovation through significant public-private partnerships and the Horizon Europe Program (HEP) for green innovation (European Commission, 2021). Developed nations have policies encouraging the mass adoption of solar and wind power (e.g., the Renewable Energy Deployment Plan in the U.S. and EU).

BRICS nations have cost driven technology adoption, cognisant of financial constraints. China and India are adopting renewable technologies at scale, driven by cost reduction and energy requirements. China is a global leader in solar PV manufacturing, while India is rapidly expanding solar power generation (IRENA, 2021). However, technology adoption in BRICS is focused on achieving energy security in correlation with JET. Technological innovation in BRICS, is a challenge to find middle ground between social impacts and workforce transitions (World Bank, 2020).

4.6 Conclusion

The assessment of non-renewable and renewable energy technologies was imperative. Knowing the necessity to transform in compliance with JET initiatives, synchronised to the Paris Climate Change Agreement in collaboration with the ILO, 2015, it is apparent that in the drive to decarbonise globally, BRICS member countries are committed to the change. With JET, it is inevitable that renewable energies will play a major role in while decommissioning the non-renewable electricity generation plants in future. Each technology has it merits and demerits with respect to cost and efficiencies. The end user or country must "pattern-fit" the best technology that is suitable for it as far as practically possible. Over the years, the implementation of energy technologies has proven to be lengthy, often extending beyond the expected timeframe. The easier technologies to implement over the short to medium term, and which stand out, are Solar PV and wind; whereas nuclear has proven that with disciplined safety and environmental management, it can be most beneficial in terms of efficiencies and reliability. Natural gas is viewed as a bridging technology from coal to renewable energy as natural gas efficiencies and CO_2 emissions are more favourable with HELE properties.

Hydroelectric power generation plants proved to be extremely viable (cost, efficiency, and no CO_2 emissions) especially with a dam or reservoir configuration from a river. Hydroelectric plants have the potential to provide large magnitudes of electricity and provide baseload power. Hydrogen was observed to be the least used at this time, since production requires electricity both in "reforming and electrolysis" methods of production and is not seen as the most cost-effective and efficient technology; however, as cheaper renewable electricity can be provided to produce H_2, it will be more viable and would be the future "Power Fuel" to fuel airplanes,

ships, cars and the like. A hybrid or combination of these technologies may reward BRICS countries with cost effective energy while meeting the Paris Climate Change Agreement terms.

In conclusion, a response to the research question in this specific chapter follows: "What energy resources and technologies are available to ensure near zero carbonisation or zero CO_2 emissions from power producing plants?

BRICS countries, including South Africa, have access to various energy resources and technologies to achieve near-zero carbonization or zero CO_2 emissions from power generation. Key options include abundant renewable energy sources such as solar power, which can be harnessed through photovoltaic systems and concentrated solar power; wind energy from onshore and offshore farms; hydropower, especially in Brazil and Russia; and sustainable biomass from agricultural and forestry residues. Additionally, advanced nuclear technologies like small modular reactors offer low-emission alternatives. Energy storage solutions, such as large-scale batteries and pumped hydro storage, enhance reliability, while Carbon Capture and Storage (CCS) can significantly reduce emissions from fossil fuel plants. Upgrading to smart grids and fostering regional cooperation on energy-sharing will further optimize resource use. Supportive policies and investments in renewable energy technologies can accelerate the transition to low-carbon power generation, enabling BRICS and South Africa to make significant progress toward their climate goals.

To address the need for sustainability in the BRICS countries (Brazil, Russia, India, China, and South Africa) and their efforts to transition to a more sustainable energy future, the technologies mentioned such as CCUS (Carbon Capture, Utilization, and Storage), Fluidized Bed Combustion (FBC) boilers, co-firing with gas or biomass will be essential. Below is a table outlining the short-to-medium and medium-to-long-term technology goals for BRICS countries, considering their unique energy challenges and needs for a Just Energy Transition (JET).

Table 7: Short-to-Medium and Medium-to-Long-term Technology Goals for BRICS Countries

Technology Goal		**Timeframe**	**Reason for Focus**	**References**
1.	**Carbon Capture, Utilization, and Storage (CCUS)**	Short to Medium-Term	CCUS allows for the reduction of CO_2 emissions from existing fossil fuel plants, especially coal, which	International Energy Agency (IEA), "Carbon Capture, Utilization and Storage" (2021)

			is still a dominant energy source in BRICS nations.	
2.	**Fluidized Bed Combustion (FBC) Reactors**	Short to Medium-Term	FBC technology is versatile and can burn a variety of fuels (coal, biomass) more efficiently and with lower emissions, supporting cleaner power generation.	World Bank, "The Role of Fluidized Bed Combustion in Sustainable Energy" (2019)
3.	**Co-firing with Gas/Biomass**	Short to Medium-Term	Co-firing reduces the carbon intensity of coal-fired power plants by blending in cleaner sources, which is an important immediate solution in fossil-dominant economies.	IEA, "Decarbonization of Power Generation in Developing Countries" (2020)
4.	**Energy Efficiency Improvements in Power Plants**	Short to Medium-Term	Improving efficiency in existing coal and natural gas power plants through advanced turbine technology and heat recovery will reduce emissions and waste.	REN21, "Renewable Energy Policy Network for the 21st Century: Global Status Report" (2021)
5.	**Expansion of Renewable Energy**	Medium to Long-Term	Solar, wind, and hydropower will gradually replace fossil fuel-based power, but integration into the grid and storage solutions are needed for reliability.	IEA, "World Energy Investment 2020"
6.	**Green Hydrogen Production**	Medium to Long-Term	Hydrogen can serve as a clean energy carrier and fuel for heavy industries (steel, cement), and it supports deep decarbonization.	International Renewable Energy Agency (IRENA), "Green Hydrogen: A Guide to Policy Making" (2020)
7.	**Advanced Nuclear Energy**	Medium to Long-Term	Small Modular Reactors (SMRs) and other advanced nuclear reactors offer a potential clean energy source for high-demand regions in BRICS nations.	World Nuclear Association (WNA), "Small Modular Reactors" (2021)

8.	**Energy Storage Technologies**	Medium to Long-Term	Large-scale storage solutions (e.g., batteries, pumped hydro) are essential for balancing intermittent renewables like solar and wind.	National Renewable Energy Laboratory (NREL), "Energy Storage: Applications and Technologies" (2020)
9.	**Smart Grid and Digitalization of Energy Systems**	Medium to Long-Term	A smart grid optimizes energy distribution and improves the integration of renewable energy sources into the existing grid.	IEA, "Digitalization and the Future of Energy" (2021)
10.	**Electrification of Transport and Industry**	Medium to Long-Term	Shifting towards electric vehicles and electrified industrial processes will help reduce fossil fuel consumption and emissions, key for JET goals.	McKinsey and Company, "Electrification of Transport and Industry: The Path to Decarbonization" (2020)
11.	**Low Carbon Cement and Steel Production**	Medium to Long-Term	Cement and steel are significant contributors to CO_2 emissions. Developing low-carbon production technologies is crucial for industrial decarbonization.	IEA, "Technology Roadmap: Low-Carbon Transition in Industry" (2021)

Short to Medium-Term Technology Goals:

- CCUS: CCUS technologies should be implemented to capture carbon from high-emission sectors, especially fossil fuel-based power generation, where decarbonization is otherwise challenging in the short term. This would allow BRICS countries to continue utilizing existing assets while reducing emissions (IEA, 2021).
- Fluidized Bed Combustion (FBC) Reactors: FBC technologies can be immediately deployed to reduce the environmental impact of coal and biomass burning. This allows for more efficient and lower-emission energy production in the near term (WB, 2019).
- Co-firing with Gas/Biomass: Blending biomass or natural gas with coal reduces emissions and allows BRICS countries to transition while relying on their existing infrastructure (IEA, 2020).
- Energy Efficiency: Improving the energy efficiency of existing power plants, especially through modern technologies, reduces emissions in the short term and helps to maintain current energy systems (REN, 2021).

Medium to Long-Term Technology Goals:

- Renewable Energy: A strong focus on solar, wind, and hydroelectric power is critical to reduce dependence on fossil fuels. However, issues such as grid integration and energy storage need to be solved to ensure reliability (IEA, 2020).
- Green Hydrogen: Green hydrogen offers potential for decarbonizing sectors that are difficult to electrify, such as steel and heavy industry, making it an essential long-term goal (IRENA, 2020).
- Advanced Nuclear Energy: New nuclear technologies like Small Modular Reactors (SMRs) can provide reliable, clean energy while overcoming many of the risks associated with traditional large-scale nuclear plants (WNA, 2021).
- Energy Storage: Storage solutions are essential for mitigating the intermittency of renewable energy. Solutions such as large-scale batteries and pumped hydro storage are critical in ensuring grid stability as renewables become more prevalent (NREL, 2020).
- Smart Grids: Digitalizing energy infrastructure allows for efficient distribution, better demand response, and integration of renewable energy sources into the grid (IEA, 2021).
- Electrification: Electrifying sectors like transport and heavy industries will reduce carbon emissions. As renewable energy sources increase, electrification will further lower emissions (McKinsey, 2020).
- Low Carbon Cement and Steel: As two of the largest industrial sources of CO_2 emissions, decarbonizing cement and steel production will be crucial for BRICS nations' long-term climate goals (IEA, 2021).

These technological goals form part of a phased and integrated strategy that will support the Just Energy Transition for BRICS countries, allowing them to reduce emissions, enhance sustainability, and drive economic development.

CHAPTER 5: SOCIAL IMPACT OF THE JET ON THE BRICS COUNTRIES.

5.1 Introduction

This chapter outlines and assesses the social impact of "Just Energy Transition" (JET) of the BRICS member countries. A summary on the causes of global warming, human health effects of global warming, climate change impacts on labour, and a summary of the "Guidelines of Just Energy Transition of ILO, 2015." Policies on social protection, enterprise development, occupational safety and health, communication, skills, promotion of green employment, education, and training in cognisance of the "ILO Guidelines for a Just Transition" (ILO, 2022).

As previously explained, the motivation to transition from fossil fuels major contributors to large-scale CO_2 emissions to net-zero renewable energy sources stems from the urgent need to mitigate climate change. A Just Energy Transition (JET) is essential not only for environmental sustainability but also for ensuring social equity. It aims to preserve existing jobs while promoting the creation of both skilled and unskilled employment opportunities, facilitating a successful transformation of the energy mix into a more environmentally friendly ecosystem. The social impact of JET is particularly sensitive, as it evokes emotional responses during the shift toward zero carbonisation. This is especially true among workers in the fossil fuel industry, who fear losing their livelihoods and facing the potential consequences of poverty.

Job opportunities in the "green energy" sector can be created directly and indirectly along the entire value chain. The jobs in the "green energy" sector are more attractive as they have conducive working conditions in terms of health benefits and salaries which can be preferable over jobs in the conventional fossil fuel (coal-fired) power energy sector ecosystem (Hirsch et al., 2017). The flexibility and modular nature of renewable energy sources allow installations in a decentralized manner ensuring easier access of energy to the consumers. This affords sustainable economic development that would benefit much of the human population. Renewable energy power plants are mostly advantageous since it improves the air quality and promote healthier conditions for the human population compared to the conventional power plants that emits large quantities of CO_2 and other toxic gases. This saves lives and potentially millions in public health care costs (Hirsch et al., 2017). To achieve zero carbon emissions and achieve the objective of the Paris Agreement and the UN SDG's global energy transition is imperative. Environmental justice should be the enabler to unite the entire world in the context of the energy transition away from fossil fuels towards renewable energy sources (Hirsch et al., 2017). The BRICS countries, apart from South Africa, are in the top 10 list of GHG emissions (WRI, 2020); emphasising the importance and crucial role of the BRICS countries to achieve net-zero emissions by 2050 for global success (ILO, 2022). The challenge is how to

influence and unite the different approaches of justice from trade unions and the ILO. Trade unions and the ILO, rightfully insist that labour rights of development and environmental groups are respected. They rightfully further stress the importance of rapidly eradicating poverty and the importance of respecting national boundaries respectively (Hirsch et al., 2017). JET must include and ensure social dialogue worldwide and within the BRICS member countries. Effectively addressing climate change should influence exploring the social and economic opportunities of climate change, whilst reducing any negative impacts and prudently managing possible trials facing administrations globally towards endorsing JET (ILO, 2022). Education, training, communication and transparency of the transition must be carefully and sensitively managed in line with the International Labour Organisation (ILO, 2015) policy, the Paris Agreement and the Climate Vulnerable Forum (CVF). Developing a concise policy must be accelerated and enforced by an alliance of developing and developed countries, civil society, trade unions, scientists, and business (Hirsch et al., 2017).

5.2 Causes of Global Warming

GHG emissions results in global warming which in turn causes climate change. GHG was explained in Chapter 1 however it's important to re-emphasise the definition and effects. In the Earth's composition of gases there are numerous gases that are termed or referred to as "Greenhouse gases". What essentially occurs is that these greenhouse gases (GHG) permit sunlight to enter the atmosphere but unfortunately some of the sunlight or solar energy is reradiated from the surface of the earth as infrared radiation (Hirsch et al., 2017). The greenhouse gases absorb and capture the heat in the atmosphere instead of allowing the gases to leave it; meaning that instead of these gases being radiated back into space, the temperatures on earth are rising over time instead of reaching the equilibrium of zero change of temperature. The majority of these gases (carbon dioxide, methane, water vapour, sulphur and nitrous oxides) are naturally occurring but there has been an exponential increase of approximately thirty percent (30%) due to anthropogenic activities over the last hundred and fifty years (UNDP, 2016). In the last twenty to twenty-five years, the combustion of fossil fuels contributed approximately 75 % to the total volume of anthropogenic emissions, which significantly increased greenhouse gases and especially CO_2. With the Earth's gas equilibrium disturbed and unstable, Nature's carbon sinks have become overloaded and ineffective, leading to an altered CO_2 or carbon balance in general, which manifests as increasing levels of CO_2 (Hirsch et al., 2017).

As GHG concentrations increase, so the Earth's surface temperature increases. There is a significant increase in the average temperatures in the last decade and a trend of higher

temperatures over the past decades, and warmer days and heat waves are experienced globally causing heat-related illnesses to humans especially when outdoors. Global warming is causing weather pattern or climate change with reduced rainfall in some parts of the world causing droughts while in other parts, increased rainfall which results in severe flooding. The two extremes of drought and heavy rainfall are causing ecosystem pattern changes and adverse effects to human activities and life. The risk of veldfires is increasing as fires start more easily and spread more rapidly when higher temperature weather conditions persist. The temperatures in the Arctic have increased at least twice as fast as global average temperatures (Hirsch et al., 2017).

5.3 Human Health Effects of Global Warming

Global warming resulting in climate change with natural and anthropogenic health stressors, impacts human health and disease in various ways. There is scientific consensus that anthropogenic activities have sped up environmental degradation resulting in *climate change*, exhaustion of natural resources, air and water pollution, soil degradation, biodiversity harm and variations in biological streams (ILO, 2022). Global temperature increases might give rise to more heat stress, impacting negatively on productivity, as it is predicted that there will be a 2% reduction in the overall amount of operational time annually by year 2030 which would impact mostly labour in agriculture and especially developing countries (ILO, 2018). The adverse climate changes caused, and will continue to cause, negative impacts on natural and human system, including the human population's livelihoods, and on labour markets (Intergovernmental Panel on Climate Change, 2014). Current health threats will become more intensive with new threats arising from the effects of climate change; however not all human populations will be equally at risk of any form of sickness or diseases. Some of the underlining considerations include age, economic resources, and location (National Centre for Environmental Health (NCEH), 2020). Global temperature rise and precipitation are raising the health risks associated with veldfires and ground-level ozone pollution. Due to global warming, increased air and water temperatures are expected to shift exposure to waterborne and foodborne diseases, affecting food and water safety. With continued warming, extreme cold weather-related deaths are forecast to decline, and extreme hot weather conditions deaths are forecast to increase substantially. The rate and severity of allergies, hay fever as an example, are expected to increase because of shorter winters and earlier and longer pollen seasons (National Centre for Environmental Health (NCEH), 2020). Climate change is also envisaged to change the geographic range and distribution of insects and pests resulting in exposing more people to ticks and mosquitoes that carry the agents that cause diseases like Lyme disease,

Zika, West Nile and Dengue as shown in Figure 41 (National Centre for Environmental Health (NCEH), 2020).

