# ASSESSING THE ACTUAL COST OF ALTERNATIVE ELECTRICITY GENERATING TECHNOLOGIES IN SOUTH AFRICA IN LINE WITH ITS ECONOMIC DEVELOPMENT REQUIREMENTS

**THESIS**

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## ABSTRACT

### Purpose

Most developing and emerging economies have a dilemma. On the one hand, there is intense global political and social pressure to limit their emissions of Carbon and Greenhouse House Gases (GHG); on the other hand, they are faced with high unemployment and high levels of poverty. Every country needs to assess its economic and social needs. Energy is a critical driver for meeting these objectives. Hence this thesis critically assesses these needs using South Africa as its example.

### Approach

Several critical steps must be followed in such an assessment. The direction of climate change is based on scientific facts about the short-, medium- and long-term natural cycles. Natural climate change and the impact on climate and weather of energy generation globally and in the region must be evaluated.

The impact of electricity generation is based on different energy sources after considering the backup required and any proven technical improvement to mitigate their impact and damage to the environment, climate and weather.

The energy sources available in the country, in this case, South Africa and the region where the electricity generation will be delivered.

The significant requirements in terms of electricity are usage to meet its economic growth and the social benefits of the country or region. These primary needs must be carefully examined and analysed, including the actual economic cost of dispatchable electric generation, supply and delivery. This analysis must include the generation supply and delivery of the electricity generated, the total backup cost, the economic cost, and the long-term impact.

### Findings

The research found that there was substantial evidence available from acknowledged experts and global experts that Anthropogenic Global Warming caused by fossil fuels was not an existential threat to humanity. Furthermore, it was likely to be highly expensive and slow economic growth and social development in countries such as South Africa. It would significantly set the country back in its primary objectives, reducing inequality, unemployment and poverty. The only successful way forward is by achieving high levels of economic growth and ensuring that policies spread these benefits across the population so that poor people benefit from the higher economic growth generated.

### Research Limitations

The subject of climate change, the economic and social development needs of an economy, the specific needs of its citizens, the energy resources available, their cost and their environmental impacts and externalities are enormous. Many of these, mainly for newer technologies, particularly wind and solar, have not yet been adequately researched. A study of Sustainable Development Goals is therefore not possible in this thesis. In addition, the study has had to be

limited to the sources of energy available in South Africa, namely solar, wind, coal, nuclear and potentially gas. These are significant sources of energy under discussion in the country at present. In addition, potential future cost improvements, efficiency and technical developments have not been considered as these are likely in all the technical fields with new development all possible.

**Practical Contribution**

The thesis has shown that emerging and developing economies rich in fossil fuels, such as South Africa, should use their cheapest natural resources to gain a comparative economic and competitive advantage. The thesis evaluates the significant elements and factors that assist in making such a decision. The queries have been answered; the hypothesis is that in South Africa's case, the primary energy resource that should be used is its coal and coal reserves. South Africa also has substantial quantities of uranium. Because of these uranium reserves, nuclear power generation should also be a significant energy source if it can be financially and economically cost-competitive. This thesis has proved this to be the case, mainly if one follows a guideline nuclear at the coast and High-Efficiency Low-Emissions (HELE) "clean coal" inland. The thesis emphasises the requirement for reliable, secure power at the lowest economic cost. All other energy sources are for backup purposes or to fulfil specialist regional or business needs at this economic and technological development stage.

**Originality and Value**

The thesis is a unique study. It has examined the research of all the critical components necessary to make a reasoned and factual choice of the best and most economical method of selecting the correct energy mix. It has developed a practical model to examine the cost of extracting and delivering each energy source, including long-term costs and the economic costs of lost production. It will permit government energy planners and industry to evaluate alternative energy sources and their supply allowing a region or country to maximise its economic growth to reduce inequality, unemployment and poverty. These are the three essential requirements for improving living standards and achieving social equilibrium.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AFOLU | Agriculture, Forestry and Other Land Use |
| ANC | African National Congress |
| AGW | Anthropogenic Global Warming |
| ASEAN: | Association of Southeast Asian Nations |
| ASGISA | The Accelerated and Shared Growth Initiative for South Africa |
| bn: | Billion |
| CAS | Complex adaptive system |
| CBM: | Coal Bed Methane |
| CCGT: | Combined Cycle Gas Turbine |
| CCUS: | Carbon Capture Use and Storage |
| CAGE | Closed Cycle Gas Engine |
| CCS | Carbon Capture and Storage |
| CCUS | Carbon Capture Utilization and Storage |
| CEA: | Construction Engineers Association |
| CLDs | Causal loop diagrams |
| CNG: | Compressed Natural Gas |
| COD | Commercial Operation Date |
| COE | Cost of Energy |
| COO: | Chief operating Officer |
| COP: | Conference of the Parties |
| COUE: | Cost of Unserved electricity |
| CO2: | Carbon Dioxide |
| CPI: | Consumer Price Index |
| CSIR | Council for Scientific and Industrial Research |
| CSP: | Concentrated Solar Power |
| DBG: | Deep Biogenic Gas |
| Degrees C: | Degrees Centigrade |
| DEA | Department of Environmental Affairs |
| DARE | Department of Mineral Resources and Energy |
| DOE: | Department of Energy |
| DSM | Demand-side management |
| ERP | Electricity Transition Platform |
| EU: | European Union |
| FDI: | Foreign Direct Investment |
| EPRI | Electric Power Research Institute |
| FGD | Flue Gas Desulphurization |
| FET: | Further Education and Training |
| FI: | Fixed Investment |
| FPL: | Food Poverty Line |
| GDP: | Gross Domestic Product |
| GEF | Grid Emission Factor |
| GFI: | Gross fixed investment |
| GHG | Greenhouse Gas |
| GHGE | Greenhouse Gas Emissions |
| GJ | Gigajoule |
| GW: | Giga Watt (one thousand Mega Watts) |
| GWh: | Giga Watt hour |
| GOS: | Gross operating Surplus |
| GVA: | Gross value added |
| Hg | Mercury |
| HELE: | High-Efficiency Low-Emissions |
| ICE | Internal Combustion Engine |
| IEP: | Integrated Energy Plan |

| | |
|---|---|
| IEA: | International Energy Agency |
| IPAP | Industrial Policy and Action Plan |
| INDC | Intended Nationally Determined Contribution |
| IPP | Independent Power Producer |
| IPCC: | Intergovernmental Panel on Climate Change |
| IRP: | Integrated Resource Plan for Electricity |
| kW: | Kilo Watt (one thousandth of a megawatt) |
| kWh: | Kilo Watt hour |
| kWp | Kilowatt-Peak (for Photo-voltaic options) |
| LBPL: | Lower Bound Poverty Line |
| LCOE: | Levelised Cost of Electricity |
| LNG | Liquefied Natural Gas |
| LPG: | Liquefied Petroleum Gas |
| LTMS | Long-term Mitigation Scenarios |
| MA: | Master of Arts |
| MBL: | Master of Business Leadership |
| MEC | Minerals-energy complex |
| MLP | Multilevel perspective |
| MPA | Mitigation Potential Analysis |
| MTSF | Medium Term Strategic Framework |
| Mt | Mega ton |
| MW: | Mega Watt |
| MWh: | Mega Watt hour |
| NDC | Nationally Determined Contributions |
| NDP | National Development Plan |
| NERSA | National Energy Regulator of South Africa; alternatively, the Regulator |
| NOx | Nitrogen Oxides |
| NVA: | Net Value Added |
| O&M | Operating and Maintenance (cost) |
| OCGT: | Open cycle gas turbine |
| pa: | Per Annum |
| PGMS | Platinum Group Metals |
| PM | Particulate Matter |
| PPD | Peak-Plateau-Decline |
| PPI: | Producer Price Index |
| PPM | Price Path Model |
| prob: | Probability |
| PV: | Photo Voltaic |
| PV | Present Value |
| QES: | Quarterly Economic Survey |
| QLFS: | Quarterly Labour Force Survey |
| RE | Renewable Energy |
| Real Cost | An estimate of the actual or true more factual and practical costs based on the assumptions used |
| REIPP: | Renewable Energy Independent Power Producer Procurement |
| REIPPP | Renewable Energy Independent Power Producers Programme |
| REIPPPP | Renewable Energy Independent Power Producer Procurement Programme |
| SA: | South Africa |
| SADC | Southern African Development Community |
| SARB: | South African Reserve Bank |
| SEIFSA: | Steel and Engineering Federation of South Africa |
| SOx | Sulphur Oxides |
| TCF : | Trillion Cubic Feet |
| TIS | Technological innovation system |

| | |
|---|---|
| TM | Transition management |
| TW | Terawatt (one million megawatts) |
| TWh: | Terrawatt hour |
| USA: | United States of America |
| $: | US dollar |
| UAH: | the University of Alabama in Huntsville |
| UBPL: | Upper Bound Poverty Line |
| UCG: | Underground Coal Gasification |
| UNCTAD: | United Nations Conference on Trade and Development |
| UNFCCC: | United Nations Framework Convention on Climate Change |
| WCA: | World Coal Association |
| WHO: | World Health Organisation |
| WTP | Willingness to Pay |
| X | Capital X is the multiplication number "times." |
| x | Small x is the variable to be defined |
| ZIZABONA | Zimbabwe, Zambia, Botswana, Namibia transmission project |

**Key terminology and Descriptions of Terminology**

Baseload electricity
Dispatchable
Non-Dispatchable
Key (primary) objectives of South Africa: poverty alleviation, reducing inequality and raising standards of living or reducing poverty, inequality and unemployment
Goods-producing sectors: Generally mining, manufacturing, industrial, agriculture and agricultural processing
Variability:
Interruptibility
Intermittency
variable, intermittent, interruptible, unpredictable
electricity generation project

***"Capacity factor"*** refers to the expected output of the plant over a specific period as a The ratio of the output if the plant operated at full-rated capacity for the period.
***"Collector Station"*** refers to the substation that connects various renewable energy generating plants and or substations together to connect these plants to the Transmission network.
***"Cost of unserved energy (COUE)"*** refers to the opportunity cost to electricity consumers (And the economy) from electricity supply interruptions.
***"Demand-side"*** refers to the demand for, or consumption of, electricity.
***"Demand-side management (DSM)"*** refers to interventions to reduce energy consumption.
***"Discount rate"*** refers to the factor used in present value calculations that indicates the time value of money, thereby equating current and future costs.
***"Distributed generation"*** refers to small-scale technologies to produce electricity close to the end-users of power.
Energiewende
***"Energy efficiency"*** refers to the effective use of energy to produce a given output (in a production environment) or service (from a consumer point of view), i.e., a more energy-efficient technology produces the same service or output with less energy input.
***"Exchange Rates"*** Where figures have been quoted in US$, they have been left in US dollars and vice-versa Rands. In many cases, the figures used to apply to different years. Each country has different inflation rates, and the exchange rates in recent years have been more volatile, making use of a standard currency not only difficult but inaccurate.
***"Fixed costs"*** refer to costs not directly relevant to the production of the generation plant.
***"Forced outage rate (FOR)"*** refers to the percentage of scheduled generating time a unit cannot generate because of unplanned outages resulting from mechanical, electrical or other failures.
***"Gross Domestic Product (GDP)"*** refers to the total value added from all economic activity in the country, i.e., the total value of goods and services produced.
***"Integrated Energy Plan"*** refers to the over-arching, co-ordinated energy plan combining the constraints and capabilities of alternative energy carriers to meet the country's energy

needs.
***"Integrated Resource Plan (IRP)"*** refers to the co-ordinated schedule for generation expansion and demand-side intervention programmes, taking into consideration multiple criteria to meet electricity demand.
***"Lead time"*** refers to a period taken to construct an asset from scratch to the production of the first unit of energy.
***"Learning rates"*** refer to the fractional reduction in cost for each doubling of cumulative production or capacity of a specific technology.
***"Levelised cost of energy"*** refers to the discounted total cost of a technology option or A project over its economic life, divided by the total discounted output from the technology option or project over that same period, i.e., the Levelised Cost of Energy indicates the discounted average cost relating to a technology option or project.
***"Operating and maintenance (O&M) cost"*** refers to all non-fuel costs such as direct and indirect costs of labour and supervisory personnel, consumable supplies and equipment and outside support services. These costs are made up of two components, i.e., fixed costs and variable costs.
***"Overnight capital cost"*** refers to the capital cost (expressed in R/MW) of a construction project if no interest was incurred during construction, assuming instantaneous construction.
***"Peaking plant"*** refers to energy plants or power stations that have very low-capacity factors, i.e., generally, produce energy for limited periods, specifically during peak-demand periods, with storage that supports energy on demand.
***"Present value"*** refers to the present worth of a stream of expenses appropriately discounted by the discount rate.
***"Reference Case (Base Case)"*** refers to a starting point intended to enable using standardisation, meaningful comparisons of scenario analysis results based on sets of assumptions and sets of future circumstances.
***"Reserve margin"*** refers to the excess capacity available to serve load during the annual peak.
***"Scenario"*** refers to a particular set of assumptions and set of future circumstances providing a mechanism to observe outcomes from these circumstances.
***"Sent-out capacity"*** refers to electricity output measured at the generating unit outlet terminal having taken out the power consumed by the unit auxiliaries and losses in transformers considered integral parts of the unit.
***"Sensitivity"*** refers to the rate of change in the model output relative to a change in inputs, with sensitivity analysis considering the impact of changes in critical assumptions on the model outputs.
***"Strategy"*** is used synonymously with policy, referring to decisions that, if implemented, assume those specific objectives will be achieved.
***"Supply-side"*** refers to the production, generation or supply of electricity.
***"Test case"*** specifies the inputs, execution conditions, testing procedure, and expected results that define a single test to be executed to achieve a particular testing objective.
***"Variable costs"*** refer to costs incurred as a result of the production of the generation plant.

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# THE ACTUAL COST OF ALTERNATIVE ELECTRICITY GENERATING TECHNOLOGIES IN SOUTH AFRICA

## 1 INTRODUCTION

### 1.1 PURPOSE AND OBJECTIVE

South Africa’s National Development Plan (NDP) 2030 offers a long-term plan for the country. It defines a desired destination where inequality and unemployment are reduced, and poverty is eliminated so that all South Africans can attain a decent standard of living. Electricity is one of the core elements of a decent standard of living. The NDP envisages that, by 2030, South Africa will have an energy sector that provides reliable and efficient energy service at competitive rates, that is socially equitable through expanded access to energy at affordable tariffs, and that is environmentally sustainable through reduced emissions and pollution.

The South African Integrated Resource Plan (IRP) 2019 sets out the electricity-generating resource needs of the country and recommends the least-cost electricity generation mix for the country for the period to 2030 (Department of Energy, 2019; Centre for Environmental Rights (CER), 2017). This thesis is an independent economic analysis of the electricity generation industry in South Africa and an assessment of the best course of action that South Africa can take to develop South Africa's electricity generation resources. The thesis has termed the full development of South Africa's electricity generation resources as "the Electricity Generation Project".

This thesis assesses the South African economy's short, medium and long-term economic requirements. It recommends correct energy sources for producing electricity to meet its economic and social objectives. The research will consider the proposed draft Integrated Resource Plan (IRP) 2018 and draft IRP 2016 and IRP 2019.

In this economic assessment of the South African economy, it is postulated that South Africa will not be able to afford the massive investment in renewables and their necessary substantial backup electricity generating and storage requirements. The considerable investment is caused by the high volumes of the highly variable, intermittent, interruptible, unpredictable low-load electricity generating technologies required in the IRP at this stage of economic development.

This statement could apply to many emerging developing industrialising economies, particularly those rich in fossil fuel resources. This will be true if the hypothesis being investigated in this thesis is substantially corroborated. If the hypothesis is confirmed, the IRPs and the Carbon Tax recommendations could be poised to take South Africa in the wrong economic direction, slowing economic growth and increasing unemployment. This could ruin a potentially prosperous industrialising developing economy like South Africa and weaken it economically, politically and socially for a generation. The research analyses several of the most critical issues involved in making decisions regarding the electricity and energy future of South Africa.

This thesis outlines the significant research envisaged and the real alternatives to be considered if the country meets its primary objectives as set out in the NDP. *(Jordaan J, 2015*).

## 1.2 THESIS OUTLINE

This thesis sets out the fundamental issues South Africa faces and many other developing and emerging economies face. It recommends the solutions to resolve them.

These countries must address three primary issues: inequality, unemployment, and poverty. These problems can be remedied only by raising the economic growth rate. A higher growth rate depends on correct public policies coupled with an adequate and growing supply of affordable electricity. Focusing on South Africa, it must develop its goods-producing base, mining and agricultural products. It, therefore, must be able to supply secure, dispatchable electricity at the lowest possible cost.

The country's future energy potential lies in those efficient, proven nuclear and coal technologies that give South Africa a competitive edge and comparative advantage, reinforced by significant solar for domestic and general business use. These, in turn, must be supported by a substantial gas expansion but only if South Africa can find it in sufficient commercial quantities. The way forward involves building new modern coal plants and refurbishing old power stations where it is economically possible to do so, not to close them. The IRP 2016 plan and follow-up plans, supported by many vested financial and ideological interests and their enthusiastic but often ill-informed idealistic public followers, are about to overinvest in technologies that have proven to be the world's least economically efficient and ineffective technologies, namely solar and wind. It is not surprising that sailing ships and clippers, although beautiful, finally became obsolete and died out in the second half of the 1800s. ESKOM officials were doing their job of looking after the interests of the country and the public. Countries that have moved significantly towards renewables, primarily wind and solar, have faced steadily increasing electricity and energy prices. Renewables, particularly wind, increase energy poverty and effectively becomes a tax on the poor (Stephen, 2018).

Future research and work in South Africa and wherever energy is vital to meet the goal of increasing economic growth and development of its citizens must include a detailed investigation based on scientific facts of at least the following:

- The direction of climate change according to scientific facts about the short-, medium- and long-term natural cycles is based on natural climate change and the impact on climate and weather of energy generation.
- The literature that is available as presented by experts on the subject. This should include recognised experts and journals on the subject.
- The needs of the citizens and the economic resources that are available. These needs require the energy and the electricity supply to meet the economic growth necessary for

the region or country and the energy sources available to meet the requirements demanded.

- The energy sources available in the country, in this case, South Africa and the region where the electricity generation will be delivered. The electricity supply must be capable of meeting its economic growth and benefits of the country or region. These primary needs must be carefully examined and analysed.
- The impact of electricity generation is based on different energy sources after considering the backup systems required and production losses caused by non-dispatchable and electricity supply sources caused by changing, unpredictable and interrupted climate and weather.
- The actual or real economic cost of dispatchable electric generation, supply and delivery. This analysis must include the generation supply and delivery of the electricity generated plus the full backup and economic cost and long-term economic impact.
- Finally, a summing up of the study's conclusions so that these can be thoroughly discussed and assessed. Future research should be guided by these findings.

This thesis closely follows the steps outlined above.

## 1.3 HISTORICAL BACKGROUND

There is much debate in the world and South Africa about the future role of renewables and the electricity generating mix going forward. Alternative energy sources are constantly being developed and considered in the light of their costs, their impact on the environment, their impact on the global economy and finally, on individual countries concerned. The problem is that decisions regarding energy sources have short- and long-term effects, could affect an entire generation of citizens, and have global implications. One consideration that must be considered in any decision involves the potential impact of ‘climate change', which is currently the subject of global debate. This thesis will attempt to balance the decisions that need to be made about this subject.

The three primary objectives of an emerging and developing country like South Africa are poverty alleviation, reducing inequality, and improving living standards. These objectives can only be achieved by maintaining a high rate of economic growth, thereby increasing employment, reducing levels of unemployment and raising the standard of living. The author believes that "Electricity is a necessary, but not a sufficient condition, for achieving economic growth" (EIA, 2019; International Energy Agency, 2018). The necessary condition is to achieve sustainable economic growth, which requires a stable and secure electricity supply at the lowest effective economic cost when delivered to the user. The sufficient condition requires that economic, social and political conditions and policies be put in place to foster and encourage domestic and foreign investment. Correct policies would create demand for productive and economically efficient industries, which in turn results in the continued demand for reliable and competitively priced electricity (Jeffery, 2020).

The thesis examines the role electricity and its energy sources play in achieving these objectives. It focuses on the economic impact of the various alternative energy sources for electricity generation that are readily available domestically for use in the South African economy. The energy sources readily available in South Africa are coal, nuclear and potentially gas, and two renewable sources, namely solar and wind power. South Africa is a relatively dry country with no major rivers suitable for large-scale hydroelectric power to be a domestic consideration. The research evaluates these sources and recommends assessing these sources and introducing the most efficient, cost-effective mix of these electrical power sources. The goal must be to provide dispatchable electrical power generation in a stable and sustained manner. This requires closely examining the country's economic and social requirements and reviewing the industrial and sector growth requirements and the economy's structural balance. It will also consider estimates of variability or intermittency costs and other hidden costs of various energy sources that generate a stable, secure electricity supply. These are often not fully considered or taken into account.

The thesis does not purport to be a detailed macro-economic impact study, which would be a major and expensive task involving many experts. However, it hopes to provide an overview and contain a fundamental analysis of major issues that should be considered in any IRP for the country. More importantly, it intends to provide guidelines and recommendations regarding the factors that need to be well-thought-out and the most likely to be the optimum mix of electricity generation energy sources that will best suit South Africa.

This thesis sets out a methodology to estimate the economic risk costs due to supply uncertainty. In this research project, variability, interruptibility, intermittency, and unpredictability will be used interchangeably, although each has a different meaning. Predictability and uncertainty are other factors that have crucial potential cost implications and must be factored into the costs.

The importance of these decisions cannot be overestimated. Where variability, intermittency and other hidden costs are high, it is suggested that these factors will raise the actual prices and expenses of generating dispatchable electricity. These are often subsidised by South African power users and become, in effect, financed payments supporting these sources of electricity. In South Africa, these costs are ultimately paid for by the South African public. In the current situation, they are effectively underwritten by ESKOM (Eskom, 2016). These additional costs must be passed on to South African electricity consumers, or ESKOM must suffer losses due to inadequate returns to cover costs.

Regarding intermittency, externalities, and external costs, the problem is that the significant uncertainties regarding estimates of these external costs make it difficult to calculate reliable Levelised Costs of Electricity (LCOE) for the different power technologies available to South

Africa (Sklar-Chik, Brent and de Kock, 2016; Pentland, 2014). Other experts justify the methodology (Rubert et al., 2019). This makes it problematic to compare prices of dispatchable as against non-dispatchable power sources. It also must be noted that specific technologies' externality costs have not yet been entirely determined. In some cases, they may have been exaggerated or underestimated.

Technology changes have also occurred. Indeed, various estimates and costings have not incorporated specific technologies' benefits and hidden costs. Adopting the suggested methodologies can cost the structures for locally available dispatchable electrical power generation options that can supply a country's time-of-day electrical power demand curve in a stable and sustained manner on an equal-cost basis.

Considering previous research and other areas such as economic and industrial policy, economic growth and employment, climate change, and experience in other countries regarding significant technology changes towards highly variable and interruptible power supplies is necessary. Climate change is a vast subject, and the research in this thesis can only be brief, giving an overview of the key findings pertinent to decision-makers and relevant to this thesis.

## 1.4 RESEARCH AIMS AND HYPOTHESIS

This thesis aims to analyse and recommend the electricity-generating energy source mix requirements for emerging and developing economies rich in fossil fuels. The analysis uses South Africa as an example. This thesis hypothesises that emerging and developing economies rich in fossil fuels should use their natural resources to gain a comparative economic and competitive advantage. The thesis assesses and evaluates the significant elements and factors that assist in making such a decision. These include:

1. The impact on climate change. Whether this is caused directly or due to the harmful contribution of anthropogenetic (human-caused) carbon dioxide, it releases into Earth's atmosphere. This potential impact governs every decision concerning energy and electricity in the modern world. It is, therefore, a critical issue that must be better understood and addressed. This section of the thesis aims to make a case that there is sufficient doubt that humans play a substantial role in causing climate change. Alternatively, the role of human-caused CO2 is not damaging to the Climate or environment of the Earth.
2. The structure of the economy. The thesis considers specific critical resources and examines the country's coal and possible gas resources. It highlights the importance of coal in South Africa's economic development and its relevance to mining and industry and the industrial heartland of South Africa in Gauteng. It established that any reduction and ultimate destruction of coal mining and coal use for electricity generation could profoundly affect the economy. By being aware of potential negative consequences, the authorities

can mitigate any possible harmful effects by utilising technical advances that have been made in these electricity-generating fields.

3. The future economic growth requirements. The economy's structure, resources, and the population's real needs and relative skills determine this. This thesis determines the country's economic growth needs. It sets out a forecast of the GDP growth potential required to achieve South Africa's primary objectives of reducing poverty, inequality and unemployment. The required economic growth will determine the electricity resources and reserves that need to be developed. This thesis examines these, and a model has been used to determine electricity generation requirements for future economic growth.
4. The real cost of generating electricity for each technology. The real cost would enable the correct least-cost energy mixture to be established. The thesis examines the strengths and weaknesses of the methodology currently favoured by renewable lobby groups and energy planners in South Africa and elsewhere in the Western World. The least-cost mix is often determined by utilising these countries' Levelised Cost of Energy (LCOE). The quality and cost of electricity delivered at the supplier gate must be distinguished from the electricity supplied at the users' premises. Dispatchable electricity needs to be differentiated from non-dispatchable power. The impact of the load factor or capacity factor and the life of the technology is discussed. Notably, risk, uncertainty and the Cost of Unserved Energy (COUE) must be included in the cost of electricity generated by each technology. A model that introduces these concepts is developed to calculate the electricity generating costs of alternative technologies.
5. It has a detailed examination and evaluation of job creation and economic growth of electricity-generating technologies. The thesis separates the number of jobs and growth each technology creates in its construction and operation. The thesis also examines the contribution each technology makes to the economic development of the economy. The resulting jobs and economic growth measures technology's contribution to the economy.
6. Reviews alternative technologies and compares them in terms of South Africa's objectives. South Africa needs to increase its economic growth rate to meet its critical social and political objectives. These vital objectives are to reduce unemployment, reduce inequity and reduce poverty. Higher growth requires the country to attract increased domestic and foreign investment. The selected energy mix needs to address and overcome several challenges. These challenges include the renewable challenge, environmental concerns and the potential problems proposed by nuclear power and Independent Power Producers.
7. Determine the best possible energy mix for South Africa

Provided all queries are satisfactorily answered, the hypothesis is that the primary energy resources that should be used are its coal and coal reserves. Furthermore, the country also has substantial quantities of uranium. Because of these uranium reserves, nuclear power generation should also be a significant energy source if it can be financially and economically cost-competitive. Finally, the country has skills and resources in these technologies, reinforcing the argument that these technologies should be used. The thesis emphasises the requirement for reliable, secure power at the lowest financial and economic cost. All other electricity-generation sources are for backup purposes or to fulfil specialist regional or business needs at this economic and technological development stage.

A statistical hypothesis test has not been done. However, a study of developed and developing economies has shown that countries that have exploited and used their substantial and cheapest energy resources have historically generally outperformed those which have not done so. Such countries include the UK coal, Germany coal, Poland coal, China coal, India coal, South Africa to 1994 coal, Scandinavia hydropower, Norway hydropower, Iceland geothermal, France nuclear, the USA fossil fuels and nuclear. Generally, these countries have higher growth rates and lower unemployment and poverty levels than many other countries. Furthermore, those countries that have adopted a policy of increasing solar and wind show a clear trend toward higher electricity prices, as shown in the figure below.

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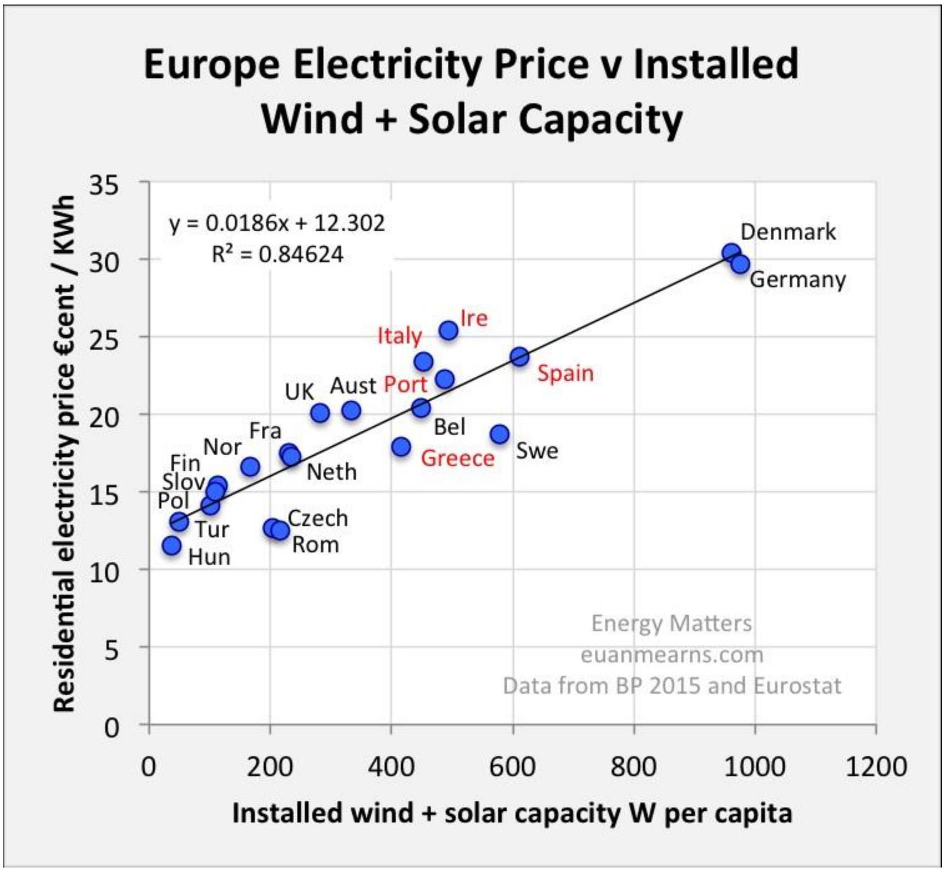



**Figure 1: European electricity prices versus wind and solar capacity**

The earth faces regular warming and cooling trends, as is indicated in line with the shorter solar cycles of approximately 300 to 400 years. The work by Zharkova 2015 and many other experts explain these cycles. The sun is heading for another solar minimum termed a Grand Solar Minimum (GSM). A GSM indicates there could be a period of global cooling ahead.

Most graphs set out a graph of increasing temperature from 1850, coinciding with a short-term period of global warming. This warming period also coincides with industrialisation and the increasing release of industrially produced carbon dioxide (CO2). In natural cycles, carbon dioxide increases with global warming, but detailed studies show that it follows warming but does not cause it. In this instance, industrialisation also contributed to increasing carbon dioxide levels. Expert opinion is that AGW had a marginal impact on the natural increase in carbon dioxide levels and global warming.

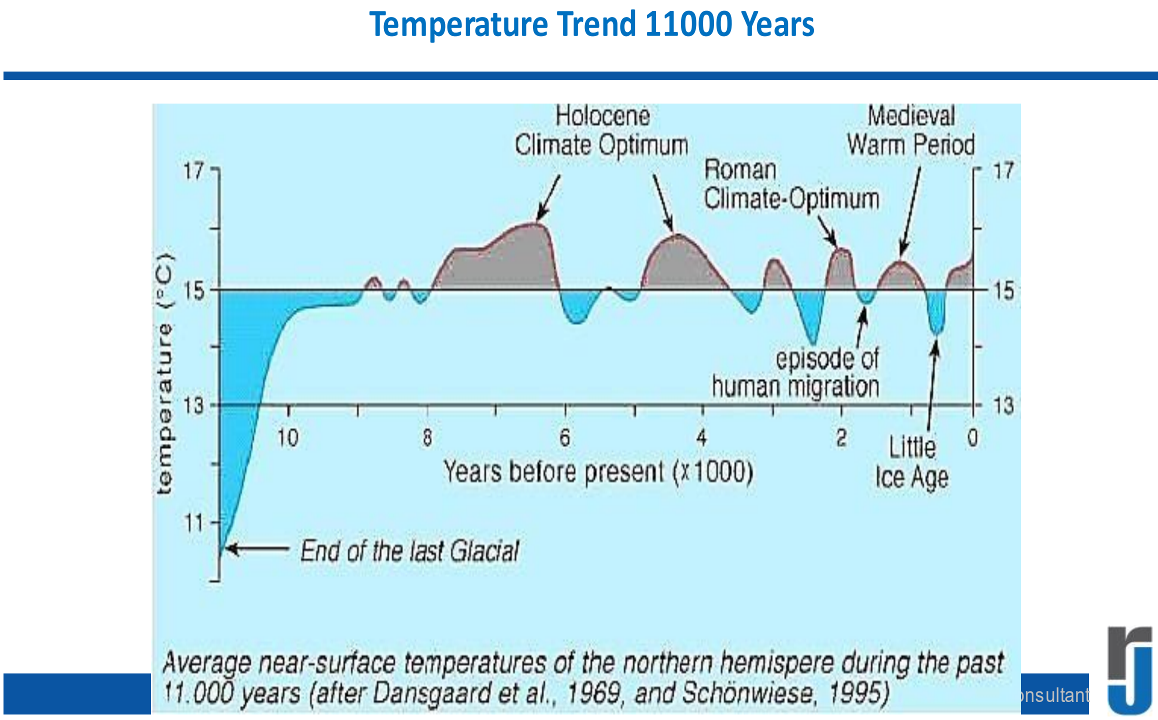



**Figure 2: Temperature Trend 11000 years.**

The earth has other temperature cycles. The major one is the well-known Milankovitch cycle which results in the deep glacial periods' last being some 11000 years ago. The earth's orbit causes these cycles around the sun, the different periods of the Earth's Eccentricity cycle, the Obliquity cycle and the Precession of Equinoxes. These are explained clearly in Chapter 3. Also shown is a figure showing temperature and carbon dioxide levels over these longer-term periods. A detailed examination of these charts shows, firstly, that carbon dioxide levels follow global warming and are not the cause of significant warming. Secondly, history and the charts show that the earth has had greater biodiversity and prosperity when the earth has been warmer and carbon dioxide levels have been far higher. There are many other factors to consider, but the facts presented support the hypothesis.

