CONFRONTING SOUTH AFRICA'S ELECTRICITY CRISI IN THE CONTEXT OF A BALANCED JUST ENERGY TRANSITION (BJET) AND THE NEED FOR A RELIABLE AND RESILIENT NATIONAL GRID.

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1. Introduction

The concept of balanced just energy transition (BJET) in the context of poverty eradication and sustainable development conveys a massage of hope towards paradigm of new economic growth which is less harmful to the ecosystem of the earth. Climate change is currently accepted as urgent crisis worldwide which calls for rapid and more extensive energy transition however the losing sight of political and ethical consequences concerning social needs is at risk (Quan & Dyer, 2008). The ageing electricity generation infrastructure resulted blackouts and loadshedding for more than a decade in South Africa which impacted the economy negatively. High consumption of coal for the generation of electricity and production of liquid fuel transformed South Africa into one of the most carbon intensive economies in the world(Energy, 2019). This problem can be solved by using renewable energy sources to decarbonize the grid. The government leaders of SA made some commitments to fulfill climate change agreements by reducing all forms of carbon footprint while compounding issues of energy demand(Council, 2022). Energy crisis across the globe is influenced by different complicated dynamics grappling with energy trilemma of security, equity and environmental sustainability(Council, 2022). The socio-economic development of any country depends on energy which plays a critical role in human needs for better living. The main requirements of socio-economic development encompass reliability, affordability, availability, and accessibility of modern energy sources (Doggart et al., 2020).

The improvement of socio-economic conditions in rural areas is possible when rural electrification is prioritized by the government. Although electrifying rural areas is highly expensive due to high transmission and distribution lines costs, electricity maintenance infrastructure costs, low-capacity utilization and lower load densities, the decentralization of renewable energy resources proved to be an efficient option that is more viable for electrification of rural areas. Digitalization empowers energy transition by transforming the production distribution and consumption of energy(Nwaiwu, 2021). Disruptive transition within the energy sector is vital and can be achieved through digital technologies which provide opportunities for power producers and consumers to utilize new models of technology to transform traditional systems of generation and consumption of electricity. The promotion of renewable energy production at a smaller scale can be enacted through deregulation of energy sector and drop energy prices, increase electricity availability and create conducive platforms for private investment (Nwaiwu, 2021).

Most industries producing electricity were state owned therefore regulated and controlled by government with the aim of creating opportunities for the participation of private companies to transform and improve the economy (Necoechea-Porras et al., 2021). The intention of deregulation however is to eliminate state-level policies and reduce control of supervision on energy industry players. Just energy transition partnership between developed and emerging economies offers opportunities that will accelerate technology innovation driven by developing countries with the assistance of international financial support. Risk assessment considers the vulnerability of electric power generation, transmission and distribution that are often exposed to threads such as criminal activities, accidents, natural disaster, negligence etc. (Řehák & Šenovský, 2014). These threads can damage the critical grid infrastructure hence identification of risks having negative functionality effects must be properly analyzed. Restructuring of power systems requires increased power generation efficiency while allocating transmission costs using fair electricity pricing amongst municipalities to satisfy consumers (Bashian et al., 2011). To achieve the intention of this paper, the objectives of this paper include the following factors:

- Overview of balanced energy transition during electricity crisis.
- Legislative matters pertaining to the industry
- Electricity aggregation
- Managing environmental sustainability in electricity crisis

- The benefit of green economy
- Electricity Grid Balancing
- Risk management in an electricity crisis situation
- Hybrid power generation
- Reliable and resilient grid
- Electricity wheeling
- Training and development opportunities in the green economy
- People development in an electricity crisis situation

2. Overview of Balanced Energy Transition During Electricity Crisis

As climate change has transformed into environmental crisis, the requirement to transition away from fossil fuels to green economy is urgent and growing globally (Kumar et al., 2021). By 2030 countries of the world were given targets to reduce carbon emission by 50% to limit the global warming worst effects. SA is the largest emitter of greenhouse gasses in the continent, the electricity generation relies solely on coal for the energy supply. Moreover, the power utility experiences challenges such as supply shortages due to old infrastructure resulting frequent power cuts increasing the electricity prices. In addition to electricity crisis, the deployment of renewables at large scale is regarded as the future vision towards green economy(Kumar et al., 2021). The integrated resource plan of 2019, established targets of increasing the capacity of renewable energy using solar and wind power at the total amount 22500MW and phase out coal generating plants by 2030 which will reduce the total power generated from coal accounting to 11000 MW(Energy, 2019). The purpose of this paper is to scrutinize the possibility of balance energy transition process when sources of anthropogenic greenhouse gas emissions (GHG) are alleviated using renewable energy systems to eradicate poverty through sustainable development.