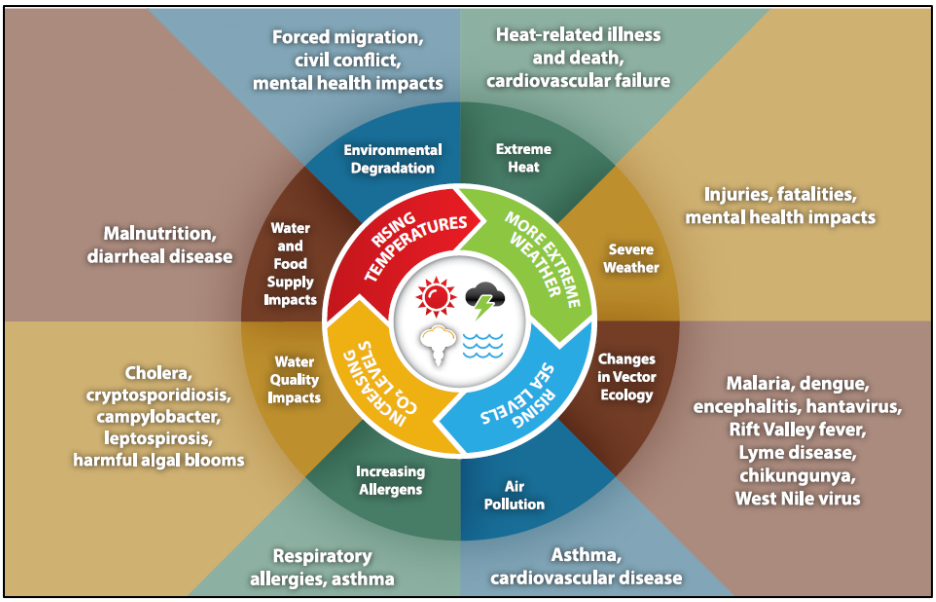


Figure 41: Impact of Climate Change on Human Health (NCEH, 2020).

Extreme weather and climate related events may subsequently have long-term mental health consequences in affected communities especially from degradation of livelihoods or community relocations (NCEH, 2020).

5.4 Climate Change Impact on Labour

There are four key factors that must be understood when assessing the correlation between the "world of work and climate change" (International Labour Organisation, 2018):

- "Directly and indirectly, ecosystems create activities which provide job opportunities and job requirements. Agriculture, fisheries, forestry, and tourism are good examples of job creation in ecosystems. Unfortunately, global warming, resulting in climate change, is a risk as well as a threat to most of these essential services (e.g., freshwater provision, biodiversity, storm protection, stock renewal), and adversely impacts economic activities, particularly jobs that rely on these ecosystems. The morale of people are negatively affected due to the economics which has a direct consequence of reduction of productivity."
- "Job activities and conducive operational environments depend on the deficiency of environmental hazards (such as storms and air pollution) and the sustainability of environmental stability (e.g., temperatures staying within a particular range and predictable precipitation patterns). Climate change, as it affects temperature and rain patterns, might

make entire regions unproductive and unbearable to conduct activities, leading to climate-induced migration, food insecurities, the proliferation of precarious and informal work and leading to an increase in unemployment rates due to weather conditions."

- "The dangers and threats linked with ecological deterioration typically disturb susceptible employees the most (mainly adult female, migrant employees, elderly individuals, persons in poverty, native and ethnic individuals, individuals with incapacities) and other susceptible clusters reliant on the geographical location, thus giving rise and continuing disparity in human rights."
- "With the tangible impacts of climate change, it is key to reflect on the influence of the application of reaction actions. Policy impacts due to climate change can exhibit mutually planned and inadvertent effects. The consequence on employment can be reflected on from four viewpoints of additional jobs that will be produced; selected occupations maybe replaced by others, selected occupations might be dropped, and the majority of occupations will be changed as a result of new industries created by the transition."

With the perspective of the labour market, environmental protection is vitally important. Human productivity has decreased due to an increase in, and the severity of natural disasters associated with anthropogenic activities. Natural catastrophes triggered or intensified by human activities developed a universal shortfall of employment time in one year equivalent to 0.8% of a year's employable time between the year 2000 and 2015 (Montt et al., 2018). Unmitigated climate change will negatively impact on working conditions, productivity and global GDP growth (Montt et al., 2018).

It is vital to effectively manage the conservation and sustainability of a healthy environment as in excess of 1.2 billion jobs globally are dependent on it (ILO, 2020). Examples such as employment in farming, fishing and forestry is dependent on environmental resources like air and water treatment, pollination, pest control, soil renewal or fertilization, remediation of life-threatening temperatures and safeguards against tempests and floods. Unfortunately, ecological ruins pose a significant risk to these ecosystem services and the job activities reliant on them (ILO, 2020). Pastoral labour, individuals in poverty, native and ethnic people of lower income countries and other susceptible classes are disturbed the most by the negative effect of climate change caused by global warming. This reiterates the urgency of JET to enable a greener economy which is not just conservation of the planet but for improvements in working conditions for labour (ILO, 2022).

It must be kept in mind that climate change has far-reaching impacts on all industrial sectors and on global GDP. Strict adherence and compliance of the Paris Climate Change Agreement with regards to more use of "renewable energy", energy efficiency and sustainable conveyance would have a positive spin-off as its projected that 24million new jobs would be created by the year 2030 if implemented globally (ILO, 2022). This would reduce the jobs in the carbon intensive energy, transport and construction sectors by approximately 6million jobs but the resultant net world-wide job growth of nearly 18million will compensate for these losses. However, there will be significant net employment gain differences between countries which prioritises the JET policies in remediating the effect of the huge sectoral, work-related and local changes that would arise (ILO, 2020).

It is clear that the JET would have different effects in different countries across the world dependant on global geographic location, administration's financial, economic, industrial, public and workforce marketplace plans. The BRICS countries are heavily dependent on fossil fuels as the main energy source as described in more detail in Chapter 2, and these countries may experience future labour market challenges (IISD, 2019). An assessment of climate change policies from 26 countries (comprising of application and improvement action) deduced that policies of nineteen (19) countries contain employment factors. Of the nineteen (19), ten (10) of the countries refer to skills, teaching and capability advancement for adaptation, eight (8) countries refer to employment formation as a goal or result of JET policies and seven (7) mention deliberate employment formation as an element of sectoral action (ILO-WESO, 2018).

The incorporation of climate change into education for almost all occupations and building the capability for adaptation strategies (cognizant of the phenomenon and its practical and structural consequences) to the re-education of specialist clusters were the other labour-related aspects that were included.
Figure 42 below depicts the breakdown of the greatest, common workforce-associated concerns in domestic climate change policies inclusive of the BRICS countries.

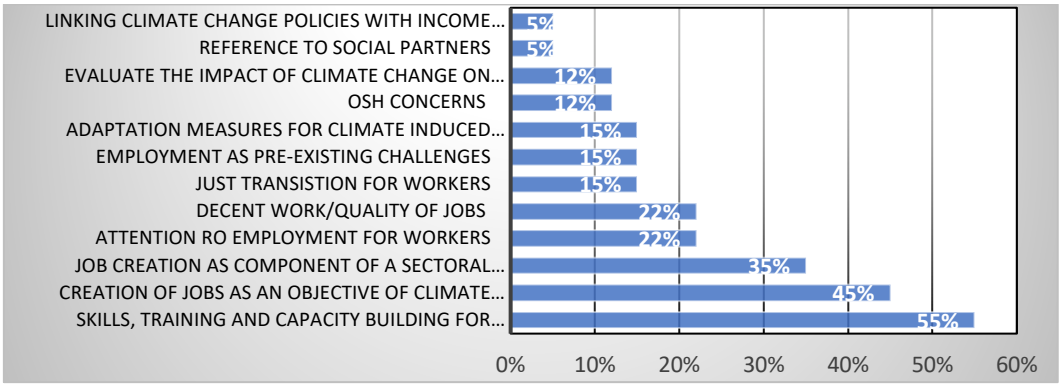


Figure 42: Breakdown of workforce Related Issues in Climate Change Policies (ILO-WESO, 2018).

5.5 Summary of the "ILO Just Transition Guidelines"

The word "Just" in "Just Energy Transition (JET)" refers to the social impact of the transition to zero carbonisation of the energy sector. The ILO compiled *"The Guidelines for a just transition towards environmentally sustainable economies and societies for all in 2015"* to equip, support and influence governments, labour and employers towards a nett-zero carbon economy (ILO, 2015). The guidelines are mutual, policy-based and hands-on instruments to assist countries globally at all stages of advancement to achieve the transition to nett-zero CO_2 emissions. In addition, they enable countries to accomplish their "Nationally Determined Contributions (NDC), National Adaptation Plans (NAP) and the 2030 SDGs. The Paris Climate Change Agreement correspondingly accepted the ILO, 2015 guidelines as an important enabler of JET (UNFCCC, 2015). The "Just Transition Guidelines" consists of nine (9) policy areas that must be addressed, which encompass environmental, economic and social sustainability. These nine (9) policy areas or factors were developed centred around a three-way agreement at the "International Labour Conference, 2013" as follows (ILO, 2020):

- "Macroeconomic and growth policies."
- "Industrial and sectoral policies."
- "Enterprise policies."
- "Skills development."
- "Occupational safety and health."
- "Social protection."
- "Active labour market policies."
- "Rights."
- "Social dialogue and tripartism."

5.6 Social Impacts of Just Energy Transition (JET) on BRICS Countries

The ILO collaborates through the "Green Jobs Assessment Institution Network (GJAIN)" to evaluate and demonstrate the occupation impacts of environmental policies (ILO, 2022). From the collaborative assessment, the general trend of the BRICS countries are summarised with an overview of economic growth (GDP), employment efficiency, returns and employment, work-related health, and safety for individual countries. The following are typical developments to consider in the BRICS countries:

- "The part of employment dependent on ecosystem services varies widely across the BRICS countries with Brazil (23%), Russian Federation (14%), India (52%), China (50%), South Africa (11%), respectively (ILO-EICCA, 2018). These ecosystems are specially in peril to climate change which include agriculture, forestry, fishing, food, drink and tobacco, wood and paper, biofuels and renewable energy sources, the pharmaceutical and chemical industries and environment connected tourism."
- "The rising rate and potency of various environmental hazards caused or aggravated by anthropogenic activities have already decreased labour productivity. Between the years 2000 and 2015, 23million working life years were lost annually at the global level because of these environmental hazards. Amongst the BRICS countries, China, Brazil, and India were the most affected countries, with 8.7, 3.2 and 1.5 working-life years lost per person per year during the year 2008 to year 2015 respectively (ILO-EICCA, 2018)."
- "Adaptation infrastructure investment will have a positive impact on employment due to the increased demand for construction work in projects to decrease climate associated risks. The amalgamated direct, indirect and induced employment impacts of adaptation infrastructure investment differ between countries. For every 1million US$ invested in the construction sector, approximately 650 jobs are anticipated to be created in India, 200 in China, 160 in Brazil, 120 in the Russia and 100 in SA (ILO-EICCA, 2018). An additional and important indirect impact of investment in climate resilient infrastructure is that it protects millions of livelihoods by reducing the negative impact of climate change associated events."
- "BRICS countries contribute approximately 40% of global GHG emissions, more than 40% of the global population and approximately 30% of the land mass globally. The BRICS countries are experiencing several environmental and resource consumption challenges, which have become apparent from the rapid development of globalization and urbanization (Tian et al., 2020). While energy transition is central, just transition and decarbonisation are not only an energy issue. It has far-reaching implications of environmental sustainability and ultimate preservation of the planet. In addition to energy, agriculture,

forestry, ecotourism, transport, formalization and economic diversification could be just a few additional examples of relevance to the BRICS group (ILO, 2020)."

The JET concept refers to a transformative shift towards sustainable energy systems, which seeks to balance environmental goals with the socio-economic needs of communities, particularly in emerging economies. The BRICS nations (Brazil, Russia, India, China, and South Africa) are at the forefront of this transition, navigating the dual challenges of promoting low-carbon energy while addressing social inequality and economic development. The JET emphasizes inclusivity, aiming to ensure that the shift to renewable energy does not disproportionately impact marginalized populations. It advocates for the creation of green jobs, the protection of workers in fossil fuel sectors, and the development of social safety nets for communities that may be adversely affected by the transition (Sustainable Development Solutions Network, 2020). In the context of BRICS countries, this transition has profound implications for energy access, job creation, and poverty reduction. For example, South Africa's approach to JET includes measures to support workers in the coal industry, as the country pivots towards cleaner energy (Theron et al., 2020).

The social impact of JET in BRICS countries can be seen as both opportunities and challenges. On one hand, it holds the potential to reduce energy poverty, especially in rural areas, by improving access to renewable energy sources such as solar and wind power. India, for instance, is investing heavily in solar energy to meet its growing energy demands while creating jobs in the renewables sector (Ministry of New and Renewable Energy, 2021). On the other hand, there are significant concerns about the displacement of workers in traditional energy sectors and the risk of exacerbating existing inequalities. The implementation of JET must therefore ensure that vulnerable populations, such as those in coal-dependent regions, are supported through education, retraining, and job placement programs. Achieving a successful and equitable energy transition in BRICS countries is critical not only for reducing global emissions but also for ensuring that the social fabric is preserved as economies modernize (International Labour Organization, 2021).

5.6.1 Brazil

Brazil has approximately 60% of the Amazon Rainforest, which is the biggest tropical forest globally, including 15 to 20% of the World's biodiversity (UNEP, 2019). The country, despite having elevated numbers of renewable energy in its energy mix for electricity generation, remains extremely prone to climate hazards and deforestation (WB-Brazil, 2021). Change in land usage, essentially deforestation, is responsible for 46% of GHG production in Brazil,

followed by agriculture (24%) and the energy segment (21%) (Mendonça et al., 2020). It is forecast that the mean yearly fiscal losses because of climate change, will be between 0.4 to 1.8% of Brazil's GDP towards the close of the century especially due to climate threatened areas, like agriculture (Souza, 2021). In the year 2017, the agriculture sector was 23.5% of the country's GDP. The area is also responsible for 38.5 %of the total countrywide exportations, positioning Brazil as the globe's third major provider of agronomic supplies (soybeans, sugar, and beef) (OECD-Brazil, 2018). It is estimated that approximately 7.1million employment opportunities could be produced as a result of the Brazilian decarbonisation process. It is envisaged that a vast number of jobs created in the plant-based agriculture sector will be sufficient to balance employment reduction in the livestock and fossil fuel segments combined (ILO & IDB, 2020).

5.6.2 Russia

Climate change has started to impact the country in numerous ways: *"as ongoing warming at a rate more than two and a half times the average rate of global warming"* as indicated in the country's "Nationally Determined Contribution (NDC)" tendered to the UNFCCC (NDC-Russian Federation, 2020). The climate change impacts currently experienced by Russia are reflected in the country's energy, agriculture, and societal pressures. Russia has less severe winters, changing precipitation patterns, melting permafrost, increase in the transmission of diseases and rise in occurrences of drought, flooding, and other severe climate events (Piliero et al., 2020). Severe floods (like the Siberia 2020 floods which ruined whole settlements and displaced large numbers of inhabitants) and droughts have been experienced in the country's fertile southern agricultural areas of Stavropol and Rostov (Conley et al., 2021). The consequence of this environmental damage (floods and droughts) from climate change is affecting, and would further negatively impact, food sources and adversely affect the future of Russian food (wheat) exports (Conley et al., 2021). Climate change will result in direct and indirect impacts in the majority of Russia's economic sectors. Natural climate (rainfall) dependent industry, agriculture and forestry, water supply systems, buildings and engineering construction, transportation and framing in the permafrost regions are extremely susceptible to climate change (Anisimov et al., 2008).

The UNFCCC-Paris Agreement global commitments render a harsh blow to the Russian economy as it has been dependent on exports of oil, coal and gas. As the global need for these fuel sources diminish, the prices of these commodities will fall drastically, pushing the Russian economy into recession (Gustafson, 2017). Economy and energy mix diversification could remain a viable blend to reduce the impact on the economy from an ecological transition.

Russia's commitment to increase the use of renewable energy for power generation will also benefit the country in reaching carbon emissions neutrality (Gustafson, 2017). The key opportunity for Russia is to be more energy-efficient and to foster decarbonisation; knowing that amongst the BRICS countries, it's energy usage per head stays considerably greater than the rest of the BRICS member countries (twice as big as the second greatest energy-concentrated nation, China) (Ritchie et al., 2017). Russia is in a severely challenging situation with the Russia-Ukraine war in progress as well as the challenge of growing worldwide condemnation, increasing technical seclusion and economic limitations (Ritchie et al., 2017). The risk and hazard of thawing permafrost and permafrost degradation might prove most challenging of all the climate change effects in the Arctic zone: the social consequences of climate change imposed on the indigenous minorities in the Arctic region, who adapted to surviving in the adverse ecological circumstances that the Arctic experiences (Ritchie et al., 2017).

5.6.3 India

In chapter 3, it was discussed that India is ranked third globally in terms of energy consumption. Energy utilisation has doubled since year 2000, with 80% of electricity production from fossil fuel (coal, oil and solid biomass) due to improving standards of living (IEA, 2021). A vast majority of the Indian population resides in countryside regions on small farms with limited or no access to electricity (Macroeconomic Outlook Report: India, 2023). The envisaged climate change consequences of pollution and drought intensify the weather extremes in the country. The heightened danger of drought and rising volumes of precipitation during the monsoon season is ruining income streams in India. This could potentially destroy agricultural crops that the rural farmers rely on for their consumption and financial support (IEA, 2021. The forecast annual temperature increase is mostly anticipated in the northern regions of India and projected to rise at a higher rate than Indian countrywide mean temperatures. In the absence of adaptation measures, heavy rainfall could result in rivers overflowing, causing floods that could adversely affect 13 to 34million of the population by the year 2040, and coastal flooding is likely to distress a further 5 to 18million of the population by the year 2070 to close of the century (WBG-India, 2021). Urgent remedial or contingency plans are required for the reorganisation of key agricultural processes and transformative funds, taking into account crop variety alterations so that there will be a sustainable supply of staple crops.