## 1.5 NOTE ON THE PERIODS ANALYSED AND THE COVID-19 VIRUS

It is essential to consider the period that needs to be analysed. Briefly, South Africa has come through a few phases, and each has a different impact on growth and electricity demand.

Phase 1: The period before 1994, when the country was effectively a military-industrial complex. Electricity intensity was high as a result

Phase 2: Between 1994 and 2008, the country demilitarised and focused on increasing employment in the services sectors and open competition with the world. The country deindustrialised, electricity intensity fell and the mining sector effectively also stopped growing:

Phase 3: This period started with a severe electricity shortage from 2008 to 2019. Unfortunately, the period became highly uncertain following disputes regarding future mining and industrial policies. This uncertainty was further compounded by confusion regarding the electricity-generating supply route the country should follow.

Phase 4: Finally, in 2020, the coronavirus caused the lockdown and uncertainty regarding the recovery path that the economy will take.

The above together have caused the worst recession, if not depression, since the 1929 depression. There has been a massive decline in the use of electricity. There is considerable uncertainty about the country's likely future growth path and future growth in demand for electricity.

The Integrated Resource Plan (IRP) for electricity prepared by the Department of Energy (DOE) aims to set the way forward for South Africa's electricity demand and supply. Over the past twenty-five years, there have been massive changes in the country's electricity needs and requirements and the future conditions for the next fifteen years. The DOE has brought out several IRPs over the last five years. Namely, Draft IRP 2016 established sound principles, as the Council for Scientific and Industrial Research (CSIR) said, followed by the draft IRP 2018. This draft was, in turn, followed by the October IRP 2019.

It is clear that as a result of the coronavirus, the latest plans will need to change radically. Rather than an update to the IRP 2019, this thesis is based on specific data taken from earlier periods of South Africa's electricity data history and the IRP 2016 and the IRP 2018. The sources are set out in the text.

It is crucial to remember that the SA economy's short-term requirements will differ materially from earlier forecasts and long-term conditions. It is essential to note that economic growth will still be dependent on a secure long-term supply of electricity in the long-term.

## 1.6 BRIEF OF THE THESIS CONTENTS

Regarding the above, this thesis aims to look at specific components that influence the mix of the future combination of electricity-generating energy resources. The components examined in this thesis include:

- Chapter 2 analyses environmental factors, climate change and the dangers that electricity-generating resources pose to the planet. Does the current view of future catastrophe for humanity warrant moving to potentially more expensive or different energy sources? Chapter 2 also investigates the impact of fossil fuel usage. For example, by utilising fossil fuels, is there adequate proof that failure to reduce the use of fossil fuels could have catastrophic and irreversible consequences for the country or the world? In other words, is there considerable doubt about potentially such a costly decision? If there is doubt about these matters, it supports a case for seriously considering alternative energy sources other than Wind and Solar.
- Chapter 3 reviews the country's economic growth needs, long-term climate change, and the impact of alternative energy technologies on growth and the environment. It is necessary to examine the structural and sectoral industrial and economic growth requirements and the policies required for South Africa to meet its critical primary objectives of reducing poverty, inequity and unemployment. This requires reviewing and forecasting the likely electricity-generating demand for alternative sectoral growth strategies. This then gives guidelines for the electricity supply requirements of South Africa. Industrialisation, re-industrialisation, and the mining sector will indicate a need for continued growth in demand for secure, reliable electricity at competitive prices from High-Efficiency Low-Emissions (HELE) 'clean' coal and potentially from gas if found in adequate economic quantities domestically. This will strengthen the arguments supporting reliable electricity sources such as fossil fuels and nuclear and only relatively minor supporting roles for variable and unreliable Wind and Solar energy sources.
- The analysis assesses the potential energy sources available for electricity-generation in South Africa. Chapter 3 examines the country's fossil fuel resources, emphasising the role of coal and the potential uses of gas. It discusses the importance of coal in South Africa's economic development with specific regard to mining, industry and the industrial heartland of South Africa in Gauteng. Examining the importance of South Africa's mineral resources and commodities in the balance of payments is reviewed. It examines the potential for developing a gas industry and its role in creating a new industry in South Africa.
- Chapter 4 examines alternative electricity growth expansion strategies and their impact on GDP growth. The effect of different electricity growth in various sectors of the economy and its impact on sectoral growth and employment growth is also discussed. The chapter examines the economic forecasts regarding the South African Integrated Resource Plan 2016 (IRP 2016) and the Integrated Resource Plan 2019 (IRP 2019). It contrasts these with the economic requirements of the economy. The thesis evaluates the real cost of generating electricity for each technology to determine a least-cost energy mixture. It examines the strengths and weaknesses of the methodology used to determine the least-

cost mix and the shortfalls in the calculation of the Levelised Cost of Energy. The impact of the load factor and the life of the technology are discussed. Finally, it is necessary to consider the role risk and uncertainty play in costs. In particular, the Cost of Unserved Energy (COUE) needs to be factored in. The thesis builds a model based on the introduction of these concepts to the electricity generating costs of these technologies. The change in these assumptions completely changes the cost of delivered electricity of each technology to the consumer and hence to the least-cost mix calculated in the IRP.

- Chapter 5 reviews the model and examines the additional costs that Wind and Solar add or impose on an energy supply system in greater detail. It is claimed that Wind and Solar are by far the cheapest source of electricity, and these sources should dominate future electricity supply. There is substantial debate regarding this subject. Many complex issues are involved, including climate change, environmental issues and many other externalities. This section focuses on known costs and subsidies but excludes externalities. All energy sources and associated technologies are subject to similar problems and additional charges to varying degrees. Still, those imposed by Wind and Solar are often hidden and subsidised by others. They are significant because of their unreliability, variability, interruptibility and unpredictability but are often left out of costing information. They are not considered in the Levelised Cost of Energy (LCOE) calculations, which only measures the costs at the supplier's gate, not the total cost of supply and delivery when supplied to the ultimate customer. In summary, LCOE does not consider the further transfer costs nor the additional system costs required to bring supply to the door of the consumer or those costs that are, as a result, imposed on the economy and the user.
    - Electricity can be delivered when not required.
    - There are additional costs that become system costs. These costs may be due to higher storage or increased inefficiency by the supplier, utility, or distributor (ESKOM).

  All these costs should be measured and estimated so the "price" to be paid to the supplier can be more accurately determined. They are currently directly or indirectly passed on to the consumer. Currently, therefore they are a subsidy to the supplier.

- Chapter 5 also appraises each electricity-generating technology's job creation and economic growth capabilities. There has been widespread discussion on this subject with a particular focus on the number of jobs and additional growth each technology creates in its own right regarding its own technology construction and operation. This section shows that this is a severely flawed approach, which misrepresents the technologies contribution to the economy. The section sets out the correct evaluation path for examining job creation and electricity generation technology's economic growth potential. It requires further analyses of the cost of different electricity-generating technologies. In particular, the thesis examines the impact of each electricity-generating technology on employment and economic growth. The figures used are based on information available from several sources on costs, jobs created by each technology, and their economic impact on South Africa's economy.

- Appendix 2 also discusses the implications of the Carbon Tax in some detail. The Carbon Tax raises the cost of electricity. This cost increase must be passed onto Eskom and ultimately to the consumer. It examines the impact of the Carbon Tax on the South African economy. This tax has been changed several times and is scheduled to be implemented in a phased approach. The first phase extends from June 2019 to December 2021, escalating at 2% above the consumer price index annually (Duncan, 2019). A public report was prepared by Jordaan and was submitted by Econometrix to the Davis Tax Committee in 2015. Once the tax is fully implemented, many of the report's findings stand today and are included in this section of the thesis. Importantly, it also covers the combined impact of the tax and renewables on South Africa's economy, their effect on domestic and foreign investment, and ultimately, their economic growth. Consideration cannot be confined to only the economic impact of renewables. It has to be combined with the effects of any Carbon Tax. The two are inseparably linked due to so-called climate change mitigation requirements proposed by the International Panel for Climate Change (IPCC) and the Paris Agreement.
- Chapter 6 reviews other crucial issues, including renewable challenges, the potential benefits of nuclear power, the difficulties Independent Power Producers face and environmental concerns. Finally, the section suggests a way forward for the South African economy regarding its power generation policy. The chapter sets out the fundamental issues faced by South Africa and recommends solutions to resolve them. The country must address three primary issues: inequality, unemployment, and poverty. These problems can be remedied only by raising the economic growth rate (ICAEW, 2017). A higher growth rate is dependent on correct public policies coupled with an adequate and growing supply of affordable electricity. South Africa must develop its industrial base and mineral resources; therefore, it must supply secure power at the lowest possible cost.

The summary reviews the critical points established and suggests future work and research. Analysing the above will allow South Africa to evaluate the various technologies and the most appropriate mix.

It must be made clear that this is not a socio-economic impact study. A complete economic impact study should be made on each alternative electricity generating mix recommended ). The methodology and techniques developed in this thesis offer economists and energy planners quantifiable methods that will allow them to make a better recommendation for the most appropriate mix of electricity-generating energy sources for South Africa. The methodology would help assess the same needs in another country, a state within a country or an entire region.

## 1.7 CONCLUSION

The National Development Plan and its predecessors have vital development areas, electricity generation, and goods-producing sectors (National Planning Commission, 2010). Electricity generation discussed in this thesis is critical to the country's developmental plans and economic growth. It becomes the essential long-term component of the National Development Plan if successfully handled. The above findings indicate the importance of considering the "electricity generation project" as a major project involving a significant long-term commitment. The project requires a substantial capital commitment at the outset. The full potential benefits of the project will not be achieved if this is not done. A careful examination of electricity generation is in all South African people's long-term economic and financial interest, all the major players and stakeholders in the industry and the economy.

# 2 LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter will show that substantial research in each investigation is necessary to prove the hypothesis that supports the overall findings of the thesis correctly. It is essential to review the significant factor driving the current energy policy of countries globally and in South Africa, namely climate and the impact of climate change by fossil fuels. In particular, the chapter addresses the major energy issues affecting three essential sustainable economic growth and development, inequality, unemployment and poverty in developing and emerging economies. Therefore, the chapter primarily addresses the relevant previous research and literature on these two subjects.

## 2.2 ENVIRONMENTAL FACTORS GLOBAL WARMING CLIMATE CHANGE

This section will argue that the literature supports the hypothesis that there is no certainty that CO2 is severely damaging to the Earth or the environment or humans. It will argue that there is sufficient doubt about this and that a body of expert opinion supports this contrarian view ICSF, 2019b).

Climate is not the key focus of this thesis. However, it is the critical issue being used to drive energy sources away from fossil fuels toward solar wind and other so-called green energy sources. It must therefore be a major discussion point as they, and the carbon dioxide they emit, have been called an existential threat to human beings. This is despite a vast body of well-established experts disagreeing with this argument.

Equally important, regardless of the view planners take (Berkhout et al., 2019; Gosselin, 2019), the economic and environmental costs for South Africa are high. The costs far exceed any short-term benefits that may arise by ceasing coal use for energy purposes, even if such benefits were measurable.

It is a historical fact that Earth's Climate has been regularly changing in natural cycles for over 4 billion years due to solar and cosmic phenomena and occasional extreme cosmic events. In recent years, in other words, the last few million years, it has been primarily driven in the longer term by the Milankovitch cycles and the shorter-term cycles by solar cycles (Zharkova, 2014; Shepherd et al., 2014; Xu et al., 2019; Zharkova et al., 2015; Zharkova et al., 2018; Soon and Legates, 2013). It is believed these shorter-term cycles drive regular warming and cooling periods, lasting a few hundred years, caused by fluctuations in the solar flux, which probably affects cosmic ray penetration of the Earth's atmosphere (Svensmark, 1996, 2016). Many experts believe this could cause a cooling period ahead as opposed to the more commonly held view that the Earth is warming. Whichever view people hold, any short- or long-term energy or electricity plan needs to consider or be aware of and consider both sides of the argument. There are strong views held by the United Nations, the IPCC and many other groups backed by individual historical reports.

Carbon dioxide is causing global warming, damaging the environment and the sustainability of various species on Earth (Leemans and Vellinga, 2017). Of greater importance, it needs to reflect new political trends and the growing consensus that the role of anthropogenic (changed or influenced by human beings) global warming caused by carbon dioxide is not a threat to humanity and could be beneficial (Moore P., 2016; Berry, 2019b; Climate Depot, 2010; Kauppinen and Malmi, 2019; ICSF, 2019b). Claims of extreme temperatures and weather events also do not hold up to scrutiny (Kelly, 2016; Lloyd, 2018; ICSF, 2019b; Plimer, 2017; Plimer, 2018; Lindzen, 2018; Lindzen, 2017; Svensmark, 1996; Svensmark, 2016; Soon et al., 2015; Spencer and de Kock, 2019).

The critical references regarding the issues raised in this chapter are set out below. These experts strongly believe that Anthropogenic Global Warming (AGW) is not the IPCC's critical issue. Carbon dioxide is not the damaging gas it is made to be. Instead, it is an odourless, colourless, non-toxic trace gas essential for life on this planet. The works of these eminent scientists and the reasons they have come to the conclusions they have form part of the essential reading of those involved in the debate regarding climate change and the discussion concerning "clean-coal" energy and its use of renewables.

There is no doubt that climate change has significant impacts on civilisations and human beings' migration patterns. The great potato famine in Ireland caused poverty and migration to the Americas, whilst climate changes impacted Chinese civilisation history (Chen, 2019).

There are many environmental factors that need to be discussed. This section focuses on key factors that must be considered when making essential energy decisions. High-Efficiency Low-Emissions (HELE) "clean-coal" as an energy source exists and has considerable support in China, India, and ASEAN countries. Some experts are sceptical of the current views regarding carbon dioxide caused by humans as a growing threat to the planet (Kauppinen and Malmi, 2019). Equally important, their views are supported by an increasing consensus of expert opinion reinforced by substantial scientific evidence that this is indeed the case (Climate Depot, 2010; Kelly M, 2016; Gosselin, 2019; Liu et al., 2015; Botkin, 2014; ICSF, 2019b; Soon and Legates, 2013; Spencer and de Kock, 2019).

## 2.3 CLAIMS REGARDING ANTHROPOGENIC GLOBAL WARMING

Some years ago, a claim was made by Bedford and Cook (2013) that "There is an overwhelming consensus within the scientific community …the Earth's global average temperature is increasing, and human emissions of greenhouse gases, especially carbon dioxide, are the main cause." The conclusion of Cook was that on AGW [Anthropogenic Global Warming], "97.1 % endorsed the consensus position that humans are causing global warming." (Cook et al., 2014). This figure is often bandied about as experts' clear-cut consensus on humans responsible for Anthropogenic Global Warming (AGW). Many other experts have strongly disputed this, notably Legates

(Legates et al., 2015). They set out strong arguments that the figure of 97% is blatant misrepresentation. In another paper by Bedford and Cook entitled "Agnotology, scientific consensus, and the teaching and learning of climate change: A response to Legates, Soon and Briggs," they defend their position (Bedford and Cook., 2013). There have been many papers and much research done on this subject. This thesis considers that the debate at this stage indicates that the Science is not settled, nor is there consensus (Siegel, 2015; Bacon, 2019). Therefore, it is reasonable for countries to put their priorities and interests first, which forms an important supporting element of the hypothesis of this thesis.

There are many conflicting reports about the role of Anthropogenic Global Warming (AGW) due to the release of carbon dioxide by fossil fuels, as set out above. It is necessary to set out some arguments against the consensus that it is an existential and costly threat to humans.

Work done by many scientists in 2021 is supported by the many peer-reviewed papers that back it up. The guest essay by Eric Worrall is entitled "Challenging UN, Study Finds Sun—not CO2—May Be Behind Global Warming"

> "Climate scientist Dr Ronan Connolly, Dr Willie Soon and 21 other scientists claim the conclusions of the latest "code red" IPCC climate report, and the certainty with which those conclusions are expressed, are dependent on the IPCC authors' narrow choice of datasets. The scientists assert that the inclusion of additional credible data sets would have led to very different conclusions about the alleged threat of anthropogenic global warming.
>
> "*New peer-reviewed paper finds evidence of systemic bias in UN data selection to support climate-change narrative by Alex Newman August 16, 2021, Updated: August 16, 2021*
>
> *The sun and not human emissions of carbon dioxide (CO2) may be the main cause of warmer temperatures in recent decades, according to a new study with findings that sharply contradict the conclusions of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC).*
>
> *The peer-reviewed paper, produced by a team of almost two dozen scientists from around the world, concluded that previous studies did not adequately consider the role of solar energy in explaining increased temperatures.*
>
> *The new study was released just as the UN released its sixth "Assessment Report," known as AR6, that once again argued in favour of the view that mankind's emissions of CO2 were to blame for global warming. The report said human responsibility was "unequivocal."*
>
> *But the new study casts serious doubt on the hypothesis.*
>
> *Calling the blaming of CO2 by the IPCC "premature," the climate scientists and solar physicists argued in the new paper that the UN IPCC's conclusions blaming human emissions were based on "narrow and incomplete data about the Sun's total irradiance."*

*Indeed, the global climate body appears to display deliberate and systemic bias in what views, studies, and data are included in its influential reports, multiple authors told The Epoch Times in a series of phone and video interviews.*

*"Depending on which published data and studies you use, you can show that all of the warming is caused by the sun, but the IPCC uses a different data set to come up with the opposite conclusion," lead study author Ronan Connolly, PhD told The Epoch Times in a video interview.*

*"In their insistence on forcing a so-called scientific consensus, the IPCC seems to have decided to consider only those data sets and studies that support their chosen narrative," he added.*

Read more: https://www.theepochtimes.com/challenging-un-study-finds-sun-not-co2-may-be-behind-global-warming_3950089.html

The following is the abstract of the study;

***How much has the Sun influenced Northern Hemisphere temperature trends? An ongoing debate***

*Ronan Connolly[1,2], Willie Soon[1], Michael Connolly[2], Sallie Baliunas[3], Johan Berglund[4], C. John Butler[5], Rodolfo Gustavo Cionco[6,7], Ana G. Elias[8,9], Valery M. Fedorov[10], Hermann Harde[11], Gregory W. Henry[12], Douglas V. Hoyt[13], Ole Humlum[14], David R. Legates[15], Sebastian Lüning[16], Nicola Scafetta[17], Jan-Erik Solheim[18], László Szarka[19], Harry van Loon[20], Víctor M. Velasco Herrera[21], Richard C. Willson[22], Hong Yan (艳洪)[23] and Weijia Zhang[24,25]*

*In order to evaluate how much Total Solar Irradiance (TSI) has influenced Northern Hemisphere surface air temperature trends, it is important to have reliable estimates of both quantities. Sixteen different estimates of the changes in TSI since at least the 19$^{th}$ century were compiled from the literature. Half of these estimates are "low variability", and half are "high variability". Meanwhile, five largely-independent methods for estimating Northern Hemisphere temperature trends were evaluated using: 1) only rural weather stations; 2) all available stations, whether urban or rural (the standard approach); 3) only sea surface temperatures; 4) tree-ring widths as temperature proxies; 5) glacier length records as temperature proxies. The standard estimates which use urban as well as rural stations were somewhat anomalous as they implied a much greater warming in recent decades than the other estimates, suggesting that urbanization bias might still be a problem in current global temperature datasets – despite the conclusions of some earlier studies.*

*Nonetheless, all five estimates confirm that it is currently warmer than the late 19$^{th}$ century, i.e., there has been some "global warming" since the 19$^{th}$ century. For each of the five estimates of Northern Hemisphere temperatures, the contribution from direct solar forcing for* *all sixteen estimates of TSI was evaluated using simple linear least-squares fitting. The role of human activity on recent warming was then calculated by fitting the residuals to the UN IPCC's recommended "anthropogenic forcings" time series. For all five Northern Hemisphere temperature series, different TSI estimates suggest everything from no role for the Sun in recent decades (implying that recent global warming is mostly human-caused) to most of the recent global warming being due to changes in solar activity (that is, that recent global warming is mostly natural). It appears that previous studies (including the most recent IPCC reports), which had prematurely concluded the former, had done so because they failed to adequately consider all the relevant estimates of TSI and/or to satisfactorily address the uncertainties still associated with Northern Hemisphere temperature trend estimates. Therefore, several recommendations on how the scientific community can more satisfactorily resolve these issues are provided.*

Read more: https://iopscience.iop.org/article/10.1088/1674-4527/21/6/131

An accusation of data cherry-picking to conceal uncertainty and, in effect, orchestrate a pre-conceived conclusion, in my opinion, is very serious. Accepting the IPCC's climate warnings at face value without considering strenuous objections from well-qualified scientists as to the quality of the procedures which led to those conclusions could lead to a catastrophic global misallocation of resources. "The report goes on with more detailed information."

Of course, one can go back to early statements by one of the great climate experts Richard Lindzen in his paper A Case Against Precipitous Climate Action (Lindzen 2011). Here he makes the point

"The notion of a static, unchanging climate is foreign to the history of the earth or any other planet with a fluid envelope. The fact that the developed world went into hysterics over changes in global mean temperature anomaly of a few tenths of a degree will astound future generations. Such hysteria simply represents the scientific illiteracy of much of the public, the susceptibility of the public to the substitution of repetition for truth, and the exploitation of these weaknesses by politicians, environmental promoters, and, after 20 years of media drum beating, many others as well. Climate is always changing. We have had ice ages and warmer periods when alligators were found in Spitzbergen. Ice ages have occurred in a hundred-thousand-year cycle for the last 700 thousand years, and there have been previous periods that appear to have been warmer than the present despite $CO_2$ levels being lower than they are now. More recently, we have had the medieval warm period and the little ice age. During the latter, alpine glaciers advanced to the chagrin of overrun villages. Since the beginning of the 19th Century, these glaciers have been retreating. Frankly, we don't fully understand either the advance or the retreat. For small changes in climate associated with tenths of a degree, there is no need for any external cause. The earth is never exactly in equilibrium. The motions of the massive oceans where heat is moved between deep layers and the surface provides variability on time scales from years to centuries. Recent work (Tsonis et al., 2007) suggests that this variability is enough to account for all climate change since the 19th Century."

An opinion piece by Kane-Berman (Kane-Berman, 2021) fully supports the views of AR Kenny (Kenny, 2015). Both Kane Berman and Kenny are well-known South African development economists and energy experts with long records of achievement and integrity. Kane-Berman. says the following.

"Facebook recently extended its 'climate science information centre' to South Africa, inter alia informing us that 'heatwaves, droughts, and wildfires' have become 'more frequent and intense' worldwide.

In October last year, the secretary-general of NATO, Jens Stoltenberg, said that the warming planet was causing 'our weather [to become] wilder, warmer, windier, and wetter', threatening sources of food, fresh water, and energy, along with 'our security'.

Similar fears have been expressed by the Pope, the Dalai Lama, Bill Gates, the World Economic Forum, the UN and its affiliates, and politicians, celebrities, and journalists across the globe. In 2013 Barack Obama repeatedly said we were seeing and would continue to see 'more extreme droughts, floods, wildfires, and hurricanes.

But does the data justify claims and scares about what the Pope calls 'extreme meteorological events'?

Let's start with droughts. In *Weather Extremes: Are they caused by Global Warming?* – a paper published last year by the Global Warming Policy Foundation – Ralph Alexander, a retired physicist, cited data from the Palmer Drought Severity Index for 1910 to 2015, showing that there have been no long-term trends in drought patterns either globally or in the US. (Alexander, 2021)

Writing last year in *Technological Forecasting and Social Change,* Bjorn Lomborg of the Copenhagen Business School cited data from the World Meteorological Association showing that there had been no increase in the global area under drought for the last 116 years. Dr Lomborg also quoted the UN Intergovernmental Panel on Climate Change (IPCC) as having in 2013 repudiated its own earlier conclusion that droughts had been increasing since the 1970s.

<u>Flood risk</u>

Regarding floods, Dr Alexander cited data from 1 907 different locations over the period 1996 to 2005. Flood risk was increasing in smaller catchment areas. However, 'globally, larger catchments dominate, so the trend in flood risk is actually decreasing rather than increasing in most parts of the globe if there is any trend at all'. He commented that there was no evidence 'that floods are becoming worse or more common, despite average rainfall getting heavier as the planet warms. Dr Lomborg cited a 2018 IPCC report as having found that more 'streamflows' in the world's largest rivers were decreasing than were increasing.

What about hurricanes, cyclones, and typhoons (which are essentially the same thing)? Dr Alexander cited studies showing that 'The frequency of landfalling hurricanes of any strength hasn't changed significantly in the nearly 50 years since 1970 – during a time when the globe warmed by approximately 0.6% C'. Dr Lomborg – who noted that hurricanes are the 'costliest catastrophes' in the world – again quoted the IPCC, which stated in 2013 that 'current data sets indicate no significant global trends in global tropical cyclone activity over the past century'.

What of heatwaves? Here Dr Alexander cited data from the US National Oceanic and Atmospheric Administration covering 1895 to 2018, showing the number of days in which temperatures in the US were above 37.8 degrees C. The number of very hot days showed a rising trend until the 1930s and a falling trend thereafter. The global story was the same, he said. Six of the seven continents recorded their highest temperatures before 1982.

Dr Alexander also noted that 'cold extremes' appear to be on the rise but that the IPCC has paid no attention to them – even though, according to Indur Goklany, a former US delegate to the IPCC, deaths from abnormal cold are 17 times more common than those from abnormal heat. This figure was based on an analysis of 74 million deaths at 384 locations in 13 countries.

And so, to wildfires. Writing in *Impacts of Climate Change: Perception and Reality,* published earlier this year by the Global Warming Policy Foundation, Dr Goklany said that 'analyses of charcoal in ice cores, lake and marine sediments, and tree rings' suggest that 'fire occurrence increased to a peak around 1850, before declining to [present-day] levels. Dr Goklany also reported that a 'recent review of satellite data found that the global burned area declined by between 16% and 33% between 1998 and 2015'.

<u>Steady decline</u>

Dr Alexander cited a study showing a steady decline in the global forest area burnt by wildfires from 1900 until 2010. He commented that 'wildfires have diminished globally as the planet has warmed'. Dr Lomborg wrote: 'Wildfire has declined dramatically, both globally and for the US, over the past century.'

All this measured data yields two conclusions. The first is that extreme climate events are not increasing. The second is that there is no correlation between such events and a (slightly) warming planet (whatever the cause of that warming might be).

The impact of natural disasters is measured in various ways. One is economic cost. Andrew Siffert, senior meteorologist at BMS, an insurance brokerage, reported earlier this year on a study by Roger Pielke of the University of Colorado, which showed a long-term downward trend from 1990 in losses from global disasters as a proportion of global GDP. Last year's $82-$83 billion in catastrophe losses were 'normal', Mr Siffert wrote. And even though Florida is a 'hurricane magnet', Miami 'has not been hit by a major hurricane directly for 28 years.

Figures showing economic losses from hurricanes and other disasters can also be misleading. Many more people today live at the coast or near forests, and their houses and other possessions are worth very much more. The apparently rising replacement cost of destruction may attract headlines while overestimating the increase in actual physical destruction. The great Miami hurricane of 1926 caused inflation-adjusted damage of $1.3 billion. But, wrote Dr Lomborg, 'The very same hurricane tearing down the same path today' would cause damage worth $254 billion.

Remain the same

Dr Lomborg cited studies showing that hurricanes currently cost about 0.04% of global GDP. If we assume that hurricanes remain the same as today – 'no climate change' – the damage in 2100 will be 0.01% of GDP. Even if we assume that climate change makes hurricanes worse, the GDP cost will be 0.02%. A richer world will thus be better able to protect itself from natural disasters than one made poorer by pushing up energy prices and so reducing economic growth rates.

The other major means of measuring the effects of natural disasters is in lives lost. According to Dr Lomborg, global death risk from natural disasters has dropped by 96% in the past 100 years.

The implication is that even if the alarming forecasts and the models on which they are based are right – which the measured data shows is not the case – the planet is now more capable than ever to cope. Greater wealth will mean greater resilience."

There are many points supported by the noted Alexander in his book "Science Under Attack: The Age of Unreason". (Alexander R B, 2018).

Specific critical issues in a report by Droz entitled *"Climate Change: The Defence of CO2"* are summarised here. That report contains many references and evidence necessary to support the view that CO2 and fossil fuels, particularly coal, are not the claimed damaging causes of climate change. The full report and the references should be read in conjunction with this summary (Droz, 2020).

1. There is considerable empirical evidence that elevated levels of CO2 follow global warming, not cause it. There is no historical or experimental evidence supporting CO2 as a significant driver of atmospheric warming (Glassman, 2006).

There is a view that human-made CO2 (AGW) is the leading cause of substantial, unusual global warming (Humlum et al., 2013). However, there are reasons to question this finding seriously. Many arguments counter the IPCC's claims, supported by Gore and Kerry, that human-made CO2 is causing Global Warming. Some arguments countering this and supporting the view that human-made CO2 is not a significant driver of atmospheric warming can be found in the article by Droz (2020)

2. A crucial part of the argument against $CO_2$ is the so-called "greenhouse gas theory." At this stage, this is purely a hypothesis, and there is significant evidence that the greenhouse gas hypothesis is oversimplified and inaccurate (Nikolov et al., 2017; Gerlich et al., 2009).

3. If the greenhouse gas hypothesis is scientifically proven, $CO_2$ is still a weak greenhouse gas (Ollila, 2014).

4. It is inappropriate to blame $CO_2$ when there is little understanding of other well-known atmospheric climate factors — e.g., clouds. These factors are likely more guilty than $CO_2$ in global warming, individually or in concert (Norris et al., 2016).

5. There is strong evidence that non-atmospheric culprits, for example, the sun, are primarily responsible for global warming and any climate change (Soon et al., 2015; Fleming, 2018).

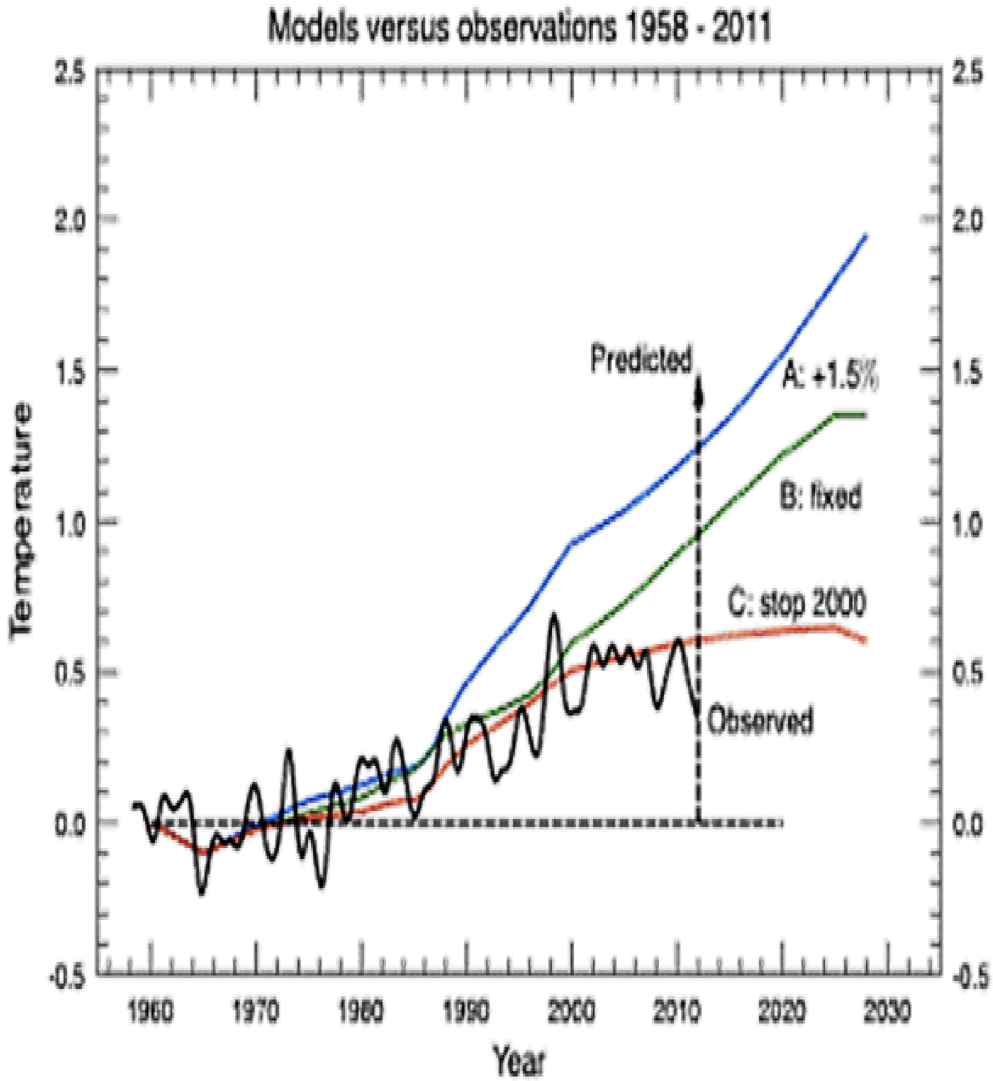
6. Even if $CO_2$ is scientifically proven to cause some global warming, there is significant evidence indicating that human-made $CO_2$ is only a tiny part of the overall global $CO_2$ generated. Importantly also, the impact of the human-made $CO_2$ is negligible (Davis et al., 2018).