3. Legislative Matters Pertaining to The Industry

The number of regulations fostering competition in the energy sector have been implemented where multiple companies functioning in electricity business will participate to decrease the electricity prices for the consumers while improving the economy of the country. Different regulations have been promulgated to ensure that stakeholders maintain compliance with the set standards in the energy sector. The intention of policy makers is to create more opportunities for private company participation impacting the energy sector thereby transforming the economy. One of the responsibilities of Department of Energy (DoE) is to undertake progressive strategic energy planning with the purpose of implementing recommendations based on future projections stipulated in the national policy. The main focus of national policy is to improve the energy trilemma i.e., security, equity and environmental sustainability of the country and review key arears in the white paper pertaining electricity generation capacity including new legislation across entire energy sector. The cabinet of South African discuses polices in details concerning new technologies that will disrupt large traditional monopoly suppliers and create opportunities for emerging small firms to compete in the energy sector both in local municipalities and provincial government. The energy sector development is governed by the white paper of 1998. The white paper emphasized objectives addressing five keys of energy supply which includes: governance improving energy sector, increase energy access and affordability, improve economic developments, managing environmental impacts; and energy security supply through diversity. In response to impact of climate change the government of South Africa made commitments to reduce greenhouse gas emission endorsed by United Nations Framework Convention on Climate Change (UNFCCC) in August 1997 complied to the Kyoto Protocol in August 2002. National Energy Policy of 1998 supported renewable energy investment while the white paper acknowledged specific conditions concerning renewables which requires careful consideration during deployment of technologies related to clean energy.

4. Electricity Aggregation

The integrated resource plan of 2019 was compiled for development of the electricity infrastructure using renewable technology to maintain balance between supply and demand while considering security and environmental sustainability(Energy, 2019). The requirement of energy policy based on robust technology will emphasize adaptation and mitigation of climate change focusing on the concept of the 4Ds which are the pillars of environmental sustainability to establish the green economy(Asif, 2022). The Independent Resource Plan of 2019 was the extension of the IRP 2010 which was promulgated to identify the energy source that will match the technology required to meet the demand of electricity growth until the end of the year 2030(Energy, 2019). Pioneering a robust green economy in South Africa requires substantial capital investment belonging to the state and private companies(Necoechea-Porras et al., 2021). To promote collaboration and coherence diversity of stakeholders such as internal development agencies, business units, government, financial institution, researchers, civil society, consumers and advisory from different sectors should participate in the balanced just energy transition(Steyn et al., 2021).

The success of BJET requires key departments that will oversee the implementation of strategies stipulated in the IRP 2019 using policy responsibilities assigned to them. During the implementation of the plan, science and technology policy will be monitored by the Department of Science and Technology (DST), state enterprises will be handled by the Department of Public Enterprises (DPE) and energy planning and regulation will be managed by the Department of Mineral Resources and Energy (DMRE). Other policy areas such as industrial policy, fiscal reform, environmental policy, industrial safety and transport policy are other supporting departments during project implementation. Department of Environmental Affairs will oversee climate change mitigation projects, Department of trade and industry will manage innovation projects, national treasury will manage the financial institutions supporting the project, and Department of Labor (DoL) will be responsible for employment equity and governance(Technology, 2007). The BJET activities are expected to support the entry of South Africa towards green economy yielding promising outcome of cultivating skilled workforce under science and technology, engineering proficiency and environmental management (Technology, 2007)