The country's GHG production is predominantly produced by the energy segment being 75%, trailed by agriculture being 14%, industrial procedures and product usage being 8% and waste producing 3% (MEFCC-India, 2021). This further emphasises that resource management and

energy efficiency is vital. Substantial deployment of renewable energy with enhancing energy security, inexpensive means to modern energy, and varying energy resources are the s of responsibility required from the country's electricity segment in order to effectively mitigate climate change (MEFCC-India, 2021).

5.6.4 China

China is currently the world's major producer and consumer of raw materials; materials that it is using to not only restrict or reduce CO2 emissions and conserve electricity more efficiently but attempt to aggressively stimulate and sustain economic growth (Bloomberg, 2021). China is also rigorously attempting to decontaminate the oil-purifying industry, enhance mine safety and have stopped global fossil fuel-related funding. Therefore, few of these policies are reducing the delivery of goods and escalating charges, resulting in higher inflation. The impact on the local industry is impacting on commodities marketplaces. Iron ore costs have declined as steel manufacture is curtailed, coal has risen, whereas energy-demanding aluminium production has increased to a 10-year high despite the power reduction crusade (Bloomberg, 2021).

Climate change in China is noticeable with extreme weather effects across various sectors of the country's economy. Projected direct economic losses due to adverse weather conditions, burdens China's economy by between 1 to 3% of GDP annually (Sall, 2013). China has experienced more extreme events (floods, droughts, storms) in recent years than ever before. The direct economic losses of $25 to $37.5billion in China per year is due to extreme weather events (DNI, 2009). Although climate change impacts will differ over the majority of China, nonetheless all regions will be prone to future climate change-related risks in energy, transport, manufacturing industries, agriculture, tourism, livelihoods, and public health (Jiana et al., 2021). Shortages of water resources, rapidly growing urbanisation and industrialisation, water pollution, reduced water prices, and the impacts of climate change on water sources could result in a future water crisis in China (Jiana et al., 2021). Owing to the country's flat and low landscape, China's coastal regions, the pillar of China's economy, are highly vulnerable to storm, flood, and sea-level rise. The rate and intensity of extreme weather conditions, for example typhoons, is a risk to economic development at local, regional, and national levels. The development of early warning systems and related monitoring systems and enhancement of the design standards of sea dikes and port docks has been instituted in China. This development is expected to absorb and reduce some of the risks of environmental or weather events. An in-depth study of the socio-economic effects of climate change in China illustrates

immense multi-disciplinary collaboration between climate adaption, poverty alleviation and nature-based solutions to remediate most of the climate change related challenges (ILO, 2022).

The objective of "Just Energy Transition" in China is to move from coal-based energy to renewable sources whilst ensuring justice for impacted societies with profound social implications (Cheng et al., 2023). As the world's largest emitter of GHG's, China is in the spotlight to offset environmental ambitions with social stability (Bloomberg, 2021). The change encompasses substantial adjustments in employment configurations, predominantly in coal-reliant territories, where labour may experience job losses or require retraining for jobs in the green energy segment (Bloomberg, 2021). This shift could aggravate social discrimination if it is not managed effectively, as certain groups may struggle to adapt to the new economy. Additionally, the change offers prospects for rural areas to benefit from clean energy projects, creating jobs and accelerating regional economies. However, guaranteeing that the advantages are consistently dispersed through the country, incorporating fewer established areas, is necessary for sustaining social consistency and evading turmoil. A "just" transition, therefore, involves not only the adoption of sustainable energy but also measures to support affected communities through education, retraining, and social protection programs, helping them to thrive in a green economy (Cheng et al., 2023).

5.6.5 South Africa

South Africa has historically had a warmer climate with moderate rainfall averages. Global warming and climate change is also observed with higher temperatures and a decline in rainfall which would reduce water resources (Chersich et al., 2019) and cause an increase in more severe droughts in the country. Extreme weather events are the most noticeable effects to date, especially the drought in the Western Cape and ensuing wildfires but rises in vector- and waterborne diseases are also gaining prominence (Chersich et al., 2019). The droughts and veldfires in the Western Cape province and the severe flooding in Durban, in Kwa Zulu Natal province, are the most noticeable effects of climate change, however the rest of the country is not immune and will feel the effects in future. Cognisant that the country is dependent on the sectors of agriculture and forestry which is quite climate reliant, food security would be under enormous risk leading to reduced yields of crops and possible loss and decline in livestock (Mugambiwa et al., 2017).

Access to food supplies would be further adversely impacted by the contry's declining economy due to climate change which is largely contingent on affordability (Masipa, 2017).

Although South Africa is not in the top 10 of highest-emitting countries, it is however the second highest producer of CO_2 emissions per capita in the BRICS member countries (after Russia, before China) (GCRI, 2023). It has been predicted by year 2030, that the impact of climate change will lead to a reduction of 3,000 jobs in the chemicals and chemical products subsectors in the country with an additional 11,400 job losses, due to changes in international trade due to non-compliance to the Paris Agreement (WWF, 2019). This could develop into opportunities in the advancement of certain chemical products utilised to manage climate change. This new industry development and chemical plants could lead to employment opportunities. It's anticipated that these enterprises could offer and create 650 jobs and together with adaptation interventions, 3,825 new jobs (WWF, 2019). For South Africa to reach emissions target, it will be imperative to avoid building fossil fuel power generation plants. The JET to zero CO_2 emissions, involves use of renewable energy power plants, activity in the lower carbon supply chain and considerably less activity in the coal mining sector (WWF, 2019).

5.7 Green Labour Employment

In point 5.5 of this chapter and chapter 3, the "ILO Guidelines for a Just Transition" and BRICS countries NDCs' were discussed respectively. The country's NDC provides the pledges and commitments to the UNFCCC to combat climate change but more measures need to be addressed in line with ILO, 2015 *"Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies."* The nine (9) ILO, 2015 guideline policy areas of macroeconomic and growth policies, industrial and sectoral policies, enterprise policies, skills development, occupational safety and health, social protection, active labour market policies, rights, and social dialogue and tripartism must be implemented in an integrated, systematic way. The guidelines' purpose is to support governments, labour and organisations and to simplify what needs to be done by them across the globe (ILO, 2022). Since the guidelines are fairly generic, governments are encouraged to prioritise, consider and implement the relevant standards of labour and appropriate regulations for their Just Transition framework with the relevant engagements with labour and stakeholder in their respective countries. The ILO guideline is also intended to encourage public investments as a special purpose vehicle for s greener economy. Public investments can contribute to developing infrastructure to restore and preserve natural resources with built-in resilience to decrease the risk of redeployment of people and organisations with the minimal environmental and social impacts. Special emphasis must be on promoting environmentally sustainable goods and services and the inclusion of Micro, Small and Medium Enterprises (MSME's) and vulnerable groups in the transition (ILO, 2022).

5.7.1 Enterprise Development and Support

The ILO, 2015 guidelines encourage enterprise-level support for greening businesses, public procurement, and investments. Financial incentives by governments are a perfect example and encouragement for businesses embracing environmentally friendly practices. This includes, however is not limited to, energy-saving and efficiency measures and measures targeted at clean sources of energy in synergy with economic and social sustainability (ILO, 2015). The ILO, 2015 guidelines emphasise "Micro, Small and Medium Enterprises" (MSME) development and resilience. The guidelines reiterate that governments can expedite these through national planning, policymaking, coordinating agendas with line ministries, improving access to labour market data, creating, supporting or implementing programmes, and promoting social interaction. It is critical that governments and social partners provide technical support, tools to establish environmental and legislative compliance management processes and systems. This would aid MSME's to transition to new activities, sectors, or markets. The ILO, 2015 Guidelines also motivate governments to play a role to support entrepreneurs in expediting the transition.

5.7.2 ILO Recommendations with Green Labour

The ILO recommends that governments and social partners direct awareness and education campaigns to promote a culture of eco-entrepreneurship, provide technical support, encourage peer learning among enterprises and labour. Education and training in JET and entrepreneurship in greening the economy to disseminate sustainable practices and the utilisation of green technologies (ILO, 2015).

5.7.2.1 South Africa's Just Energy Mitigation to ILO Recommendations

South Africa's Just Energy Transition (JET) policy's goal is to transition the country from coal-dependent energy to renewable sources while addressing the social and economic impacts on communities, particularly those reliant on coal mining and power generation. Several key policies and programs have been implemented to assist these communities:

- Just Energy Transition Partnership (JETP): This partnership between South Africa and international partners, such as the United States, the United Kingdom, France, and the European Union, provides financial support for the country's energy transition. It includes funding to help coal-dependent regions diversify their economies, create new jobs in the renewable energy sector, and support workers with retraining and reskilling opportunities.

- The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP): This initiative is aimed at accelerating the development of renewable energy projects across the country. The REIPPPP includes community development requirements, ensuring that local community's benefit through job creation, skills development, and local enterprise opportunities. Some projects also incorporate community trust funds to improve local infrastructure and education.

- The Integrated Resource Plan (IRP) 2019: South Africa's IRP outlines the country's energy mix for the coming decades, with a strong emphasis on renewable energy. It includes a focus on minimizing the social impacts of the transition by planning for the phased closure of coal plants and investing in the regeneration of local economies through green jobs.

- Social and Labour Plans (SLPs): These plans are a mandatory part of South African mining regulations, requiring mining companies to contribute to the welfare of the communities around mining operations. As coal mines begin to close in the face of the energy transition, these plans ensure that communities receive support in the form of education, healthcare, and alternative employment opportunities.

- The Climate Change Bill and Green Economy Initiatives: South Africa's government has also developed policies to foster a green economy that can help displaced workers and communities transition into renewable energy jobs. These initiatives provide technical training, support for small businesses in the green economy, and focus on creating a sustainable and inclusive future for affected areas.

- Through these policies and programs, South Africa is working to ensure that its energy transition is not only environmentally sustainable but also equitable, supporting vulnerable communities through financial assistance, skills development, and economic diversification.

5.7.2.2 Brazil's Just Energy Mitigation to ILO Recommendations

Brazil has an integrated labour market planning policy into the energy transition strategy, concentrating on occupational education, youth presence, and green job creation. The implementation would be through programs like SENAI (National Service for Industrial Training), Brazil is upskilling people for renewable energy sectors and advocating local employment centres (International Labour Organisation (ILO), 2023)

5.7.2.3 Russia's Just Energy Mitigation to ILO Recommendations

The Russian policy of Workforce 4.0 Strategy highlights technical training, specialist retraining, and employer commitment in programme design. The government is joining forces with Rosatom Corporate Academy (RCA) and other associations to align energy sector requirements with labour market improvements (International Labour Organisation (ILO), 2023).

5.7.2.4 Indian Just Energy Mitigation to ILO Recommendations

Policies that India is focusing on is the Digital Skilling, STEM education, and Green Entrepreneurship, with a focus on rural and informal workers. The initiation will use Skill India and National Electricity Plan (NEP) for retraining coal associated employees and increasing renewable energy employment (International Labour Organisation (ILO), 2023).

5.7.2.5 China's Just Energy Mitigation to ILO Recommendations

Policies that China is implementing is China's Five-Year plan which includes the Modern Energy System strategy with targets for energy education, occupational training, and gender inclusion. The implementation would be through institutions similar to China's Renewable Energy Engineering Institute (CREEI) and China University of Petroleum which are leading curriculum developments and education schedules (Energy Transition Skills Report 2023; ILO, 2023).

5.7.2.6 Summary of BRICS Countries to ILO Recommendations

While all BRICS countries have acknowledged the importance of aligning energy transition with labour market reforms, South Africa stands out for its comprehensive approach. India and Brazil are achieving success via focused education programs. However, Russia and China face challenges in integrating social negotiation and comprehensive labour policies.

5.7.3 Skills for green jobs and public employment programmes

It is imperative in the JET, to pay attention to employment requirements transitioning into renewable energy and the greener economy - training, education to skill or to reskill existing and future labour force (ILO, 2019). It is a myth to think that new and emerging green jobs are more scarce and tend to emerge at higher skill levels and this is where it's essential to educate (through formal or informal training and education in educational institutions) all stakeholders as this could cause immense resistance to transform and embrace JET at a lower skill levels.

However, low skilled jobs tend to require less adaptation to greener work processes that requires more change in the work environment (example, artisans) (ILO, 2019). There is a need or demand for technical (example, engineering and construction), core or soft skills (examples, entrepreneurship, networking, marketing, innovation, analytical thinking, management, etc.) to understand and adopt the JET at a basic level. Countries should be cognisant of the importance of making provision to fund training and education schemes for greener jobs. It's unfortunate that progress is extremely slow in promoting education and training towards JET according to the following ILO reports:

- "World Employment and Social Outlook Trends, 2024."
- "Quality Apprenticeships Recommendation, 2023
- "Aligning Skills Development and National Social Protection Systems, 2023

The ILO, 2015 guidelines encourage public employment programmes particularly in 'green works' employment programmes. Green Works refers to the employment intensive development, restoration and maintenance of public infrastructure, community assets, natural areas and landscapes to contribute to environmental goals such as adaptation to climate change and natural disasters, environmental rehabilitation, ecosystem restoration and nature conservation (ILO, 2019). Soil, water conservation, afforestation, reforestation, irrigation, and flood protection are examples of green works.

Fortunately, BRICS countries have the green works programmes in place and theses will be monitored and improved as they progress. The green works programmes for the BRICS countries with the objective to manage climate change, reinstate ecosystems, and establish sustainable jobs. The following shows significant initiatives per country, illustrating how each is contributing to a greener future:

- Brazil: Green Resilient Model Cities Program with the focus on urban climate resilience and low-carbon development. It was initiated by Brazil's Ministry of Environment, which supports 50 cities in implementing climate actions like electrifying bus fleets and restoring urban green spaces. The clear goal is synchronised with local climate action with national targets and COP30 commitments (Lynch et al., 2010).
- Russia: Clover Green Building Assessment System which aims for sustainable construction and energy-efficient infrastructure developed with support from VEB RF. This system evaluates buildings for environmental performance and promotes green materials and technologies to transition to low-carbon urban development and decrease in emissions in the built environment (Sokolov, 2016).

- India: Green India Mission (GIM) with the goal of forest rejuvenation and ecosystem services. Part of India's National Action Plan on climate change, GIM aspires to reforest 5 million hectares and improve forest quality on additional 5 million hectares of land. The aim is to restore carbon sinks and support jobs of forest-dependent communities (Umajyothi et al., 2024).
- China: Grain for Green Program is geared to reforestation and land restoration which is one of the world's biggest ecosystem renewal initiatives, converting degraded farmland into forests and grasslands. The success achieved is approximately 28 million hectares of forest restored since year 1999. Reduction in soil erosion, sequestering carbon, and improving rural livelihoods is an absolute necessity (Delang et al., 2015)
- South Africa: Environmental Protection and Infrastructure Programme (EPIP) focuses on job creation through environmental restoration. EPIP employs thousands of workers through Expanded Public Works Programme (EPWP) principles, focusing on waste management, greening, and eco-infrastructure. The object of the project is to alleviate poverty while enhancing environmental sustainability (Ngandu et al., 2019).

Social protection plans could also be a useful instrument to protect populations that are prone to greater risk of climate-related hazards. Social protection systems that are engineered or designed can serve as a significant relief and restoration in the event the country faces extreme weather conditions (storms, droughts and floods), which are increasing globally. These social protection plans would aid to offset losses of income or assets that could endanger people's livelihoods and wider economic activity. The advantages of the social protection plans are that it would make of workers more resilient and provide income support and unemployment benefits during periods of transition from one job to another (ILO, 2019).

5.8 Developed countries versus BRICS countries JET adaptation related to Social Impact

Developed countries' social impact is at the core of JET strategies. The European Green Deal (EGD) includes measures to ensure that the transition to clean energy is comprehensive and that regions heavily reliant on coal and other fossil fuels are supported through the Just Transition Mechanism (JTM) (European Commission, 2019). In the U.S., Germany, and the U.K., there are detailed re-education programs for labour transitioning from fossil fuel industries to green jobs, such as renewable energy and energy efficiency sectors (ILO, 2021).

In BRICS countries, social equity policies are less developed than developed counties. While South Africa has advanced agendas for social impact through the Just Energy Transition

Partnership (JETP), other BRICS countries such as India and Brazil face challenges in ensuring that communities and workers affected by JET are sufficiently supported (ILO, 2021). Social consultations and inclusion of disregarded communities are frequently reactive rather than proactive in BRICS countries (ILO, 2021).

5.9 Conclusion

JET social impact programs in the BRICS countries present effective learnings to balance the transformation to sustainable energy with social justice and financial growth. Individual member country has undertaken distinct methodologies, bearing a selection of experiences and awareness. By analysing the achievements in each BRICS country, South Africa can recognize essential approaches to successfully execute its own JET initiatives.