7. The residence time of $CO_2$ in the atmosphere is critical, as the longer, it remains in circulation, the longer any purported artificial imbalance will exist. The IPCC position (unproven) is that $CO_2$ atmospheric residence time is 100+ years. Further evidence indicates that the $CO_2$ atmospheric residence time is more like ten years (or less) — an extraordinarily significant difference with major ramifications (Harde, 2017).

8. The evidence also says that the $CO_2$ global effects are saturated (Davies, 2018; Dayaratna et al., 2017). This means that what (if any) harm that $CO_2$ allegedly might have done, the worst has already occurred. In other words, if the concentration of $CO_2$ were doubled (which could take over a hundred years), the $CO_2$ additional effect on Climate would only increase by something like 10%. Two relevant technical factors here are Equilibrium Climate Sensitivity [ECS] and Transient Climate Response [TCR] (Spencer and de Kock, 2019).

9. The IPCC claim they used results of scientific investigations to prove their arguments. However, they did not use the Scientific Method in their cases. The Scientific Methods should verify the evidence and be central to the argument (Munshi, 2016).

10. Computer models are extensively used to prove that CO2 is the cause of excessive global warming, yet they have not been proven reliable methodologies on the complicated matter of climate change (Henderson and Hooper, 2017; McKitrick, 2019). Further, they are provably inaccurate in this situation. For full details, read Droz (2020) Section Three




*Temperature forecast Hansen's group from the year 1988. * The various scenarios are 1.5% CO2 increase (blue), constant increase in $CO_2$ emissions (green) and stagnant $CO_2$ emissions (red). In reality, the increase in $CO_2$ emissions by as much as 2.5%, would correspond to the scenario above the blue curve. The black curve is the ultimate real-measured temperature (rolling 5-year average). Hansen's model overestimates the temperature by 1.9°C, which is 150% wrong.*

**Figure 3: Model versus observations 1958-2011 Hansen in 1988**

The conclusion is that $CO_2$ is innocent of much criticism against it. There is strong evidence that the criticism is a mixture of innuendo, hearsay, speculation, pseudo-science, and outright fabrication. Despite the many incorrect accusations, the document by Droz and the references have scientifically refuted every so-called claim against $CO_2$. The renewable lobby and climate change alarmists claim that "the science is settled" is another indictment of the possible deceptions and incompetence of those making their claims against $CO_2$.

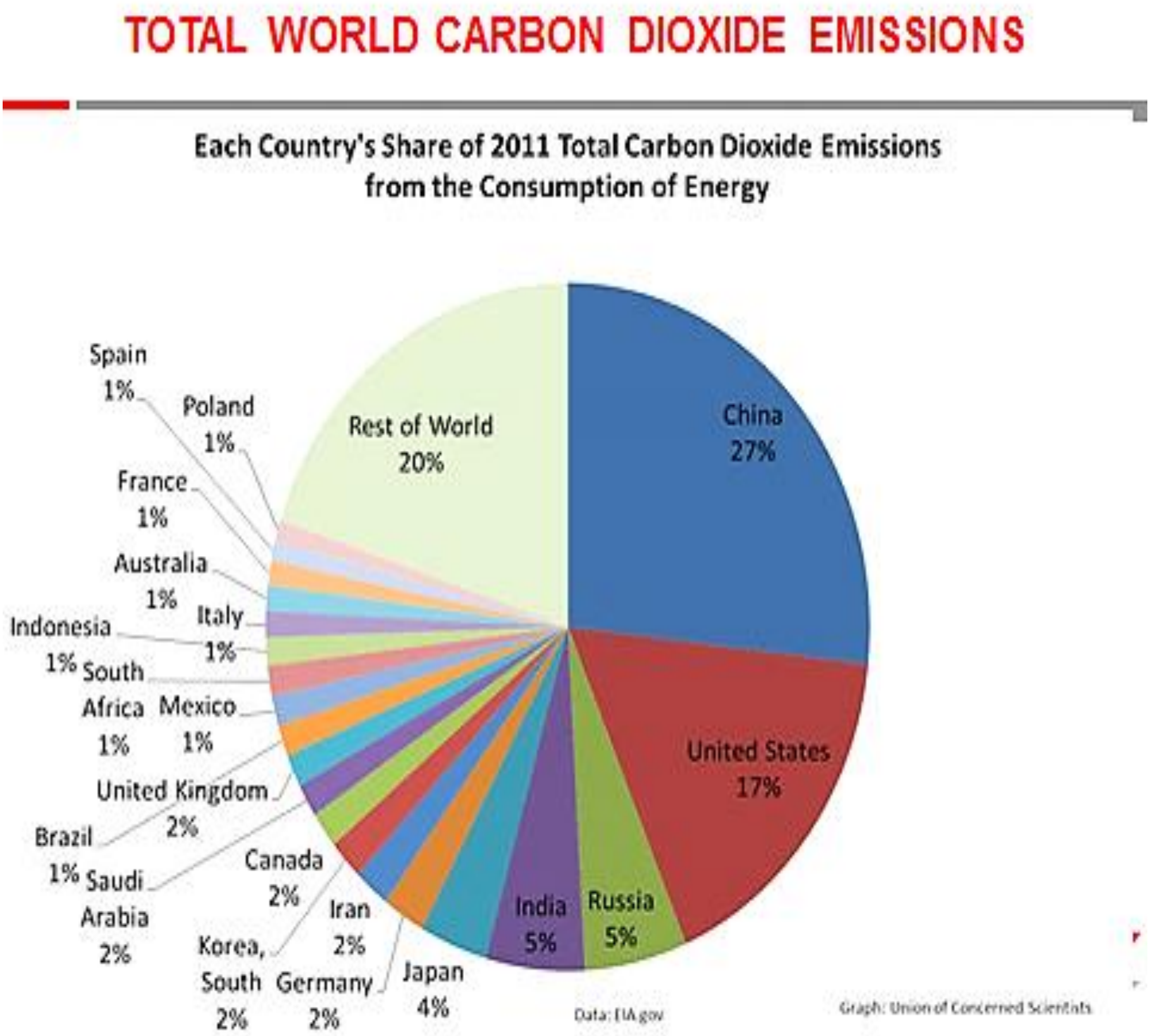
The arguments presented in the document by Droz have legal severability. In other words, if one of the contentions is deemed inadequate for whatever reason, then that decision does not affect the consideration or veracity of any of the remaining arguments. The arguments against $CO_2$ have not proved their core claims irrefutably but have ignored abundant evidence available to the contrary. Most of these statements are supported by Lomborg (Lomborg, 2020).

In addition, there is another closely related critical matter. Another unjustly maligned industry, particularly coal, has been severely affected, namely fossil fuels. An examination of history must conclude the same arguments and verdicts against $CO_2$ have been used to malign and damage the fossil fuel industry. The extensive cases above, in effect, overturn the case against the fossil fuel industry, particularly coal.

Additional arguments supporting the falseness of the claims against $CO_2$, fossil fuels, and coal must be investigated further. The evidence is available but has not been debated in the Droz document. There are many references on each subject below which are available.

## 2.4 ENVIRONMENTAL AND TEMPERATURE CONCERNS

Any significant decline in the growth of carbon emissions in China and India is unlikely in the period up to 2035 as these countries continue their pursuit of economic growth (Jeffrey, 2015a; Suryadi, 2016a; EIA, 2019).




Source: Union of Concerned Scientists

**Figure 4: Country's share of carbon dioxide emissions**

Furthermore, the argument regarding global warming has changed considerably over the last few years (Lindzen, 1994). The fact is that global temperature has not increased materially for more than 20 years. The figure below graphs UAH Satellite-Based Temperature considered the most accurate measurement of global temperatures.

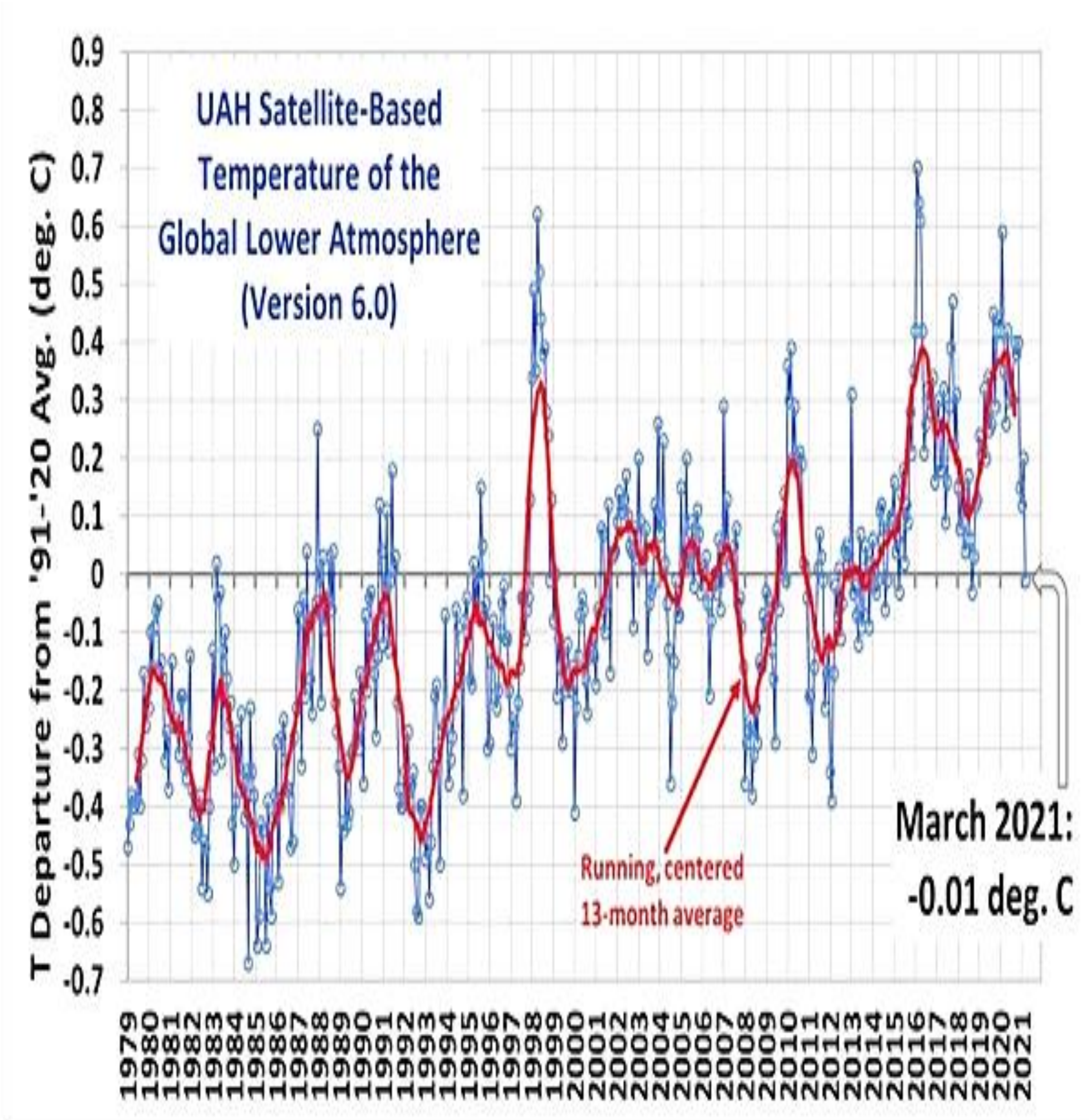



**Figure 5: UAH Satellite-Based Temperature**

A few points are relevant:

The annual increase in China's carbon emissions has been 520 million tonnes each year over ten years compared to South Africa's total annual carbon emissions of approximately 440 million tonnes in 2013.

A saving of 20% in South Africa would amount to 88 million tonnes, but India's annual growth in carbon emissions over ten years exceeds 90 million tonnes yearly.

- South Africa is responsible for approximately only 1% of global carbon emissions. Any impact that the Carbon Tax or renewables in South Africa may have on any decline in such emissions or its effects on climate change will be less than measurable (Jeffrey, 2015c).
- The detrimental economic impact on the South African economy and its citizens will be substantial, particularly on the poor and underprivileged (Interest, 2016).

A vital issue in every energy decision's background is climate change and the commitment to COP 21. The outcome of COP 21 was the Paris Agreement. What was important was not only what was agreed upon but, more importantly, what was not agreed (Mathai and Narayan, 2017; Allan, 2019; Strek et al., 2016; Jeffrey, 2017a).

Governments negotiated a set of sound, long-term global objectives. The Paris Agreement reflects a “hybrid” approach, blending bottom-up flexibility to achieve broad participation with top-down rules to promote accountability and ambition (Paris Agreement, 2019; Strek et al., 2016). Notably, the agreement asked for no firm commitments by any country. Many provisions establish common goals while allowing flexibility to accommodate different national capacities and circumstances. An objective or goal without binding obligations was that various countries could not reach widespread political agreement internally, for example, the U.S.A. (Jeffrey, 2017).

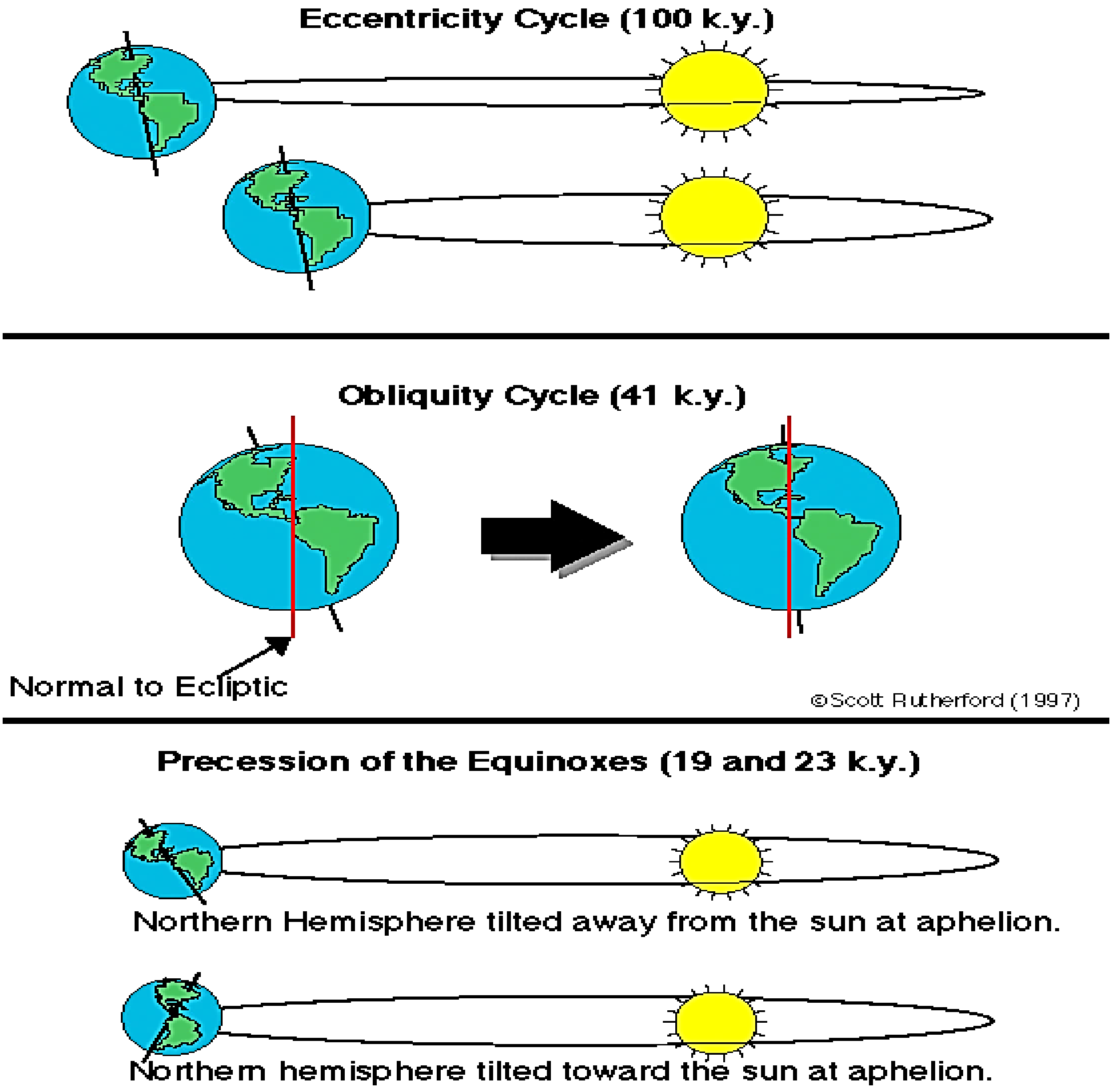
Emerging countries could not make commitments as they have other priorities, such as high poverty levels or abundant fossil fuel reserves. In summary, in terms of the Paris Agreement, countries were expected to do what was in their best economic, commercial and financial interests. Many countries indeed exploited these wording factors. All emerging economies with elevated poverty levels and extensive, relatively cheap fossil fuel resources, such as South Africa, should use them (Anielski, 2016).

Some governments have considered reversing their support for the IPCC views on climate change and fossil fuel recommendations. The last administration officially withdrew the USA from the Paris Agreement, but Biden has recently reversed that decision.

At present, there is a powerful media and populist led movement involving young people to ban coal to slow climate change. Notwithstanding this, for the reasons above, Poland, Eastern European countries, Russia, India, China, and the ASEAN countries are not strictly following the policies laid down by the IPCC and COP 21 (von Storch et al., 2019). South Africa must use this opportunity to give its key objectives priority.

### 2.4.1 NATURAL CLIMATE TEMPERATURE CHANGE

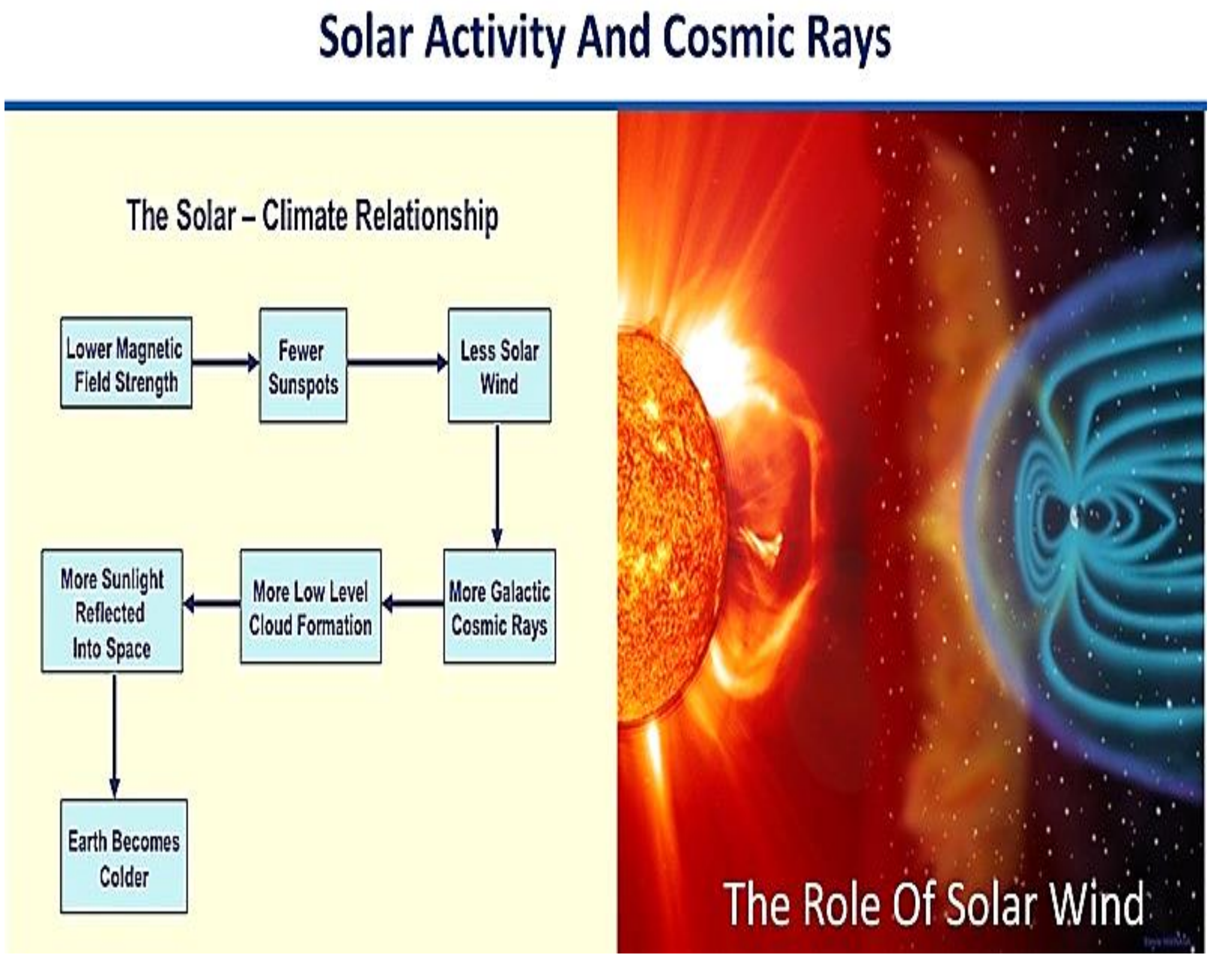
Almost all scientists believe that natural forces have driven long-term climate change in the past. The earth's history shows that climate change is a process taking place for over four billion years. There would appear to be broad agreement that long-term climate change cycles are driven by the Milankovitch cycles, the history of which is well recorded. The earth’s orbit causes these cycles around the sun, the different periods of the Earth’s Eccentricity cycle, the Obliquity cycle and the Precession of Equinoxes. The figure below clarifies what is meant by these terms.




Source: Scott Rutherford

**Figure 6: The Milankovitch Cycles**

Until the last 200 years, any significant climate change has been naturally driven As noted earlier, it is believed by many experts that these shorter-term cycles are driven by solar cycles. (Zharkova, 2014; Shepherd et al., 2014; Xu et al., 2019; Zharkova et al., 2015; Zharkova et al., 2018; Soon and Legates, 2013). These are caused by fluctuations in the solar flux, affecting cosmic ray penetration and cloud formation in the earth's atmosphere leading to warming and cooling periods. Figure 20 below gives a chart and pictorial representation of the process leading to cloud formation and a global cooling period. The cloud-producing impact of cosmic rays has been verified in the Cosmics Leaving Outdoor Droplets (CLOUD) experiments using the Large Hadron Collider at CERN in Switzerland.




Source: Scott Rutherford

**Figure 7: Solar Activity and Cosmic Rays**

The question of what causes solar cycles requires clarification. The work by Zharkova et al. (2020) has put forward a convincing hypothesis involving two magnetic dynamos with different periods in the Northern and Southern Hemispheres of the sun. The conclusion of this latest work is set out in full below because of its great historical and future importance.

> "In this editorial, I have demonstrated that the recent progress with understanding a role of the solar background magnetic field in defining solar activity and with quantifying the observed magnitudes of the magnetic field at different times allowed us to enable reliable long-term prediction of solar activity on a millennium timescale. This approach revealed a presence of not only 11-year solar cycles but also of grand solar cycles with a duration of 350–400 years. We demonstrated that these grand cycles are formed by the interferences of two magnetic waves with close but not equal

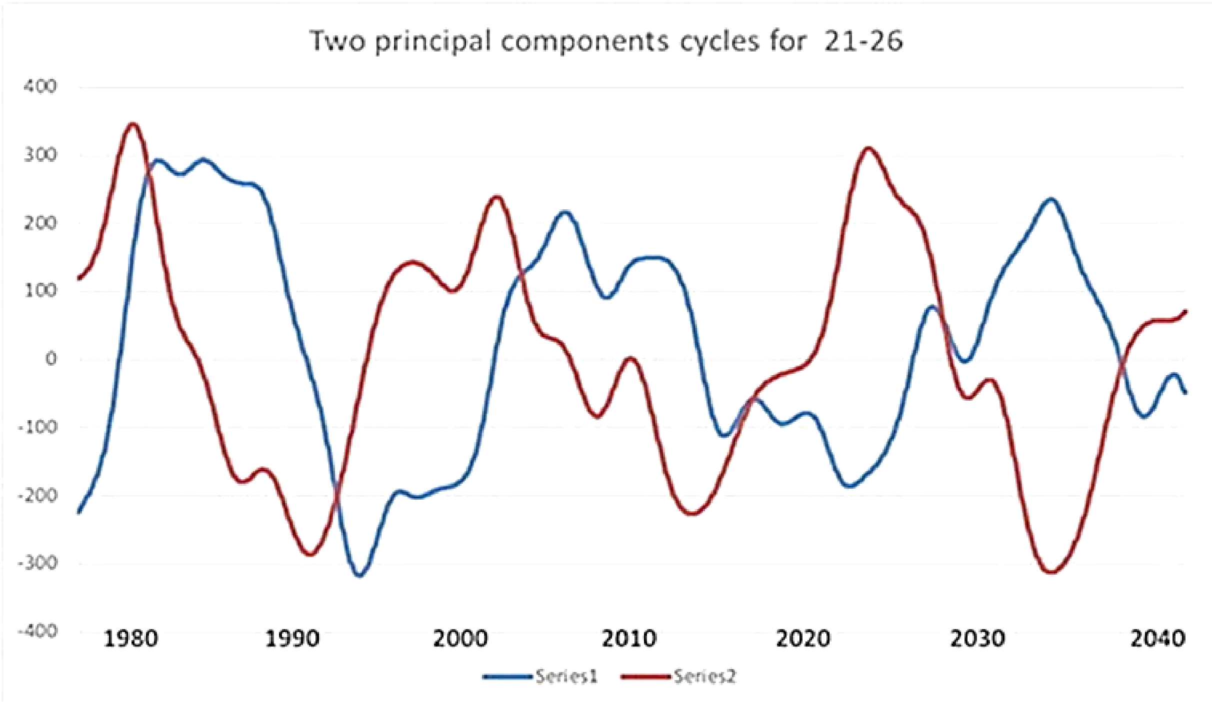
frequencies produced by the double solar dynamo action at different depths of the solar interior. These grand cycles are always separated by grand solar minima of Maunder minimum type, which regularly occurred in the past, forming well-known Maunder, Wolf, Oort, Homeric, and other grand minima.

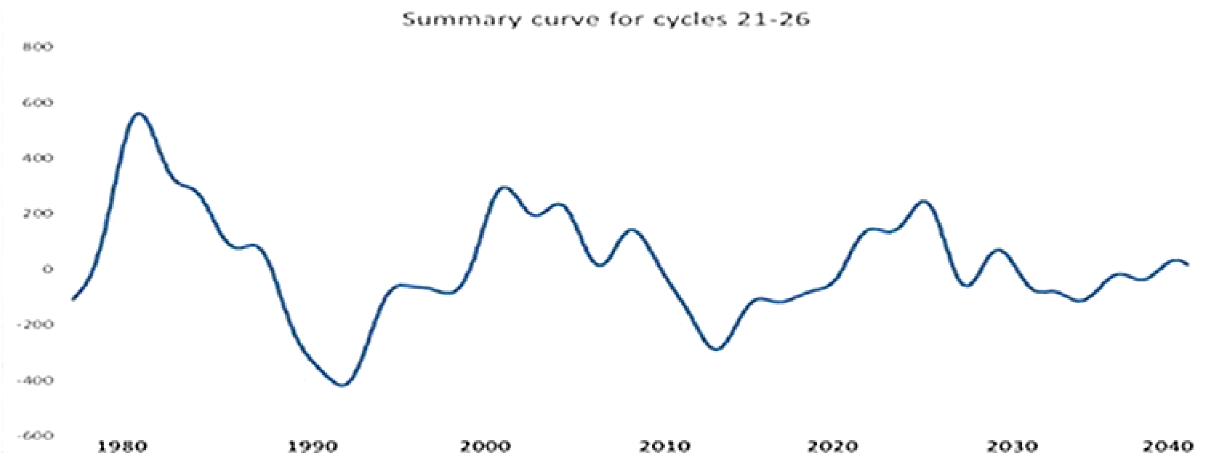
During these grand solar minima, there is a significant reduction of the solar magnetic field and solar irradiance, which reduce terrestrial temperatures derived for these periods from the analysis of terrestrial biomass during the past 12,000 or more years. For example, the most recent grand solar minimum occurred during the Maunder Minimum (1645–1710), which reduced solar irradiance by 0.22% from the modern one and decreased the average terrestrial temperature by 1.0°C to 1.5°C.

This discovery of double dynamo action in the Sun quickly warned us about the upcoming grand solar minimum. The solar magnetic field and its magnetic activity will be reduced by 70%. This period started in the Sun in 2020 and will last until 2053. During this modern grand minimum, one would expect to see a reduction of the average terrestrial temperature by up to 1.0°C, especially during the periods of solar minima between cycles 25–26 and 26–27, e.g., in the decade 2031–2043.

Reducing a terrestrial temperature during the next 30 years can have important implications for different parts of the planet on growing vegetation, agriculture, food supplies, and heating needs in both the Northern and Southern hemispheres. This global cooling during the upcoming grand solar minimum 1 (2020–2053) can offset for three decades any signs of global warming and would require inter-government efforts to tackle problems with heat and food supplies for the whole population of the Earth." (Zharkova *et al.*, 2020)

The first figure below shows the two principal components (PCs) of the solar background magnetic field (blue and green curves, historically and predicted set out above. The second figure shows the summary curve derived from the two PCs above for the "historical" data (cycles 21–23) and predicted for solar cycle 24 (2008–2019), cycle 25 (2020–2031), and cycle 26 (2031–2042).




https://doi.org/10.1080/23328940.2020.1796243

Source: (Zharkova et al 2020)

**Figure 8: Solar Activity and Principal Components for Solar Cycles**

The first graph below gives the modulus summary curve (black curve) obtained from the summary curve above versus the averaged sunspot numbers (red curve) for the historical data (cycles 21–23). The second graph plots the modulus summary curve associated with the sunspot numbers and predicts this forward to Cycle 26.

> The figure "presents the summary curve calculated with the derived mathematical formulae forwards for 1200 years and backwards 800 years. This curve reveals the appearance of Grand Solar Cycles of 350–400 years caused by the interference of two magnetic waves. These grand cycles are separated by the grand solar minima, or the periods of very low solar activity. The previous grand solar minimum was the Maunder minimum (1645–1710), and the other one before named the Wolf minimum (1270–1350). As seen in the figure from predictions by Zharkova et al., in the next 500 years, there are two modern grand solar minima approaching in the Sun: the modern one in the 21$^{st}$ century (2020–2053) and the second one in the 24$^{th}$ century (2370–2415)" (Zharkova et al. 2020).

An abstract from the previous work of Zharkova (Zharkova et al. 2018) is set out below:

> "We derive two principal components (PCs) of temporal magnetic field variations over the solar cycles 21–24 from full-disk magnetograms covering about 39% of data variance, with $\sigma = 0.67$. These PCs are attributed to two main magnetic waves travelling from the opposite hemispheres with close frequencies and increasing phase shift. We also derive mathematical formulae for these waves using symbolic regression analysis and calculate their summary curve, which we show is linked to the solar activity index. Extrapolation of the PCs backward for 800 years reveals the two 350-year grand cycles superimposed on 22 year-cycles. The features show a remarkable resemblance to sunspot activity reported in the past, including the Maunder and Dalton minimum. The summary curve calculated for the next millennium predicts a further three grand cycles, with the closest grand minimum occurring in the forthcoming cycles 26–27, with the two magnetic field waves separating into the opposite hemispheres leading to strongly reduced solar activity. These grand cycle variations are probed by the $\alpha - \Omega$ dynamo model with meridional circulation. Dynamo waves are found generated with close frequencies whose interaction leads to beating effects responsible for the grand cycles (350–400 years) superimposed on a standard 22-year cycle. This approach opens a new era in investigation and confident prediction of solar activity on a millennium timescale."

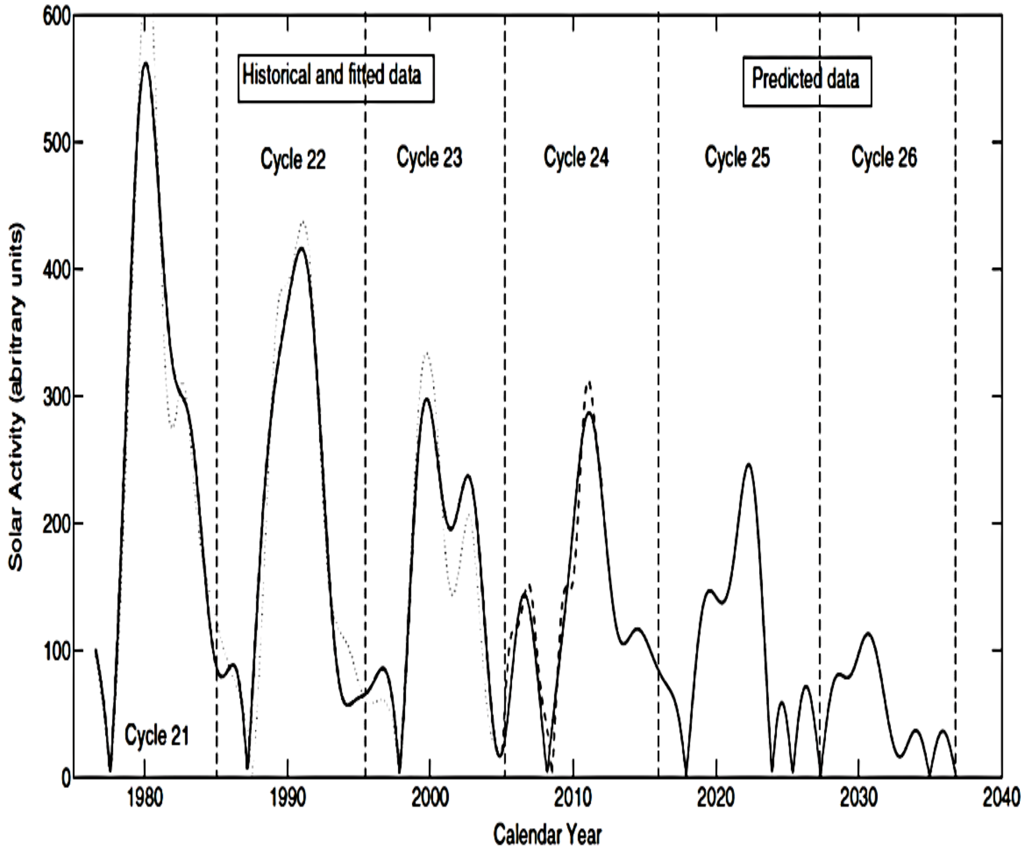



**Figure 4.** Modulus summary principal component (solid curve) calculated from Equations (6) and (7) for cycles 21–23 and predicted for cycles 24–26, the modulus summary PC derived from SBMF in cycles 21–23 (dotted curve) and in cycle 24 (dashed curve).