5. Managing Environmental Sustainability in Electricity Crisis

The impact of climate change from anthropogenic greenhouse gas emissions threatens the livelihood of humanity on a daily basis but renewable energy as defence policy plays a critical role in all the strategies compacting environmental issues(Quan & Dyer, 2008). Energy plays a critical role in the socio-economic development of any country (Doggart et al., 2020). In the midst of electricity crisis, pillars of dimensional transition for environmental sustainability (4Ds) are required to evolve the energy trilemma in SA to guarantee energy security with renewable energy sources such solar, wind and hyro PV, equity and sustainability. Digitalization, Decentralisation Decarbonisation and Deregulation are forces that can drive innovation for renewable energy supply to meet electricity demands(Asif, 2022). The objective of energy trilemma index encourages policy makers, governments, and private sector investors to improve the performance of policies within the energy sector by introducing innovation and development sustainability. In 2022 South Africa was ranked 58th, improving from 74th in 2020, in the world energy trilemma index(Council, 2022) . The implication of the energy trilemma ranking is for the development of a policy for significant investment in renewable energy technologies.

5.1 Energy Security

The threats opposing energy supply and security highlighted by the Russia-Ukraine war resulted in the recommendation and development of energy policies across many countries. Many countries including South Africa realised the need for redesigned resilient energy systems in response to international supply shocks (Aydin, 2015) Conversely the electricity crisis in the country is aggravated by ageing infrastructure and poor quality of fuels during electricity generation(Volk, 2013). On the contrary losses identified in the transmission and distribution lines exert negative pressure in the economic growth of the country. The major South African welfare interruptions affecting households and businesses are electricity shortages and poor infrastructure (Volk, 2013). South Africa possesses large coal reserve

therefore 80% of electricity generation is produced from coal whereas deployment of renewable grow at a very slow pace affected by poor investment. The national development plan (NDP) states that the energy infrastructure that is effectively stable has strong impact towards economic growth therefore should be extensively robust to achieve current and future social, commercial and industrial needs of South Africans. Post the deployment of Renewable Energy Independent Power Producers Programme (REIPPP), NDP and Eskom roadmap were established to encourage the ambition of the nation with policy framework and the micro-economic impacts of green economy. The success of energy security of any country requires the energy transition such as Mexican reforms where climate mitigations produced successful political and economic benefits of low electricity prices for affordability and accessibility(Necoechea-Porras et al., 2021).

5.2 Energy Equity

One of the barriers of green economy is the electricity prices from renewable energy that is highly cost effective at the initial stages of production. Fossil fuels are cheaper than renewable energy technology which are more sensitive to the rising of project finance. Socio-economic stresses and shocks that can lead to conflicts can be controlled by the deployment of renewables (Necoechea-Porras et al., 2021. People in the rural arears can get access to clean energy and receive employment opportunities through sustainable developments. Although projects connected with renewable energy have low operating expenditure over time, the upfront investment for new project infrastructure is too expensive. Renewable energy projects are exposed to cost of capital variations (Sweerts et al., 2019). The major obstacle for deployment of renewable technologies in our country is normally the initial cost of project finance and capital. Deregulation contest against vertical integrated utilities allowing private sector participation to bring competition thereby backing reduction and affordability of electricity prices(Sweerts et al., 2019). Monopoly entities limit consumers options to choose their preferred suppliers because there is lack of competition in the electricity market therefore electricity tariffs will continue to increase irrespective of loadshedding (Necoechea-Porras et al., 2021.

5.3 Environmental Sustainability

The energy sector contributions towards GHG emissions are approximately 80% from the generation of electricity and 50% from the production of liquid fuels. South Africa is number 42 major emitter per capita among the developing countries. If GHG Emissions are not addressed in SA, the country might probably face constraints regarding global imposed emission in the future. In the past during industrial revolution, energy transition occurred and energy systems were formally based on geographically concentrated resources such as oil, coal and natural resources. Moden industrialisation has largely been driven by the extraction of fossil fuels which became abundant energy source of electricity and synthetic oils (Tena, 2021). Some of the coal fired power plants in Eskom have reached the end of design life in 2019 already. Responding to climate change and reduction of greenhouse gas emissions the deployment of renewable energy emerged as a solution to allow countries to decarbonise their economies. Lately, development of clean energy technologies has encouraged many countries to increase investments and funding towards renewable energy projects (Martins & Carton, 2023a). Energy transition will vary from one country to another when local conditions are put into considerations. Since the economy of South Africa is carbon intensive the sterilization of power generation from abundant coal reserves is pointless, however energy efficiency projects and technologies specializing with cleaner coal environments and low emissions should be considered (Energy, 2019). Cleaner coal technologies which can be used for the exploitation of coal include ultra-supercritical, integrated gasification combined cycle, supercritical, carbon capture utilization and storage(Energy, 2019). The power plant in South Africa meets air quality regulations under the National Environmental Management Act (Act No.39 of 2004. Part of South Africa's national determined contribution plan was to reduce greenhouse gas emissions honouring the Paris Agreement commitments, protect the wellbeing of the people.