Brazil has unified JET doctrines within its broader climate change and energy policies. The country's JET attempts mainly concentrate on the growth of clean energy technologies, such as wind and solar power, while encouraging rural development. The region of Ceara in the northeastern part of Brazil has been a pioneer in integrating renewable energy with socio-economic growth. The region saw an expansion in local job creation in the wind sector, and attention on education courses has been fundamental in preparing workforce for new energy sectors (Lima et al., 2020). Brazil has similarly concentrated on energy access in rural and remote parts of the country. This aided in the reduction of energy deficiency and provided new prospects for marginalized communities. For South Africa, Brazil's emphasis on local renewable energy centres and identified job creation could assist as a blueprint for leveraging the country's existing district inconsistencies for fair energy transition results.

Russia's JET approach has been more cautious, reflecting the country's dependence on fossil fuels, particularly oil and natural gas. However, the government has started to focus on modernizing its energy infrastructure, particularly through natural gas and nuclear energy, to reduce carbon emissions. Russia has emphasized the importance of integrating green technologies without disrupting the livelihoods of those employed in the fossil fuel industry. The creation of retraining programs for workers and promoting the development of new industries in regions reliant on coal and oil provides lessons on balancing job protection with environmental transition goals (Nikiforov, 2021). For South Africa, the key takeaway from Russia's approach is the importance of a gradual and adaptive transition strategy, especially in regions with high fossil fuel dependency like Mpumalanga, where coal mining is a dominant industry.

India’s strategy to JET has focused on the extensive development of renewable energy, specifically solar and wind energy. India’s solar parks, especially in Gujarat and Rajasthan, have generated thousands of new jobs, offering training and employment prospects to local communities. The country has also initiated explicit policies to assist labour moving from conventional energy sectors, such as coal, into renewable energy sectors (Rao & Ranganathan, 2021). India has made considerable advancement in ensuring that its energy transition is comprehensive, with precise emphasis on enabling women and disregarded factions in the renewable energy sector. South Africa can draw knowledge from India’s large-scale renewable energy projects and its capability to incorporate social policies, such as gender inclusion and rural empowerment, into the wider energy evolution.

China has been an international leader in the renewable energy sector, both in terms of manufacturing and deployment. The country has invested heavily in wind, solar, and electric vehicle (EV) technologies, which has created millions of jobs. China has also prioritized the development of green industries in areas traditionally reliant on fossil fuels, such as coal. A significant part of China's approach to JET has been government-led initiatives to retrain workers, while also ensuring energy access in less-developed regions (Zhao, 2020). South Africa can learn from China’s strong state intervention in driving both economic and social goals simultaneously. China’s ability to establish large-scale infrastructure projects while simultaneously fostering job creation and social equity could guide South Africa’s execution of more elaborate green policies with direct socio-economic advantages for susceptible groups.

South Africa started to recognise the essential requirement for JET, especially due to its heavy reliance on coal for electricity production. The authorities have committed to decreasing carbon emissions and moving towards renewable energy sources. South Africa’s JET efforts, such as the Just Energy Transition Partnership (JETP) signed at COP26, intention to encourage and invite financial and technical support from intercontinental allies to change to clean energy whilst creating green employment and curtailing the effect on coal-dependent communities (International Institute for Environment and Development, 2021). However, South Africa’s challenge remains the social impact of this transition, particularly in areas like Mpumalanga, where a significant portion of the population is employed in the coal industry. Addressing the needs of these communities through retraining programs, as well as guaranteeing that energy access for marginalized populations is maintained, is crucial.

Salient Points for South Africa**:**

- Localized Solutions for Job Creation: The BRICS countries, particularly Brazil and India, have emphasized regional energy hubs and localized training programs as effective strategies for integrating JET. South Africa can adapt this model to create localized renewable energy industries, particularly in areas like the Western Cape and Eastern Cape provinces, that could serve as new job centres.
- Gradual Transition with Workforce Protection: Russia's model shows the importance of a gradual transition to clean energy, alongside protection for workers who may lose their jobs in the fossil fuel industry. South Africa could enhance its policy on retraining workers and ensuring adequate social safety nets for those affected by the transition.
- Government-Led Initiatives with Broad Social Inclusion: China's top-down, government-led approach to JET, combined with its large-scale renewable energy investments, offers a clear example of how a state can drive both infrastructure development and social equity simultaneously. South Africa should consider stronger state intervention to create green industries and ensure the transition benefits marginalized communities.
- Gender and Social Inclusion: India's integration of gender and social equity within its energy transition offers important lessons. South Africa's JET policies should not only focus on job creation but also on empowering marginalized groups, including women, youth, and rural communities, in the renewable energy sector.

It was concluded that communication, education, and training would contribute to effectively manage any perceived negative social impacts and concerns on JET initiatives in South Africa in accordance with ILO, 2015 imperatives. The resultant would be a net global job increase of approximately 18million despite a reduction of jobs in the carbon intensive energy, transport, and construction sectors by approximately 6million jobs. The large net job gain reemphasises that JET policies are vital in remediating the impact of the large sectoral, occupational, national and regional changes that would occur (ILO, 2020). This would encourage the transformation towards a JET synergistically with social justice and job creation opportunities in BRICS, globally and including South Africa.

5.9.1 Response to Research Question

In response to the research question "Will unemployment rates increase due to the impacts of JET?"

The transition from coal and other fossil fuels may lead to job losses in traditional energy sectors. The African Climate Foundation notes that this shift could exacerbate South Africa's already high official unemployment rate of 32.9%, with some estimates suggesting a real

unemployment rate closer to 42.5%. For instance, in the first quarter of 2023, Mpumalanga province experienced a 2.4% increase in unemployment, equating to approximately 45,000 job losses, partly attributed to changes in the coal value chain (ACF, 2023).

In response to second part of the research question on the social impact of JET, "*How will South Africa manage and reduce the negative social impacts?"*

To manage and reduce the negative social impacts, several strategies have been proposed as discussed in the chapter:

- Support for Micro, Small and Medium Enterprises (MSME's) and vulnerable groups in the transition (ILO, 2022). Encouraging MSME's, specifically in townships, can create jobs and promote economic growth. This requires eliminating regulatory barriers, reducing entry barriers, and providing financial access to industrialists. In addition, advancing private sector partnerships with emerging community businesses can combine them into comprehensive supply chains (ILO, 2022).
- Social protection programs to improve social safety nets, such as unemployment benefits and funding, can soften the effect of job losses during the transition (AFD, 2023).
- Investment in green skills and education in developing skills relevant to the green economy can prepare the workforce for emerging job opportunities. Educating young and even older workforce on sustainability and environmental protection, equipping them for future green jobs (JET IP, 2023).
- Inclusive policy development to ensure that policies are inclusive and considerate of the socio-economic challenges faced by communities is crucial. The JET process in South Africa has benefited from wide consultations, including labour, academia, youth, and affected communities, to align the transition with social and political imperatives (JET IP, 2023).

By implementing these strategies, South Africa can manage the social impacts of the energy transition, striving for a balance between environmental sustainability and socio-economic well-being.

CHAPTER 6: JET FUNDING INITIATIVES

6.1 Introduction

This chapter provides an overview of key financial frameworks and initiatives related to sustainable development, focusing on green funding, sustainable financing, and the alignment of financial strategies with the Paris Agreement. It covers significant topics such as the concept of "The Vulnerable 20," the "Just Energy Transition Partnership," and the "Global Stocktake." The chapter highlights how these efforts support the Just Energy Transition (JET), in accordance with Article 2.1(c) of the Paris Agreement, the Sustainable Development Goals (SDGs) of 2015, and the Addis Ababa Agenda 2030 on Financing for Development.

The UN proposed that countries should work together on integrating sustainability into global trade, development, and finance systems (WCED, 1987). The multilateral commitments of 2015 re-emphasise the centrality of the financial system in responding to the sustainability and climate breakdown. Specifically, the Addis Agenda promotes “cohesive nationally owned sustainable development strategies, supported by integrated national financing frameworks” as the paramount aspect of member states endeavours to finance sustainable development. The “Addis Ababa Agenda 2030” gives prominence to integrating and creating coherent and supportive trade, finance, monetary and economic systems to deliver on the SDGs (UN, 2015a); therefore, it is imperative to have financial structures in place to ensure the drive towards decarbonisation of the electricity generation sector is achieved and aligned to the “UNFCCC-Paris Climate Change Agreement”. Article 2.1(c) of the Paris Agreement was not included into formal financial negotiations and discussions, and this has resulted in ambiguous interpretations and applications of the article particularly during informal discussions since year 2015 (Whitley et al., 2018). The UNFCCC’s “Standing Committee on Finance” (SCF) in its year 2020 "Biennial Assessment Technical Report” (BATR) enforced a framing for mapping actions relevant to Article 2.1(c) as follows (Naidoo et al., 2023):

- “Actions: What voluntary or mandatory actions ‘make finance flows consistent’?”
- “Object: What finance flows are impacted as a result of such actions?”
- “Effects: Do such actions to make different finance flows consistent have particular effects, especially in support of Articles 2.1(a) and 2.1(b)? Are such effects consistent?”
- “Goal: What is the goal of the actions, and are the actions consistent in light of such a goal?”

At the COP27 (27th Conference of the Parties) in year 2022 held in Egypt, parties agreed to advance work on Article 2.1(c). The GST was inaugurated under Article 14 of the Paris

Agreement, to systematically *"assess the collective progress towards realising the intention of the Paris Agreement and its long-term goals"* (UN, 2015). ""Global Stocktake" (GST) is the formal process established under the Paris Agreement to systematically, take stock of cumulative progress toward its long-term goals. The "Finance Working Group" (FWG) of the "Independent Global Stocktake" (iGST) is an open joint venture assembling a range of expert perspectives from the global north and south on the advancements made towards financing climate action, and is co-chaired by Charlene Watson and Raju Pandit Chhetri of the Prakriti Resources Centre. The FWG's goal is to support the official UNFCCC's GST process and is coordinated encompassing two reciprocal themes, *"the provision of support to developing countries to alleviate and adapt to climate change and the consistency of finance flows with low-emission, climate-resilient development"*, as defined in Article 2.1(c) of the Paris Climate Change Agreement (Athanasiou et al., 2022).

6.2 Green Funding

Green funding or finance is a loan or investment that supports environmentally conducive activity. An example could be purchasing environmentally friendly goods and services, or building environmentally friendly infrastructure. This form of financing comprises of any financial instruments, whose revenue are directed towards environmentally related initiatives and more precisely structured for decarbonisation objectives (Wire, 2021).

It is recognised that it's a challenge for governments, organisations and individuals and it's the objective of green finance to close this disparity by offering incentives that make it easier and affordable to make greener choices of economic, industrial, commercial and individual lifestyle choices. Fortunately, more banks and financial institutions are offering green finance, and they are making it available and accessible which is of immense significance to ensure a sustainable drive to green initiatives. The typical types of green finance are as follows (Wire, 2021):

- "Green loans: loans made use by local governments, organizations and private companies to obtain funds for green projects."
- "Sustainability-linked loans: loans that support the mortgagor or debtor to accomplish sustainability performance targets that incentivise companies' sustainability performance by linking the interest rate to the improvement of the companies' ESG score or to the improvement on tailored sustainability KPIs."
- "Environmental Social Governance (ESG) derivatives: a system utilised to determine an organization's business practices and performance on various sustainability and ethical principles."

- "Green bonds: are designated bonds proposed to promote and boost environmental sustainability and to support climate-related projects."
- "Green investment funds: a means of financing intended to provide capital for projects and companies that are focused on mitigating climate change."
- "Green mutual funds: an investment fund that prioritises companies and projects that meet particular ESG criteria."
- "Sustainability-linked bonds: bonds with an ambition to establish the fundamental role that debt markets can perform in funding and encouraging companies that contribute to sustainability (from an ESG perspective)."
- "Renewable energy credits: credits that were introduced to promote renewable energy, when a renewable energy source (wind, solar, hydroelectric, etc.) generates one MWh of electricity and sends it to the grid. (For example, if an onshore solar power facility produces 5 MWh of electricity, they have 5 renewable energy credits that they can either sell or keep)."
- "Climate risk insurance: a type of insurance to reduce the financial and other risk associated with climate change."
- "Sustainable securitisations: the sustainability of the assets endorsing the securities, the possible consolidation of sustainable assets into pools to fund sustainable development or the sustainable use of proceeds of the securities."

The "Alliance for Financial Inclusion" (AFI) has priority areas to promote its endeavours with comprehensive green finance that are known as the Four P's, and are described as follows (Wire, 2021):

- "Promotion: Prepare the private sector to offer financial services that address climate change."
- 'Provision: Provide financial resources for green projects and activities to qualified beneficiaries."
- "Protection: Socialise climate risk and associated potential losses through risk-sharing mechanisms."
- 'Prevention: Avoid undesirable outcomes by lowering social and environmental risk."

6.2.1 Benefits and Importance of Green Funding

Green funding contributes to economic and environmental benefits that should be carefully managed to ensure there is a contribution in the cause of JET nett-zero CO_2 emissions. Green financing also places huge emphasis on minimising the social impact of the transition, therefore

increasing accessibility to a vast number of susceptible organisations and individuals to environmentally conducive services and commodities. This promotes the transformation to a nett-zero CO_2 economy - unbiased and promoting substantial socially inclusive growth (Wire, 2021). Green finance offers vast potential to create a greener future for new businesses with a more sustainable economy resulting in favourable job opportunities. The vigorous advancement and promotion of large-scale green finance would result in greater preference to environment-related projects over less sustainable business investments that would spearhead a faster greener future to manage climate change. Biodiversity, natural preservation of the environment and healthier quality of life would be a welcomed side effect of the green financing initiatives (Wire, 2021).

6.2.2 Green Bonds

Green bonds are debt instruments issued to finance or refinance projects that deliver environmental benefits**,** such as climate mitigation, renewable energy, and sustainable infrastructure (Tamplin, 2023). Structurally, they resemble conventional bonds, where investors lend money to issuers in exchange for periodic interest payments and the return of the principal investment at maturity (Maltais et al., 2020). However, the key distinction lies in the use of proceeds**,** which are exclusively allocated to green projects. These bonds often include a "use-of-proceeds" clause that ensures funds are directed toward environmentally sustainable investments, rather than general corporate expenses (Maltais et al., 2020). To enhance transparency and credibility, issuers typically adhere to frameworks like the Green Bond Principles (GBP) and may seek third-party verification from organisations such as the Climate Bonds Initiative (GBI) (Tamplin, 2023). Reporting mechanisms are also required to track environmental impact and fund allocation, making green bonds a cornerstone of sustainable finance and ESG investing (Maltais et al., 2020).

6.2.2.1 Green Bonds Implementation and Success

Green bonds have been successfully implemented in the following BRICS countries:

- China is the largest green bond issuer among BRICS, with a robust national green taxonomy introduced in 2015. The country issued approximately $100 billion in green bonds by year 2020 which financed renewable energy, clean transport, and pollution control (Khudyakova et al., 2021).
- India sovereign green bonds launched in year 2023 to fund climate mitigation, biodiversity, and clean energy; and raised approximately $2billion in order to support Paris Agreement imperatives (World Bank, 2023).

- Brazil issued approximately $10billion in green bonds by year 2020 that were focused on renewable energy and forest preservation. This success was proven to support successful reforestation and hydropower development in the country (Khudyakova et al., 2021).
- Russia's implementation was to develop a national taxonomy for green funding but the **i**mplementation lags regulation in the country (World Bank, 2023; Khudyakova et al., 2021).
- South Africa implemented green bonds in municipalities in Cape Town and Johannesburg that financed water infrastructure and sustainable transport (Novák et al. (2025).

6.3 Sustainable Funding

Sustainable funding is a cognitive ESG process of deciding on investments in the financial sector that manifests into sustainable economic activities for more long-term investments. This type of funding covers a broader spectrum of environmental activities, inclusive of climate change mitigation and adaptation but the latter is not a statutory requirement. Social considerations of ESG, may cater for issues of discrimination, labour relations, investment in people and their skills and communities, inclusive of the human rights aspects. Sustainable funding forms an integral part of assuring the inclusion of social and environmental considerations in the decision-making process of public and private institutions as well as management structures, employee relations and executive remuneration. (EC, 2023).

Sustainable funding is referred to as finance to support economic growth and simultaneously alleviating the stress on the environment to assist in attaining the environment and climate change goals of the "European Green Deal" (EGD), taking cognisance of social and governance aspects. Sustainable funding or finance also covers transparency when it comes to risks related to ESG factors that could adversely impact on the financial system. The moderation and management of such risks through the appropriate financial and corporate governance structures is imperative (EC, 2023).

6.3.1 Importance of Sustainable Funding

Sustainable funding has a vital role in conveying the policy aims covered by the EGD and EU's international commitments on climate and sustainability intended objectives. EGD achieves these objectives by directing private investment into JET, to a nett-zero CO_2 emissions, climate-resilient, resource-efficient, and equitable economy. Sustainable finance promotes investments that support a sustainable, resilient economy. The EU supports the transition to a

greener sustainable more resource efficient economy, strengthening a financial system that supports sustainable growth (EC, 2023).