Source: Zharkova et al

**Figure 9: Solar Activity and Cosmic Rays**

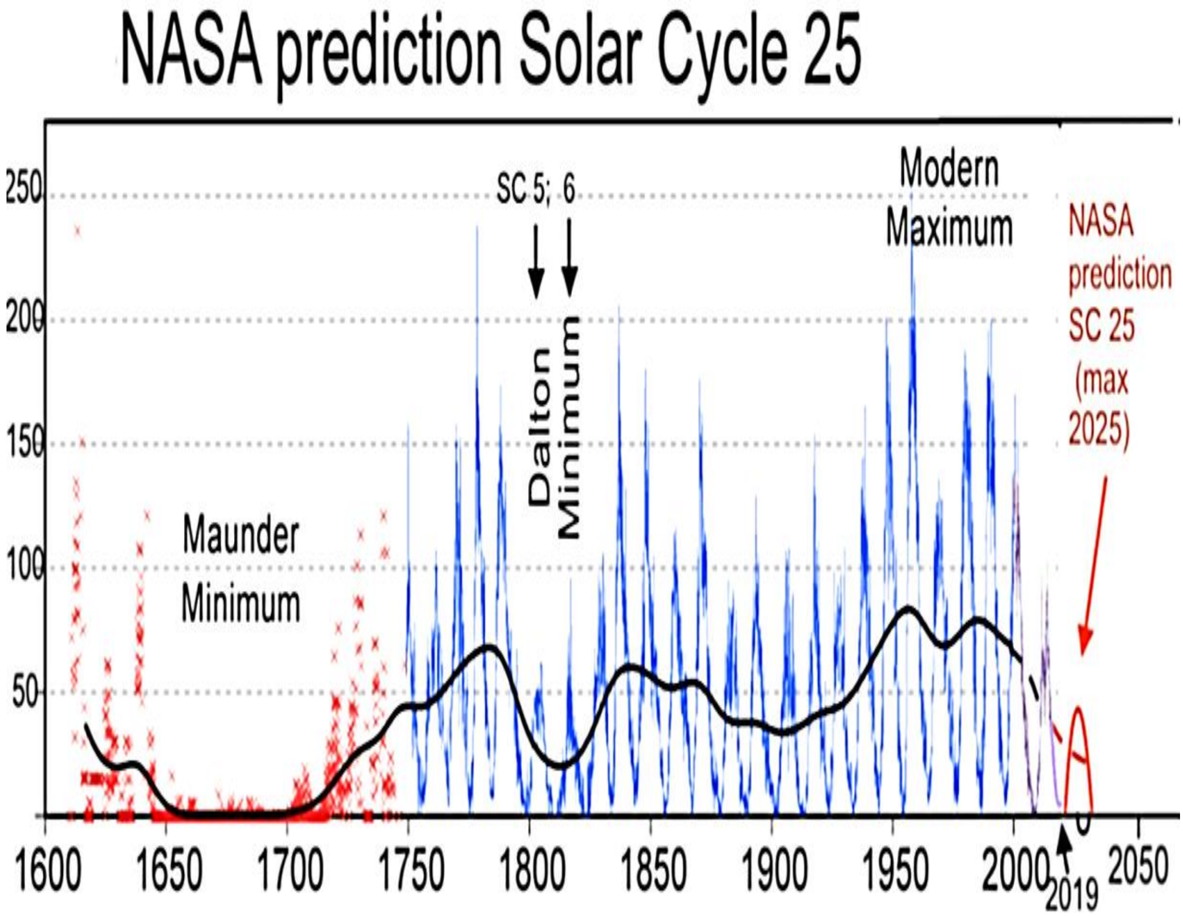
The historically low solar activity would appear to bring about a thirty- or forty-year period of global cooling. It is interesting to compare the above with the NASA forecast of the upcoming solar cycle 25 based on sunspot numbers and a prediction of an upcoming solar grand minimum

**Scientific predictions for the upcoming grand solar minimum**

The above summary of the paper by Zharkova is just one of the ever-mounting evidence warning the next epoch will be one of sharp terrestrial cooling.

- Prepare for the cold times and a refreezing of the mid-latitudes: events occurring in line with historically low solar activity, cloud-nucleating Cosmic Rays, and a meridional jet stream flow, with both NOAA and NASA appearing to agree, *if you read between the lines* — NOAA says we're entering a 'full-blown' Grand Solar Minimum in the late-2020s, and NASA sees this upcoming solar cycle as "the weakest of the past 200 years", with the agency correlating previous solar shutdowns to prolonged periods of global cooling here."

(Electroverse, 2020)




Source: NASA

**Figure 10: NASA Solar Irradiance**

The remaining question is how much humans currently contribute to short-term global warming (Berkhout et al., 2019; Climate Depot, 2010; Gosselin, 2019; Hertzberg, 2015). Earth has been in similar short-term natural warming phases eight times over the last 11 000 years, with the average temperature dropping over that inter-glacial time. The graphs below show the cooling over 11 000 years. The Irish Climate Science Forum ( ICSF) report overviews the Latest Climate Science for Policy Makers (ICSF, 2019a).

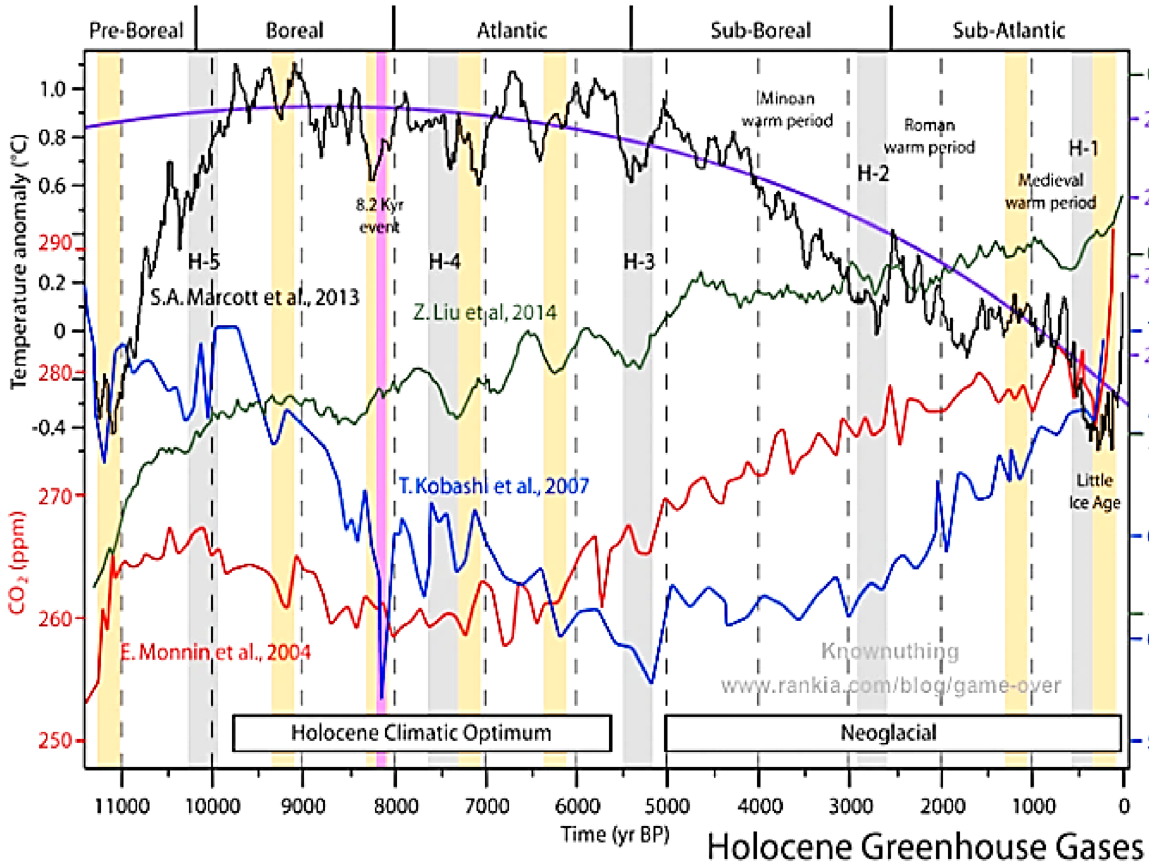



**Figure 11: Cooling over 11000 years**

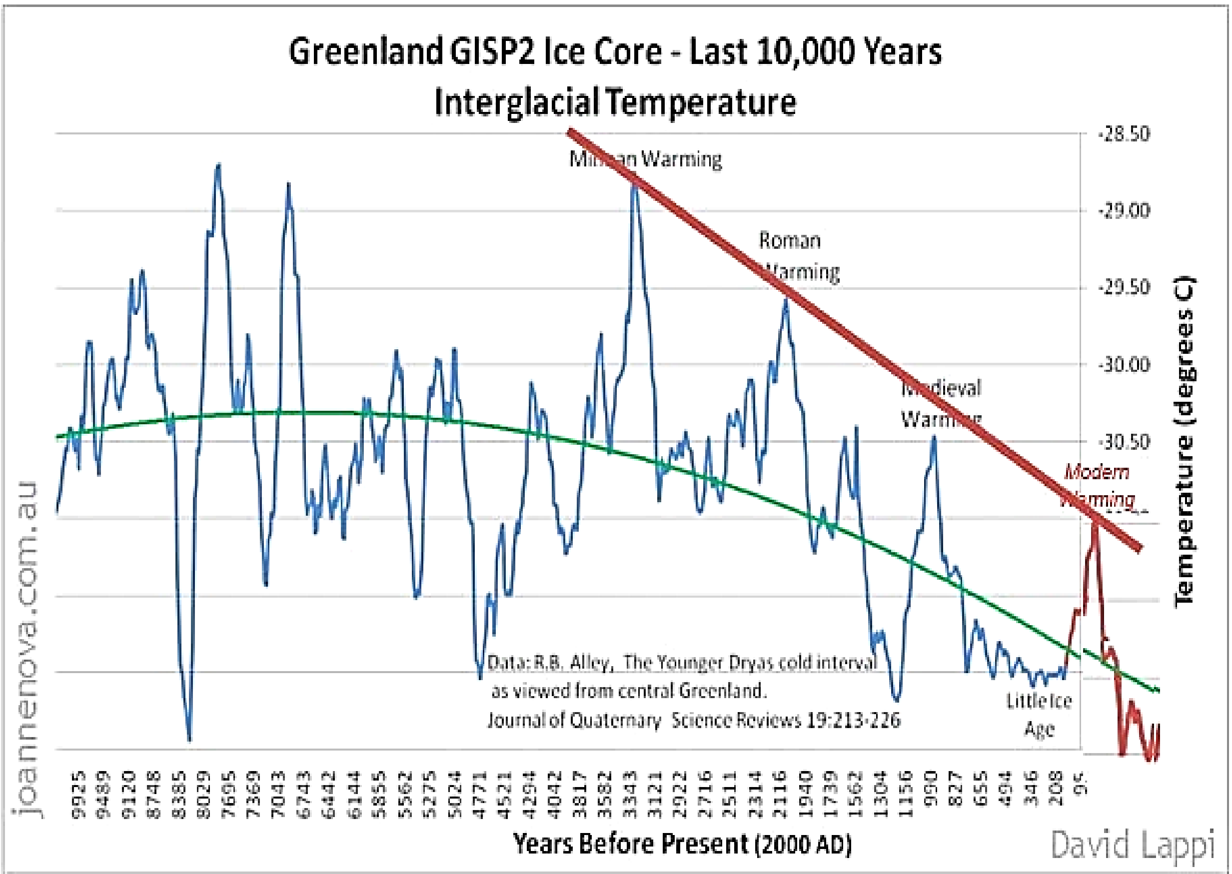



**Figure 12: Greenland GISP2 Ice-Core Temperature Last 10000 years**

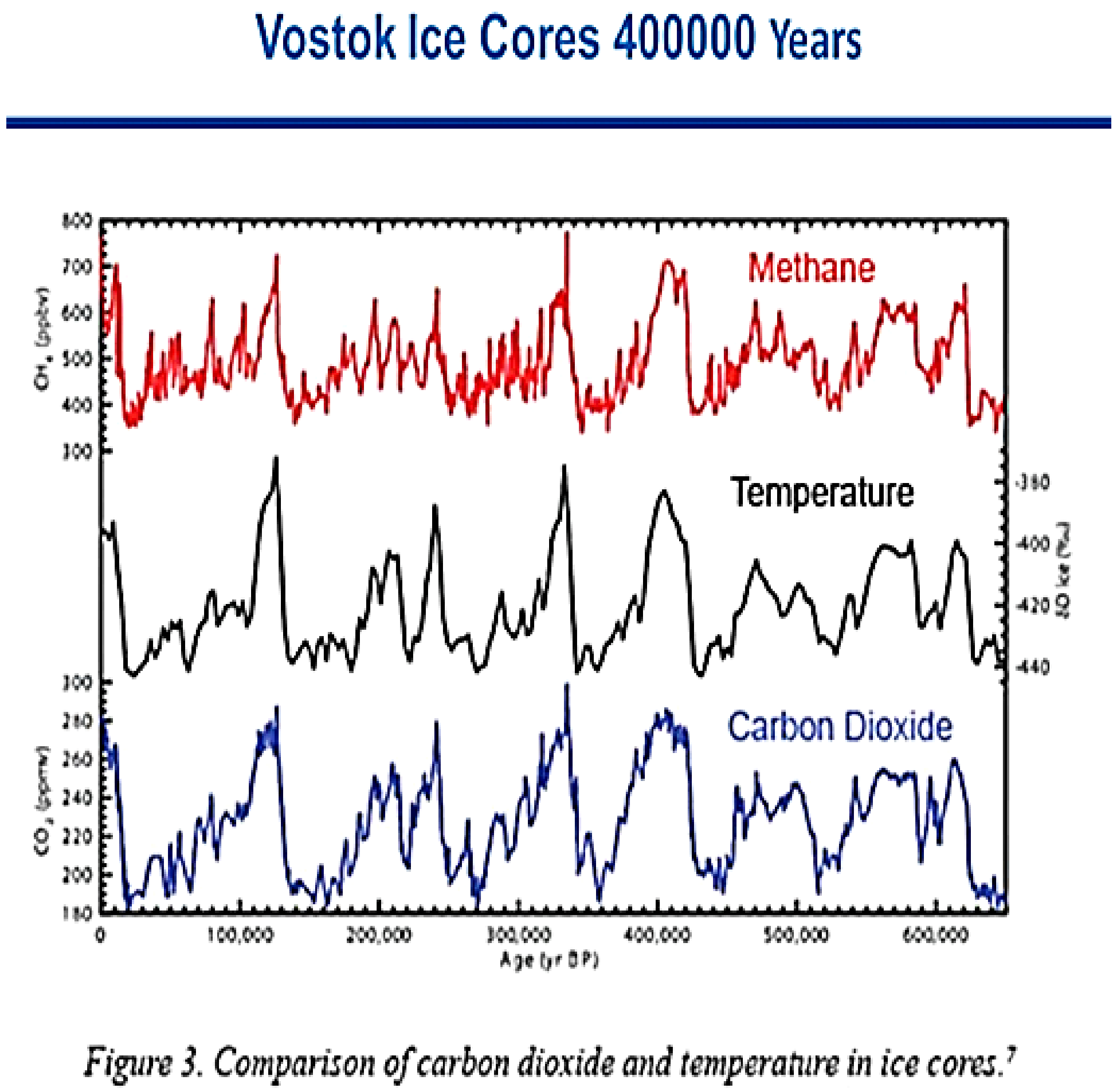



**Figure 13: Vostok Ice Cores 400000 years**

The Pleistocene/Eemian Interglacial was a notably warm period 129k-114k years ago with a sea-level some 6m higher than now. This was followed by the most recent Ice Age 110k-17k years ago, where sea levels fell to 120m below those prevailing today. After the last Glacial, the sea level rose 120m in 20 thousand years, the most rapid stage being a 20m rise in 340 years.

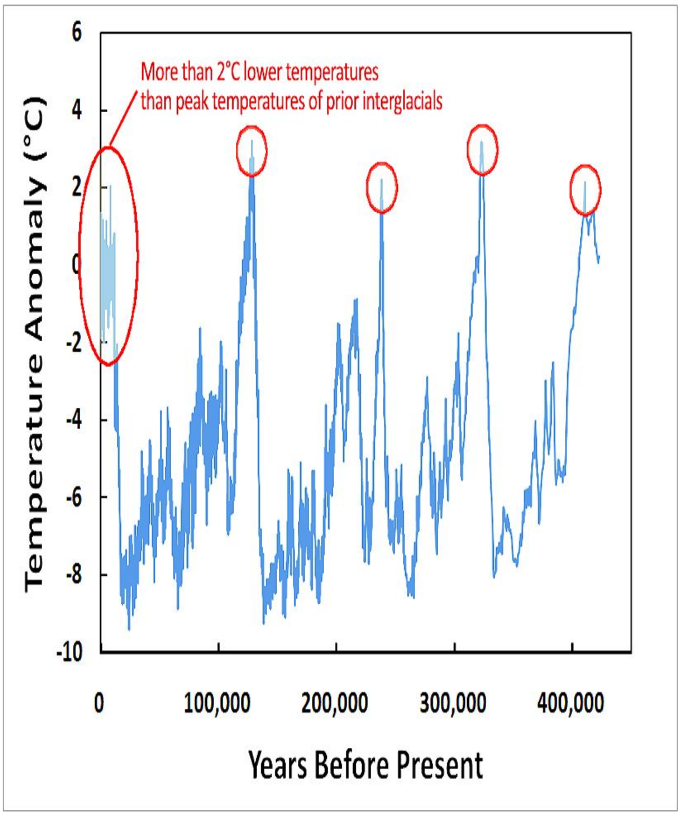



Figure 37: A 420ky history of the Earth's near-surface air temperature, extracted from Antarctic ice cores; temperatures were up to 2°C higher in all four recent Interglacials. Source [25].

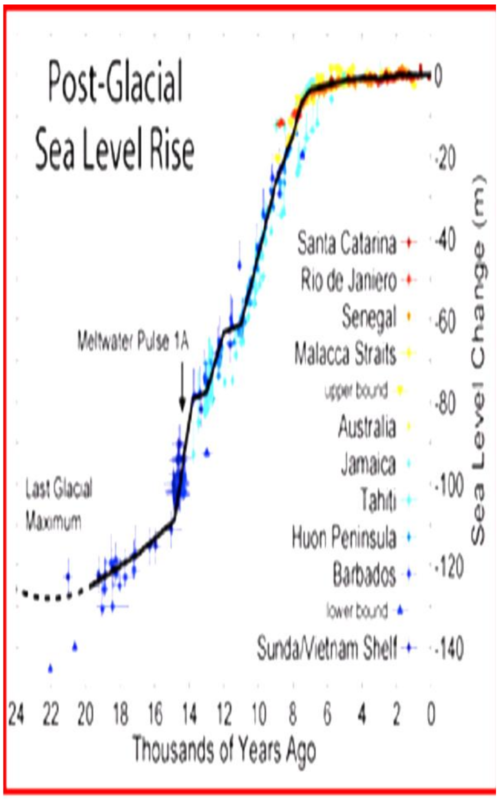



Figure 38: Reconstructed global sea-level since the last Glacial Maximum 20kya, based on worldwide peat and coral deposits. Source [25].

**Figure 14: 420k year Earths air temperature**

**Figure 15: Reconstructed global sea levels**

In the meantime, recent temperature warming trends have slowed (Morano, 2016). They do not support radical worldwide warming and are supporting the current assessments by the new US administration. These, in turn, are backed by the latest data and by the views of many experts on the subject (ICSF, 2019b).

Temperatures worldwide were higher a thousand years ago than they are now, while CO2 was lower. Further back in time, CO2 has been much higher than now while the planet was far warmer and contrary to the prophets of doom, the earth had far greater biodiversity. Nothing suggests that the present warming differs from previous natural warming events. The scientific evidence and movements that says carbon dioxide is not a contaminant or harmful in the quantities likely to be released by humans but is highly beneficial to the planet are proliferating. These views are expressed by many experts, including Dr Patrick Moore, the former head of Greenpeace (Paris Agreement, 2019; Moore, 2014; Moore, 2016).

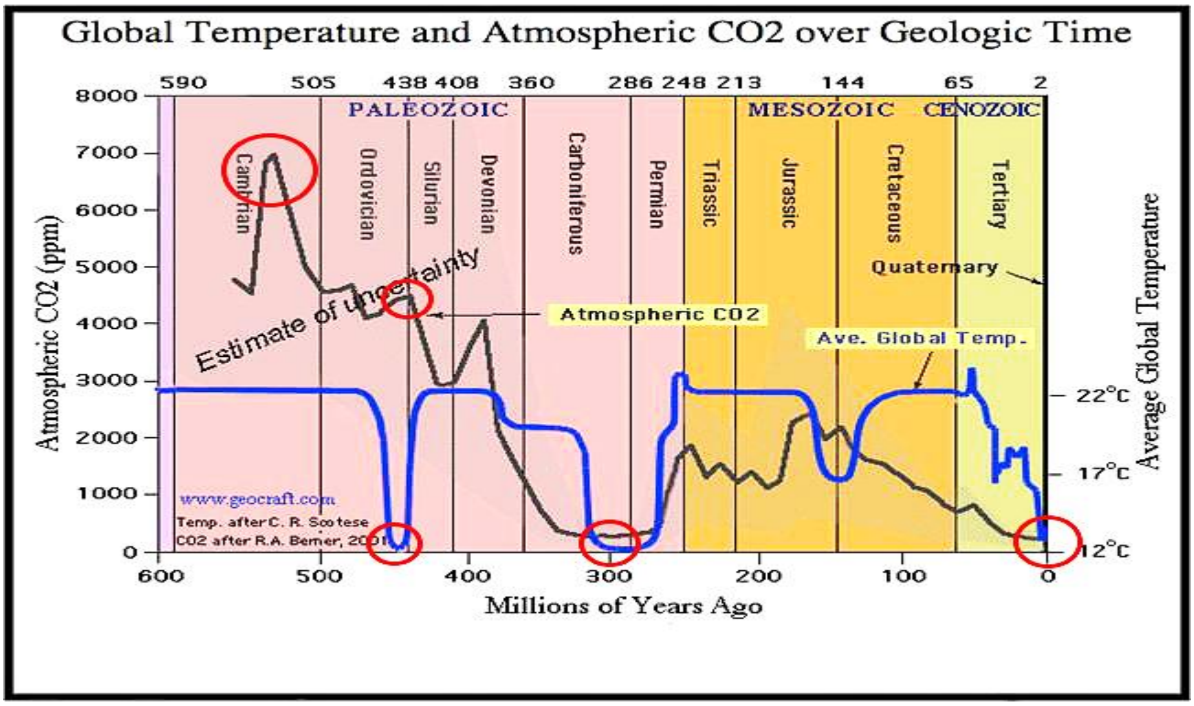



**Figure 16: Geological time: Temperature and CO2**

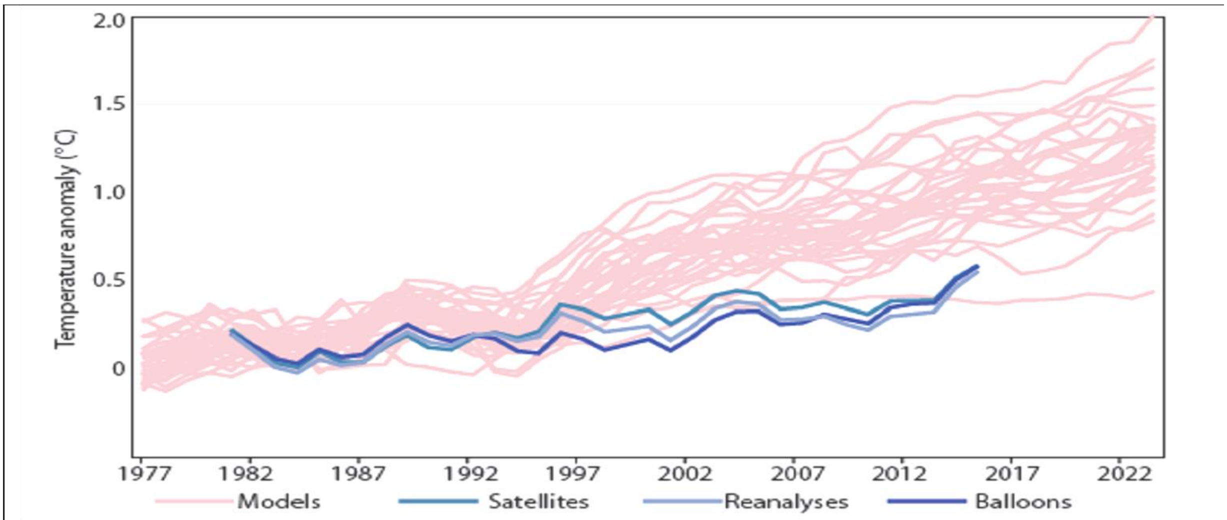



Figure 1: This graph demonstrates that tropical mid-troposphere temperatures, based on various observational datasets (in blue), lie about 0.5°C below the mean of all IPCC AR5 models projections (in pink), and the divergence continues to widen. Source: Dr John Christy [2,87].

**Figure 17: IPCC Temperatures and forecasts since 1977**

The graphs showing temperature are often incorrect. Many use temperature measurements from land-based thermometers, which are often inaccurate, prone to urban heat island warming and very patchy. Some experts view that the models being used by the IPCC automatically overestimate future global warming because of the incorrect assumptions being used (Monckton, Soon, et al., 2015). The IPCC forecasts compared to experience would seem to support this view.

Many experts view NASA as manipulating this sparse data to show alarming warming. The earlier graph of global temperatures is based on the most accurate possible source, satellites.
Lindzen summed the situation up neatly (Lindzen, 1994)

> "In this brief paper, the author barely touched upon numerous and fundamental difficulties with present climate models (such difficulties are discussed by Stone (Stone, 1992). Rather, the focus has been on specific reasons for current models to predict substantial global warming from increasing CO2. These reasons are essentially spurious. In particular, present predictions of amplified response to CO2 increases depend on positive feedback from upper tropospheric water vapor. The physical processes currently believed to dominate the upper-level water vapor budget are largely absent in current models. This is the main point of the present paper. In addition, there is both observational and theoretical evidence that current predictions substantially exaggerate the likely warming."

Unfortunately, on many occasions, so-called climate change experts have manipulated the data they have presented to enhance the arguments that man is causing global warming. One of the most infamous incidences involved Mann, an American climatologist and geophysicist. He contributed to the scientific understanding of historic climate change based on the past thousand years' temperature records. As stated in documents, he pioneered techniques to find patterns in recent climate change. He presented data in a graph that became famous as the Mann Hockey Stick graph showing alarming warming over the past 150 years. He was accused of manipulating data, but an academic panel cleared him of wrongdoing. A prominent sceptical climate scientist, Ball, accused Mann of fraud in generating the Hockey Stick graph. Mann accused him of defamation, but on August 23, 2019, the British Columbia court dismissed Mann's claim with prejudice and awarded court costs to Ball. The importance of all this lies in the fact that there are several incidences where data has been manipulated to exaggerate the impact of global warming and humans' influence on global warming (ECD, 2019). It is almost certain that evidence can be found on the other side of humans minimising global warming. The proof can only be found in the data. In particular, when it comes to climate change, the figures can only be considered and examined in the light of the long-term trend and the correct proportions. This must only be looked at in patterns of more than 100 years, more than a thousand years and more than ten thousand years. The planet has been in existence for over four billion years. The charts in the figures below illustrate the arguments presented in this section (ECD, 2019).

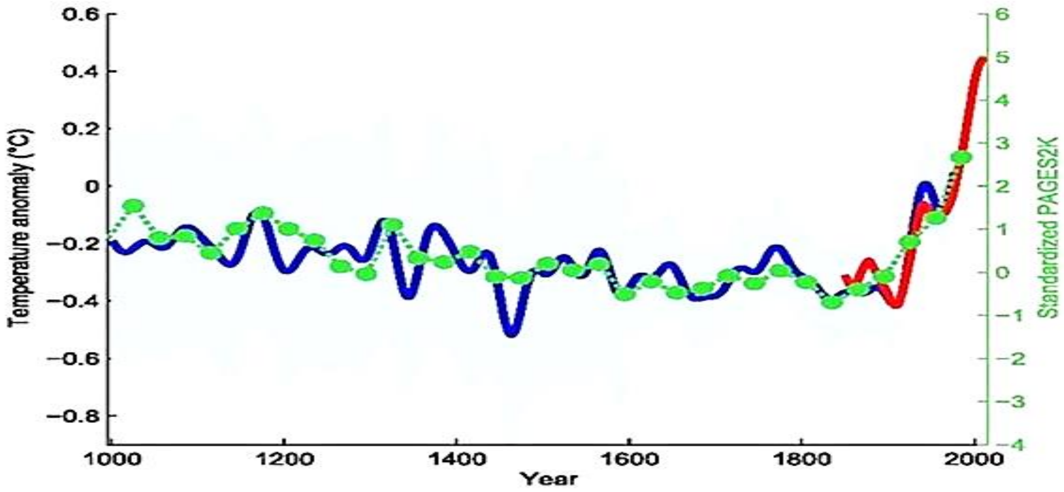



**Figure 18: Mann's Hockey Stick**

A view of the data over a more extended period gives a different perspective.