6. The Benefit of Green Economy

In the next century, economic development will continue to rise impacting the energy demand to grow significantly, driven from the increased population emerged from poverty background. Equity which is the energy access and affordability will continue to be limited in African continent because only few households have access to electricity. Every year the population of African continent grow by 2% far exceeding the rate of energy accessibility restraining the people, households and businesses to connect to modern energy services(Sweerts et al., 2019). The continent of Africa failed to observe the implication of United Nations Sustainable Development Goal 7 and realised that universal accessibility is vital to "ensure access to affordable, reliable, sustainable and clean energy for all" (Sweerts et al., 2019). Majority of people in Sub-Saharan Africa still depend on traditional biomass for cooking and heating. The population growth affecting the energy demand is not the only reason for considering alternative energy supply options, coal like other fossil fuel produces carbon dioxide during combustion which becomes a serious environmental thread across the globe. The reliance from fossil fuel can significantly be reduced to the option of renewable energy transition as part of sustainable energy supply (Volk, 2013). The economic vulnerability of South Africa will be reduced when larger use of renewable energy disrupts the reliance of imported fuel for energy production. Surplus renewable energy produced will be exported globally increasing the economy of South Africa. Power utilities adopted strategies of embracing technologies that will satisfy customers therefore new technology in the electricity industry impacted the economy by reducing the costs of operational utilities and electricity prices (Necoechea-Porras et al., 2021). Some vertical intergraded utilities experienced financial setback and introduced energy reform to privatized business activities from public to private ownership with the aim of bringing innovation i.e., technology changes to improve delivery services and satisfy customers (Necoechea-Porras et al., 2021). The independent power producers (IPP) can be adopted successfully through privatization processes restructuring business environment to allow competition, change technology and reduce electricity prices(Necoechea-Porras et al., 2021). Green economy will improve the political power for South Africa with the advantage of fossil fuel plant refurbishment using clean energy technologies, decrease reliance on concentrated energy source and deployment of renewables from proximity to the point of utilization. This transformation decision will eradicate poverty and increase employment creation to support the social welfare of the people.

7. Electricity Grid Balancing

Systems services intending to maintain network reliability at the same time support competition in the electricity market can be regarded as network operations. The other name for network services is ancillary services which prevent supply imbalance and infrastructure overloading to avoid generator damages, blackouts, technical failures occurring in the power network(Volk, 2013). Although network operations are designed as engineering services, the government uses administration services to focus more on the cost for socialisation rather than improving the network infrastructure of electricity supply. (Volk, 2013) South African government turns to focus on providing more people with electricity while the system was not designed to function over specification capacities as a result demand exceed supply. In additional most state-owned entities own old infrastructures with poor maintenance due to lack of investment for network modification and lack of revenues for new projects capital expenditure (Mirzania et al., 2023. Majority of electricity systems are vertically integrated utilities meaning the government is regulating power utilities to follow UN sustainability Goal 7, however the electricity grid system has insufficient capacity to accommodate energy from conventional fossil fuel coal plants and renewable energy (Volk, 2013). If power generation from fossil fuel remains in operation to increase energy accessibility for all, then renewable energy requires new electricity infrastructure network to meet extra electricity demand (Volk, 2013). Electricity network in South Africa is based on centralised energy systems, however ageing electricity infrastructure including coal fleet will limit the pace of transitioning to renewables. Grid reliability and availability requires understanding of maintaining electricity systems balance between power supply and demand to attain security supply (Mirzania et al., 2023). Frequency deviations, below or above the 50Hz happens when supply and demand imbalances are experienced in the network (Volk, 2013). If South African grid is not diversified with new network infrastructure to accommodate renewables, parts of loads from electricity supply sources can be disconnected temporarily due to bottlenecks from transmission network infrastructure eventually

involuntary loadshedding will be resulted (Volk, 2013). Electricity system capabilities can be disrupted by network congestion from renewable integration when availability of network is exceeded by renewable feed-in sources (Volk, 2013). Clean energy transition requires investment for project capital expenditure, investors conversely require higher rates of return due to financial risk caused by political, low economic growth, weak regulatory framework and political interference in the electricity sector(Mirzania et al., 2023). Investors from renewable requires stable companies to make sure that the project will generate revenue for their return on investment (Mirzania et al., 2023).