6.4 Adoption of Finance within the Paris Agreement

in endeavouring to meet the targets of the Paris Agreement and then adopt it, many interventions were held to understand what equity meant in the context of common global objectives on climate change. The objectives for limiting the global temperature to rise to 1.5^{o} C and no more than 2^{o} C, while strengthening countries' abilities to manage the adverse impacts of climate change more effectively which was noticed from the vulnerabilities of parties of "Small Island Developing States" (SIDS) and "Least Developed Countries" (LDCs) (Naidoo et al., 2023), the Paris Agreement recognised the importance of the role of the financial system in achieving the climate change goals as illustrated in Article 2.1(c) of the Paris Agreement (UNFCCC, 2015).

6.4.1 The Advancement of Finance within the Paris Agreement

The Paris Agreement, 2015 and the Addis Ababa Action Agenda 2030 on "Financing for Development" (Addis Agenda), converged to focus on the financial aspects to enhance the actions of climate change by UN related processes (Naidoo et al., 2023). The first finance goal is associated to the Addis Agenda, inviting an aspiring and firm financial environment to direct execution of the SDGs. The Addis Agenda encourages "cohesive nationally-owned sustainable development strategies, supported by integrated national financing frameworks" as pivotal attributes of member states' endeavours to sustainable financial development (UN, 2015b). The "Addis Ababa Agenda 2030" gives prominence to integrating and creating coherent and supportive trade, finance, monetary and economic systems to deliver on the SDGs (UN, 2015a). The second finance goal is associated to Article 2.1(c) of the Paris Climate Change Agreement, which is to "*make finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development"* (UN, 2015a).

It is however observed and acknowledged that the Paris Climate Change Agreement, Article 2.1(c) references to finance flows are ambiguous and inconsistent regarding its long-term objectives for development. Consistent finance flows are paramount to achieve global climate change objectives. Article 2.1(c) emphasises comprehensively the requirement from a finance standpoint to realise the emission and resilience objectives of the Paris Climate Change Agreement (Whitley et al., 2018). Article 2.1(c) of the Paris Climate Change Agreement and Addis Ababa Agenda 2030 are noteworthy as they emphasise a commitment among countries that places finance and financial systems at the forefront of the SDGs and the global climate

response (Whitley et al., 2018). The United Nations (UN) 2019 Financing for Sustainable Development Report (FSDR), encourages countries globally to establish financial frameworks to incorporate sustainable development in accordance with the Addis Agenda (Whitley et al., 2018). The report emphasises that financing policies cannot be isolated and any common financing challenges must take into consideration the broad development perspective. The FSDR further recommends that countries align their financial sector regulation, financial strategies, labour market policies, social protection systems, competition policies and trade policies with the new realities of development (Naidoo et al., 2023).

The UN is developing guidelines for countries to respond to these finance-related goals. The "Biennial Assessment Technical Report, 2018" of the SCF of the UNFCCC provides datasets that could be utilised to monitor the consistency of finance flows (SCF, 2018). Quantitative and qualitative measures are included into the data categorised by the type of finance flows (bank lending, bond markets, listed equity, private equity, insurance and reinsurance, assets under management and financial services) (SCF, 2018). The "Biennial Assessment Technical Report, 2020" (BATR) paid special attention to guidance on mapping the range of activities being taken by countries' financial sectors to execute Article 2.1(c) (SCF, 2021). BATR, 2020 also reflected and covered the requirement to develop a Key Performance Indicator (KPI) to measure and monitor the effect of these commitments. Particularly, how they assist towards achieving consistency of finance flows; however, the rudimentary challenge in monitoring progress, relative to Article 2.1(c) is the absence of consensus among the parties on how to move forward with the article either collectively or according to the country's position (SCF, 2022b; 2022c). This elementary dissimilarity, results in challenges of understanding the basis for common reporting and monitoring, to track collective progress on Article 2.1(c) (SCF, 2022c).

6.5 The Vulnerable 20

The Maldives government initiated the Climate Vulnerable Forum (CVF) prior to the UN Climate Change Conference in Copenhagen in year 2009, with the aim of promoting awareness of countries defined as vulnerable (CVF, 2015). In November 2009, a meeting was held in Malé, Maldives where eleven governments from Asia, Africa, America and the Pacific, representing the most vulnerable countries to climate change convened. There was a declaration by these governments communicating their concern at the rate of change and harm due to global warming, categorically expressing a statement that this environmental state is "an existential threat to our nations, our cultures and to our way of life" and *"undermine the internationally protected human rights of our people"* (CVF, 2009).

Subsequently, a group of countries contributing to lesser quantities GHG approved the CVF declaration, committing to guide the world to a low-carbon economy with the objective of reaching the target of nett-zero CO_2 emissions. The CVF acknowledged the crucial requirement for global assistance to reach these climate change goals in vulnerable countries (CVF, 2009). This requirement gave rise to negotiations with heads of countries of the United States and China at the Copenhagen summit in year 2009 (COP15, 2009). The declaration by the CVF, was a pledge to realise a concentration of no more than 350ppm (parts per million) of CO_2 in the atmosphere and therefore contribute to limiting global warming to 1.5^{o}C. The declaration was also adopted and welcomed by the "Alliance of Small Island States" (ASIS), Antigua, Barbuda, Costa Rica, Ethiopia, the Marshall Islands and Samoa reiterating their commitment to carbon neutrality (CVF, 2009).

The official CVF was launched in year 2015, chaired by the Philippines government composed of the top 20 counties worldwide that are most adversely impacted by global warming and climate change (CVF, 2015). The members of the bloc are Afghanistan, Bangladesh, Barbados, Bhutan, Costa Rica, Ethiopia, Ghana, Kenya, Kiribati, Madagascar, Maldives, Nepal, Philippines, Rwanda, Saint Lucia, Tanzania, Timor-Leste, Tuvalu, Vanuatu and Vietnam. The addition of 23 new members that joined the CVF in 2015 as incoming members in the V20 initiative (CVF, 2015) have bolstered its ranks. The V20 functions on a voluntarily basis in conjunction and in partnerships with acknowledged commonalities and differences; and takes a country ownership approach to provide support to V20 countries (UNFCCC, 2022a).

6.5.1 V20 Global Shield

The "Intergovernmental Panel on Climate Change" (IPCC) predictions on the impacts of increasing temperatures forecast declining resilience, irrevocable loss of settlements and frameworks, depleting food and water security and negative socioeconomic impact worldwide. (Pörtner et al., 2022). These predictions are materialising, and it's observed in the vigour of climate-driven disasters covering not only developing countries but also affecting developed countries in the period of year 2020 to year 2022. These include storms (Europe), floods (South Africa, Pakistan), and heatwaves (Pakistan, China), droughts (China) and veldfires or wildfires (South Africa, Europe, and United States), amongst other natural climate-related disasters. (Ripple et al., 2022; Trenberth, 2022; World Economic Forum, 2023). The Paris Agreement's Article 2.1(b) acknowledges the requirement to strengthen resilience to climate change induced disasters. SIDs and LDCs, with their current vulnerabilities (social, economic and environmental), are most adversely impacted. These counties are already financially

constrained due to non-climate related commitments and are further burdened by climate related disasters and recovery (Markandya et al., 2019). At COP17, the UNFCCC acknowledged the challenges of these vulnerable countries and initiated working groups to mitigate the lack of economic, social and environmental resilience. Finally, at COP27 in year 2022, the decision to initiate a “loss and damage fund' was endorsed. Rapid plans to execute are required to ensure a positive move towards the goals and purpose of Article 2.1(b) (Naidoo et al., 2023). Concessional debt and grants are the forms of financial support provided to LDCs and SIDs to strengthen climate resilience, unfortunately as with any initiatives there are shortcomings that require contingency measures and constant improvement as highlighted at COP27 in the Implementation Plan (UNFCCC, 2022b). The V20 formulated Climate Prosperity Plans (CPPs) and the Global Shield (GS) to mitigate these precise challenges.

The V20 makes advances through self determination to participate and act on climate change and to encourage climate resilience and greener development with competence in managing economic and financial challenges (V20, 2015: 2). Enabling consistent finance flows would ensure that the physical, adverse impacts of climate change are fully identified and included in the mission of climate resilient development pathways. An intense drive towards the quality of finance promotes the V20 methodology to financing resilience, taking into consideration the challenges and issues of high debt levels. To address these concerns, the V20 objectives are to promote and encourage climate finance options for vulnerable and indebted countries. The aims are to reform sovereign debt and, through development finance institutions like the development banks, grow their financing without jeopardising their countries' credit ratings (V20, 2022c).

6.5.2 Global Shield Objectives

The “Global Shield” (GS) is a coalition with the “Vulnerable Twenty” (V20), the “Group of Seven” (G7), members of the “InsuResilience High-Level Consultative Group” (IHLCG) and the Program Alliance” committed to jointly work towards a “Global Shield against Climate Risks” (CVFS, 2021). The GS will offer greater protection for financially challenged and vulnerable populations by delivering and expediting significantly greater and superior pre-arranged finance against disasters (V20, 2022a); and greater financial insurance and quicker and enhanced reliable disaster preparedness and management. This will assist with cost-efficiently and effectively preventing, reducing and managing losses and damages compounded by climate change (V20, 2022b).

The GS is presently assuming the form of packages between developed G7 countries (Canada, France, Germany, Italy, Japan, the UK, and the US) and an assortment of developing countries (Bangladesh, Costa Rica, Fiji, Ghana, Pakistan, the Philippines and Senegal) known as pathfinder countries (Naidoo et al., 2023). Individual pathfinder countries' "Climate Prosperity Plans" (CPP) are connected to the GS financial protection package, as part of an investment plan to warrant the most aspiring conceivable climate action while improving socioeconomic status. GS is one of many protection options that exists, and serves as a complementary measure rather than as a replacement (V20, 2020). Constituents of social protection or insurance, contingency funds and insurance elements and included in the GS. The GS insurance offer is an apt declaration of the climate justice principles of the V20 encompassing structure, which is focused on supplying climate justice and strong climate security for fortunate (developed groups) and vulnerable groups, especially our women, children, the financially constrained and future generations (V20, 2020).

The GS financing framework is also directed by principles of subsidiarity and complementarity, by which countries must solicit climate disaster risk finance and insurance support. Ranking will be reliant on the targeted group's risk and vulnerability; and the country's requests should be aimed at one or more of the financing means under the financing framework (V20, 2022a). Considering these principles, equity will benefit as country ownership is realized through the country's request for support, which is based on self-determination and specific country requirements. Ranking criteria will be established based on urgency and vulnerability, which will help to identify which country requires what funding most urgently (BMZ, 2022). The balance between financing climate change, sovereign debt issues and how this will be managed, will also be crucial; in particular, when climate finance mobilisation packages are negotiated (for example, through means such as the JETP's and in financing the CPP's) as this will have to consider the country's policies and economic structure (BMZ, 2022).

6.6 Just Energy Transition Partnership (JETP)

"Just Energy Transition Partnership" (JETP) is a voluntary funding partnership between developing and developed (or wealthier) countries, that are majorly dependent on fossil fuels; and will support these developing countries to accelerate decarbonisation and transition towards clean energy with social justice (Naidoo et al., 2023).

6.6.1 JETP Background and Progress

The South African government, Eskom (SA's power utility company) and a few developed countries (France, Germany, the UK, the USA and the EU) had numerous interactions which

resulted in the conceptualisation of JETP. Initially, the concept concentrated on a 'just transition transaction' as advocated by the South African think-tanks and Eskom. It became apparent that the requirements for financing converged on economic, technology and adverse social conditions for heavily fossil fuel reliant countries. The impetus for JETP originated with Eskom, a now highly indebted power utility, that needed to develop and build renewable energy power plants through bespoke financial agreements which conventional climate finance methods did not cater for. (Naidoo et al., 2023).

The first JETP, between South Africa and the "International Partners Group" (IPG) consisting of France, Germany, the UK, the USA, the EU and the CIF, was announced at the COP26 in Glasgow, UK in the year 2021. This was inclusive of the JET execution plan for year 2023 to 2027 in support of South Africa's decarbonisation plans (The Presidency, South Africa, 2022). To support of South Africa's JET initiative, the IPG will provide the country with a sum of $8.5 billion over a five-year period (2023 to 2027) in support of its electrical power sector, initiate a green hydrogen sector and advance "New Energy Vehicle" (NEV) development (The Presidency, South Africa, 2022).

Since then, two additional JETPs for Indonesia and Vietnam respectively were announced, with an expanded IPG (including Japan, Italy, Canada, Denmark and Norway) in November 2022 at the G20 summit in Indonesia. Indonesia received $20billion, and Vietnam received $10billion from the IPG (European Commission, 2022a). The second was announced between Vietnam and the extended IPG for $15.5 billion of public and private finance to support the country in December 2022 (European Commission, 2022b). Further developments on JETP's are underway for India and Senegal (Kramer, 2022). However, the possibility of an Indian JETP looks uncertain due to India's stance on phasing out or phasing down coal, although it is raising the country's renewable energy capacity (van Diemen, 2022). India's position is hinged on the perspective that phasing down coal does not support with the India's wider developmental goals and requirements. (Srivastrava, 2023).

Developing countries like, South Africa, Indonesia, Senegal and India, and other fossil fuel dependent countries, are prone to enormous challenges in transitioning to a nett-zero emissions and climate change impacts (Araújo, 2014). The effect and speed of the transition directly affects economic and social structures and thus needs a perspective that considers the expensive and chaotic consequences on health, livelihoods, fossil fuel ecosystem and smaller businesses. JET funding has specific properties that are technologically centred, innovative, time-sensitive and socially aware (Araújo, 2014; Jasanoff, 2018; Naidoo, 2018). The remedial pathways

suggest enormous and disruptive changes in economic frameworks, with vast distributional effects, within and between countries inclusive of shifting income and jobs during the transition from high to low emissions activities as observed the IPCC's 6th Assessment Report (Intergovernmental Panel on Climate Change, 2023).

6.6.2 Just Energy Transition Partnership Objectives

The Just Energy Transition Partnership (JETP) presently represents the structure of arrangements between developed (IPG and extended IPG) and developing countries such as Indonesia, South Africa, Vietnam and others that are engaged into fossil fuel development pathways (Kramer, 2022). A JETP is promoted by a proposal to support developing countries in implementing their NDC objectives in an enterprising, fair and inclusive way, through bespoke financial agreements. The JETP notion of change is that, through the provision of finance at scale by developed countries, a succession of projects can be initiated that will boost developments for bigger investments encompassing the intention of the NDC. In this process, the JETP permits progress towards Article 2.1(c). These projects should be crucial for supporting energy transitions that takes into consideration the chaotic social consequences of the transitions and link with the wider developmental aims of the beneficiary developing countries (Kramer, 2022).

The ambition of the JETP's for South Africa, Indonesia and Vietnam is decreasing CO_2 emissions and the transition of the energy sector and the larger economy. The financing for individual JETP's is additionally reliant on the development and simultaneous of an investment plan between the counterparts (The Presidency, South Africa, 2021; European Commission, 2022a; 2022b).

6.6.3 South Africa JETP

The South African JETP is the most improved in terms of governance, negotiation and investment configuration. It supplies functional intuition for assessing the relationship between equity and Article 2.1(c) of the Paris Agreement, through its attention to justice and its proposal of bespoke finance arrangements that can have a huge influence on aligning future finance flows with the Paris Agreement's aims (Naidoo et al., 2023).

The JETP lead and directed by the specifically formed Presidential Climate Finance Task Team created by President Cyril Ramaphosa. The Presidency, South Africa, 2022, as the key interface between the South African government and the IPG. The financial proposal was considered, and the "Just Energy Transition Investment Plan" (JET IP) emerged via this process, with the

technical backing of a Secretariat (The Presidency, South Africa, 2022). The Political Declaration by South Africa and the IPG made the initial proposal conditional to concurrence on the investment framework, rendering it a precondition for the provision of financing for South Africa's JETP (The Presidency, 2021).

6.7 South Africa's Just Energy Transition Investment Plan (JET IP)

South Africa's "Just Energy Transition Investment Plan" (JET IP) for the five-year period from year 2023 to year 2027, describes the magnitude of the activities and the funding requirements to accomplish the decarbonisation pledges committed by South Africa in the NDC's (JET IP, 2023). The JET IP is aligned with the country's revised Nationally Determined Contribution (NDC) which shared with the UNFCCC at COP 26 in Glasgow, UK in November 2021, together with the country's "Low-Emissions Development Strategy" (LEDS). South Africa pledged its commitment to decreasing its emissions to within a range of 420-350 Mt CO_2 equivalent ($MtCO_2$-eq) by 2030 in the latest NDC (JET IP, 2023). This pledge is reiterating what was in the first NDC commitments made to the UNFCCC, in compliance with Article 2.1(a) of the Paris Agreements climate change objectives, where a goal of 420 and Mt 350 Mt is congruous with an equitable contribution to a 2 ^oC and 1.5 ^oC temperature increase limit aspiration by 2030 respectively (JET IP, 2023). There was a disclaimer on the updated NDC, that meeting the lower range of 350 Mt is reliant on financial back the country obtains.