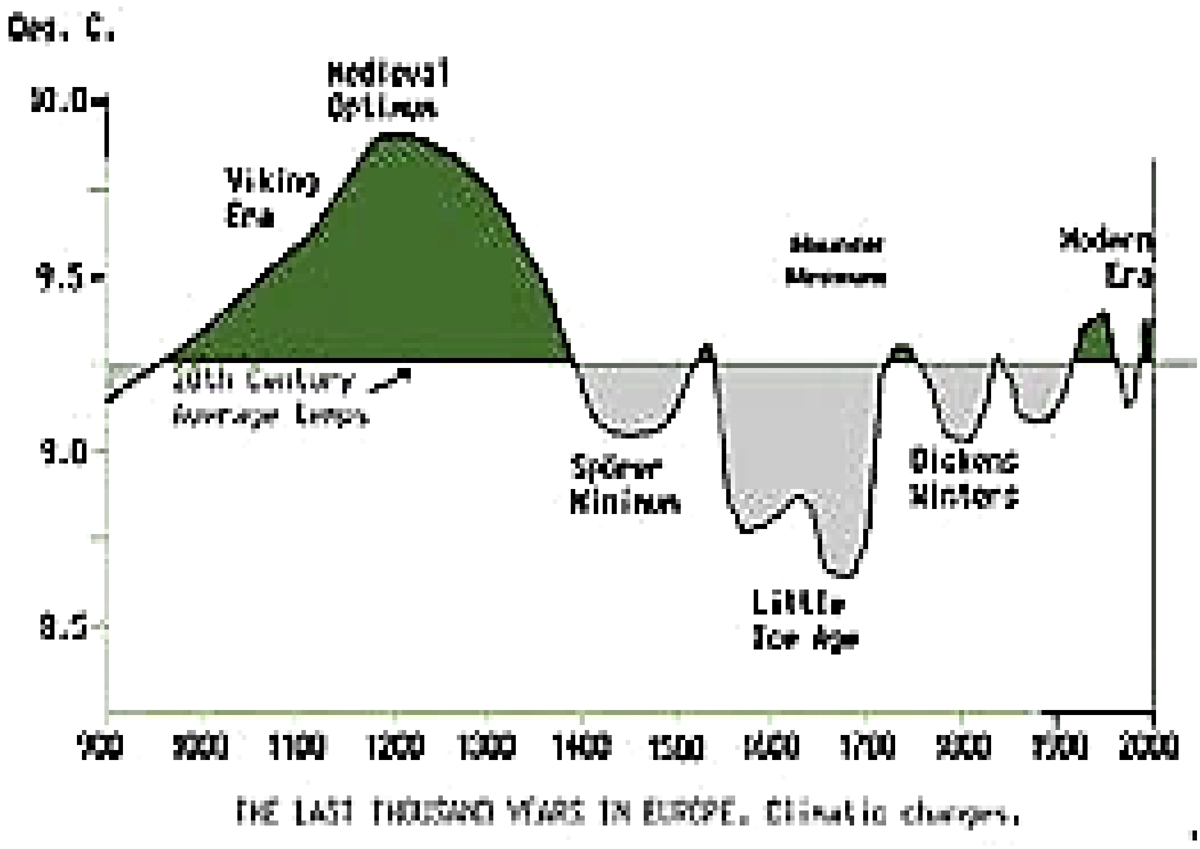



**Figure 19: The actual temperature performance**

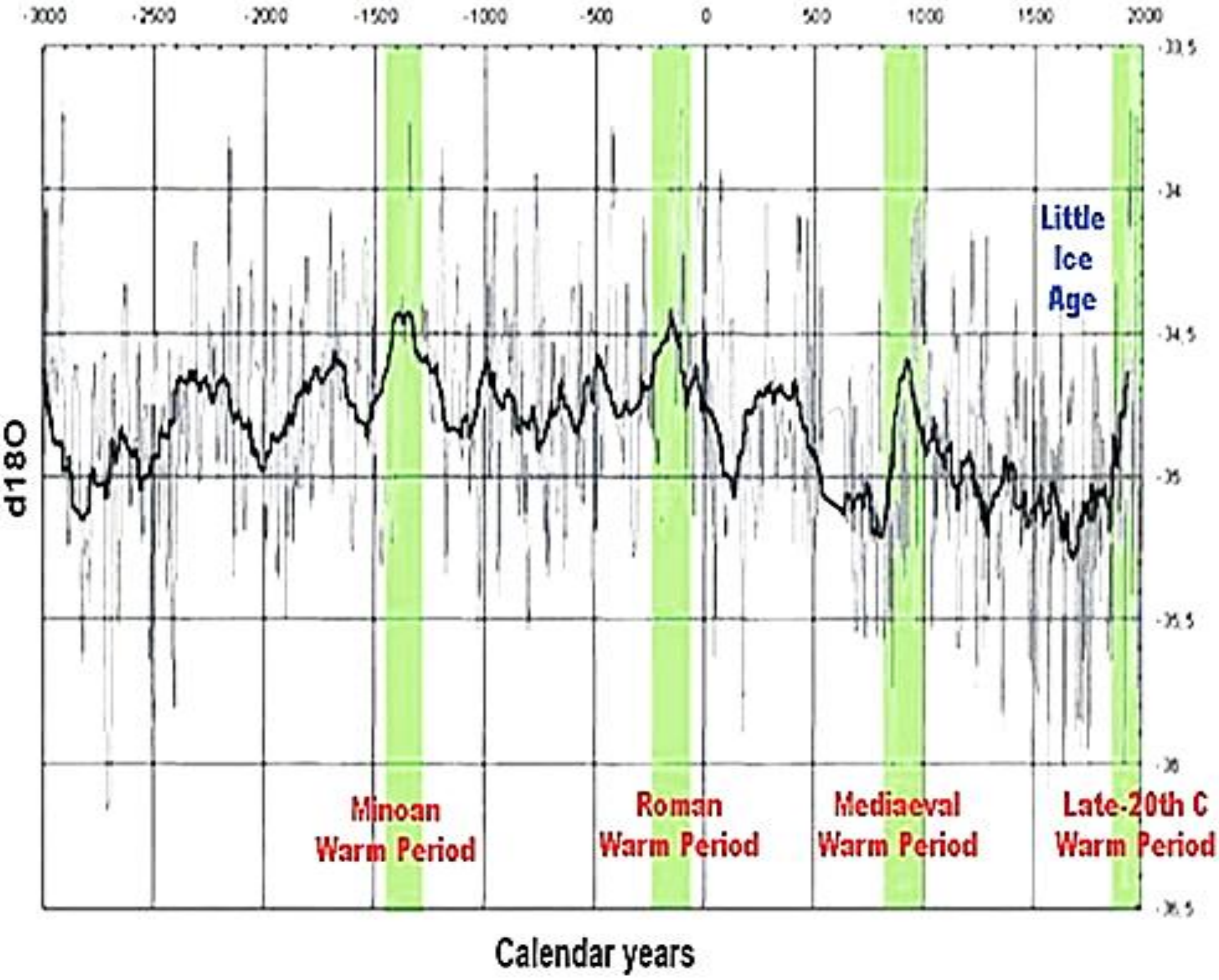



**Figure 20: Earth Temperatures over 5000 years**

### 2.4.2 FACTORS OTHER THAN TEMPERATURE CHANGE

The alarmists should note that they avoid satellite records and only use land-based records (Uscinski et al., 2017). The earlier graph shows that there has been no warming for about 20 years, during which CO2 has risen considerably. The spikes of 1998 and 2016 are caused by El Niño, a natural heating event in the Pacific Ocean. 2016 is slightly warmer than 1998. It was the warmest year since records began in the 19th Century (Morano, 2016). However, it is only 0.02 degrees Centigrade warmer than in 1998, which is statistically insignificant. A sharp temperature drop as El Niño faded away and was replaced by a strong La Niña. More recently, there has been another rise in Carbon Dioxide, but there has been no substantial increase in Temperature of statistical significance. Furthermore, the "*so-called menacing droughts*" have been replaced by floods which are generally associated with these natural and regular climatic events.

It should also be noted that the IPCC temperature forecasts have been consistently incorrect and have exaggerated the extent of global warming (ECD, 2019). The graphs shown here are primarily taken from the ICSF (Irish Climate Change Forum) report entitled An Overview of the Latest Climate

Science for Policymakers. This report is a detailed review of the latest scientific evidence that has been published (ICSF, 2019b).

There are many scare stories about climate change and its effects on the environment, temperatures and sea levels on both sides of the argument (Warne, 2015; Kench et al., 2014). Work has been done in these fields by South African scientists. One of the foremost scientists was Lloyd of CPUT University. He was himself one of the scientists on the IPCC panel. These scientists participated in the report that led to the IPCC being awarded the Nobel Peace Prize. His report on aspects of this subject referenced here is a good summary refuting Anthropogenic Global Warming claims (Lloyd, 2018). Interestingly, over 30 years, the land area has increased more than the sea area. This is the reverse of what would be expected if the sea level rises excessively (Donchyts et al., 2016).

"Reducing Arctic Sea ice extent is viewed by many as the clearest demonstration of global warming, with predictions of its demise before 2050. Arctic sea-ice extent and volume have declined since 1979, but have effectively been at a standstill since 2007" (ICSF, 2019b; Connolly et al., 2017).

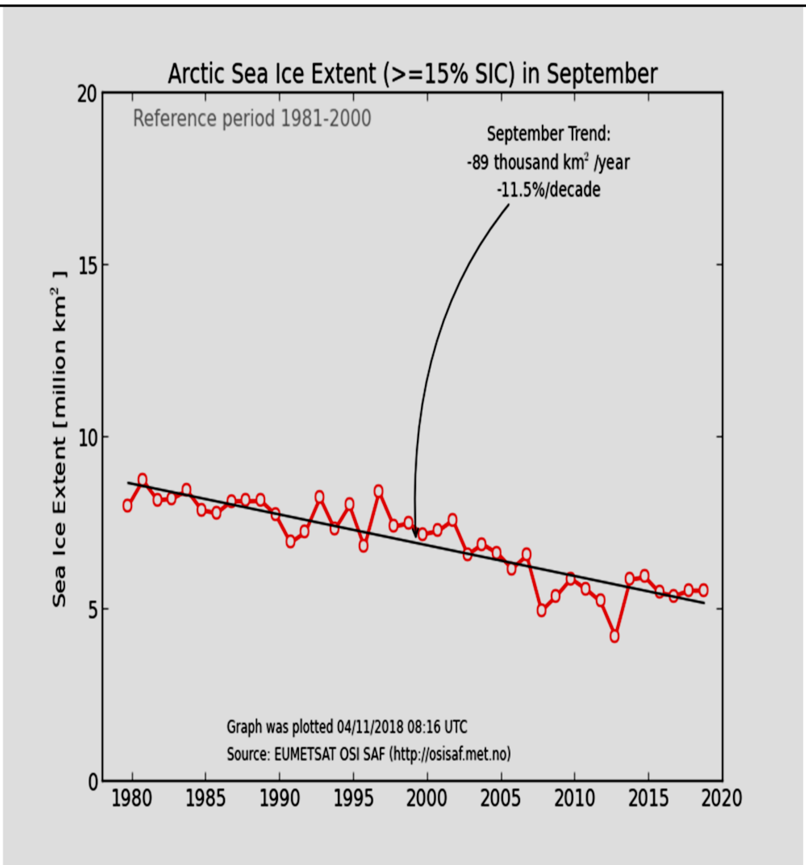



Figure 9: Arctic Sea Ice September low extents since satellite records began in 1979, demonstrating stabilisation since 2007 [Source: DMI, http://ocean.dmi.dk/arctic/icecover_30y.uk.php.].
The 2017/2018 season saw a cold summer with high levels of precipitation, which benefitted the ice sheet, whilst glaciers have maintained their area during the last six years, source http://polarportal.dk/fileadmin/user_upload/polarportal-saesonrapport-2018-EN.pdf

**Figure 21 Arctic Sea ice since 1979**

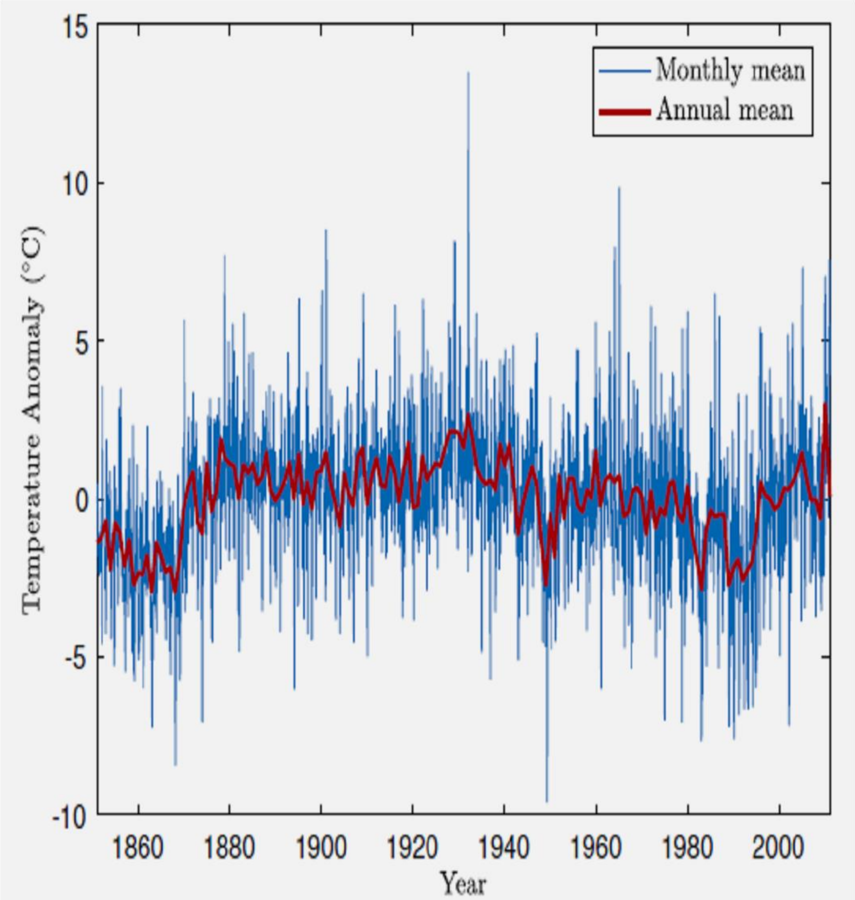



Figure 12: Observed fluctuations in Greenland's temperatures since 1851, based on re-analysis by KNMI, showing current temperatures to be similar to those as far back as the 1880s. [Source: https://www.the-cryosphere.net/12/39/2018/tc-12-39-2018-supplement.pdf].

**Figure 22: Greenland's temperature fluctuation since 1851**

One of the most emotional issues raised is that polar bears are being decimated by global warming. Yet scientific studies conflict with the views and findings of such reports. In one recent study, Crockford (Crockford, 2021) states, "while the climate narrative insists that polar bear populations are declining due to reduced sea ice, population surveys and the scientific literature don't support such a conclusion". Polar bears are more flexible in their habitat requirements than experts assumed, and less summer ice has so far been beneficial rather than detrimental. Further findings include:

• Results of three new polar bear population surveys were published in 2020, and all were found to be either stable or increasing.

• Southern Beaufort polar bear numbers were found to have been stable since 2010, not reduced as assumed, and the official estimate remains about 907.

• M'Clintock Channel polar bear numbers more than doubled from 284 in 2000 to 716 in 2016 due to reduced hunting and improved habitat quality (less multiyear ice).

• Gulf of Boothia numbers were stable, with an estimated 1525 bears in 2017. Body condition increased between study periods and thus showed 'good potential for growth.

• At present, the official IUCN Red List global population estimate, completed in 2015, is 22,000-31,000 (an average of about 26,000). Still, surveys conducted since then, including those made public in 2020, would raise that average to almost 30,000. There has been no sustained, statistically significant decline in any subpopulation.

• Reports on Viscount Melville surveys (completed 2016) and Davis Strait (completed 2018) have not yet been published; an East Greenland survey is expected to be completed in 2022.

• In 2020, Russian authorities announced the first-ever aerial surveys of all four polar bear subpopulations (Chukchi, Laptev, Kara, and Barents Seas) to be undertaken between 2021 and 2023.

• A new study has shown that polar bear females in the Svalbard area of the Barents Sea were in better condition (i.e., fatter) in 2015 than they had been in the 1990s and early 2000s, despite contending with the most significant decline in sea ice habitat of all Arctic regions.

• Primary productivity in the Arctic has increased since 2002 because of extended ice-free periods (especially in the Laptev, East Siberian, Kara, and Chukchi Seas and in the Barents Sea and Hudson Bay). More fodder for the Arctic food chain explains why polar bears, ringed and bearded seals, and walrus thrive despite profound sea ice loss.

• In 2020, contrary to expectations, the freeze-up of sea ice on Western Hudson Bay came as early in the autumn as it did in the 1980s (for the fourth year in a row) and sea-ice breakup in spring was also like the 1980s; polar bears onshore were in good condition. These conditions came despite summer sea-ice extent across the entire Arctic being the second-lowest since 1979. Data collected since 2004 on the weights of female polar bears in Western Hudson Bay have still not been published. Polar bear specialists have transformed standard body condition data collected from 1985–2018 into a new metric for population health they call 'energetics', which cannot be compared with previous studies. Meanwhile, they continue to cite decades-old raw data from previous studies to support statements that lack of sea ice is causing declines in body condition of adult females, cub survival, and population size.

• Contrary to expectations, many polar bears remained on the deteriorating sea ice much longer than usual in summer in Western Hudson Bay. They stayed ashore longer in the fall after official freeze-up thresholds had been reached, calling into question the assumed relationship between sea-ice coverage and polar bear behaviour and health. Some bears that left the ice in late August and then returned before late November would have spent only three months onshore – about one month less than typical in the 1980s and two months less than in the 1990s and 2000s.

• There were few problem polar bear reports in 2020 except for August's fatal polar bear attack in a campground near Longyearbyen, Svalbard. Ryrkaypiy, Chukotka, which in 2019 was besieged by more than 50 bears that had congregated to feed on walrus carcasses nearby, avoided a similar problem in 2020 by posting guards around the town. The town of Churchill saw the lowest number of problems bears in years.

• In 2020, virtually all polar bear research was halted across the Arctic for the entire year due to restrictions on travel and efforts to isolate vulnerable northern communities from Covid-19.

Meanwhile, Antarctic sea ice appears not to have declined in over 100 years (Morano, 2016).

On a global level, figures show hurricane activity peaked in the 1990s. Quotations (ICSF, 2019b)

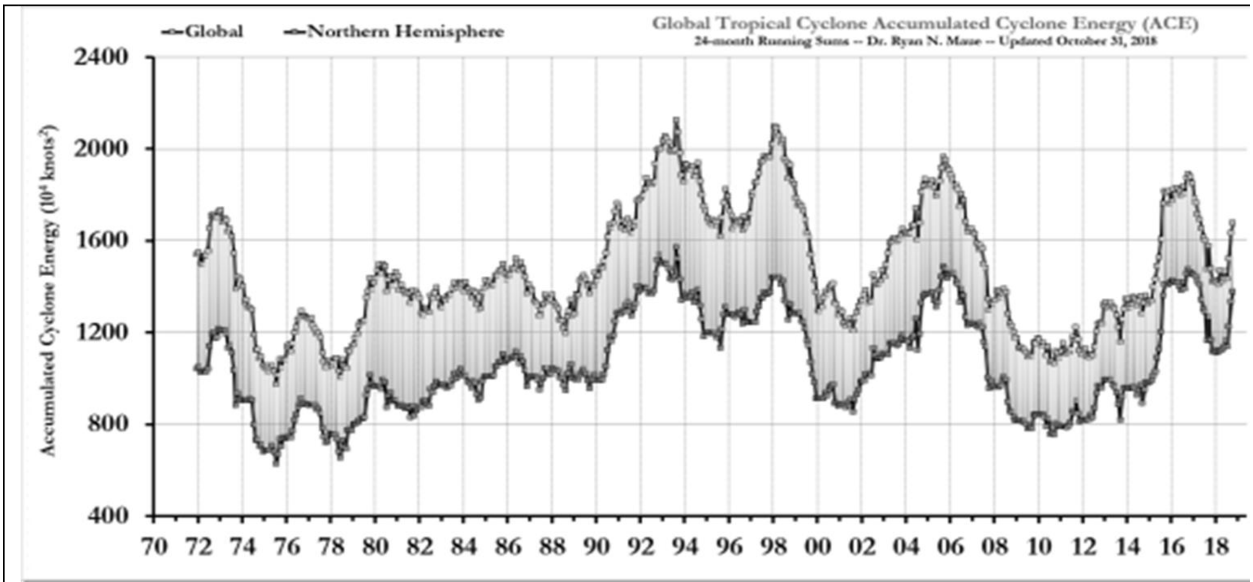
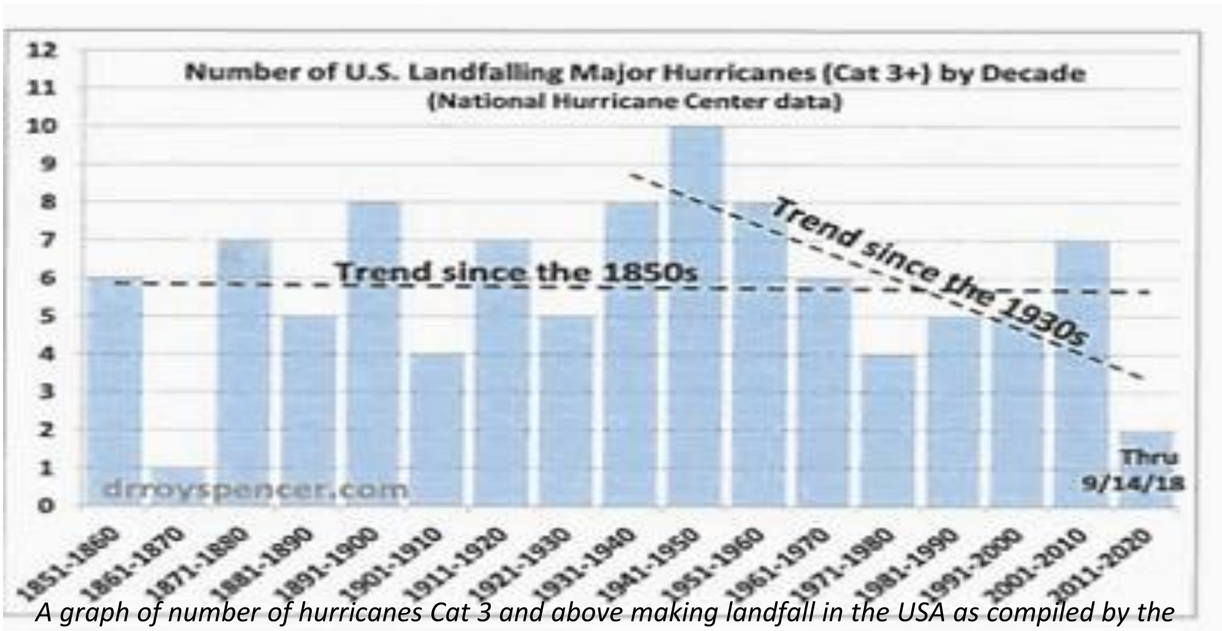



Figure 22: Trend of global accumulated cyclone energy peaked in the 1990s, source: http://www.policlimate.com/tropical/

**Figure 23: Global accumulated cyclone energy from 1970 to 2018**

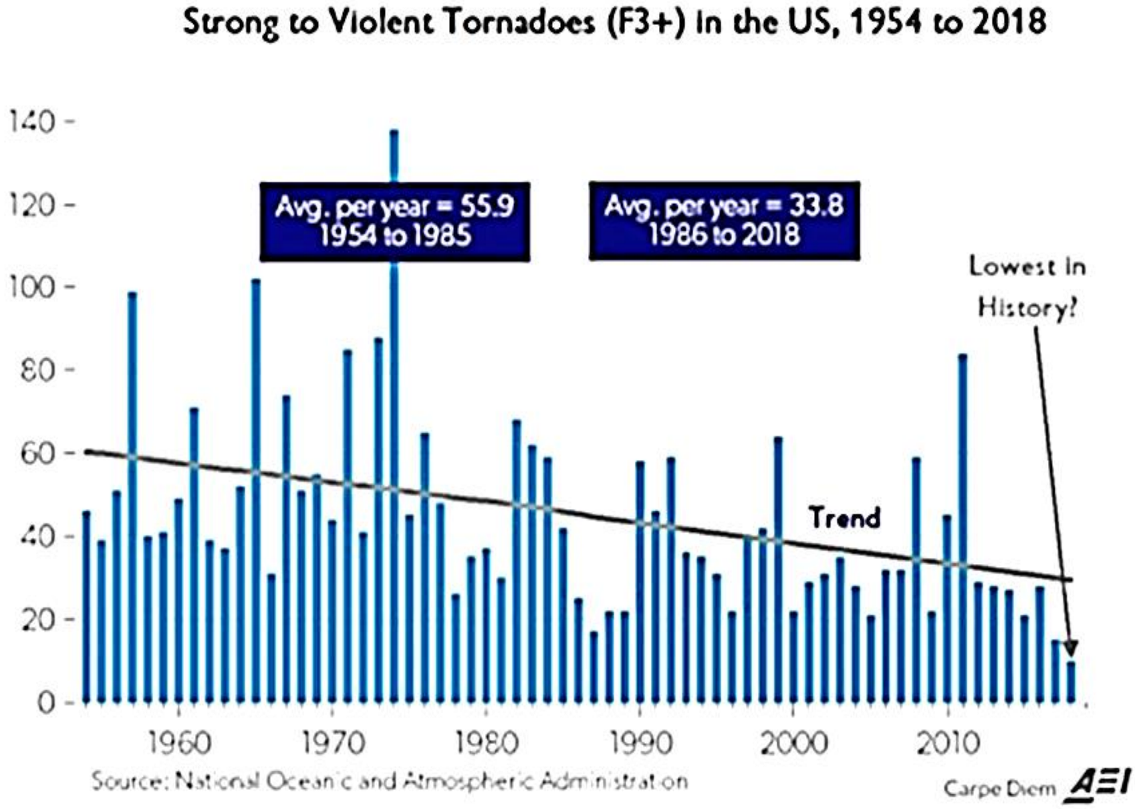



*A graph of number of hurricanes Cat 3 and above making landfall in the USA as compiled by the National Hurricane Center. Clearly the worst decade is not the present one, but the 1950's; and then the 1940's and 1960's. After this, there seems to be a decrease in the number of hurricanes*

**Figure 24: Number of strong hurricanes in the USA 1851-2020**

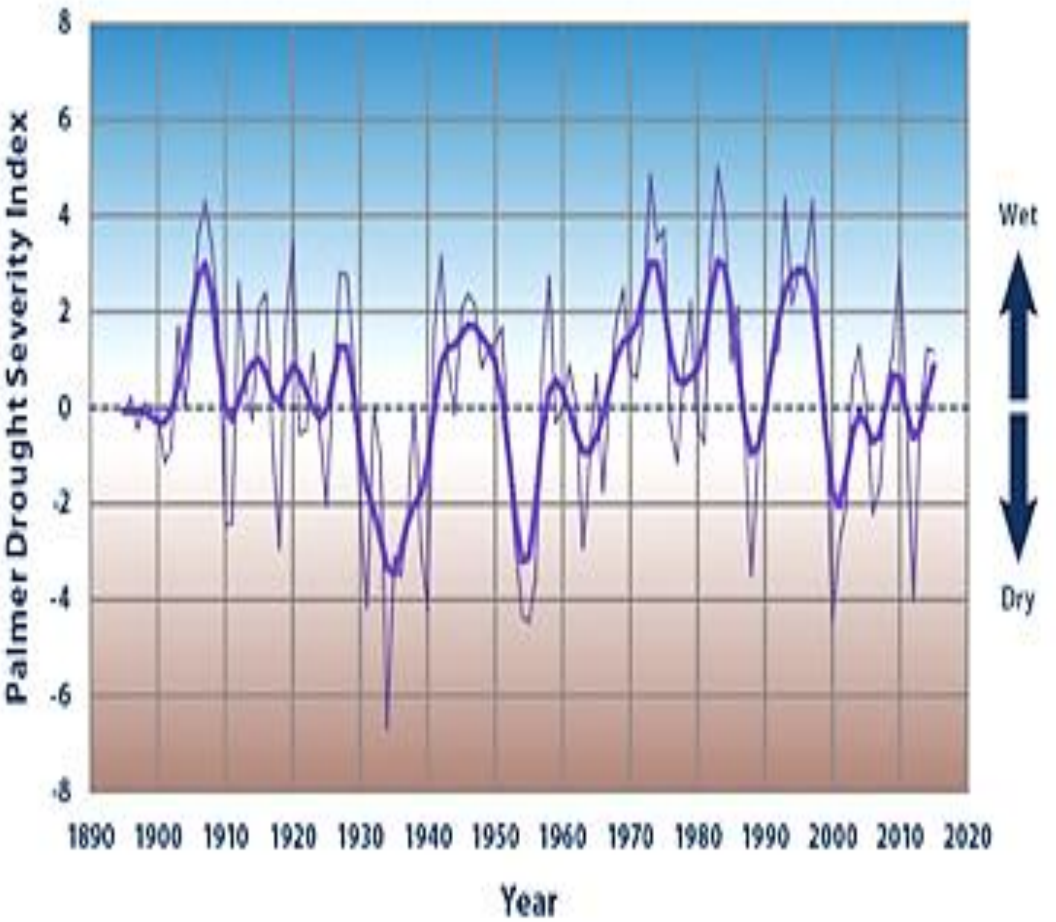
As stated previously, the purpose of raising these issues on the impact of CO2 on climate and the environment is not to prove that humans and CO2 have no impact on the environment. It shows sufficient facts available to suggest that there is considerable doubt that CO2 growth generated by coal does not pose a threat and danger to the planet made out by the IPCC, and environmentalists. Naturally, they also have data available that would appear to support their argument. In this instance, they would point to NOAA data for Atlantic Basin Cyclone counts for the past 170 years (NOAA 2020). This data would appear to have a clear upward trend - even allowing for some under-measurement in the early years!

Source: National Oceanic and Atmospheric Administration




*A plot of the number of strong to violent tornados (F3 and above) year by year from 1954 to 2014. Clearly there is no correlation with an increase of $CO_2$ in the atmosphere; in fact if anything the number of these storms seem to be slightly decreasing with increasing atmospheric*

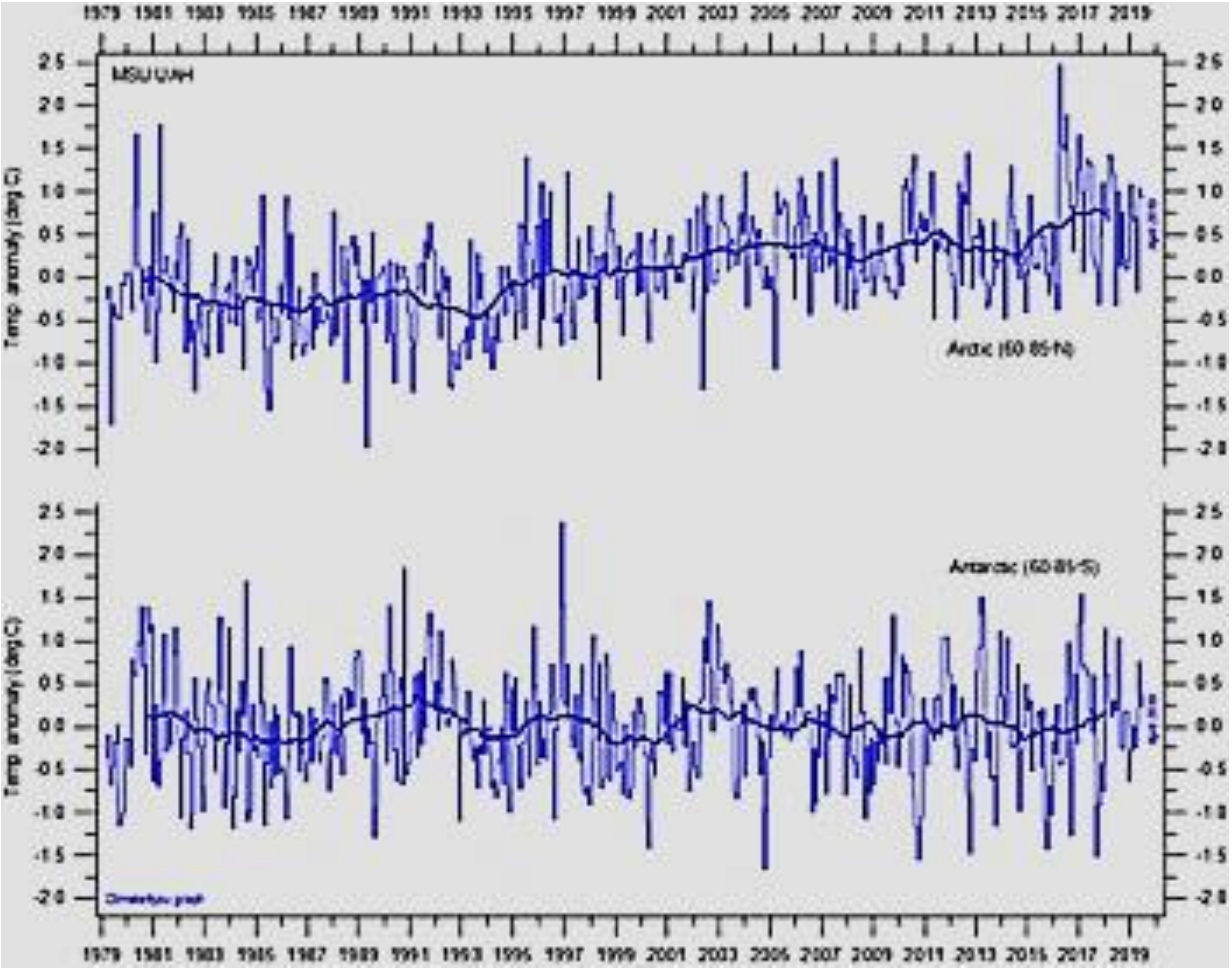
**Figure 25: Strong tornados in the USA 1954-2014**




This chart shows annual values of the Palmer Drought Severity Index, averaged over the entire area of the contiguous 48 states. Positive values represent wetter-than-average conditions, while negative values represent drier-than-average conditions. A value between -2 and -3 indicates moderate drought, -3 to -4 is severe drought, and -4 or below indicates extreme drought. The thicker line is a nine-year weighted average.

Data source: NOAA, 2016[5]
Web update: August 2016

**Figure 26: Palmer drought severity in USA 2016**




*Global monthly average lower troposphere temperature since 1979 for the North Pole and South Pole regions, based on satellite observations (University of Alabama at Huntsville, USA). This graph uses data obtained by the National Oceanographic and Atmospheric Administration (NOAA) TIROS-N satellite, interpreted by Dr. Roy Spencer and Dr. John Christy, both at Global Hydrology and Climate Center, University of Alabama at Huntsville, USA. Thick lines are the simple running 37 month average, nearly corresponding to a running 3 yr average.*
*As the Figure shows, there has been a slightly increasing temperature in the Northern polar region for about the last 25 years, after about a 15-year period of a slightly decreasing temperature. In any case, the warming is much more gradual than the Today Show indicated. Also, it is worth noting that in the southern Polar Regions, the temperature has been about constant; possibly one could even see a very slight temperature decrease there.*

**Figure 27: Temperature for the North Pole and South Pole regions**

This list of scientific findings refuting the IPCC claims proclaimed in the popular press can be extended, but the above figures clarify the essential issues. The report Latest Climate Science Nov 2019, entitled "An Overview of the Latest Climate Science for Policymakers" by the ICSF, states that the latest forecast of global warming indicates:

> "Monthly satellite observations since 1979 (see Figure 5) confirm a high degree of natural variability, most prominently in the naturally-occurring El Niño peaks [14,15] of 1998 and 2015/16. These observations, now spanning 40 years, indicate average warming of just under 0.1°C per decade. Extrapolation of this trend would indicate less than 1°C further warming by 2100, again providing no evidence of a 'climate emergency'." (Jeffrey, 2014).

Research by many scientists corroborates this view ( Berry, 2019b; Berry, 2019c; Lomborg, 2016).