8. Risk management in an electricity crisis situation

Vulnerable and critical infrastructure are identified within electricity power systems. Electric power lines are usually exposed to different kind of threads especially around generation, transmission and distribution services. Grid malfunctions such as ageing infrastructure and limited investment resulted high technical problems, commercial losses and poor availability and reliability of assets even though other aspects such as vandalism, natural disasters, overgrown vegetations from remote arears contributed towards the poor performance of the grid. Risk with such negative effect must be identified and analysed to find solutions for improvement. Risk assessment is suitable to assess vulnerability that has the capability of damaging critical infrastructure. The method of multi criteria analysis (MCA) is suitable to assess risks in the electric power systems(Řehák & Šenovský, 2014). MCA model contains three types of criteria which should be ranked through decision making: 1. Decision options must be established from alternatives, 2. Set of standards must be considered to identify the relevant technical measure, 3. Through decision and standards quantity performance measure shall be selected. In the first stage of the assessment the evaluator will define the standard according to his opinion. The standard will then will endorsed by the stakeholder consensus. In the second stage the standard specification for electric power lines performance will be presented with index values. The third stage actual calculation values will be compared to the specification standard index values (Řehák & Šenovský, 2014). If the calculated values are above the specification corrective maintenance action must be implemented to improve the performance of the grid. Digitalisation offers a cheap solution to address all these challenges. Digitalization cannot be confused with digitisation which involves physical replacement of things using digit version(Nwaiwu, 2021). This technology focus on the root cause of the problem, monitoring critical infrastructure for capacity and resilience. Digital innovation involves digital technologies that are used to change business models and while new revenue is provided with new production value opportunities. New economic models such as renewables can be facilitated by the deployment of digital technologies addressing production and consumption of energy through digital optimization process (Nwaiwu, 2021). Smart grids adopt and implement advanced technologies to monitor and manage transmission network using the method of digitalisation to meet different electricity demand across South Africa. Digital technologies can use new renewable energy models and transfer them to existing production and consumption.

9. Hybrid power generation systems

Developed countries have indicated that renewable energy sources such as wind, biomass, solar, and hydro have contributed greatly to the environment, sustainable energy development and brough socioeconomic benefit of several nations(Aliyu et al., 2018). Africa is vulnerable towards climate change effect this was noticed by the United Nations. The cause of vulnerability is due to the fact that the continent has more population growth and associated human activities, impeding water crisis and overdependence on agriculture. Renewable energy is a sustainable option that can relief Africa from fossil fuels. The use of more renewable energy will increase the economy, create jobs and stop depending on imported fuel (Aliyu et al., 2018). Department of Minerals and Energy developed the renewable energy white paper setting renewable energy target for energy contributions including strategic applications. The country has large and vital potential benefits coming from renewable energy resources, the contribution will be evident in the energy sector, economy and improved lifestyle of South African society. The cost of energy is very crucial because it is the factor that determines the prize of renewable technologies. Serious attention to the deployment of hydropower for electricity production was not noticed in South Africa due to water scarcity (Aliyu et al., 2018). The

overall capacity of hydropower electricity in South Africa is about 5%. Solar energy has the highest resource potential for renewable energy production in South Africa. (Aliyu et al., 2018). Technologies that are most popular with electrical energy production from solar radiation is concentrated solar power (CSP) or solar thermal energy and Photovoltaic (PV) solar energy. Northern Cape has the highest solar radiation potential with the total area approximating 194,000 km^2. This province has the best solar resource in the world and can produce 1300 MJ/m2 per year which is equivalent to 1 kWh/m^2. The greatest wind prospect in the entire sub-Saharan Africa was identified in the Western Cape with the wind speed ranging from 7.29 to 9.70 m/s which was recorded in the Cape Alguhas through Cape point. The studies revealed that South Africa possess the potential wind energy between 500MW to 56 000 MW (Aliyu et al.,). South Africa has a significant amount of energy from biomass for generation of electricity. Bagasse from sugar mills and paper packaging can produce biomass to generate steam that will be converted into electrical energy from biomass accounting to approximately 210 GWh of electricity per year (Aliyu et al., 2018). South Africa has the ability to tackle energy challenges in this country using the best model of wind, solar and hydro technologies to improve the economy and create employment.