The South African "National Development Plan" (NDP) 2030, is supported by the JET IP with the country's priority on combating the sequential challenges of job losses, poverty, and inequalities. Promotion and encouraging industrial development, innovation, and economic diversification is an envisaged welcomed positive spin off from South Africa's quest for decarbonisation with its JET objectives through appropriate international funding partnerships such as JETP. (JET IP, 2023). It is acknowledged that, the interregnum would take a few decades to implement by following a well-defined and structured plan aligned to the JET policies with public and private sector resources. To reiterate, South Africa's JETP's purpose was to have "Established long-term partnership to support South Africa's pathway to low emissions and climate resilient development, to accelerate the just transition and the decarbonisation of the electricity system, and to develop new economic opportunities such as green hydrogen and electric vehicles amongst other interventions to support South Africa's shift towards a low carbon future." Subsequent to signing the declaration, a "Presidential Climate Finance Task Team" (PCFTT) was convened by South African State President, Mr Cyril Ramaphosa in February 2022 to consult with the IPG, counsel and develop South Africa's JET IP, thus guiding the finance methodologies to an Inter-Ministerial Committee (IMC) set

up for this drive, chaired by the Minister in the Presidency (JET IP, 2023). JETP Secretariat was appointed to be able to serve the IPG and the PCFTT effectively.

The JET IP has nine guiding principles as follows (The Presidency, South Africa, 2022):

- "Finance should follow the principles for support to developing countries established under the UNFCCC whereby developed countries commit to provide finance, capacity building and technology transfer to developing countries to advance their climate response, taking account of their respective capabilities and their national circumstances and priorities."
- "Finance should be additional to existing climate and development commitments and not divert critical development assistance away from existing development funding."
- "The composition of financing instruments should reflect South Africa's unique needs as reflected in the JET IP, taking account of the need for fiscal sustainability, and incorporate appropriate and equitable risk-sharing arrangements. The grant component should be reflective of the finance demands entailed in enabling a just and inclusive transition."
- "Financing of the just transition components (relating particularly to impact on livelihoods, local government, and small businesses) should be mainstreamed into the design of all JET IP projects and programmes as an integral and essential feature of South Africa's climate response."
- "Any debt-related terms for the sovereign should be more attractive than South Africa's National Treasury could secure in the capital markets without unduly onerous reporting requirements."
- "Finance flows from partner countries should be predictable and certain, to avoid delays and enable a sustained momentum of the broader investment plan."
- "Finance flows should be channelled through the institutions which are best placed to manage them for the intended outcomes and in the most cost-efficient manner."
- "Partnerships with the private sector should be supported to foster appropriate risk sharing arrangements, recognizing that private sector financial institutions equally need to decarbonise their portfolios and align with just transitions."
- "Governance and safeguards must be in place to manage risks."

It is acknowledged that the JET IP identified three priority areas of NEV, electricity, and green H_2 that need a total sum of ZAR1.48 trillion ($98.7 billion) (calculated a R15/US$ exchange rate) for the period of 2023 to 2027 to realise a green economy aligned with the country's NDC. The funding is made up of $8.5 billion (ZAR127.5 billion) IPG contribution towards the JET IP and ZAR1.48 trillion investment forecast for the next five years (2023 to 2027), however

there is a deficit of ZAR1.35 trillion ($90.2 billion). Other sources include possible investment funding from private partnerships of ZAR500 billion ($33.3 billion) and ZAR150 billion ($10 billion) from possible public sector investment over the abovementioned five-year period; however, this leaves a potential deficit of ZAR0.71 trillion for the same period (Naidoo et al., 2023). JET IP will also foster and influence wider economic development directed by the NDP (The Presidency-South Africa, 2022).

The JET IP has defined the tracking and assessment structure as well as the parties executing the directives (Naidoo et al., 2023). The JET IP's social element included the three main investment elements: specifically, skills development, national and municipal infrastructure, and social support financial requirements. The JET IP highlights that social protection and insurance are crucial measures for the JET and identifies the requirements for policy alignment to establish such protection. The JET IP is not prescriptive on how progress against objectives of the JET IP will be assessed and does not cover specific long term strategic plans or timelines on how to meet the South African NDC aspirations for now that requires further, careful development. It is apparent from the JET IP that it was compiled with consideration for and strict adherence to the Just Energy Transition (JET) principles related to environmental, social, green economy objectives. Shorter-term funding initiatives in Eskom's power system network performance enhancement aim to increase reliability, capacity, and dependability by rapidly deploying renewable energy and reducing the reliance on fossil fuel-powered power plants. Social responsibility is mentioned in the JET IP when shutting down power generating plants with the emphasis on possible repurposing and repowering the plants so that the social impact is softened for communities around the end-of-life power plants, especially in the Mpumalanga province (Naidoo et al., 2023; The JET IP, 2023). The JET IP is essential for providing the foundation and directing JET investments supportive of the country's commitments to the Paris Climate Agreement without being specifically prescriptive as it would be rendered too rigid and limiting to innovation in meeting the objectives (The Presidency-South Africa, 2022). The qualitative imperatives aid social equity with reference to the country's "Just Transition Framework" (JTF), which emphasises distribution, restoration and procedural balance and equality. The majority of social associations or organisations are required to comply with and focus on JET initiatives, and the restriction of global warming as contained in the country's JTF (PCC, 2022). The JET IP also contains the investment criteria and guidelines for resource utilisation against the allocation of ZAR1.48trillion potential investment budget and outlines the distribution of the $8.5billion of IPG finance obtained from the JETP. A generic investment guideline for similar JET priorities is outlined in the JET IP to add efficiency for future projects development with their individual strategies (Naidoo et al., 2023).

The JET IP is instrumental in managing the investment initiatives such as the JETP. Strict governance measures must be adhered to by all stakeholders in the transition ecosystem, with the supervision of the South African National Treasury.

6.8 SA Partnerships with BRICS energy investors

South Africa was fortunate to be nominated as the chair of BRICS from January 2023. While the world is emerging from the adverse social and financial conditions of COVID-19, there is a war between Russia and Ukraine that has exacerbated the already challenged global economy. This has resulted in a cascading effect on the basic necessities of energy and food and exacerbated by trade and economic sanctions by the UN, USA, and EU. Russia, a crucial leader in the BRICS alliance, is the third largest oil producer, second largest natural gas producer and a top producer of steel and wheat globally. These consequences of the war and sanctions against Russia resulted in significant astronomical energy and food ecosystem demands due to the sudden constraint. As with any scarcity, comes higher prices as demand outweighs supply and this has an unprecedented effect on food and energy prices. As a mitigation to this adverse impact, especially the energy crisis in SA with regular loadshedding, SA has developed the "South African Economic Reconstruction and Recovery Plan" (SAERRP). The objective of the SAERRP to aid the power or electricity sector to mitigate the challenges facing Eskom and country to attain short to long term investment and eradicate the energy crisis which is aligned to the country's NDC. SA, being a member and chair of the BRICS alliance, requested support in January 2023 from BRICS to fulfil its aim to alleviate the current and future energy crisis, and the country's economic rehabilitation (SAERRP, 2023). Coincidentally, the 2023 BRICS theme is "Partnership for Mutually Accelerated Growth, Sustainable Development, and Inclusive Multilateralism" (Sooklal, 2023). BRICS member countries are fortunate that they have vast natural resources, technology, and are in a suitable financial position to assist member countries.

The benefits of being 'complementary' amongst its member countries was a pivotal point in the BRICS alliance at inception. BRICS has a framework in the form of a roadmap to achieve member countries' objectives. The BRICS "Energy Research Cooperation Platform" (ERCP) was initiated to attract and merge cooperation of subject matter specialists, organisations, and research institutes to manage and expedite the similar ambitions of BRICS in formulating and encouraging innovation in technology and governance (Sooklal, 2023). So far, the progress for the first phase was exceptional with eight completed studies and presented at the BRICS, Ministers of Energy meetings including the study on developing renewable energy and smart

grids in the BRICS countries. The research on energy security is currently being executed by Russia which is essentially the beginning of the second phase of the roadmap. The last phase is a spin off from this third phase and is focused on building complementary, mutually beneficial cooperation, sharing best practices, using advanced BRICS technologies, trade, and funding opportunities in individual BRICS member countries' economies (SAERRP, 2023).

There are deep economic and significant trade relations with the BRICS countries. Within the coal export market in South Africa, India acquires approximately 50% of the total coal exported annually by South Africa and China has recently engaged in negotiations with SA for coal as well. The trade of oil and gas has been strengthened between Russia, China, India, and Brazil in year 2022 and renewable energy trade with South Africa (Sooklal, 2023). There is interest shown by China and India in the clean coal technologies of SA. ROSATOM, the Russian State Atomic Energy Corporation agreed with SA to build a hydropower plant in the Mpumalanga province of South Africa. This would be the first venture with Russia in SA to meet JET priorities of nett-zero CO_2 emissions, job creation, stimulating the economy and a start in resolving the country's electricity challenges with renewable energy (SAERRP, 2023).

The BRICS energy and green economy working group objective is to develop tangible deliverables on the JET. Currently, the BRICS countries are engaging on the possibility of developing a BRICS "African Centre of Excellence" (ACOE) to further the progress on JET. The function of the ACOE would be to provide subject matter experts to research technology, social, economic and environmental components of the JET. It is acknowledged by the South African National Treasury that there are funds available to the tune of $12trillion globally for green energy projects from various green funding financial institutions. Especially developing countries would be able to obtain these funding with Article 2.1(c) of the Paris Agreement although developing countries are seen a higher risk. BRICS can also assist SA with obtaining these investments despite policy impediments identified by the South African regulatory bodies.

"Green Masala Bonds" and "Green Panda Bonds" are innovative means by India and China respectively to obtain investment funding globally for renewable energy projects. The New Development Bank (NDB) is multilateral development bank endorsed and initiated by BRICS, and issues "The Green Panda Bonds' (Sooklal, 2023). Sustainability is fundamental to the founding principles of the bank; and its mission is to administer substantial assistance to BRICS member countries, with an estimated target of 40% of its total approved climate mitigating and action investments. Fortunately, the major benefactors of these green and sustainable funding

initiatives to date are China and South Africa. The benefits of South Africa being part of the BRICS is immense in so many ways in global or at least BRICS trade, attraction of investors, decarbonisation, job creation, skills development, re-skilling, training of labour, innovation and encourage African countries to engage in JET imperatives (Sooklal, 2023).

6.9 Global Stocktake Status

The Global Stocktake (GST) is the formal process established under the Paris Agreement to systematically, take stock of cumulative progress toward its long-term goals over and above their updates on the NDC's shared at the COP to the UNFCCC (UN, 2015a). The GST would be the perfect stimulus to encourage parties to be more committed in the execution of their climate change pledges whilst obtaining valuable support and guidance. (Hermwille et al., 2018). There was a clear decision taken at COP24, in Katowice, Poland in year 2018 that progress appraisal of Article 2.1(a-c) of the Paris Agreement must be included in the GST "*and that, through the GST process, the opportunities and challenges for enhancing action and support in the light of equity and the best available science, as well as lessons learned and good practice, should be summarised*" (UNFCCC, 2018). It was also decided that the GST would study information at a cumulative level with regards to finance on:

"The finance flows, including the information referred to in Article 2, paragraph 1(c), and means of implementation and support and mobilization and provision of support, including the information referred to in Article 9, paragraphs 4 and 6, Article 10, paragraph 6, Article 11, paragraph 3, and Article 13, in particular paragraphs 9 and 10, of the Paris Agreement" (UNFCCC, 2018).

It is apparent that the GST finance must encompass the cumulative growth towards ensuring finance flows are consistent with reduced CO_2 emissions and climate-resilient improvement. Further, GST promotes and aids in climate finance drives covering developed and developing countries in equilibrium between transitional and mitigation finance, whilst equitably providing preference to the most vulnerable, Small Island Developing States (SIDS) and Least Developed Countries (LDCs) (Watson et al., 2019).

6.9.1 Progress in the GST

At the COP26 in Glasgow, UK in year 2021 the first period of the GST began and ended at COP28 in the United Arab Emirates in year 2023, since GST is a 2-year process and 5-year cycle (Naidoo et al., 2023). In year 2018, the Katowice decision set out the fundamentals of GST procedure which started the process of engaging all parties, the chairs of the subsidiary

bodies, facilitators, and the UNFCCC (Obergassel et al., 2019). Technical assessment, information collection and preparation, and consideration of outputs are the three phases of the GST process that were set down at Katowice (UNFCCC, 2018).

The Katowice decisions acknowledged that a large collection of information sources from parties, non-party stakeholders, and UN agencies would be suitable for inclusion in the GST, particularly during the information phase (Naidoo et al., 2023). The Biennial Assessment and Overview of Climate Finance Flows was identified as a formal input into the finance discussions of the GST, financing of climate change pledges and effectiveness (SCF, 2022a). The GST has appointed a facilitator from South Africa and one from the United States (US) to facilitate three technical conversations as an element of the wider GST that took place in June 2022, November 2022, and June 2023 (Naidoo et al., 2023). Between the facilitators they have compiled memos and non-formal articles with the intention to provide direction and clear priorities for stakeholders to develop pertinent information to discuss in the technical innovative interventions such as via plenaries, roundtables, a world café and creative spaces with a 'learning-by-doing' methodology to make the process efficient and effective (CDP, 2022). The facilitators can be commended on their immense contribution to bring together a diverse group of parties during the technical phase of the GST and creative protocols that parties and non-parties can convene and add value to the GST (CDP, 2022).

6.9.2 Outcomes of the first GST

The outcome at the conclusion of the GST meeting was shared at COP28 December 2023. The dual intention of the GST is to aid updates on NDCs and encourage large scale climate change mitigation measures in concert with the UNFCCC endeavours (Srouji et al., 2022). The COP28 meeting reemphasized many critical articles of the "The Paris Climate Change Agreement" (CMA4, 2023).

The articles of the Paris Climate Change Agreement that were reemphasised, are the following:

- "Article 2, paragraph 1, of the Paris Agreement, which provides that the Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty."
- "Article 2, paragraph 2, of the Paris Agreement, which provides that the Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

- "Article 2, paragraph 2, of the Paris Agreement, which stipulates that the Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."
- "Article 3 and Article 4, paragraph 3, of the Paris Agreement, and reaffirms that each Party's successive nationally determined contribution will represent a progression beyond the Party's current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."
- "Article 3 and Article 4, paragraphs 3, 4, 5 and 11, of the Paris Agreement and requests Parties that have not yet done so to revisit and strengthen the 2030 targets in their nationally determined contributions as necessary to align with the Paris Agreement temperature goal by the end of 2024, taking into account different national circumstances."
- "Article 4, paragraph 2 of the Paris Agreement, which states that each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve, and that Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions."
- "Article 4, paragraph 4, of the Paris Agreement and encourages Parties to come forward in their next nationally determined contributions with ambitious, economy-wide emission reduction targets, covering all greenhouse gases, sectors and categories and aligned with limiting global warming to 1.5 °C, as informed by the latest science, in the light of different national circumstances."
- "Article 4, paragraph 4, of the Paris Agreement, which provides that developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets, and that developing country Parties should continue enhancing their mitigation efforts and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances."
- "Article 4, paragraph 9, of the Paris Agreement, which states that each Party shall communicate a nationally determined contribution every five years in accordance with decision 1/CP.21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement and be informed by the outcomes of the global stocktake."

- "Article 4, paragraph 15, of the Paris Agreement, which states that Parties shall take into consideration in the implementation of the Paris Agreement the concerns of Parties with economies most affected by the impacts of response measures, particularly developing country parties."
- "Article 7, paragraphs 10–11, of the Paris Agreement, each Party should, as appropriate, submit and update an adaptation communication, and that the adaptation communication shall be, as appropriate, submitted and updated periodically, as a component of or in conjunction with other communications or documents, including a national adaptation plan, a nationally determined contribution as referred to in Article 4, paragraph 2, of the Paris Agreement and/or a national communication, and that Parties may, as appropriate, also submit and update their adaptation communication as a component of or in conjunction with the reports on impacts and adaptation as stipulated in Article 13, paragraph 8, of the Paris Agreement."
- "Article 8 of the Paris Agreement, in which Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage, and according to which Parties should enhance understanding, action and support, including through the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, as appropriate, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change."
- "Article 14, paragraph 1, of the Paris Agreement, that the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall periodically take stock of the implementation of the Paris Agreement to assess the collective progress towards achieving the purpose of the Agreement and its long-term goals, and that it shall do so in a comprehensive and facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science."
- "Article 14, paragraph 3, of the Paris Agreement, that the outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of the Agreement, as well as in enhancing international cooperation for climate action."
- "Article 15, paragraph 1, of the Paris Agreement and recognizes the role of the Paris Agreement Implementation and Compliance Committee in facilitating implementation of and promoting compliance with the provisions of the Paris Agreement in a

transparent, non-adversarial and non-punitive manner that pays particular attention to the respective national capabilities and circumstances of Parties."