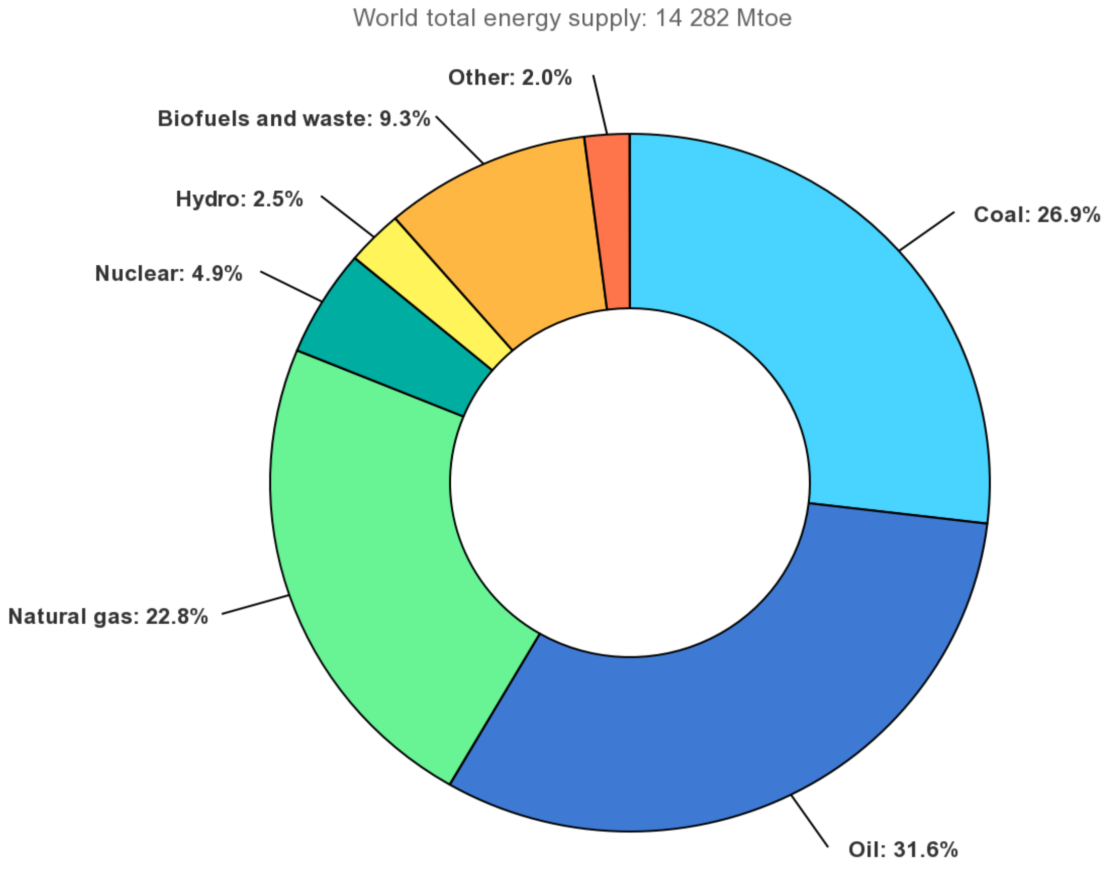
## 2.5 FOSSIL FUELS AND THE GLOBAL COST OF CUTTING CARBON

Lomborg states that "Climate change is real, and its impacts are mostly negative, but common portrayals of devastation are unfounded. Scenarios set out under the UN Climate Panel (IPCC) show human welfare will likely increase to 450% of today's welfare over the 21st century. Climate damages will reduce this welfare increase to 434%" (Lomborg, 2020).

Lomborg stated that based on United Nations figures, if every country were to make every promised carbon cut, the Paris treaty 2016-2030 would reduce temperature rises by 0.31 degrees Fahrenheit, i.e. 0.207 degrees Centigrade (Morano, 2016; Lomborg, 2016; Homewood, 2017). Simultaneously, Lomborg calculates these costs, using the best peer-reviewed economic models– through slower gross domestic product growth from higher energy costs — would reach $1 trillion to $2 trillion every year from 2030 (Smith et al., 2017). Based on South Africa's GDP, Global GDP and SA emissions of 1.1% of global emissions, the Carbon Tax, renewables, and other effects would cost SA between R35 billion and R 51 billion per annum (Lomborg, 2016). South Africa's efforts will reduce global temperature increases by only about 0.0026 degrees Centigrade by 2100. These figures amount to R1 trillion by 2035 (Jeffrey, 2015a). This figure is almost the same as estimated and set out in Appendix 2 on Carbon Tax.

Moreover, the value calculated offers substantial support to the numbers set out in that chapter. It is estimated that the Carbon Tax and the renewable programme's cost through higher prices, unstable electricity supply, reduced investment, and slower economic growth will reduce GDP by 2035 by between R1 trillion to R1.5 trillion per annum. Apart from the loss in investment, they are effectively taxes on efficient economic activity.

**Global share of total energy supply by source, 2018**

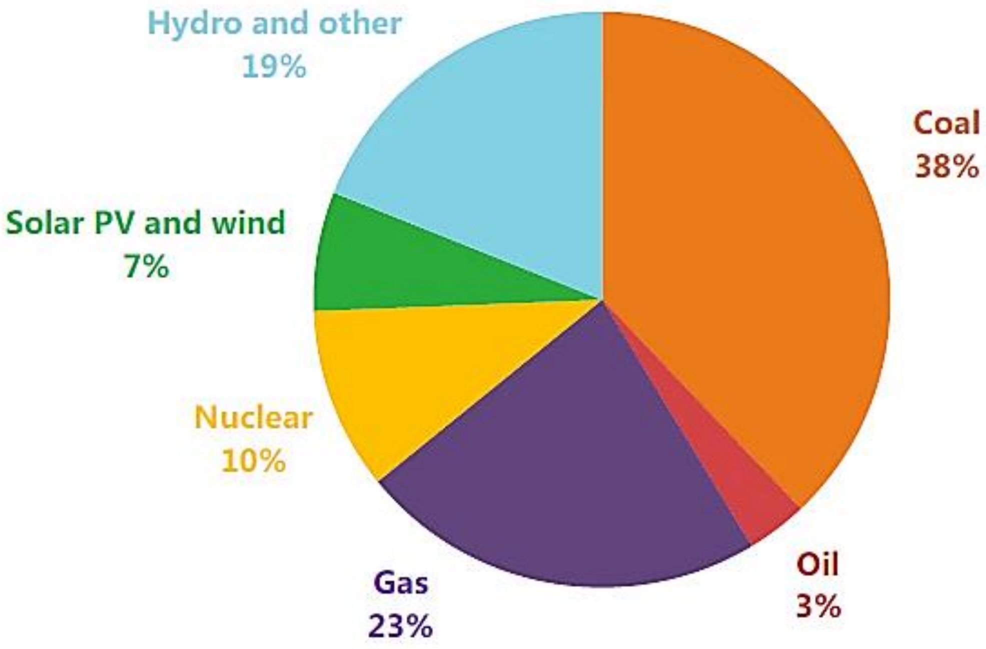



Sources: IEA, World Energy Balances, 2020.

**Figure 28: Global energy supply**

The world includes international aviation and international marine bunkers. In these graphs, peat and oil shale are aggregated with coal. Others include geothermal, solar, wind, tide/wave/ocean, heat and other sources.

- Fossil fuels provide 80+% of the global energy supply (power, transport, heat)
- Wind and Solar provide 7% of the nameplate global energy supply




The electricity generation mix, 2018.
Image: IEA, Global CO2 Status Report, 2019

**Figure 29: Electricity generation mix 2018**

- Total world electricity generation 25.7 TWh;
- Fossil fuels provide 64% of global electricity, 74% if nuclear is included;
- Coal = 38%;
- Gas = 23%;
- Nuclear = 10%;
- Wind Solar = 7% (of which 5% wind, 2% solar);
- Replacing fossil fuels is a lengthy and costly programme (Gregory, 2016).

A summary of various figures analysed and downloaded from https://climatepolicyinitiative.org/climate-finance/) include:

- Of total investment of 1.3 Trillion in USD per annum, excluding battery and infrastructure and excluding energy efficiency, the following can be said:
  - 24% or more than 300 Bn USD go into renewable power, here mainly Wind and solar (without battery);
  - 16% or about 200 Bn USD go into coal and fossil fuel power generation; coal is probably less than half, about 80 Billion USD).

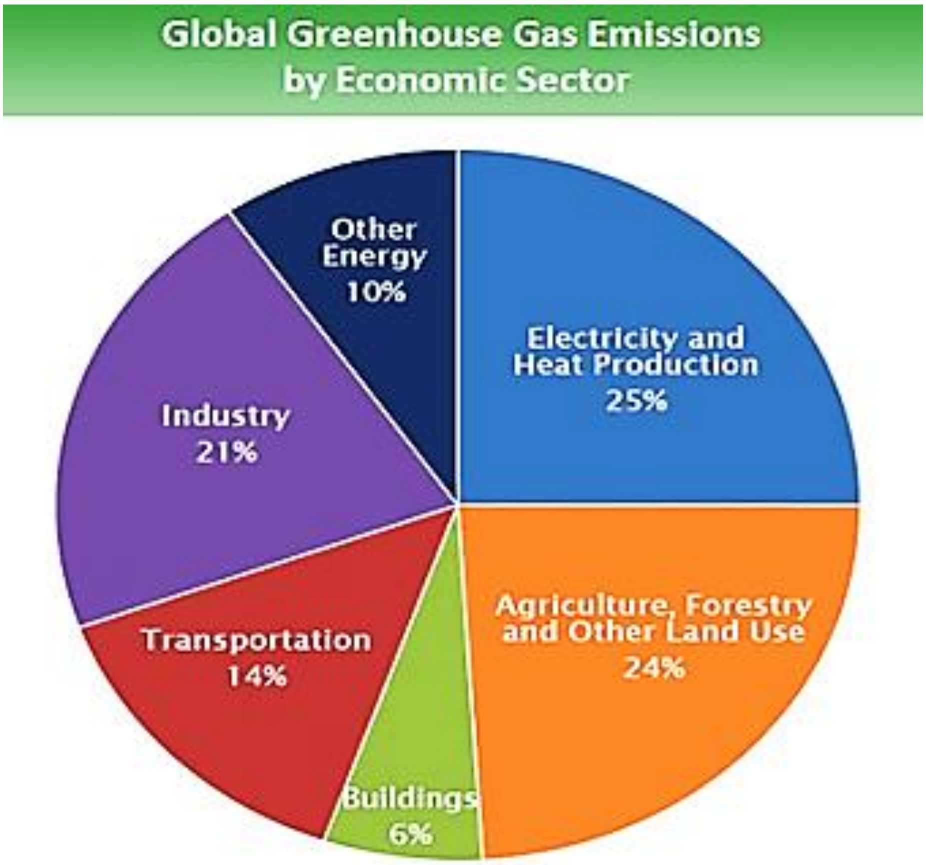
On the transportation side:

- about 725 Bn USD go into oil and gas (this is mostly for transportation, not so much for power)
- about 140 Bn USD goes into "low carbon transportation"…

Further information on estimated investment and expenditure on renewables

- The entire renewable industry is estimated to receive 500-600 Bn USD in investments annually.
- It is assumed that about 4 Trillion USD was invested in renewables (mainly Wind, Solar, and batteries) in the past ten years to get to where the industry is today: 2% primary energy supply and 5% wind and solar share in global power.
- This compares to probably 2 Trillion (half), which was invested into fossil fuel power generation (excluding nuclear), which accounts for 67% of global power.

These costs and questions must be answered because they point to the formidable, nearly impossible, and costly task the Green Lobby recommends.

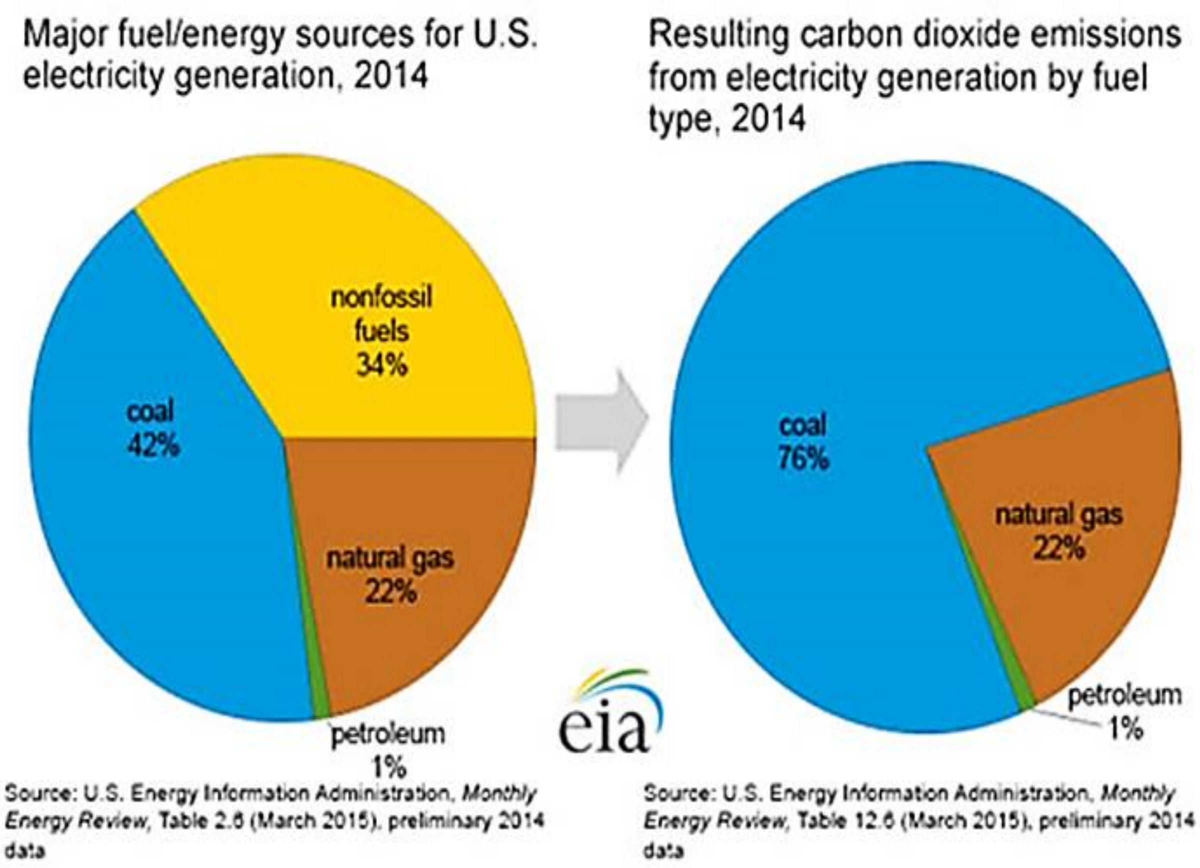



Source: EPA US Environmental Protection Agency

**Figure 30: Greenhouse gas emissions**

A growing percentage of scientists, possibly 40%, believe that humans currently contributed only a maximum of 20% to 25% to the global warming rise in the current 150-year global warming cycle. Growing scientific analysis suggests that natural forces are the dominant cause of global warming (Climate Depot., 2010). The Earth has warmed and cooled over a more extensive range of temperatures many times over the past 10 000 years of the Holocene period, during which times temperatures were often higher than now with no help from humans. The 25% attributable to humans can rise or fall depending on the strength of the natural forces at work at any one time.

Apart from warming associated with Greenhouse Gas Emissions (GHGE) from energy sources, the human contribution to global warming includes deforestation, farming, land use, cities and urban complexes, and other industrial processes. Electricity and heat production account for 25% of the GHGE by the economic sector (IPCC 2014), is set out above. It could, therefore, be assumed that electricity production accounts for 25% of the 25% attributable to global warming, i.e., 6.3%.



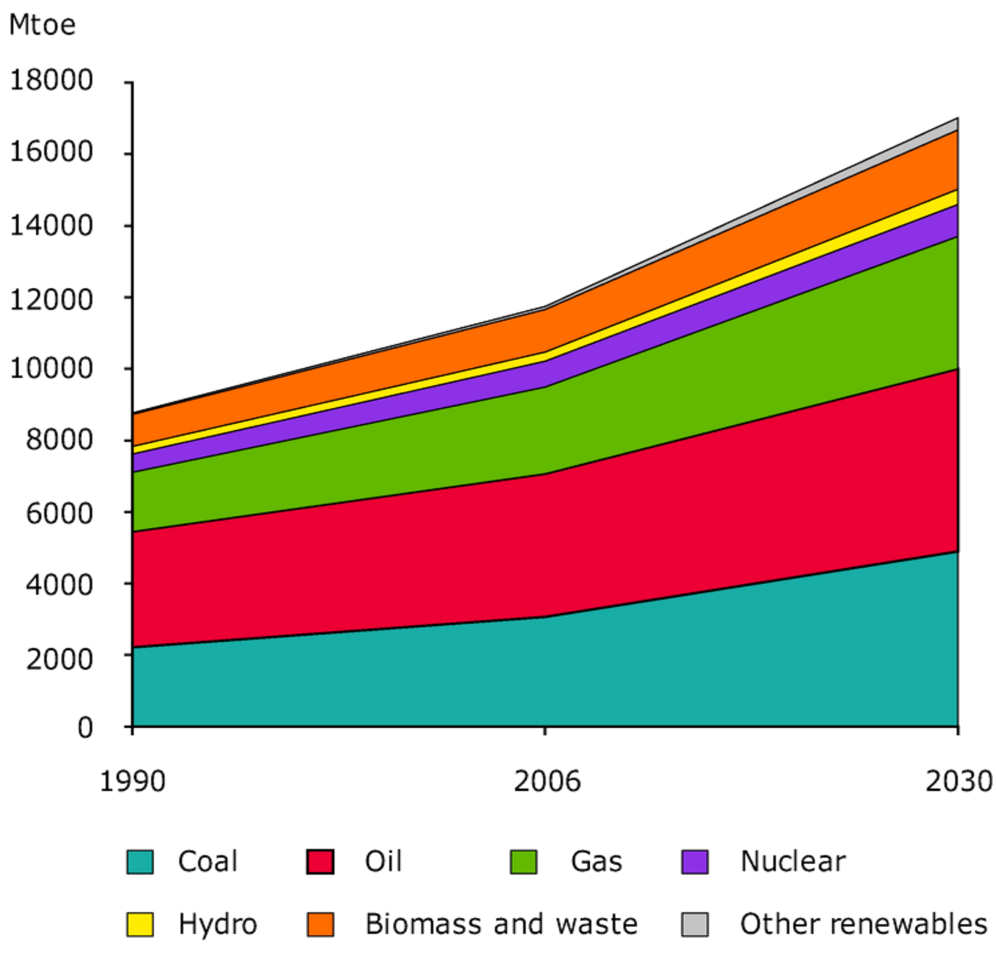

Source: IEA 2019, US Electricity Information

**Figure 31: US Electricity generation and CO2 emissions**

Coal's contribution to global electricity production in 2019 amounted to 38.3% (IEA Electricity Information, 2014; IEA, 2019). In the United States, the IEA's equivalent figures in 2014 were 42%

of electricity generation. They were responsible for 76% of carbon dioxide emissions from electricity generation by fuel type (IEA Electricity Information 2014). Assuming these ratios apply worldwide and if one believed their impact on CO2 and GHG production were in the same proportion, their effects on global warming would presumably be in the same ratio. It can then be calculated that coal is responsible for approximately 76% of the 6.3% attributable to anthropogenic global warming or 4.8% of global warming (Lane, 2018).

Based on these assumptions, unless there is a compelling argument to the contrary, eradicating coal usage as an energy source would amount to 4.8% of the postulated 6 degrees Centigrade Warming by 2100. These factors would result in a possible 0.29 degrees Centigrade reduction in temperature if global coal were eliminated by 2100. A 33% reduction in the emissions output by global coal by 2100 would, therefore, amount to a maximum decrease in global temperatures of 33% multiplied by 0.29 degrees, or approximately 0.096 degrees Centigrade over the period to 2100. The temperature change works out at 0.0011 degrees Centigrade per annum over the remaining years of this century.




Sources: IEA, World Energy Balances, 2020.

**Figure 32: Global energy consumption**

The significant reduction from commonly accepted values arises from the assumption held by many experts that human-induced global warming only amounts to a maximum of 25% of total global warming, the balance being natural. The IPCC and the green lobby assume that human-induced global warming accounts for the overall global warming that the Earth has incurred over the past 150 years. They anticipate this will continue. This assumption would appear to contradict the facts established by other experts set out above. Much, therefore, appears to depend on the underlying assumptions being made in this regard. The graph above shows that fossil fuels globally will play a significant and vital role in global demand and consumption for many years. They are accelerating the change rate with so few immediate benefits that it will be immensely costly. Many developing countries with significant economies and populations continue to use fossil fuels worldwide. Such countries include India, China and the ASEAN countries, including countries such as Indonesia and Vietnam. These factors must be carefully reconsidered when making such a decision. Several of them import coal from South Africa and are South Africa's direct competitors. Other developed economies such as Poland and Russia are extending coal, nuclear and gas use for baseload power. Where coal is involved, all are building new HELE 'clean' coal power plants and withdrawing the old dirty coal power stations as the new generating facilities come online.

## 2.6 THE IMPACT OF COAL AND FOSSIL FUELS ON CLIMATE CHANGE

### 2.6.1 HELE OR "CLEAN COAL"

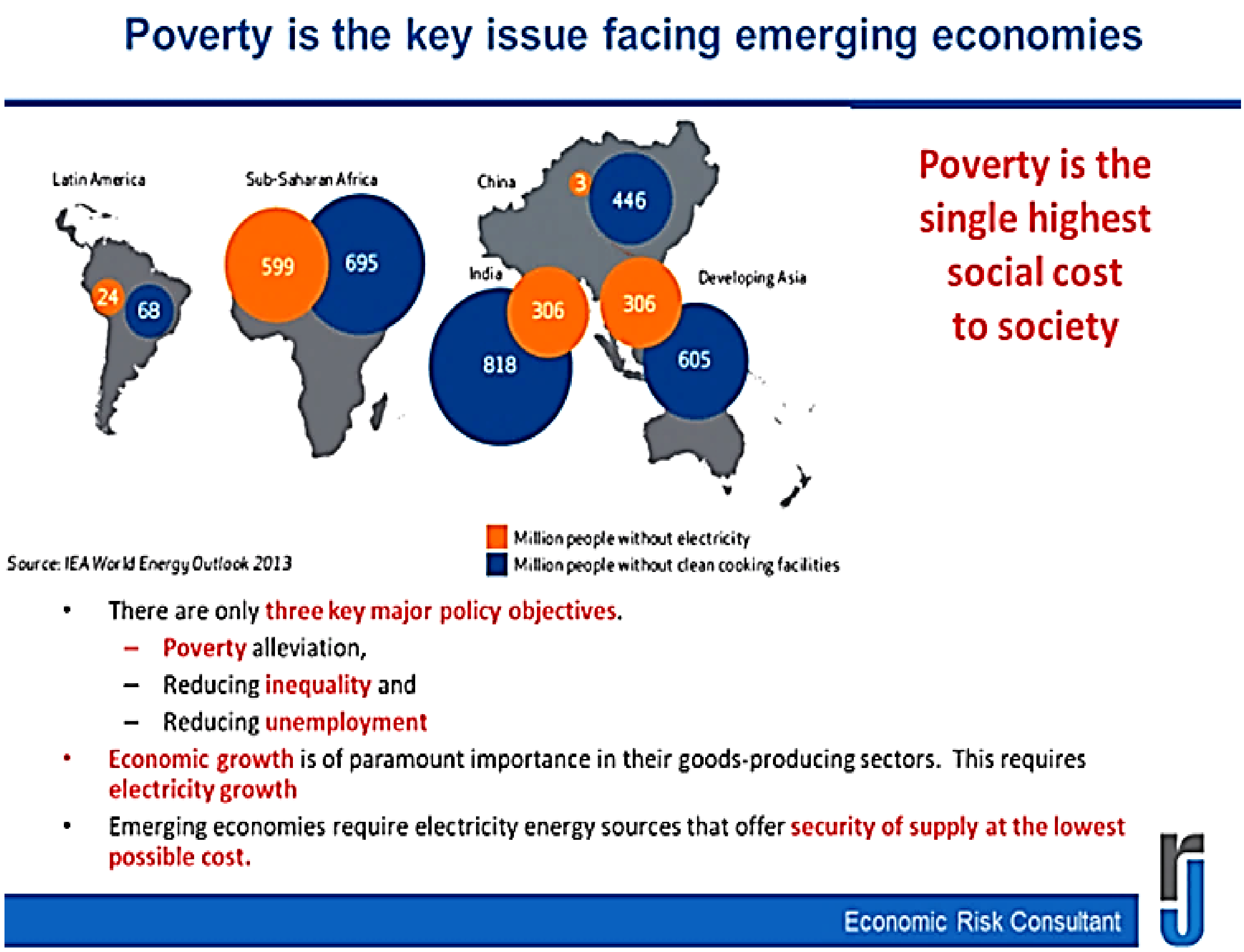
High-Efficiency Low-Emissions (HELE) or "clean-coal" is different from "old dirty coal" power stations. There is a substantial misconception about the role of "clean-coal" and the extent to which it contaminates and pollutes the atmosphere. There is no doubt that older coal-fired power stations were responsible for pollution. London and many other world cities proved that electricity generated by significant power stations in this manner was far more efficient and cleaner than heating and cooking over open fires and stoves, which was historically the case. Today, this is still the case in many developing countries.

Nevertheless, even current dirty coal power generation is very different from the reality of a modern coal-fired power plant utilising High-Efficiency Low-Emissions Technology (HELE) (Falcon, 2018; Sandor, 2017). Modern coal plants have reduced Greenhouse Gas emissions (GHG). ESKOM's oldest plants produce 1.10 – 1.25 t CO2e/MWh emissions. New super-critical technology will produce emissions of just under 0.80 tons CO2e/MWh, a reduction of 33%. These reductions compare favourably with the savings from switching to gas (Terbrugge and Collins, 2017). Sporton, Chief Executive of the World Coal Association (2017), noted that there are now 1.2 billion people worldwide without electricity. Energy poverty is spread across the developing world. It is particularly severe in sub-Saharan Africa. More than 620 million people live in the region without access to electricity. For those who do have access to modern energy, they face very high prices, and insufficiency and unreliability are a constant plague (Sporton, 2017).

Poverty is the most significant externality and problem that emerging economies have and need to overcome. This is often mentioned in reports and presentations (Jeffrey (2019). Roodt of the Efficient Group, on 14 April 2020, in his published notes, says

> "There is no doubt that poverty kills more people than all the nasties together. …..?" Poverty should lead policymakers to take this factor into account regarding any policy decision that slows the growth and increases unemployment

Poverty is linked directly to many things, including education, housing, overpopulation and work availability, amongst many others. The most critical objective in emerging developing markets is to increase employment by increasing the economic growth rate. For this to occur, it requires increasing energy supplies - primarily electricity demand. Electricity supply must be stable, secure and at the lowest cost. An examination and analysis of the subject show that poverty is inextricably linked to energy poverty. The following chart gives a clear indication of the extent of the poverty problem.




Source: IEA world Energy outlook

**Figure 33: Poverty is a critical issue in emerging economies**

Cilliers set out the link between economic growth and energy poverty.

> "Over the last 140 years, burning coal for electricity generation has provided the backbone of economic development, supported industrialisation and became the backbone of an exponential improvement in the quality of life.
>
> More than a hundred years ago, the discovery of oil in the Middle East resulted in similar advances in the quality of life and wealth accumulation and supported the world economy to such an extent that it seems virtually impossible to break our dependence on it.
>
> Of course, this fossil-fuel-based economic growth was made possible by the 2 to 3.5-fold increase in energy density than by burning wood for our energy needs. Subsequent economic development has enabled people in developed countries to afford to be more environmentally conscious – and that is a good thing.
>
> However, large parts of the world have been left out of this massive development: wealth gaps have grown to such an extent that countries in Africa and Asia will remain dependent on 'developed countries' support. In fact, energy poverty is the largest limiting factor to economic growth facing the developing world today" (Cilliers, 2020).

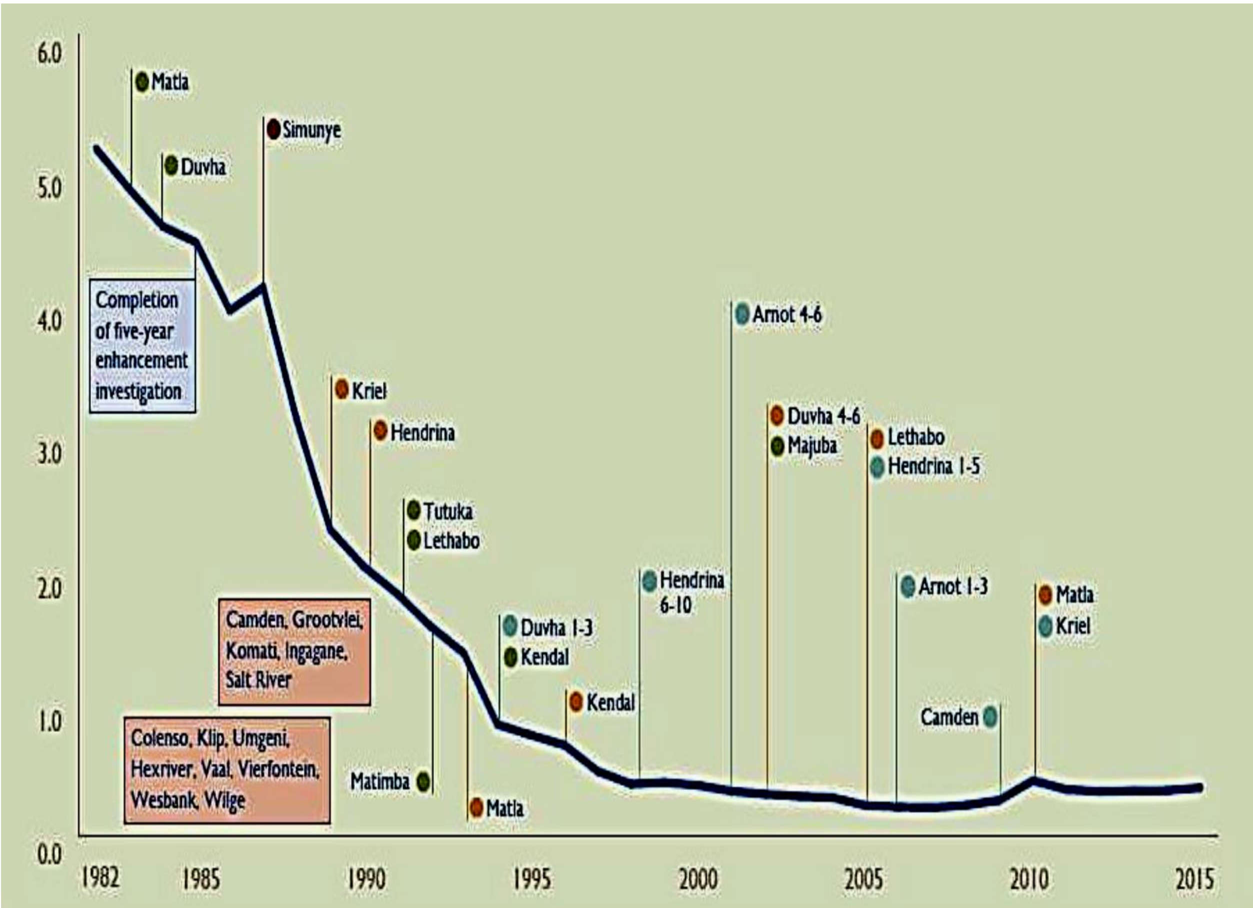
As with many developing and emerging economies, Africa's socio-economic success is directly linked to its ability to provide stable, reliable and affordable energy for all its citizens. With rapid urbanisation and population growth, the need for dependable and accessible electricity has never been higher – affordable, reliable, convenient, and accessible. It is the foundation of prosperity in most modern economies (Jeffrey, 2017b; Musango, 2014; Nkosi and Dikgang, 2018).

Coal is a critical building block for development. Metallurgical coal is essential for steel and cement production (Falcon, 2018; Terbrugge and Collins, 2017). Per a report from the International Energy Agency (IEA), coal will remain a significant supplier of the on-grid electricity needed to meet global energy requirements for many years. Certainly, this is the case in China, India and the ASEAN countries (Jeffrey, 2017d; IEA, 2019).

Technologies, which significantly improve the environmental performance of coal, are available and are being used today. Viable, highly effective techniques have been developed to tackle environmental challenges, including releasing pollutants – such as oxides of sulphur (SOx) and nitrogen oxides (NOx) – and particulate matter. Particulate matter is exceptionally harmful and constitutes a significant cause of smog, haze and polluted air. Motor vehicles and open fires are the primary cause of this pollution (Reid G, 2016). In practice, the improvements to coal-fired power plants' efficiency significantly reduce CO2 emissions by up to 35% compared to older technology. High-Efficiency Low-Emissions (HELE) coal technologies, as they are termed, have proven to provide significant efficiency gains and are financially viable. They are the default coal technology in countries like China, India, the ASEAN countries, and Japan, has new build and refurbishment programmes (Sporton, 2017; WCA, 2018; WCA, 2015; WCA, 2016).

Twenty-two nations identified a role for HELE technology in their climate pledges made in the run-up to the Paris Agreement. Among these were five African countries: Kenya, Egypt, Ghana, South Africa and Nigeria.

HELE coal technologies are crucial because they are an essential first step to reducing carbon emissions, which may be necessary if it is deemed obligatory to meet the long-term global objectives of the Paris Agreement (Paris Agreement, 2019; Moore, 2014; Sandor, 2017; Strek et al., 2016). Some decision-makers are reconsidering their country's obligation to the Paris Agreement. Carbon Capture Use and Storage (CCUS), in the light of the latest scientific data and assessments, are expensive and probably unnecessary. CCUS reduces emissions from coal power production by up to 90%. However, the cost is high, and the benefits, at best, are highly questionable regarding the latest findings that CO2 benefits the atmosphere and the environment (Moore, 2016; ICSF, 2019b). Without action to support the deployment of low-emission coal technologies, achieving climate targets will be difficult, if not impossible.