10. Reliable and resilient grid

Rapid growth of population and industrial operation require more electricity in this present era hence power demand will continue to increase. Development of national grid and attempt to mitigate power generation to balance supply and demand is still a mystery in South African power network systems. Power shortages or load shedding have the capability of controlling transmission losses and improve the transmission lines but this is a temporary solution at the expense of the consumers. The modernization of transmission and distribution lines can be implemented by Smart grid technologies(Vijayapriya & Kothari, 2011). Smart grid is relevant for reliable and resilient network because it is basically the digital upgrade transmission grids intending to reduce losses, optimize current operations to open new energy markets for alternative production. Modernized electricity network has the ability to reduce power consumptions during peak hours limiting consumers to demand more electricity using the technical control measure called demand side management. This method of control enables grid connection with power generators like wind turbines, photovoltaic arrays, micro hydro and combined heat power generators to incorporate grid energy storage and balance load during distributed generation and eliminating failures (Vijayapriya & Kothari, 2011). Smart grid promotes services and products innovation using intelligent monitoring communications, technologies, controls to facilitate operation of generators efficiently. Modernized electricity gives consumers an opportunity to optimize operation systems efficiently on the energy consumption side of the value chain. Reliable and resilient grid is possible through permits acceleration towards network system procedures to make power lines more efficient to expand network grids and accommodate new infrastructure designs. Network asset innovation will improve the performance of existing high voltage lines through refurbishment of superconductivity technologies (Vijayapriya & Kothari, 2011).

11. Electricity wheeling

South Africa is not the first country to experience loadshedding, power systems of many developing countries went through the same process of restructuring power generation to satisfy the consumers of electricity. Transmission lines was given more attention after the restructuring of power generation based on creating incentives for investment and transmission field investment recovery. The definition of electricity wheeling is the use of transmission facilities owned by utilities in order to transmit power for other buyers and sellers(Bashian et al., 2011). A wheeling contract refers to the right of a buyer and seller to transfer energy using transmission network belonging to the utility. Wheeling transaction include the buyer, Seller and utility transmission network. The operator of utility transmission network can be called a wheeler. Two wheeling principles regarding costs models is includes transmission capacity costs and cost of transmission capacity usage for any transaction. Wheeling transaction is simultaneous network injections and retrieval of one or more nodes and can be separated in three entities: 1. Point to point wheeling transaction from meaning injection and retrieval location is based on the same network for example independent power producer injection and retrieval using Eskom

power network. 2. Interconnected system point meaning the injection happens outside the network while retrieval of electrical energy is released in the network distribution. 3.Point-inter connected system meaning the injection happens inside the distribution network while electrical energy retrieval occurs on the outside of the network (Bashian et al., 2011). Like any network several impacts affect the wheeling contracts like power generation deviations, transmission congestion and increasing infrastructure losses. In terms of the wheeling contract any network losses will be called forced losses meaning a buyer or a seller will recover them through maintenance payment. It is very important for transmission and distribution costs to be allocated fairly among network users (Bashian et al., 2011). Wheeling contracts should encourage fairness of transmission tariffs for the buyers and sellers during peak and off-peak periods. National Energy regulator of South Africa must intervene and make sure that fair electricity pricing is required during transmission cost allocations. To attract production and transmission investment, proper transmission pricing is required to promote efficient operation and maintenance of electrical energy systems (Bashian et al., 2011).