6.9.2.1 Summary of the First GST

The GST reflects a deficit in the reduction of CO_2 emissions with a shortfall of 24GT of CO_2. It was reiterated that GHG emissions must be decreased by 43% by year 2030 and approximately 60% by year 2035 with reference to the year 2019 emissions (being 36.8GT) to meet zero CO_2 emissions by year 2050 (COP28, 2023). JET in all areas is urgently required, and ramping up renewable energy production is prudent by phasing out non-renewable fuels (fossil fuels like coal and gas especially) and curbing deforestation is imperative. Funding, technology and capacity building have a fundamental impact on global warming and hence, the global financial mechanisms should keep up with the requirements of JET and provide financial backing to reduce CO_2 emissions. The financial structure should be robust to support "climate resilient" growth especially in developing countries (COP28, 2023). A major conclusion of the GST is that historical data of CO_2 emissions focused more on affluent developed countries and now must also include developing countries. It must be acknowledged that the citizens of countries, organisations, and the private sector have an important role to play to aid governments globally in combating climate change (COP28, 2023). A method to measure these contributions must be devised to monitor this. It couldn't be stressed more, that green energies and technologies are required for JET and sharing of the technologies that were promoted to curb global warming is a global aim. JET must be acted upon with these innovative technologies rapidly, as time passes it would become more difficult to reduce the effects of global warming and to reverse climate change (COP28, 2023).

6.10 Developed countries versus BRICS countries JET adaptation related to Funding

Developed nations can invest in large amounts of public and private financing for clean energy projects. The EU's Just Transition Mechanism (JTM) provides €17.5billion to support areas transforming from coal and other fossil fuels to green energy (European Commission, 2020). Equally, the U.S. Inflation Reduction Act (2022) includes $369billion in climate and energy investments (U.S. Congress, 2022). With private sector investment, the U.S. and the U.K. are leveraging private sector investments via green bonds and other financial instruments.

BRICS nations, particularly South Africa, depend largely on external funding for their energy transitions. The Just Energy Transition Partnership (JETP), initiated with South Africa, is funded by major countries like the U.S., U.K., and EU (South Africa Government, 2022). While China has substantial state resources, India and Brazil face financial constraints and rely

on international climate finance mechanisms such as the Green Climate Fund (GCF) (World Bank, 2020).

6.11 South Africa's Progress in Implementing Financial Structure

South Africa has made significant progress in establishing financial mechanisms for JET.
JET Implementation Plan (JET IP) approved for years 2023 to 2027, with six portfolios including electricity, green hydrogen, and skills. The JET funding platform was launched to match projects with grants and ensure transparent funding flows (Just Energy Transition Implementation Plan, 2024). A US$474.6million loan was signed with the African Development Bank in July 2025 to support infrastructure and green growth (JETIP, 2024). International pledges have reached USD 13.8 billion, including support from the EU, UK, US, and others.

6.11.1 Measures to Strengthen South African Finances

It is necessary to strengthen the JET Inter-Ministerial Committee that would promote alignment across ministries and municipalities. Finance models that will combine concessional loans, private equity, and climate bonds to de-risk JET investments must be developed. In addition, local government must be empowered, which means equipping municipalities with financial tools and mechanisms to support embedded renewable energy (JETIP, 2024).

6.12 Conclusion

In this chapter, green funding, sustainable funding, JETP, JET IP, IPG and V20 options together with measures of V20 GS, and GST was comprehensibly discussed to reflect their progress and effectiveness. The assessments on climate related funding revealed ambiguity in Article 2.1(c) of the Paris Agreement and the mitigations measures and interventions that was initiated to resolve the concerns. The UNFCCC's SCF in its year 2020 "Biennial Assessment Technical Report" (BATR) enforced a framing for mapping actions relevant to Article 2.1(c) (Naidoo et al., 2023).

6.12.1 Response to Research Question

How can the future energy initiatives and power plants be funded in South Africa?

Funding future energy initiatives and power plants in South Africa, particularly in alignment with its Just Energy Transition (JET) goals, requires a multi-faceted approach that leverages various financial mechanisms and partnerships. South Africa's energy transition toward

greener, sustainable, and low-carbon solutions can be supported through green funding, sustainable funding models, and international frameworks like the Just Energy Transition Partnership (JETP), JET Implementation Plan (JET IP), the International Partnership for Green Growth (IPG), and the V20 (Vulnerable 20 Group). These funding avenues should be supported by a comprehensive measurement framework that includes the V20 Green System (GS), updated Nationally Determined Contributions (NDCs), and the Global Stocktake (GST) to track progress and ensure that commitments lead to effective action.

In South Africa, green bonds, climate finance mechanisms, and green investment funds could be instrumental in funding large-scale renewable energy projects. Additionally, sustainable funding involves long-term investment strategies that support projects with positive environmental and social impacts. South Africa can leverage these mechanisms to attract both domestic and international investors interested in green and low-carbon investments. South Africa could issue green bonds to raise capital for renewable energy projects, like solar and wind farms, with proceeds earmarked exclusively for projects that reduce carbon emissions. These bonds offer investors an opportunity to contribute to South Africa's green economy while earning returns. South Africa can tap into international climate finance through mechanisms such as the Green Climate Fund (GCF), which provides financial assistance for projects that aim to reduce emissions or enhance resilience to climate impacts. These funds can be used for power plant development, grid modernization, and energy storage solutions.

The JETP is an international collaboration model that aims to help countries like South Africa transition to a low-carbon energy future. This partnership can provide both technical and financial support for transitioning energy systems, ensuring a just shift that takes into account the social impacts on workers and communities. It is particularly relevant in areas dependent on fossil fuels, such as the coal industry in South Africa. The JETP could provide direct funding or support through international loans, grants, and investments, which would facilitate the development of renewable energy infrastructure and assist in the transition of affected communities, including through retraining programs and social protection schemes. Collaborative Efforts in South Africa could work with development banks, donor nations, and international organizations under the JETP framework to secure investments for renewable energy projects while ensuring the inclusion of social measures for vulnerable workers and communities. The JET Implementation Plan (JET IP) outlines the roadmap for South Africa’s energy transition, focusing on tangible outcomes, timelines, and funding sources. The JET IP provides a structured approach to fund the transition in a way that minimizes disruption and ensures equitable development.

The plan could rely on a mix of Public-Private Partnerships (PPPs), where government funding and private investments are pooled together to implement clean energy projects. To ensure long-term financial sustainability, the plan could include the development of a just transition fund that supports communities and workers in coal-dependent areas, enabling them to transition into new employment opportunities in the green economy.

The IPG is a global initiative that promotes green growth through multilateral cooperation and investments in clean technologies. South Africa can collaborate with other countries through the IPG to secure funding and share knowledge on transitioning to sustainable energy. South Africa can tap into the IPG's financial instruments, such as concessional loans, equity investments, and joint ventures, to finance renewable energy projects and sustainable infrastructure. Funding under IPG could also support technology transfer from developed countries to enhance South Africa's capacity in renewable energy technologies like solar, wind, and energy storage.

The V20 (Vulnerable 20 Group) represents countries most vulnerable to climate change, including South Africa. Through V20 mechanisms, South Africa can access financial resources aimed at addressing both climate change mitigation and adaptation needs: The V20 Green System (GS) could be used as a framework for tracking and securing funding for green initiatives in South Africa. The V20 GS encourages climate finance flows into vulnerable countries to help them meet their climate targets, reduce emissions, and develop resilient energy infrastructure. South Africa can leverage the V20's influence to ensure fair financing for its energy transition, focusing on both carbon reduction and the socioeconomic impacts on local communities.

South Africa's updated Nationally Determined Contributions (NDCs) outline the country's climate goals and strategies for meeting international climate agreements, such as the Paris Agreement. The Global Stocktake (GST), held every five years, provides a review mechanism to assess the progress of NDCs and the effectiveness of the global climate framework. South Africa's updated NDCs should include clear, actionable commitments to zero-carbon power generation, increased renewable energy capacity, and the phasing out of fossil fuel-based energy. GST and a progress-tracking process will allow South Africa to review progress towards these goals, offering a mechanism to adjust funding strategies and policies. Through regular updates, South Africa can ensure its NDCs align with evolving international standards and green finance initiatives. To ensure that funding is used effectively, and progress is made,

South Africa needs to implement monitoring and evaluation measures that track the outcomes of its energy transition. These measures can include monitoring the social impacts of JETP and JET IP, particularly on vulnerable communities, to ensure that the energy transition benefits all citizens equitably; as well as evaluating emissions reductions and renewable energy capacity increases against the targets set in South Africa's NDCs and the global climate framework. Regular progress reports must be submitted to the Global Stocktake (GST) to ensure transparency and accountability in both national and international commitments. Impact assessments must be conducted to measure the effectiveness of funding received through green bonds, climate finance, and other sources, ensuring that the projects contribute meaningfully to reducing carbon emissions and creating green jobs.

CHAPTER 7: CONCLUSION

7.1 Introduction

This chapter would refer to the research questions, objectives, hypothesis and provide a conclusion.

7.2 Research Question on Policy

What will be the most effective strategy for South Africa to meet the JET transformation efficiently?

This was addressed in chapter 3 of the thesis and recommendations are covered in chapter 8.2. South Africa has made great progress with the JETP, South African NDP 2030, JET Pathways, SPD and the JTF to form the pillars of JET. BRICS alliance and support has helped South Africa immensely to steer the transition forward, however, like all policies the execution requires discipline, management and constant improvement which SA has demonstrated extremely well thus far.

The second question was "Is the Paris Climate Change agreement, COP22 and global warming initiatives achievable and if not, what's the consequences and remedial actions will be required?

In chapter 3, it deliberated on whether the BRICS member countries are committed to the cause of nett-zero targets by submissions of NDCs however, except for South Africa, all other BRICS member countries would not meet the deadline of year 2050. The NDCs reflect: Brazil by 2060, Russia by 2060, India by 2070, China by 2060, and South Africa by 2050. In summary and with the discussions in the policy chapter, the global warming initiatives are definitely achievable however more time will be required for most countries. The consequences of not achieving the timelines of zero carbon emissions by 2050 needs ongoing assessment and innovative mitigation actions. The accuracy or criticality of year 2050 also needs continuous assessment by organisations such as the IEA and IRENA with reports submitted to UNFCCC and discussed at future COP meetings. The current efforts and awareness generated through the intensive interventions of V20, BRICS, G7, and COP, along with consistent updates on NDCs and the GST, are likely to accelerate the pace of zero carbonisation as global momentum increases, extending beyond just the BRICS member countries. The further consequences of not curbing global warming with the target of not exceeding 1.5^{o}C and no more than 2^{o}C was discussed in chapters 3 and 4.

7.2.1 Lessons Learnt in Policy Adoption in BRICS Countries

Across the BRICS nations, effective energy policy design has proven to depend on flexibility, scientific evidence, and strong community involvement. India's revision of its Flue Gas Desulphurisation (FGD) policy highlighted the dangers of rigid mandates, showing that a shift to technology-neutral standards based on pilot studies saved over ₹1.4 lakh crore in avoidable costs. Similarly, Brazil and South Africa have emphasised inclusive, locally grounded approaches, with South Africa pioneering Just Energy Transition (JET) policies that consider social equity and job creation. Russia's energy plans acknowledge the importance of fairness and the social impacts of climate change, even if not explicitly framed as JET. China and Brazil have also focused on integrating energy policy with broader development goals, including climate resilience and digital infrastructure. Across the bloc, energy communities and multi-level governance have emerged as key tools to build public trust and ensure that transitions are not only technically sound but socially accepted. These lessons show that BRICS countries benefit most when policies are adaptable, evidence-based, and rooted in the needs of their diverse populations.

7.3 Research Question on Technology

What energy resources and technologies are available to ensure near zero carbonisation or zero CO_2 emissions from power producing plants?

This question has been answered comprehensively in chapter 4 of the thesis which discussed various energy sources and technologies that would contribute individually or with other mitigations technologies to provide the desired zero CO_2 emissions.

7.3.1 The Key Insights for Technology

The BRICS countries demonstrate diverse technological approaches to the Just Energy Transition (JET), with a strong emphasis on scaling renewable energy, local manufacturing, and workforce reskilling. Solar PV, wind, and hydropower dominate the energy mix, while emerging technologies like green hydrogen, battery storage, and agrivoltaics are gaining traction. Although natural gas is used as a transitional fuel, its long-term role is limited due to carbon emissions and the high cost of CCUS technologies, which most BRICS nations are avoiding. Instead, they focus on cost-effective renewables and strategic investments in local capabilities, supported by formal and informal skills development programs to ensure inclusive growth and labour sustainability.

7.3.2 Recommendation for Technology

South Africa should align its energy planning with BRICS best practices by prioritising the replacement of aging coal plants with renewable technologies especially solar PV coupled with battery storage and integrating these into a broader master energy strategy. Local manufacturing of energy components and ethical joint ventures should be promoted to reduce costs and support Supplier Development and Localisation (SD&L). Investment in emerging technologies like green hydrogen and microalgae-based CCUS should be explored for long-term viability. To ensure a just transition, South Africa must implement targeted policies for workforce reskilling, local content requirements, and innovation incentives, all aimed at achieving nett-zero emissions by 2050 while fostering economic resilience and social equity.

7.3.3 Lessons Learnt in Technology Adoption in BRICS Countries

Technological innovation has proven to be a powerful driver of cost reduction and scalability in the energy transition across BRICS countries. Advances in solar, wind, and battery storage have enabled these nations to deploy renewable energy solutions more rapidly and affordably. China stands out as a global leader in solar panel manufacturing and wind turbine deployment, capitalizing on economies of scale and robust domestic research and development. Meanwhile, India has made significant strides by integrating digital tools and smart grid technologies, which have enhanced energy access and operational efficiency across its vast and diverse energy landscape.

7.4 Research Question on Social Impact

Will unemployment rates increase due to the impacts of JET and how will the country manage and reduce the negative social impacts?

With reference to chapter 5 that dealt with the social impacts, the chapter provided in-depth information on the impacts and mitigations. In summary, as set out in Table 8, there will be 6million job losses in the carbon intensive energy including the transport, and construction sectors, with a forecast 24million new jobs created with green energy which would be a resultant net gain of 18 million job opportunities globally. The communication, education and training areas would contribute to effective management of any perceived negative social impacts and concerns.

South Africa faces a complex challenge in managing the social impacts of its Just Energy Transition, particularly in coal-dependent provinces like Mpumalanga. While the global forecast suggests a net gain of 18 million jobs through green energy expansion, the local reality is more nuanced. Coal-mining communities are deeply tied to carbon-intensive industries, and

the loss of approximately 6million jobs globally. Many concentrated in sectors like transport, construction, and fossil fuel extraction will disproportionately affect regions with limited economic diversification.

To balance these losses, South Africa must implement targeted, place-based strategies:

- Reskilling and upskilling programs where workers in coal regions should be prioritised for training in solar, wind, and energy efficiency technologies. This would require partnerships between government, industry, and educational institutions.
- Infrastructure investment in affected areas, renewable energy plants should be located near coal communities to facilitate smoother labour transitions and local economic stimulation.
- Social dialogue and stakeholder engagement is imperative and in the best interests of all parties; there must be transparent communication with unions, local governments, and civil society to help manage expectations and reduce resistance to greener energies.
- Social protection measures of income support, job placement services, and transitional funding can cushion the impact of job displacement if aligned and synchronised effectively.

Without these interventions, the risk is that new green jobs will emerge in different regions or require skillsets that displaced workers do not possess. This may result in geographic and structural unemployment. The table below set out the benefits and drawbacks of JET-related employment.

Table 8: Pros and Cons of JET-Related Employment

Pros	**Cons**
Creation of 24 million green jobs globally	Loss of 6 million jobs in carbon-intensive sectors
Opportunity for cleaner, safer work environments	Skills mismatch between old and new industries
Economic revitalization through innovation	Geographic displacement of job opportunities
Potential for inclusive growth if managed well	Risk of social unrest in coal-dependent communities

7.4.1 Key Insight on Social Impact of JET

The JET in BRICS countries reveals that social equity, labour sustainability, and inclusive development are critical to the success of decarbonisation efforts. South Africa stands out for

its formal Just Energy Transition framework, which explicitly addresses job creation, retraining, and community engagement. Other BRICS nations, while not always using the JET label, have implemented policies that support social outcomes such as Brazil's rural electrification programs, China's large-scale green job creation, and India's renewable energy workforce initiatives. However, disparities remain in how effectively these countries integrate vulnerable populations, informal labour, and historically disadvantaged communities into the energy transition. The key insight is that without deliberate social planning, energy transitions risk deepening inequality and resistance, especially in regions dependent on fossil fuel industries.

7.4.2 Recommendation for Social Impact

To ensure a socially JET, BRICS countries especially South Africa should embed equity-focused policies into national energy strategies. This includes establishing formal reskilling and upskilling programs for workers displaced by fossil fuel phase-outs, supporting community-owned energy projects, and ensuring that new energy investments prioritize job creation in underserved regions. Governments should also promote inclusive stakeholder engagement, particularly with labour unions, local governments, and civil society, to build trust and transparency. Social protection measures, such as income support and retraining stipends, must be integrated into JET funding mechanisms. By learning from each other's successes and challenges, BRICS nations can design energy transitions that are not only environmentally sustainable but also socially inclusive and economically empowering.