Source: Eskom

**Figure 34: ESKOM genuine pollution reduction**

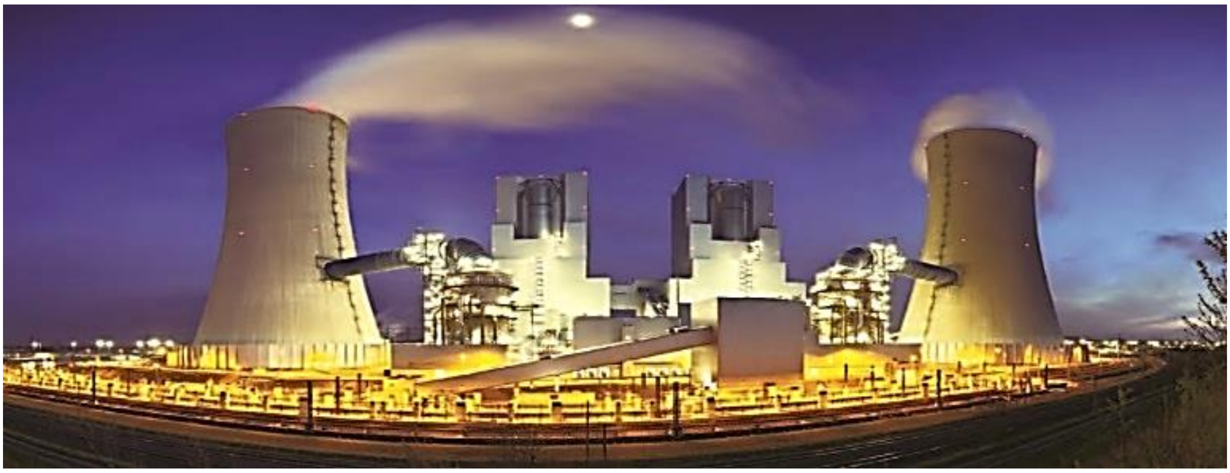


**Figure 35: A modern new "clean-coal" power station**

### 2.6.2 THE IMPACT OF FOSSIL FUELS ON GLOBAL TEMPERATURES

There are many articles suggesting that clean energy will save the planet. A recent article, "*Clean energy will not save us",* is accurate for many reasons (Reid, 2016). It is a fact that high birth rates are associated with high levels of poverty, inequality and unemployment, the critical overriding objectives of South Africa and many other developing economies (Nicolson, 2015). In South Africa, reducing inequity, unemployment, poverty and critically raising all citizens' living standards can best be achieved by increasing economic growth. In most other countries, this would most likely also be the case. (Jeffrey, 2017d).

It is irresponsible to restrict the amount of electricity generated by HELE coal power generation. Such a plan does not consider some of the economic and social problems of achieving such a goal. Modern coal plants are more efficient, create substantially less pollution, and reduce greenhouse gas emissions (GHG) than previous generation coal power plants (Stats SA, 2015). In Poland and Eastern Europe and many emerging countries, such as South Africa, India, China, Indonesia and the ASEAN countries, modern generation HELE coal technology remains the cheapest source of generating a stable and secure dispatchable electricity supply. Dispatchable electricity is essential for industry and an industrialising nation, effectively supplying "baseload electricity" (Suryadi, 2016b; EIA, 2019; Vishwanathan, Garg and Tiwari, 2018; International Energy Agency, 2018). The above countries, excluding South Africa, acknowledge these facts and have significant and ongoing plans to increase electricity output from coal and gas. Not surprisingly, as a result, they have higher current and planned economic growth rates. Their current and future projected growth rates exceed 5% (Epstein, 2015; Martin, 2016; Suryadi, 2016a; WCA, 2015).

**Table 1: Treasury's Macro-Economic Outlook**

Treasury's Macro-Economic Outlook
MTBPS 2020 vs February 2021
% Change

| | 2020 | | 2021 | | 2022 | | 2023 | |
|---|---|---|---|---|---|---|---|---|
| Gross Domestic Product | -7,8 | -7,2 | 3,3 | 3,3 | 1,7 | 2,2 | 1,5 | 1,6 |
| | | | | | | | | |
| Household Consumption | -7,9 | -5,9 | 4,7 | 2,9 | 2,2 | 2,4 | 1,9 | 2,0 |
| Gross Fixed Capital Formation | -19,6 | -18,4 | -1,4 | -2,4 | 3,9 | 3,9 | 3,9 | 3,9 |
| | | | | | | | | |
| Consumer Price Inflation | 3,2 | 3,3 | 4,1 | 3,9 | 4,4 | 4,2 | 4,5 | 4,4 |
| | | | | | | | | |
| Current Account as % of GDP | -0,8 | 1,7 | -1,6 | -0,1 | -2,0 | -1,0 | -2,7 | -1,4 |

**MTBPS 20*

*Source: National Treasury*

South Africa's sustainable longer-term economic growth outlook is less than 2.8% per annum and is currently less than 1%. This year it will decrease, and for the next few years, starting high from a low base, there will be a recovery, and it will remain below 2%, according to the World Bank and the latest forecasts from Econometrix (QEO, 2019) and Treasury.

This is not due to energy policy alone, but energy policy is a significant factor driving future economic growth (Jeffrey R, 2016). It encourages investment policy, and that alone is sufficient to support potential future economic growth significantly. There are many structural impediments to economic growth. To achieve that, South Africa needs to address the critical structural impediments holding back economic growth performance. As noted by Irma Venter (Venter, 2021), writing about a talk given by Jammine (Jammine 2021), these impediments include:

- Corruption and State capture, which had also then led to the deterioration of State-owned enterprises:
- South Africa is also continuously investing less like a country and consuming "more and more;
- Energy insecurity – load-shedding – also does not imbue investors with the confidence to commit to longer-term;

- Due to the high cost of data and interconnectedness; there is an urgent need to provide the broader community within South Africa with greater digital access and broadband to improve the country's competitiveness; data is far too expensive for that purpose;
- Economic policy uncertainty had also been holding back investment into the country; these included uncertainty around the expropriation of land without compensation, nationalising the Reserve Bank and introducing a national health insurance scheme at substantial cost;
- Massive overregulation and bureaucracy impede investment. There is a lack of capacity to implement the various structural programmes the government has intended to launch.
- The cause is many public servants are relatively incompetent. Part of this problem arose from the fact that many civil servants had been put into their positions not based on their capability and qualifications but because they were well connected to cadres of the ANC;
- There is undue power of the 'golden triangle', namely government, big business and organised labour;
- Finally, at the heart of all South Africa's problems was the lack of capacity on the educational front. "The outcomes that we are producing throughout our educational system leave much to be desired.

An indication of this last point came with the publication of the matric results. The number of students taking maths for matric has fallen by 15 000 compared with the year before. "If we don't improve our technical capability, our mathematical and scientific ability, we won't be able to cope with the new technological world."

The logic of believing that climate change will be solved by reducing fossil fuel-based electricity, particularly coal in South Africa, and failing to introduce nuclear by massively increasing wind-generated power is fallacious. Any attempts will come at a substantial economic and social cost (Lucas et al., 2017). A brief examination of some facts reveals the irrationality of the "vested financial and idealistic interest" driving the plans to reduce electricity production from coal substantially.

Calculations indicate that reducing coal-fired electricity globally would have no measurable impact on any possible global warming that may occur, as projected by the IPCC, the United Nations and many other international bodies and institutions. This is particularly true of South Africa, responsible for less than 2% of global emissions. This situation will be whether human beings play any leading role in any long-term impact on global temperature change. An increasing number of respected scientists disputed the IPCC argument that anthropogenic carbon dioxide is the primary cause of global warming unless man cuts the CO2 production (Climate Depot, 2010; Kauppinen and Malmi, 2019). The Bray and Von Storch 5$^{th}$ International Survey of Climate Scientists in 2015/2016 reveals that 75% are convinced there is global warming, but only 49% are convinced human beings are behind the Warming (Bray, 2016). The extensive list of scientists, experts and knowledgeable persons in the appendices suggests that many more do not hold the views set out by the IPCC and others (Climate Depot, 2010; Hertzberg, 2015). To believe that humans are today the primary driver or could become the driver of climate change when nature has been doing this over a far wider temperature and carbon dioxide range for over four billion years is illogical and arrogant.

### 2.6.3 THE BENEFITS OF HELE COAL AND COAL POWER STATIONS

It must be noted that the recent Ukraine crisis has had a major impact on the energy market in Europe. Many policies have had to be shelved. Many issues raised in this thesis have been fully vindicated by the recent events in Europe. Many countries in Europe have lost their energy sovereignty to Russia. In addition, energy prices have risen dramatically due to the switch to wind, solar and gas. All these factors have been raised as potential dangers in this unique thesis. Much of it was written more than two years ago. Two recent headlines and articles warrant attention.

On 25 June, Bloomberg and other media outlets headlines that Germany is asking for a reversal of the G7 fossil fuel commitments “Big blow to climate change as Germany pushes for G7 reversal of fossil fuel commitments”. Other media headlines include

“FRANKFURT/MILAN, June 20 (Reuters) - Europe's biggest Russian gas buyers raced to find alternative fuel supplies on Monday and could burn more coal to cope with reduced gas flows from Russia that threatens an energy crisis in winter if stores are not refilled.

Germany, Italy, Austria and the Netherlands have all signalled that coal-fired power plants could help see the continent through a crisis that has sent gas prices surging and added to the challenge facing policymakers battling inflation.”

An article by Xavier Provost, a well-known South African expert on coal markets and coal stated in an article dated 24 June 2022, the following

**“Europe scrambles to boost coal generation as Russia cuts gas.”**

“Germany, Austria, and other European countries are taking emergency action to bring back or extend the life of coal-fired power plants to fill gaps in gas generation, as Russia slashes shipments to the region.

Last week, Russia’s Gazprom reduced gas flows through its Nord Stream 1 pipeline to Germany by 60%, triggering widespread fears that Europe could face a severe power shortage this winter.

In response, Germany raised its emergency gas alert level to the “alarm” stage, launching a series of gas-saving measures that include an increase in coal generation by as much as 10 GW.

“We mustn’t delude ourselves: cutting gas supplies is an economic attack on us by (Russian President Vladimir) Putin,” said Economics Minister Robert Habeck in a statement: “Even if you don’t really feel it yet: we are in a gas crisis. Gas is now a scarce commodity.”

The government has written to power plant operators to begin preparations to bring coal-fired power plants back from standby. Legislation that will allow such action will be debated by parliament on 8 July.

**Others in Europe act too**

In Austria, the government this week announced it would reactivate the country's last coal-fired power plant, which closed in spring 2020.

Verbund, the country's largest power producer, has agreed to bring back the 246 MW Mellach power station to the grid reserve in case there is not enough gas.

"We must not be under any illusions: Russia is using energy supplies as an instrument in a dispute to stoke up great uncertainty, to drive up prices and to make storage more difficult for us," said Austria Climate Protection Minister Leonore Gewessler following an emergency cabinet meeting. "That is why we act at all levels and are prepared for all scenarios, up to and including a complete stop in deliveries from Russia."

The Netherlands on Monday followed Germany's move to boost coal generation, with the cabinet declaring the first level of a gas crisis.

With the risk of gas shortages increasing, the government withdrew production restrictions for coal-fired power stations for 2022-2024 with immediate effect.

"This means that the coal-fired power stations are allowed to produce at full capacity again, so that less gas is needed for the production of electricity," the cabinet said in a press release.

In Italy, the government approved plans to purchase additional coal to maximise the use of its coal-fired power plants if needed to conserve gas, Reuters reported.

In the UK, power utility EDF agreed last week to extend the life of two coal-fired units at its 2 GW West Burton A plant by a further six months in response to government requests to keep the units available this winter.

The UK grid has not wasted time in setting up agreements with power producers with coal-fired plants amidst concerns of energy shortages.

The government formally requested the National Grid operator on 30 May to "explore and seek to deliver frameworks to support the operations of additional non-gas-fired capacity" to ensure grid stability and security of power supply for the 2022-2023 winter heating season."

Naturally, as the article points out, the long-term plan remains to phase out fossil fuels. At present, however, this remains the current situation.

These statements supported by those made by Bloomberg are supported by many other statements in the media. Although there is no certainty that action will follow these words, the impact of the current situation will be long-lasting. In effect, these statements support the arguments of the importance of maintaining energy sovereignty which has been emphasised repeatedly in this Thesis. It is hoped that the South African government will take cognisance of the situation.

The reasons for these actions by the EU do not have just to do with Russia and Ukraine. It also has to do with the realisation by many of those in power that coal-fired power stations are not the primary threat if it is HELE or clean coal. Secondly, that countries cannot lose their energy sovereignty in almost any circumstance. There is extensive literature supporting these decisions. Only two will be cited here.

Dr Lars Schernikau and Prof. William Hayden Smith published a paper (Schernikau et al., 2022) entitled “Climate Impacts of Fossil Fuels in Today’s Energy Systems”, which was adjusted from a paper published by the Scientific Journal of the South African Institute of Mining and Metallurgy. In the abstract, this paper states, “Investors should support all reliable energy systems in a manner which avoids an energy crisis and allows human development and eradication of poverty. If CO2 emissions need to be reduced, one of the most effective ways would be to install ultra-supercritical power plants with CCUS technology. However, the undisputed benefits of increased CO2 concentrations in the atmosphere because of its photosynthetic and growth effects (fertilization) on plants need to be considered in energy policy decisions as well. The authors suggest that future research and development should concentrate on reducing net emissions of fossil fuel power plants and providing cost-effective and reliable conventional new power generation, utilizing clean coal and clean natural gas technology.”

Furthermore, in conclusion, “The authors suggest that future research and development should concentrate on reducing the negative environmental impact of fossil fuel power plants and providing cost-effective and reliable conventional new power generation. This should be dedicated to ultra-super-critical (USC) power plants for increasing their efficiencies, whether fossil fuel-fired or biomass-fired. The introduction of USC technologies is already growing in China and other countries and should be introduced – possibly at no cost to accelerate their deployment – to all developing countries, such as Bangladesh, Pakistan, Vietnam, Indonesia, South Africa, Kenya, Nigeria, and countries in South America. China, instead of forswearing the support of coal-fired plants outside its borders, could then justify support for efficient USC plant construction worldwide. Such advanced high-efficiency and low-emission (HELE) plants could replace less efficient existing power plants or even provide new power plants, all of which would support increasing economic activity, emissions reduction, and improving quality of life for the growing population.”

## 3 ANALYSIS OF THEORETICAL CONSTRUCTS

The Integrated Resource Plan (IRP) determines South Africa's future electricity needs. The planning process is extensive because electricity-generating build programmes require substantial capital expenditure and have long construction and operating lives. It involves short-term, medium-term and long-term requirements of the economic and energy needs of the country. The IRP 2016 considers the requirements and needs as far forward as 2050.

Therefore, the planning process is complex and embraces a forecast of likely global change and South Africa's development requirements in the global environment. Forecasting models are the necessary tools to assist in this process. However, the assumptions become critical in determining the best outcomes and plans to meet future needs.

*** South Africa's contribution of Carbon Dioxide to the atmosphere sufficient to warrant the possibly high financial, economic and social cost to the country? Is

### 3.1 CRITICAL ISSUES NEEDING INVESTIGATION

The key issues that need to be investigated include

- Different electricity-generating technologies have widely varying capital costs and delivery capabilities. Their load factors range from less than 20% to over 90%. Their working lives vary from less than 20 years to more than 60.
- The Levelised Cost of Electricity (LCOE) calculated should consider the above factors and, significantly, the uncertainty of supply and its economic consequences. The estimated cost of random variability and unpredictability results in substantial risks and hence an economic loss resulting from failure to deliver power to downstream industries and businesses. The economic loss is called the Cost of Unserved Energy (COUE) and has been calculated by the National Energy Regulator of South Africa (NERSA). The COUE was calculated at R77.30/kWh, approximately 50X (50 times) the cost of electricity, in the draft IRP 2016 (Department of Energy, 2010) and R87.85/kWh in the IRP 2019 (Jeffrey, 2019; America's Power, 2019).
- The current calculation of the electricity supply expenses excludes many additional costs arising from different technologies. Such charges include additional grid costs, backup costs, electricity supply when not required but must be paid for, the risk of a shortage of supply at critical moments, plus jobs lost in other energy industries and additional system costs.
- An assessment of the possibility of environmental damage needs to be made. These should be considered or assessed and measured against each technology's perceived or actual benefits. These factors and the costs associated with them are based on assumptions that are difficult to calculate.

When comparing combinations, the cost of a technology mix that excludes COUE estimates and other risk factors could substantially reduce a fair estimated electricity price. The costs, or estimated costs, used, are often fundamentally incorrect and misleading. The difference in electricity prices due to using the wrong mix based on underestimated prices or misallocation of costs would significantly slow economic growth and reduce investment, particularly in energy-intensive goods-producing industries. These additional costs would come because of higher insecurity of supply, less stable supply and higher prices. GDP growth could be reduced, resulting in reduced growth in employment creation, affecting many dependants (Minnaar et al., 2017).

It is often argued that the number of jobs created by sizeable capital-intensive energy, electricity-intensive, mining, minerals-beneficiation and manufacturing projects does not justify their high cost. This is particularly true in countries where job creation is a priority. Internationally, small and medium enterprises often create more jobs at a lower cost per job than megaprojects. However, the failure rate of developing small and entrepreneurial businesses is exceptionally high. Megaprojects can successfully sustain and assist many small and medium-sized enterprises.

The GDP and jobs created by the electricity generated by the project are of critical importance. GDP and employment depend on the reliability, intermittency and dispatchability of a reliable, secure electricity supply. Many emerging economies, such as South Africa, have a number of natural resources and commodities that can be developed and used directly to generate electricity. These need to be developed. Furthermore, there is a growing population that needs to be housed. The goods-producing sectors, namely agriculture, Agri-processing, mining, industry and manufacturing, are generally more labour-intensive and result in the development of downstream industries and, in particular, the suppliers responsible for the mines' inputs. The direct and indirect effects on the local economy of these sectors, through strong inter-industry linkages with suppliers of goods and services and the increased viability for downstream industrial developments, have a very substantial multiplier effect on the economy. Importantly, these projects form the nucleus of economic and social development in many regions.

## 3.2 POLICY REQUIREMENTS

The thesis highlights the necessity of South Africa and countries similar to it to have balanced growth, increased exports, and increased employment. The policy implications of the above include (Jeffrey, 2016c):

- South Africa must become an attractive destination for Foreign Direct Investment (FDI) and investment.
- The focus should be on growing and improving the efficiency of the mining, agriculture, and non-mining goods-producing industries, particularly export-orientated industries. This sectoral growth objective is necessary to both increase exports and reduce imports. These

developments are critical to the Southern African economy's future balanced growth if the country is to increase employment, particularly of less-skilled labour.

- The emphasis should be on making the service sectors efficient and effective and having an infrastructure to meet the economy's needs. The thesis highlights the necessity to have, in particular, an efficient and effective logistics infrastructure, namely energy, electricity, rail, road and ports.
- If South Africa is to re-industrialise, the country must develop its goods-producing industries. It must build its manufacturing, mining resources, minerals beneficiation, agriculture and Agri-processing industries. The focus should be on export-orientated and import replacement with a significant focus on goods that its poorer population urgently require. These include affordable quality housing and food.
- Notwithstanding the above economic policies, the country needs to recognise that lack of education, and the inefficiency of South African labour hampers economic growth. Policies need to be introduced to upskill and improve the efficiency of South African labour for balanced growth to be restored.

All these policies and the sectors involved require a secure supply of baseload electricity for the security and growth of their operations. The fundamental issue is that a secure electricity supply is a necessary condition for economic growth, but it is not a sufficient condition.

The need for service sector efficiency and the need to re-industrialise and develop its goods-producing sectors, namely manufacturing, mining and agribusinesses, are objectives that many economists have emphasised. Unfortunately, these policies have not been followed. The opposite has occurred. The country has been deindustrialising. This subject and the country's best industrial and sector growth policy strategy in the future have been under scrutiny for many years. Reports focussed on this subject included a report by Econometrix in 2005 (Twine, 2005). Two of the conclusions in that report were that "The development of an effective and efficient service sector is critical to the future balanced growth of the South African economy, growth in the Gross Domestic Product, increased employment and rising standards of living." A second conclusion was that "Expanding the manufacturing and industrial sectors will more effectively address the unemployment problem amongst the less skilled population. Increasing manufacturing would directly impact services due to the additional services input required. There would be an indirect benefit to the service sector through the additional demand for services by the employees".

Shortly after that, Rodrik, Professor of the International Political Economy at Harvard University, said in his research on the South African economy entitled "Understanding South Africa's economic puzzles" (Rodrik, 2006; Rodrik, 2008).

> "The disappointing growth and employment trajectory of the South African economy since its democratic transition is best understood as a consequence of the underperformance of its

non-resource tradables sector, and manufacturing in particular. Had the South African manufacturing sector expanded rapidly, economic growth would have been higher and far more jobs would have been created for the relatively unskilled. In principle, jobs can also be created by cutting the cost of labour. But reducing unemployment by expanding the capacity of the economy to provide high-productivity, high-wage jobs for the unemployed is a far better strategy. Therefore, the health and vitality of the formal manufacturing sector have to be at the core of any strategy of shared growth".

The National Development Plan, and its predecessors, announced by the government, have identified several priority areas (National Planning Commission, 2010; Economic Development Department., Jeffrey, 2017a). Infrastructure development is recognised as a critical driver of jobs across the economy. The documents define investments in five physical and social infrastructure areas: energy, transport, communication, water, and housing. Sustaining high levels of public investment in these areas would create jobs in construction, operations and infrastructure maintenance (Jeffrey, 2016c; Budget Review, 2019). The National Development Plan and its predecessors (National Planning Commission, 2010) set out a programme to create jobs and identify priority areas for development, including, amongst others:

- Jobs will be created in agriculture through interventions to improve efficiency by addressing the high fertiliser costs and other inputs and upscaling processing and export marketing.
- The call is for increased mineral extraction in the mining sector by reviewing the existing legal framework and improving infrastructure and skills development. It focuses on beneficiation on the final manufacture of consumer and capital goods, creating large-scale employment, rather than only smelting and refining, which are relatively capital and energy-intensive.
- The re-industrialisation in the South African economy is based on improving manufacturing performance through innovation, strong skills development and reduced input costs.

The above statement sets clear, sound priorities and objectives for the country. These are aligned with the findings and policy requirements of this thesis. There is considerable debate regarding the methods of achieving these objectives.

## 3.3 MINING PROJECTS

It is essential that the country take full advantage of the competitive advantage in many of its primary natural resources. To unlock their value, it is necessary, amongst other factors, to:

- Embark on significant project developments rather than adopting fragmented approaches
- Ensure that the industries are not fragmented to maximise competitive advantages
- Ensure the logistics, primarily rail and the port infrastructures, are cost-efficient and effective
- Plan expansions to meet long-term, not short or even medium-term volume requirements

- Ensure there is adequate, reliable electricity at competitive prices and other support infrastructure
- Minimise bureaucratic and other obstacles
- Ensure there is certainty regarding ownership and tenancy

Employment in the mining sector has tumbled, particularly since the end of the 1980s. This is particularly lamentable in the South African labour scenario, as mining has always provided a means of absorbing large quantities of unskilled labour, which currently accounts for a substantial proportion of South Africa's unemployed. Since 1995, the growth in minerals exports has slowed. The finding by Econometrix that mining growth in South Africa is lagging behind its potential is strongly supported by another research. Other studies found that during the 2000 to 2008 commodities boom South Africa's mining industry shrank by 1% per annum in dollar terms. In comparison, mining in China grew by 19% per annum, 10% in Russia and 8% per annum in India. The above situation has recently been confirmed by the findings published in various reports, including the Fraser Institute annual survey on mining investment destinations (Fraser, 2018). These critical surveys rank mining destinations based on several policy factors, including labour laws, skills, security, political stability, infrastructure and regulatory efficiency. The main rankings place South Africa in the bottom quartile, whereas it was historically in the top half of the rankings. This trend has reversed as there was a positive response when Ramaphosa replaced Zuma. Unfortunately, this honeymoon period has not lasted long. The economic downturn and the severe economic impacts caused by the coronavirus have undermined that optimism. It remains to be seen whether it can be reversed.

## 3.4 HISTORICAL DATA ANALYSIS OF ELECTRICITY SALES IN SA

A statistical analysis of the historical data has been conducted. From 1980 to 2008, there was a relatively high correlation between total electricity sales to the economy's productive sector and the value added by the economy. This period was selected because electricity generation and the economy were not negatively affected by electricity generation shortages. Since then, thanks to electricity shortages and policy uncertainty concerning energy and other matters, economic growth and electricity growth have fallen, and currently, in 2018 and 2019, it has fallen below 1.2%. From 1990 to 2008, the growth rate of electricity consumed was 2.6% per annum, and the GDP growth rate was 2.5%. These numbers are not matched by the correlations of these variables for all the productive sector sub-sectors. The reasons for some of the findings include the following.

- Mining changed the nature of its overall operational profile after the gold boom of 1980/1981. Much of the output growth moved away from the efforts of the power-intensive deep-level gold mines. There was relatively low growth in mining production and little investment in this vital sector over this period.

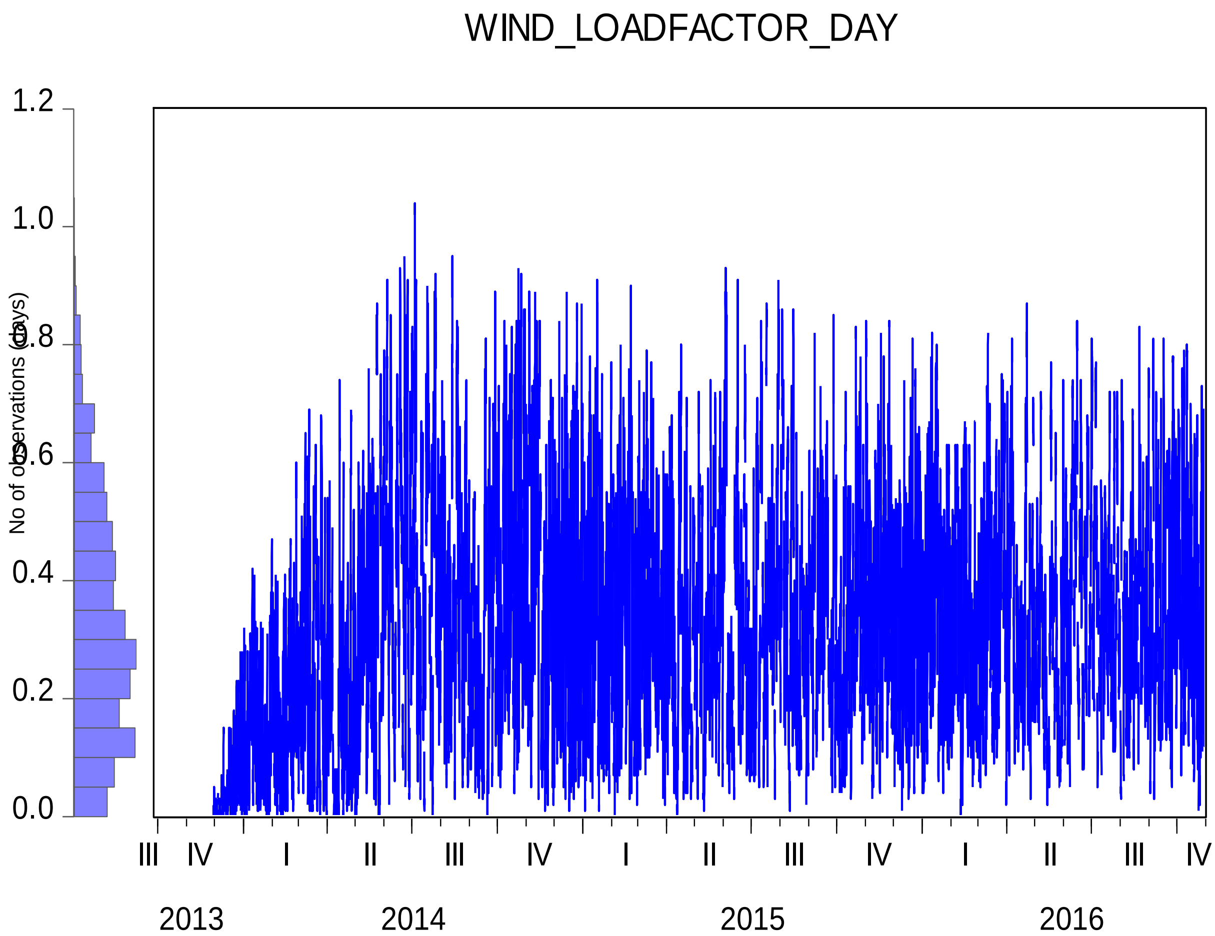
- The agricultural sector's demand for electricity correlated reasonably strongly with the value added by the sector.
- The South African economy's industrial or secondary sector has positively affected its electricity usage and GDP. However, this sector underwent substantial structural change in 1994 following the movement from a military-industrial focus to a market-related emphasis on international trade and increasing competition. It can be said that the period also saw relatively low investment due in part to the relatively strong Rand and hence subject to weak export performance and intense import competition. Investment in this vital sector has fallen far short of what it should have been, and this trend has continued (Jeffrey, 2016c). South Africa has effectively been deindustrialising.
- Mining and the industrial or secondary sector are far more energy-intensive than the agricultural or services sector.
- Today, the economy's extensive services sector (about 68% of the total GDP) has displayed a high relationship between expanding its real contribution to GDP and its electricity off-take throughout the period under review. However, it is not as energy-intensive. This sector has had high growth. It is a derived demand and utilises skilled labour at comparatively high wage rates. South Africa is also a net importer of services
- Until the last few years, there has been relatively high growth in the services sector. This sector includes the government and municipal sectors. This growth and the lack of growth in mining and manufacturing, combined with high consumer expenditure and the comparatively strong Rand, has resulted in high imports, weak exports, a current account deficit and a structural imbalance in the balance of payments. Growth in electricity generating capacity will create a potential for higher economic growth. It will also generate employment continuously, as a regular power station build programme will become necessary in the future. The more sectoral growth is transferred from high growth in services to higher growth in mining and manufacturing, the greater the potential to increase exports, reduce imports and increase employment, particularly amongst the less skilled. High growth in the goods-producing sectors will only occur if conditions are conducive to increasing investment in these sectors and a more efficient services sector (Jeffrey, 2016c). A necessary part of this process depends on having an appropriate level for the Rand to promote exports and import substitution. Moving from service to industrial growth will reduce average remuneration as more unskilled persons at lower remuneration levels are employed. This will reduce unemployment. It will also raise the economy's energy intensity and GDP growth from the relatively current, more moderate levels or the immediate past trends (Lane, 2018).

In summary, the above shows that sectoral demand for electricity may be influenced by factors outside of the sheer volume of real output or value-added delivered by any individual sector.

Furthermore, future electricity demand growth will likely increase as the mining and manufacturing sectors grow. The decline in energy intensity will be arrested and possibly increased despite efficiency improvements (Lane, 2018).

### 3.4.1 ANALYSIS OF DATA AND FORECASTS

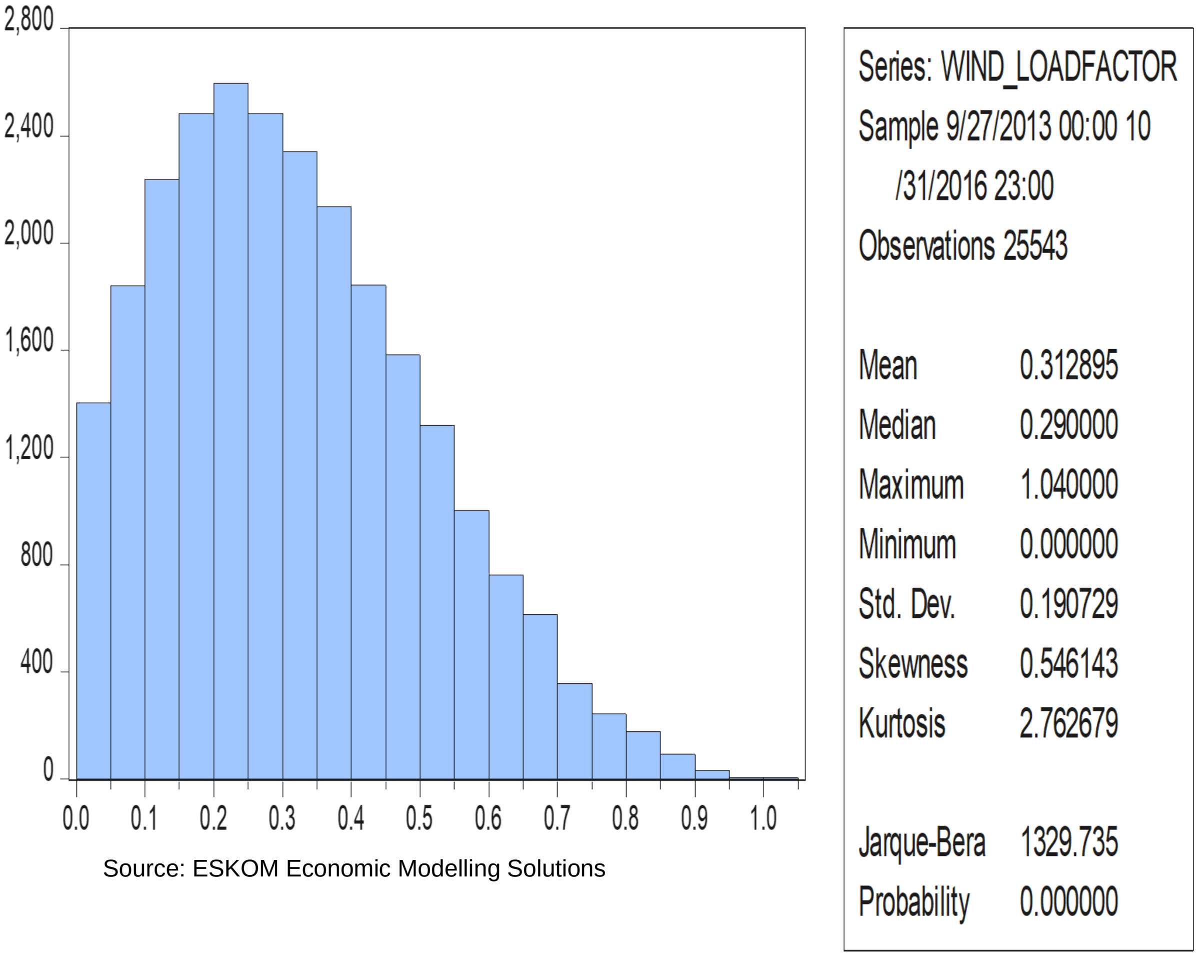
The ultimate plan that the renewable lobby and the green party planners envisage for the future energy plan in South Africa is a movement towards a 100% renewable. Once again, the analysis illustrates the following point. The higher the use of unreliable, intermittent and unpredictable renewables, the higher the risks and economic costs. This section analyses data concerning wind and future forecasts of energy in South Africa. The first part is an analysis by Jordaan of Economic Modelling Solutions of data made available by ESKOM.