12. Training and development opportunities in the green economy

The supply of skills to invent, develop, deploy, and operate technologies to solve operational and environmental challenges is one of the key enablers for technological change. According to Pollet, Staffell, and Adamson (2015), a highly skilled labour base is necessary for driving new innovation and critically leveraging new technologies. Promotion of human development in green economy is driven by problems of human induced climate change which led transformation interests around sustainable growth (Bowen, 2012). The right approach of sustainable growth is poverty eradication and safety of human lives not reduction of welfare and productivity is the result of environmental degradation caused by impacts of climate change. Climate smart policies focus on enhancing development, decrease carbon footprint through financing just energy transition projects and mitigate the vulnerability of human beings and power system infrastructure(Bowen, 2012). The consequence of green growth is based on developing electricity infrastructure to decarbonise the grid rather than growth for labour markets and health and safety of humans affected by the impact of climate change. Green jobs are associated with environmental crisis and upskilling of employees working in fossil fuel plants to be competent in renewable industries (Bowen, 2012).

The emerging of green economy exposed the limitation of renewable technological labour related problems in South Africa. The requirement of skills and training for green jobs is one of the challenges that department of labour is facing because environment, health, technology, electricity and mining is involved. History revealed that producing a labour force predominantly for technological intensive industries such as power generators, construction of renewable energy systems, design and manufacturing power system infrastructure, refurbishing power system infrastructure is challenging in the growing labour market of South Africa's green economy (Cosbey, 2011). During the process of just energy transition people might lose jobs and income hence an industrial policy is required to foster competition and create employment in the private companies to participate in building the green economy (Cosbey, 2011). To further increase the skills capacity, EWSETA in partnership with the Department of Science and Innovation (DSI), has undertaken to train unemployed graduates from technical and vocational training (TVET) and universities of Technology with N4 to N6 level qualifications in chemical, mechanical and electrical engineering on green technologies. This will contribute to the growth of renewable technology skills in the country and benefit the country positively in achieving its decarbonization goals.

13. People development in an electricity crisis situation

Job analysis of skills availability requires identification of coal sector employees with skills gaps. Employees in the coal sector requiring upskilling and reskilling should be recognised by department of labour (Bank, 2018). The approach for upskilling and reskilling must be identified with the intention of closing skills gaps between fossil fuel and renewable energy. The action plan development like upskilling and reskilling program must be established and approved by all stakeholders involved in balance energy transition. Voluntary separation packages (VSPs) can be avoided by reskilling

employees during restructuring process, employment from construction of renewables can allocate remuneration until the production of electricity from greenfield projects is established. Long- and short-term strategies concerning upskilling and reskilling of fossil fuel employees must be developed and implemented. Utilization of coal policies to gradually phase out coal industries should be promulgated for participation of all stakeholders. The coal qualities improvements shall be practiced to maintain compliance at the mines for the remaining extension of existing coal power plants to maintain base loading. The processes for bidding must be reviewed to exercise competition and appropriate tender processes (Bank, 2018). The timeline against milestone is important for monitoring and evaluating the progress for reskilling and upskilling. Continuous improvement assessment is vital to revise and correct all deviations and mistakes identified. Identified upskilling and reskilling approaches disturbing the progress of development should be corrected and adjusted. Clear goals and strategies of stakeholder engagement must be communicated to the relevant parties. Ongoing reskilling and upskilling improvements will be implemented as the project progresses (Bank, 2018). Discussions of any changes must be communicated in English via emails and departmental meetings.

14. Conclusion

It is proven that climate change has transformed into environmental crisis therefore urgent transition away from fossil fuels to green economy is essential. Electricity crisis in South African can be resolved by the deployment of renewables at large scale and refurbishment of existing infrastructure to improve energy efficiency with the aim of transitioning eventually to green economy in the future. A policy framework focusing on implementing new technologies to disrupt vertical integrated utilities and create opportunities for private companies and emerging small firms to compete in sub-Saharan Africa energy sector. To promote collaboration and coherence diversity of stakeholders requires supervision from the public and private companies to ensure smooth participation during the process of balanced just energy transition. To improve the performance of energy policy the energy trilemma and 4Ds of energy transition are key points to guarantee security, equity and environmental sustainability when renewable energy sources such solar, wind, hyro and biomass are utilized. Privatization of existing generators and Independent Power Producers (IPP) will accelerate restructuring of business environment to allow competition, change technology and reduce electricity prices. Grid reliability and availability involves balance between power supply and demand to attain security supply. Electricity system capabilities can be disrupted by network congestion from renewable integration when availability of network is exceeded by renewable feed-in sources. Digitalization must not be confused with digitization which involves physical replacement of things using digit version rather digital innovation involving digital technologies to change business models for new productions. South Africa has the ability to tackle energy challenges using the best model of renewable energy technologies such as wind, solar and hydro to achieve green economy and create employment to eradicate poverty. Quality maintenance to produce power at acceptable specification requires integration of new renewable generators, refurbishment of old existing infrastructure and development of power systems. Attraction of production and transmission investment entails proper transmission pricing to promote efficient operation and maintenance of electrical energy systems. Climate smart policies focus on enhancing development, decrease carbon footprint through financing just energy transition projects and mitigate the vulnerability of human beings and power system infrastructure.