7.5 Research Question on Funding

How can the future energy initiatives and power plants be funded?

This research question was answered comprehensively in the conclusion of chapter 6. For South Africa to successfully fund JET and future power plants, it will need to use a combination of green funding mechanisms, international partnerships, and support frameworks of JETP, JET IP, IPG, and V20. By aligning these efforts with updated NDCs and GST reviews, South Africa can ensure that the transition is both effective and equitable, driving sustainable energy development while supporting vulnerable communities and industries.

7.6 Research Question on Congress of Parties (COP) 22

Is the Paris Climate Change agreement, COP22 and global warming initiatives achievable for South Africa and if not what's the consequences and remedial actions will be required?

Achieving the Paris Climate Change Agreement, COP22, and global warming initiatives in the context of South Africa is not fully achievable in the near term (year 2030) due to significant challenges, but it is possible over the longer term (by year 2050) with appropriate actions and support. For South Africa to achieve these goals presents significant challenges, but also opportunities. I have summarised below what was discussed in chapters 3,4,5 and 6 in the South African situation, consequences and remedial actions required.

Achievability for South Africa**:**

- South Africa's energy sector is heavily reliant on coal, which accounts for about 90% of its electricity generation. Transitioning to renewable energy is a complex and costly process, particularly given the economic importance of coal exports and employment.
- South Africa is one of the largest emitters of CO_2 in Africa. The country's emissions are mainly from energy production and industrial activities, which are difficult to rapidly decarbonise. South Africa's emissions in 2019 were about 510MTCO_2, and the country is classified as a "high emission" economy. (UNFCCC, 2021).
- South Africa faces significant economic and social challenges, including high unemployment and inequality. A swift transition to a green economy may exacerbate these issues without proper planning, especially for communities and workers dependent on coal-related industries.

Consequences of non-achievement:

- Increased climate vulnerability due to failure to meet Paris Agreement targets could exacerbate climate-related risks in South Africa, including extreme weather events (droughts, floods, heatwaves), water scarcity, and impacts on agriculture, which is a key part of the economy.
- International reputation and trade risk as result of non-compliance with the Paris Agreement could damage South Africa's international reputation and limit access to climate finance, technology transfers, and green investments. Additionally, failure to meet global climate goals could lead to economic penalties, such as border carbon taxes on South African exports (particularly from industries like steel and cement).
- Local health and environmental risks due to a continued reliance on coal which leads to air pollution, health problems, and environmental degradation, contributing to respiratory diseases, water contamination, and biodiversity loss.

Remedial Actions Required**:**

- South Africa needs to scale up its renewable energy capacity, focusing on wind, solar, and potentially hydropower, as well as exploring nuclear and green hydrogen solutions.
- Implementing energy efficiency measures across all sectors (residential, industrial, and transport) would reduce emissions while helping to mitigate economic costs.
- It is crucial to ensure a "Just Transition" to address the social impacts of decarbonisation. This includes retraining workers in the coal industry, developing green jobs, and ensuring the equitable distribution of the benefits of clean energy technologies.
- In addition to mitigation efforts, South Africa should invest in adaptation strategies to cope with the inevitable impacts of climate change, particularly in agriculture and water management.

Conclusion:
South Africa faces considerable obstacles in meeting the Paris Agreement and global warming targets, but with the right policies and support, a transition to a low-carbon economy is possible. The consequences of failure to act include environmental degradation, economic isolation, and social instability. South Africa must act promptly, focusing on renewable energy development, energy efficiency, and social equity in the transition.

7.7 Conclusion

The hypothesis of the thesis: “The Just Energy Transition (JET) is an essential and inevitable pathway for South Africa to reduce and eliminate greenhouse gas (GHG) emissions, with a targeted outcome of zero carbonisation by 2050.”

It’s an affirmative “Yes,” this hypothesis is correct. A Just Energy Transition (JET) is fundamental for reducing and eliminating greenhouse gas (GHG) emissions, with a specific focus on achieving zero carbonisation by 2050. To reiterate the discussions and outcome of the thesis demonstrates that the hypothesis holds true:

- JET is crucial to achieving global climate goals, as it ensures that the shift towards cleaner energy is equitable and just. It focuses on reducing GHG emissions while minimising negative social impacts by addressing issues like job losses in fossil fuel industries and ensuring that marginalised communities are not left behind.
- The Paris Agreement and the global push for carbon neutrality by 2050 requires all countries to drastically reduce GHG emissions. A fair transition means that both the environmental and social impacts of this process are taken into account (UNFCCC, 2021).

- The majority of countries globally, including BRICS and South Africa, have committed to achieving nett-zero emissions by 2050. This goal is widely accepted in international climate agreements (e.g., COP26). To meet this target, transitioning from fossil fuels to clean energy sources is essential.
- Strategies like renewable energy development, energy efficiency, electrification of transport, and the development of carbon capture technologies are part of the roadmap for achieving zero carbonisation (IEA, 2020).

Futuristic Approaches: Policy Formulation, Technologies, and Funding Models

- Energy Policies: Effective policy frameworks are essential to guide the transition, incentivise renewable energy, and regulate emissions from high-carbon industries. Governments need clear long-term policies and regulations that align with the global commitment to carbon neutrality (IRENA, 2020).
- Technologies: Advanced technologies such as renewables (solar, wind, hydro), energy storage, green hydrogen, and smart grids are key to facilitating the transition to zero carbon. The development and deployment of these technologies will play a pivotal role in meeting the 2050 target (IEA, 2021).
- Funding Models: Transitioning to a low-carbon economy requires significant investment, particularly for developing countries. New funding models will be needed to ensure financial support for the transition, including international climate finance, private investments, and innovative mechanisms like carbon pricing (UNFCCC, 2021).

Conclusion:

The hypothesis is correct because JET is essential to achieving the global climate targets, particularly zero carbonisation by 2050. It involves the development of forward-thinking policies, the integration of sustainable technologies, and the creation of inclusive funding models to ensure minimal social and economic disruption. Without these strategies, the transition to a low-carbon future would be less effective and biased.

7.8 Future Research

Based on my thesis covering the BRICS Just Energy Transition (JET) with a focus on technology, policy, social impact, and funding models, there are several interest areas for future research that could emanate from my thesis. These areas will help further understand and advance the JET process in BRICS and globally and promote global sustainable JET transformations. The following future research is suggested:

- Assess the scalability and integration of renewable energy technologies in BRICS with a focus on hybrid systems and energy storage solutions.
- Explore policy synergies and conflicts in BRICS countries' energy transition and opportunities for cooperation.
- Evaluate the social implications JET specifically on job creation and reskilling in BRICS.
- Engage partners in JET and formulate best practices for community involvement in BRICS.
- The impact of international climate policies on BRICS JET by analysing the effectiveness of climate agreements.
- A comparative study on the role of carbon pricing mechanisms in support of JET in BRICS.
- Assess the role of decentralized and off-grid renewable energy systems in BRICS member countries.

Conclusion:

These research topics will not only contribute to the ongoing discourse on BRICS' energy transition but also support practical recommendations that can help each country navigate their unique challenges. Future research can also aid practical approaches for overcoming barriers and realising the full potential of a Just Energy Transition (JET) in BRICS member countries.

CHAPTER 8: RECOMMENDATIONS AND LIMITATIONS

8.1 Introduction

This chapter covers the recommendations of the policy, technology, social impact and funding that was discussed in their respective chapters. In addition, the limitations which influenced the direction of the research project are also provided at the end of this chapter.

8.2 Recommendations on Policy

It is strongly recommended that South Africa adopt a phased and integrated approach to its energy transition, informed by the Integrated Energy Plan (IEP) and the energy policy frameworks of other BRICS nations. The next iteration of the Integrated Resource Plan (IRP) should re-examine and align with global best practices, particularly those from BRICS countries that have successfully implemented renewable energy strategies, local manufacturing incentives, and workforce reskilling programs.

The IRP must include a comprehensive assessment of South Africa's electricity requirements over the next eight years, taking into account the retirement of approximately 8,201 MW of aging coal-fired power stations by 2030. While natural gas may offer short-term efficiency gains, its continued use poses challenges for long-term decarbonisation. Technologies such as Carbon Capture, Utilization, and Storage (CCUS) and co-firing with biomass may reduce emissions but also increase costs, potentially undermining the economic viability of gas plants in a nett-zero framework. To meet the 2050 nett-zero carbon emissions target, South Africa must prioritise the replacement of end-of-life fossil fuel plants with renewable energy alternatives, particularly solar PV coupled with Battery Energy Storage Systems (BESS). China's success in deploying over 6,500 MW of solar and BESS capacity demonstrates the feasibility and cost-effectiveness of this approach. Establishing local manufacturing facilities for solar panels and auxiliary equipment would further reduce costs and support Supplier Development and Localisation (SD&L) initiatives.

The IRP should also support hybrid energy models, such as agrivoltaics or aquaponics, which combine energy generation with agricultural productivity. These models should be evaluated based on regional climate conditions and economic viability. For newer fossil-based plants with remaining lifespans of 20–25 years, the economic feasibility of retrofitting CCUS should be rigorously assessed. Given that many BRICS countries have opted against CCUS due to its high costs, South Africa should explore alternative CCUS technologies, such as microalgae-based systems, which could produce spirulina and generate pharmaceutical revenue streams to offset costs (Condor et al., 2011),

In parallel, hydrogen power plants should be considered as transitional technologies to provide grid stability and support while the country evaluates the long-term viability of nuclear, wind, and gravitational energy systems. These emerging technologies must be assessed for their carbon reduction potential, cost-effectiveness, and scalability. To ensure a just and inclusive transition, South Africa must implement specific policies that:

- Mandate local content requirements for renewable energy projects.
- Provide financial incentives and tax relief for green manufacturing and innovation.
- Establish formal and informal reskilling programs for workers transitioning from fossil fuel industries.
- Promote joint ventures between public and private sectors to ensure ethical and cost-effective technology transfer.
- Create a national green jobs strategy aligned with energy sector reforms.

BRICS countries have demonstrated the importance of policy enablers, such as skills accreditation, funding mechanisms, and local manufacturing mandates, to accelerate energy transitions. South Africa is well-positioned to leverage these lessons and integrate them into a master energy plan that supports its 2050 nett-zero goal while ensuring economic resilience, energy security, and social equity.

8.3 Recommendations on Technology

Chapter 4 of the thesis provided a comprehensive assessment of renewable and non-renewable energy technologies, highlighting the urgent need to transform the energy mix from high CO_2-emitting sources to nett-zero emissions between 2030 and 2050, in alignment with the Paris Agreement, while BRICS countries, including South Africa, anticipate a longer transition period extending to 2070, the imperative to act remains immediate.

There is no singular energy technology capable of leading the transition independently. Each option whether solar, wind, hydro, nuclear, or hydrogen carries distinct advantages and trade-offs in terms of social impact, environmental footprint, cost, safety, lifespan, and implementation efficiency. BRICS countries therefore, must adopt context-specific strategies aligned with their Nationally Determined Contributions (NDCs), selecting technologies that best suit their geographic, economic, and infrastructural realities.

Globally, countries like Germany and Sweden offer valuable lessons. Germany's Energiewende has successfully scaled wind and solar PV, now contributing over 50% of its

electricity mix, with solar capacity surpassing 100 GW in 2024 and a national target of 215 GW by 2032. Sweden, meanwhile, has achieved over 60% renewable electricity generation, primarily through hydropower, bioenergy, and wind, supported by market-based policies and green electricity certificates.

For South Africa, the following technologies should be prioritized to meet its 2050 net-zero target:

- Solar Photovoltaics (SPV): Rapid deployment of rooftop solar and agrivoltaics can accelerate domestic and utility-scale adoption. South Africa's high solar irradiance makes this a cost-effective and scalable solution.

- Battery Energy Storage Systems (BESS): Essential for grid stability and peak demand management, especially when paired with intermittent renewables like SPV and wind.

- Wind Energy: Onshore wind farms should be expanded, particularly in coastal regions with consistent wind patterns.

- Hydroelectric and Pumped Storage: Viable in regions with sufficient water flow, offering reliable baseload and peak demand support.

- Green Hydrogen (H_2): Electrolysis powered by renewables should be prioritized over reforming to avoid GHG emissions. Hydrogen can serve as a future fuel for baseload power, heavy transport, and aviation.

In the interim, natural gas and nuclear energy may serve as transitional baseload sources, offering reduced emissions compared to coal while ensuring grid reliability. Converting aging coal-fired plants to gas-fired facilities could be economically viable if emissions limits are met.

South Africa's Renewable Energy Masterplan (SAREM) and Just Energy Transition Investment Plan (JET IP) emphasize the need for decentralized generation, competitive procurement, and grid modernization. The country must also invest in skills development, transmission infrastructure, and policy coherence to unlock private sector investment and meet its annual renewable energy targets of 6–8 GW from 2030 onward.

In conclusion, while all energy technologies have merits and limitations, a diversified, phased, and locally adapted approach supported by global best practices will be essential for South Africa and other BRICS nations to achieve a successful and equitable Just Energy Transition.

8.4 Recommendations on Social Impact

The social impact of a Just Energy Transition (JET) is both highly sensitive and frequently misunderstood, particularly in the context of global climate action. Chapter 5 has explored the misconceptions surrounding JET, as well as the anticipated economic and health effects of climate change. A successful JET must prioritize inclusive social dialogue at both national and international levels, especially among BRICS member countries, to ensure equitable outcomes. According to the International Labour Organization (ILO), addressing climate change effectively requires not only mitigating its negative effects but also exploring its social and economic opportunities through coordinated policy frameworks (ILO, 2022).

Central to this approach are the ILO's JET guidelines, which outline nine key policy areas of macroeconomic and growth policies, industrial and sectoral policies, enterprise development, skills training, occupational safety and health, social protection, active labour market policies, rights at work, and mechanisms for social dialogue and tripartism (ILO, 2020). These guidelines provide a comprehensive framework for achieving environmental, economic, and social sustainability, and must be strictly adhered to in national transition strategies.

Education, training, and transparent communication are essential to managing the transition sensitively and effectively. These elements must align with the ILO's 2015 policy framework, the Paris Agreement, and the priorities of the Climate Vulnerable Forum (CVF). If implemented globally, compliance with the Paris Agreement particularly in areas such as renewable energy, energy efficiency, and sustainable transportation is projected to generate approximately 24million new jobs by 2030. While this transition may result in the loss of around 6million jobs in carbon-intensive sectors such as energy, transport, and construction, the net global employment gain is estimated at 18million jobs (ILO, 2022).

The distribution of these job gains however, will vary significantly across countries and regions, underscoring the importance of tailored JET policies. These policies must address the sectoral, occupational, and geographic disparities that will arise, ensuring that vulnerable populations are protected and supported through robust social protection systems and active labour market interventions (ILO, 2020). Ultimately, the success of a JET depends on its ability to balance environmental imperatives with economic equity and social justice.

8.5 Recommendations on Funding

The various forms of climate change funding, initiatives and reporting requirements was discussed in chapter 6. The assessments on climate related funding revealed ambiguity in Article 2.1(c) of the Paris Agreement and the mitigation measures and interventions that were initiated to resolve the concerns. The UNFCCC's SCF in its year 2020 Biennial Assessment Technical Report (BATR) enforced a framing for mapping actions relevant to Article 2.1(c) (Naidoo et al., 2023).

The recommendations for climate funding would be as follows:

- It is of vital importance to have financial structures in place to ensure the drive towards decarbonisation of the electricity generation sector is achievable and aligned to the UNFCCC-Paris Climate Agreement.
- Continuous measurement and work on Article 2.1(c) of the Paris Agreement understanding by all parties and this should be a standing agenda item at COP moving ahead.
- GST, which is the formal process, established under the Paris Agreement to systematically, take stock of cumulative progress toward its long-term goals should be embraced by all BRICS member countries. GST would aid countries in identifying the gaps in reaching their NDCs and would be the perfect stimulus to encourage parties to be more committed in the execution of their climate change pledges whilst obtaining valuable support and guidance.
- Updates to NDCs with inputs from the GST should continue.
- JETP should be monitored, enhanced and used as a vehicle to obtain climate related funding with the support from IPG's.
- BRICS member countries should market and encourage prioritisation of combating the sequential challenges of job losses, poverty and inequalities with initiatives such as the South African NDP 2030, JETP, SA's JET IP, etc.
- Encourage private and public participation in funding JET.
- The V20, V20 GS and the CVF initiatives of SIDs and LDCs with their current vulnerabilities are most welcomed and encourage G7 countries to support these initiatives.

8.6 Limitations

The general observation was that the energy policies of BRICS member countries covered governance and plans to direct the JET together with their NDCs and SDGs but did not have generic renewable technology selection criteria embedded. In-depth cost analysis versus the

benefits in the form of “Life Cycle Cost” (LCC) analysis is not accessible. Hybrid renewable energy ecosystem studies and assessments are lacking in general although it’s understandable that it might be conducted at utility or country level but not published based on “Intellectual Property” (IP) rights. On the funding of the JET, the thesis did not consider the carbon tax incentives but covered the major funding initiatives and plans available. Safety aspects of each renewable technology assessment and hybrid technologies safety management plans are not part of most studies.

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