References:

Aliyu, A. K., Modu, B., & Tan, C. W. (2018). A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria. *Renewable and Sustainable Energy Reviews, 81*, 2502-2518.

Asif, M. (2022). *The 4Ds of Energy Transition*. https://www.wiley.com/en-in/The+4Ds+of+Energy+Transition%3A+Decarbonization%2C+Decentralization%2C+Decreasing+Use%2C+and+Digitalization-p-9783527831432.

Aydin, U. (2015). Theoretical Framework of the European Union's Energy Security Challenges in 21st Century. *Eurasian Studies Journal*, *2*(2), 48-60.

Bashian, A., Sharifian Attar, T., Javidi Dasht Bayaz, M. H., & Hojjat, M. (2011). DETERMINATION OF TARIFF FOR WHEELING CONTRACTS CONSIDERING FAIRNESS CONGESTION COSTALLOCATION. European Power and Energy Systems) EuroPES 2011),

Bowen, A. (2012). 'Green'growth,'green'jobs and labor markets. *World bank policy research working paper*(5990).

Cosbey, A. (2011). Trade, sustainable development and a green economy: Benefits, challenges and risks. *The Transition to a Green Economy: Benefits, Challenges and Risks from a Sustainable Development Perspective*, 40.

Council, W. E. (2022). *World Energy Trilemma Index.*

Doggart, N., Ruhinduka, R., Meshack, C. K., Ishengoma, R. C., Morgan-Brown, T., Abdallah, J. M., Spracklen, D. V., & Sallu, S. M. (2020). The influence of energy policy on charcoal consumption in urban households in Tanzania. *Energy for Sustainable Development*, *57*, 200-213.

Energy, D. o. (2019). *Integrated Resource Plan*.

Kumar, A., Höffken, J. I., & Pols, A. (2021). *Dilemmas of energy transitions in the global south: balancing urgency and justice*. Taylor & Francis.

Mirzania, P., Gordon, J. A., Balta-Ozkan, N., Sayan, R. C., & Marais, L. (2023). Barriers to powering past coal: Implications for a just energy transition in South Africa. *Energy Research & Social Science*, *101*, 103122.

Necoechea-Porras, P. D., López, A., & Salazar-Elena, J. C. (2021). Deregulation in the energy sector and its economic effects on the power sector: A literature review. *Sustainability*, *13*(6), 3429.

Nwaiwu, F. (2021). Digitalisation and sustainable energy transitions in Africa: assessing the impact of policy and regulatory environments on the energy sector in Nigeria and South Africa. *Energy, Sustainability and Society*, *11*(1), 1-16.

Quan, J., & Dyer, N. (2008). Climate change and land tenure: The implications of climate change for land tenure and land policy (Land Tenure Working Paper 2).

Řehák, D., & Šenovský, P. (2014). Preference risk assessment of electric power critical infrastructure. *Chemical Engineering Transactions*, *36*.

Steyn, G., Tyler, E., Roff, A., Renaud, C., & Mgoduso, L. (2021). The just transition transaction: A developing country coal power retirement mechanism. *Meridian Economics, Cape Town. Available online*.

Sweerts, B., Dalla Longa, F., & van der Zwaan, B. (2019). Financial de-risking to unlock Africa's renewable energy potential. *Renewable and Sustainable Energy Reviews*, *102*, 75-82.

Technology, D. o. s. a. (2007). *Corporate Strategy*.

Vijayapriya, T., & Kothari, D. P. (2011). Smart grid: an overview. *Smart Grid and Renewable Energy*, *2*(4), 305-311.

Volk, D. (2013). Electricity Networks: Infrastructure and Operations. Too complex for a resource?