Source: ESKOM Economic Modelling Solutions

**Figure 36: ESKOM wind load factor 2013 to 2016**

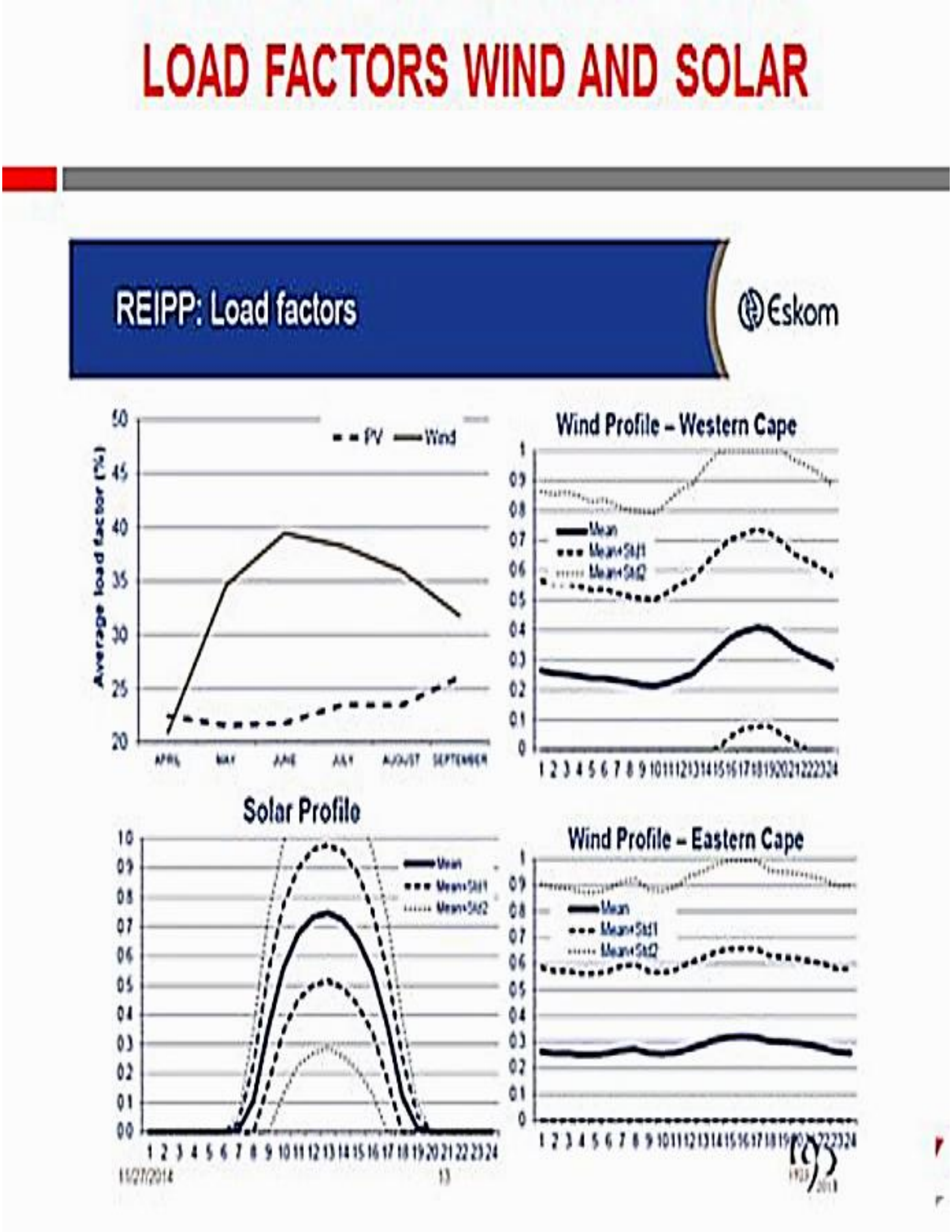
This indicates the variability, intermittency and unpredictability of windfarms at that time. Statistical analysis of the above data revealed the following.




Source: ESKOM Economic Modelling Solutions

**Figure 37: ESKOM wind speed from 2013 to 2016 mean and standard deviation**

The above figures for the load factor are below the mean used in the statistics for the latest IRPs and the standard deviation is higher than those used in the risk analysis. Notwithstanding that, there has probably been an improvement in wind performance. The last financial and costing analysis statistics appear conservative, and economic activity losses could be higher than estimated. The real COE of wind would also be higher than the estimate contained in this thesis. Other data made available by ESKOM tends to confirm the data set out above. Another set of figures also provided by ESKOM revealed the following averages. To calculate the Average load factor, a simple average of the load factor for each project in each case (running from their COD/ early operating period) was taken to 31 October 2016.




Source: ESKOM http://www.eskom.co.za › IR2016 › Documents

**Figure 38: ESKOM Load factors wind and solar**

The SD was the simple average of the standard deviation across the projects in each technology. The standard deviation for each project was the SD of the load factor in every hour of operation.

**Table 2: System Comparison of risk related LCOE**

| | Average Load Factor (from COD to 31 Oct 2016) | Standard Deviation (from COD to 31 Oct 2016) |
|---|---|---|
| **Wind** | 34.40 | 32.21 |
| **Solar PV** | 25.22 | 33.67 |
| **CSP** | 26.14 | 36.10 |
| **Hydro** | 65.25 | 22.72 |

Source: ESKOM Economic Modelling Solutions EconomicRisk

The figures indicate that wind and solar have lower load factors and higher standard deviations than the assumptions used in this thesis. They also confirm that wind and solar have high variability and intermittency. The figures and table confirm the data used in this thesis. The analysis completed is conservative. The variability and additional cost of wind and solar are higher or worse than those calculated. These data and investigations tend to confirm the findings of this thesis. They confirm that using wind and solar energy sources comes with high risk and a potentially high economic cost associated with their non-performance. Solar has an exceptionally high standard deviation, as it can only produce during daylight hours (Boretti, 2019). Furthermore, they reinforce that increasing the use of these energy sources (i.e., increasing the penetration of these sources of energy) results in increased risks and electricity supply costs ( Quezada, 2006).

## 3.5 THE IRP 2019 AND FUTURE ENERGY PLANS

### 3.5.1 THE IRP 2019 BUILD PROGRAMME

The table below sets the IRP 2019 build and decommissioning programme to 2030.

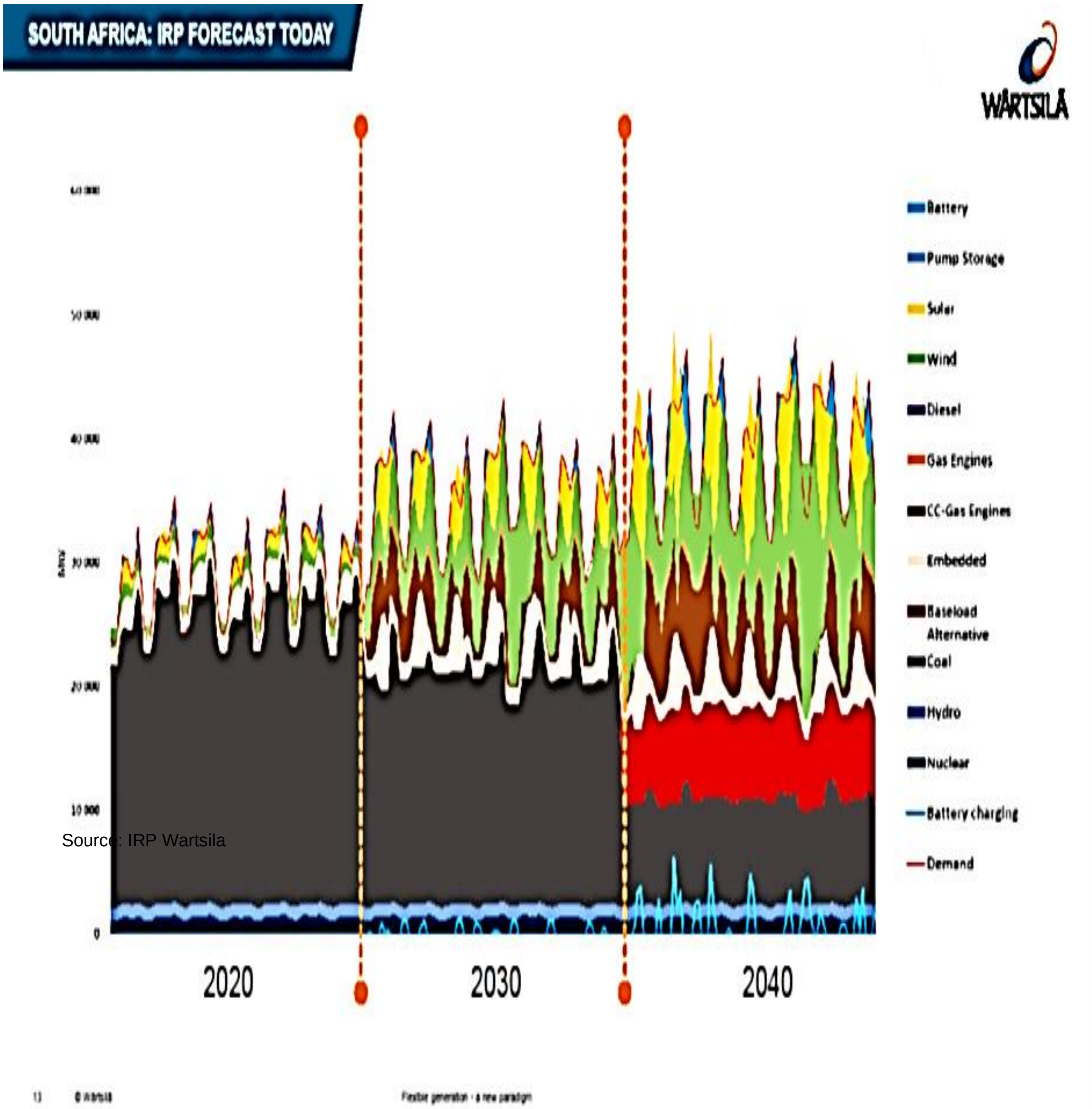
**Table 3: IRP 2019 the forecast build and decommissioning of technologies**

| | IRP 2019 FORECAST BUILD AND DECOMMISSIONING OF TECHNOLOGIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coal | al Decommissii | Nuclear | Hydro | Storage | PV | Wind | CSP | Gas & Diesel | Other generation | Total excl other |
| Current Base | 37149 | | 1860 | 2100 | 2912 | 1474 | 1980 | 300 | 3830 | 499 | 51605 |
| 2019 | 2155 | 2373 | | | | | 244 | 300 | | | 2699 |
| 2020 | 1433 | 557 | | | | 114 | 300 | | | | 1847 |
| 2021 | 1433 | 1403 | | | | 300 | 818 | | | | 2551 |
| 2022 | 711 | 844 | | | 513 | 1400 | 1600 | | | | 4224 |
| 2923 | 750 | 555 | | | | 1000 | 1600 | | | 500 | 3350 |
| 2024 | | | 1860 | | | | 1600 | | 1000 | 500 | 4460 |
| 2025 | | | | | | 1000 | 1600 | | | 500 | 2600 |
| 2026 | | 1219 | | | | | 1600 | | | 500 | 1600 |
| 2027 | 750 | 847 | | | | | 1600 | | 2000 | 500 | 4350 |
| 2028 | | 475 | | | | 1000 | 1600 | | | 500 | 2600 |
| 2029 | | 1694 | | | 1575 | 1000 | 1600 | | | 500 | 4175 |
| 2030 | | 1050 | | 2500 | | 1000 | 1600 | | | 500 | 5100 |
| Totals | 44381 | 11017 | | | | | | | | | |
| INSTALLED CAPACITY | | 33364 | 3720 | 4600 | 5000 | 8288 | 17742 | 600 | 6830 | 4499 | 80144 |
| New build | 7232 | | 1860 | 2500 | 2088 | 6814 | 15762 | 300 | 3000 | | 39556 |
| % new build | 18.3% | | 4.7% | 6.3% | 5.3% | 17.2% | 39.8% | 0.8% | 7.6% | | 100.0% |
| % Installed Capacity (% of MW | | 41.6% | 4.6% | 5.7% | 6.2% | 10.3% | 22.1% | 0.7% | 8.5% | | 100.0% |
| % Ann Energy Contr (%MWh) | | 53.7% | 6.7% | 7.4% | 8.1% | 4.3% | 12.5% | 0.4% | 6.9% | | 100.0% |
| Total MWh | | 26691.2 | 3348 | 3680 | 4000 | 2154.88 | 6209.7 | 180 | 3415 | | 49678.8 |
| Load factor | | 80% | 90% | 80% | 80% | 26% | 35% | 30% | 50% | | |

Source: IRP 2019

The figures confirm that the IRP 2019 includes a massive decommissioning of coal and a huge wind energy build-up. These figures align with the study in 2016 of the "Wind and Solar PV Resource Aggregation Study for South Africa". It is not in line with the reality of data from ESKOM, the real costs of solar and wind analysed in this thesis, the reports of numerous global experts, nor the reality of global data available from many countries in the world (Primary Research, 2019).

The impact of this is set out in this figure made available in a presentation by S Nygard of Wartsila (Nygard, 2019).

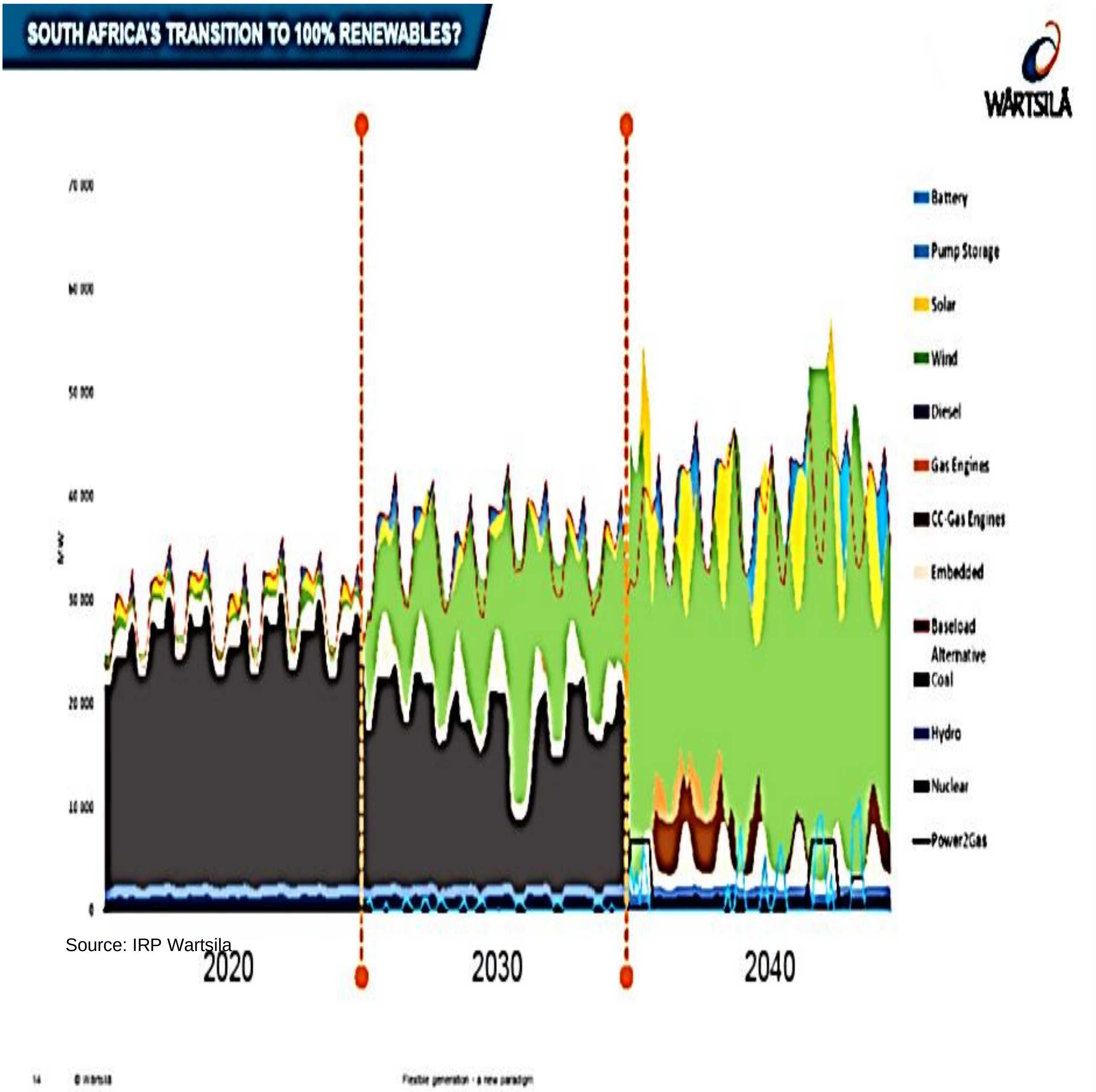



Source: IRP Wartsila

**Figure 39: South Africa: IRP forecast today**

A visual scan of this figure confirms the decline of coal and baseload alternatives. It reinforces the current plans envisaged by the IRP 2019 and increases non-dispatchable variable and intermittent solar and wind. The rise in intermittency and variability is visible and indicates and affirms the view set out in this thesis that risks and uncertainties, and hence costs, will rise.

The figure below shows the planned increase to 100% renewables which was clearly indicated as favoured in the CSIR planning document. It was clearly outlined as an alternative in the IRP 2016 document. The figure below shows a further increase in variable, interruptible and unpredictable electricity-generating wind and solar sources. It is clear that there are many more changes in supply, so risk and uncertainty will increase further. The visual view reinforces perceptions that the mathematical and statistical analysis indicates that risk and uncertainty will increase with increased non-dispatchable intermittent wind and solar renewables. The earlier study shows that these increases will result in growing economic costs due to economic activity loss.




Source: IRP Wartsila

**Figure 40: South Africa: Transition to 100% Renewables**

These charts show visually the high variability of wind and solar as energy sources and the fact that this variability will increase as the penetration of these renewable energy sources increases (Renewable Energy Institute, 1965). The ESKOM data's statistical analysis confirms existing facilities' high wind and solar variability. As Fraunhofer's study clarifies, the only way of overcoming this is to build massive excess capacity and 100% backup (Fraunhofer, 2016). Furthermore, this must be generally supported by effective and enhanced grid management systems and systems management.

### 3.5.2 THE IMPACT OF COVID - 19

The impact of the coronavirus has had a dramatic negative effect on economic activity and electricity demand due to the enforced economic and financial lockdown. This has had a short-term impact and long-term effects.

Any lockdown affects both the supply and demand side of the economy. Unfortunately, the longer the lockdown, the more profound the impact on each side of the economy. In the final analysis, it also affects all stages of the economy ranging from the last stage distribution through an intermediate stage, manufacturing and ultimately to resource extraction. Regarding the critical aspects relevant to this thesis, it reduces economic activity in all fields. The reduction in operations, in turn, reduces electricity demand, employment and ultimately, the demand for goods. The global economic downturn reduces demand for SA exports, while the higher unemployment levels and increased uncertainty reduce domestic demand.

Most financial and economic experts believe there are three alternative economic recovery possibilities from the downturn caused by the coronavirus.

- The first is that the disruption is short-term, and there will be a sharp V-shaped recovery.
- The second is that the slowdown will be U-shaped with a more extended disruption of a year or two before a sharp recovery.
- The third is that the recovery, once it does begin, will be a slow and extended L-shaped recovery lasting into 2023.

**Table 4: Forecast GDP Growth 2019 to 2023**

| Year | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|
| **Most Likely GDP y/y%** | 0.4 | 1.4 | 0.8 | 0.2 | -9.0 | 1.3 | 0.0 | 0.3 |

Source: Economic Modelling Solutions,

In 2020, GDP growth could vary, say +-3% above or below 9%, giving figures between -6% to -12%. The loss in GDP is most likely to be not less than R400 billion. After that, one can only hope that the numbers are upside of the most likely forecast shown above. The findings of the Suzman Foundation are closely aligned with these figures ( Simkins, 2020).

**Table 5: Forecast Unemployment from 2019 to 2023**

| Year | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|
| **Unemployment** | 5753 | 6120 | 6103 | 6579 | 9900 | 9440 | 9820 | 10280 |
| **Unemployment rate %** | 25.4 | 27.5 | 27.1 | 28.7 | 33.3 | 33.0 | 32.5 | 33.5 |

Source: Economic Modelling Solutions,

It is unlikely that unemployment will be less than the 9.9m forecast above. Unfortunately, the current statistics and projections suggest that unemployment could be approximately one million higher. This is an increase in unemployment of between 3.5 million and 4.5 million. Given the circumstances at this date, it would appear that the recovery could be slower and favour an L-shaped recovery process. Unemployment will increase dramatically. Electricity demand has fallen. Figures released in May 2020 indicate that the economic downturn has already caused an under-recovery shortfall for the South African Revenue Service of R285 billion. Social security costs will likely increase by a minimum of about R150 billion per annum.

Some people may interpret that electricity demand has permanently been diminished. This should not be the case. South Africa must increase its economic growth rate, particularly from 2023. It is critical that from 2022 South Africa have the correct political, economic, and energy policies to increase foreign and domestic investment and, by this means, raise the country's economic growth. Regarding electricity demand and supply, it is clear that electricity demand has fallen in the short-term. There is a temporary excess in theoretical electricity supply if all plants operate efficiently and have been adequately maintained. In the longer term, this surplus will vanish. The demand for secure baseload power will increase to ensure economic growth, reindustrialise the country, and redevelop its mining industry.

The government should use this temporary respite to refurbish and repair, where possible, its existing generating resources. The demand is not for immediate increases in new generating capacity. Rather it favours the more extended build programmes of nuclear and HELE “clean coal” generating capacity. This high load factor power capacity can then be brought on stream to give the country a steadily increasing supply of secure baseload electricity from 2025 (America's Power, 2019).

### 3.6 COMPARISON WITH SOME OTHER COUNTRIES

The practical experience is that Germany’s electricity prices are approximately 55% higher today than in France and Poland.

By any measure, when dominant wind mixes are measured against the alternative nuclear or coal-dominated systems, they work out to be more expensive based on a nameplate LCOE basis. Furthermore, wind quantity increases are claimed to make them relatively less costly, which is an illusion. The cheapness comes at a price of increasing risk of shortages, blackouts and substantial economic activity costs, plus higher grid costs and grid management costs. Once the variability and unpredictable impacts on the Costs of Unserved Energy (COUE) are factored in, the exact reverse is the case. Nuclear and coal-dominated systems are far cheaper in terms of economic value. Further, the more they relatively dominate the system, the less expensive the electricity on the grid becomes in financial terms.

Practical experience in the world, particularly in Germany, Denmark, and South Australia compared to Poland and France, proves that the greater the penetration of wind and solar, the higher electricity costs tend to become. Ireland is also approximately 30% more expensive. Furthermore, managing these complex systems is intricate. There are more unknowns than expected, except possibly in smaller countries such as Ireland and other countries with small grids. These reasons are precisely why the ASEAN countries, India and China, continue their rapidly increasing coal-fired fleets (Suryadi, 2016b). India and China also have significant renewable programmes, but their primary focus is ensuring reliable nuclear and coal power supplies (Martin, 2016). China has adopted this with the ulterior motive of becoming a major supplier of solar panels and components to Western Industrialised nations. The scientific evidence and movement, which says that carbon dioxide is not a contaminant or harmful in the quantities likely to be released by humans but is beneficial to the planet, is snowballing.

Many factors must be considered when considering an electricity supply system. Critical components include the COUE and recognising the differences between nameplate supply and real deliverable supply. A wind-based and solar-based system becomes economically far more expensive to build, operate and manage than equivalent coal and nuclear-based system. Nuclear systems are now based on a 60-year life period. The additional costs become even more apparent when all the factors are considered over this period. Apart from the variability and unpredictability elements, the above indicates that a renewable system would have significant cost implications for South Africa's emerging economy and goods-producing industries. These sectors require the security of supply at the lowest economical price. The damage to its industrial base would be significant, and the economic devastation caused to the mining, manufacturing, and coal industries could become an irrecoverable economic and social catastrophe. This will set South Africans back a generation. Associated Rainbow Minerals (ARM) and Associated Ore (Assore) decided to place their manganese smelter in Malaysia is an example of the long-term damage done to this economy. This thesis should be read in conjunction with news on the following from South Africa and overseas on wind and other relevant subjects, including:

- Environmental and ecological impact reports;
- The failure of *Energiewende* in Germany;
- The weaknesses of wind in South Australia, the UK, and California;
- Rising levels of energy poverty in industrialised Europe and elsewhere;
- The detrimental impact on the coal industry in South Africa by the Carbon Tax and renewables;
- The damaging economic effects of the Carbon Tax and renewables in South Africa;
- The high growth strategy is primarily based on coal in India, China and ASEAN countries;
- The need to overcome poverty in emerging and developing economies.

The recommended mixed system is based on nuclear and coal. However, a mix of Solar PV and gas is no more expensive to build when measured over the 60-year life of a nuclear plant. These facts are due to the size of the IRP envisaged system and the system's variability and unpredictability, which requires full backup.

The above shows clearly that over the life of the plant and the present value of the alternative energy sources, the IRP 2016 Base CSIR system is more expensive than the mixed system due to the factors mentioned. The reality of the situation in other countries is shown in the examples in the Figures below.

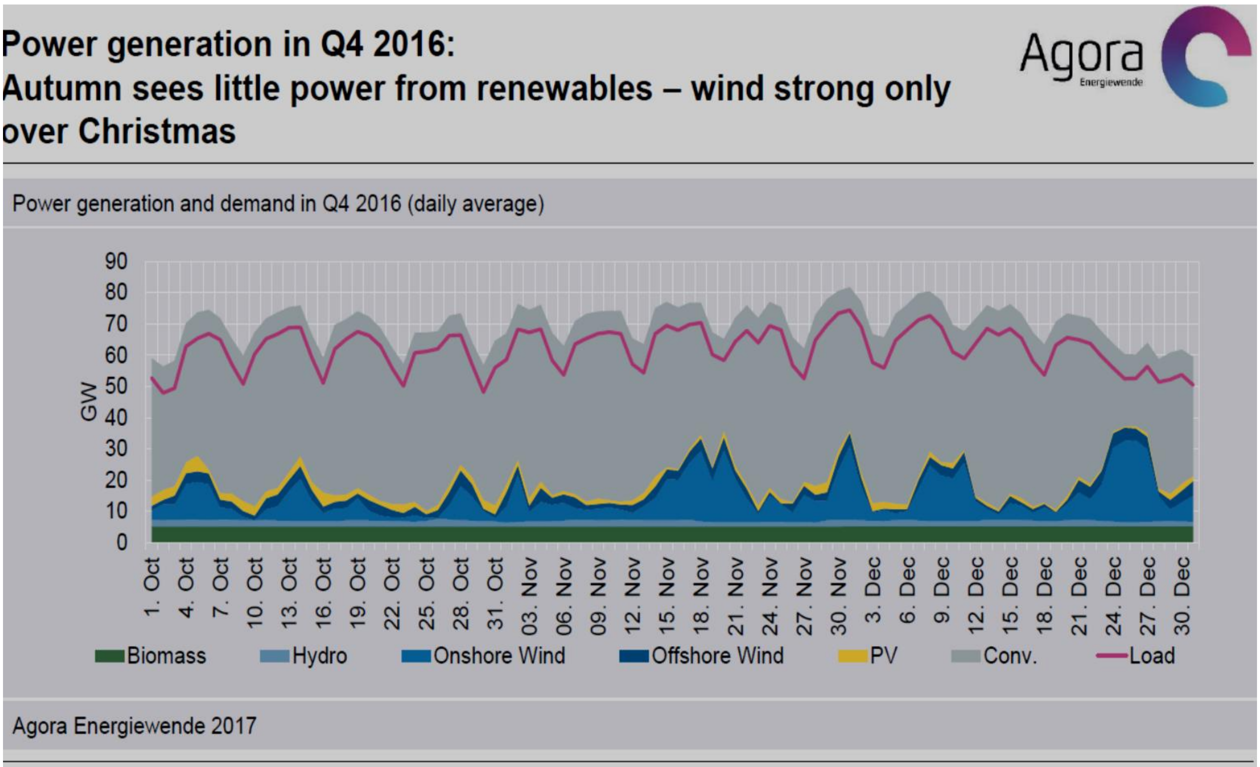



**Figure 41: Power generation Germany Q4 December 2016**

In Germany, in December 2016, very little power was supplied by wind and solar, resulting in massive variations in power supplied to the grid. The disaster that befell Germany in December 2016 became apparent to all in the months leading up to that month. It resulted in a total rethink on their *Energiewende* programme and probably the withdrawal or suspension of subsidies and a ceiling or cap on such power.

Had the renewable programme been more extensive as proposed in South Africa, the result would have been catastrophic.

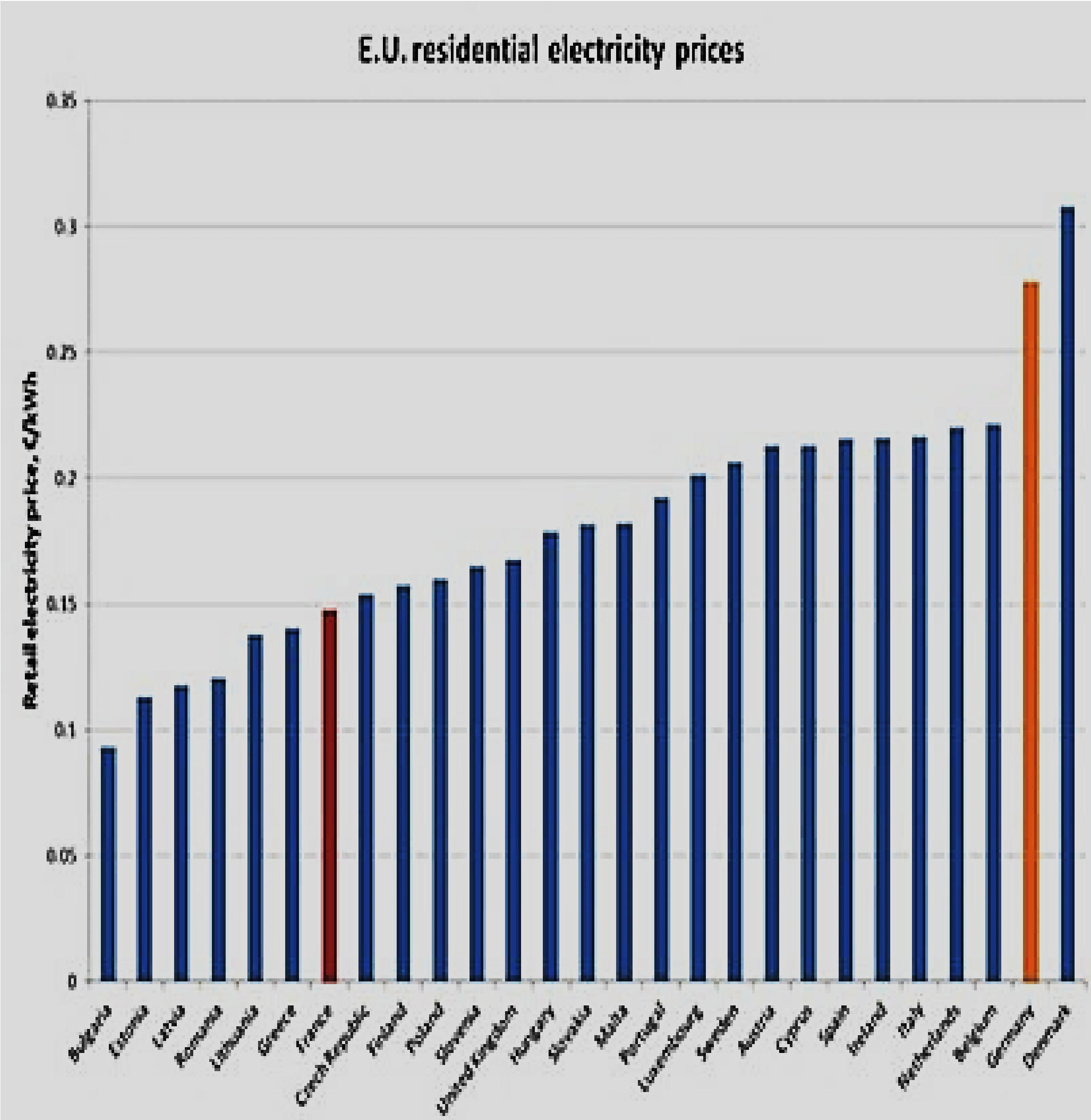



**Figure 42**: **EU residential electricity prices**

The figure above sets out EU residential prices. The situation has not changed significantly over the years. It is easy to compare considerably higher prices of Germany and Denmark (large wind electricity generation) with France (nuclear) and Poland (primarily coal). Others to note are Bulgaria (coal and nuclear). South Australia has experienced significant problems with its major expansion of windfarms over the past few years. These came to a head over the Southern Hemisphere summer a few years ago. There were calls to scrap the programme and a scramble to take remedial action to remedy the emerging problems. Leadership changed due to the economic damage caused by their renewable programme. The immediate plans are to increase gas power. Now nuclear and coal are being reconsidered.

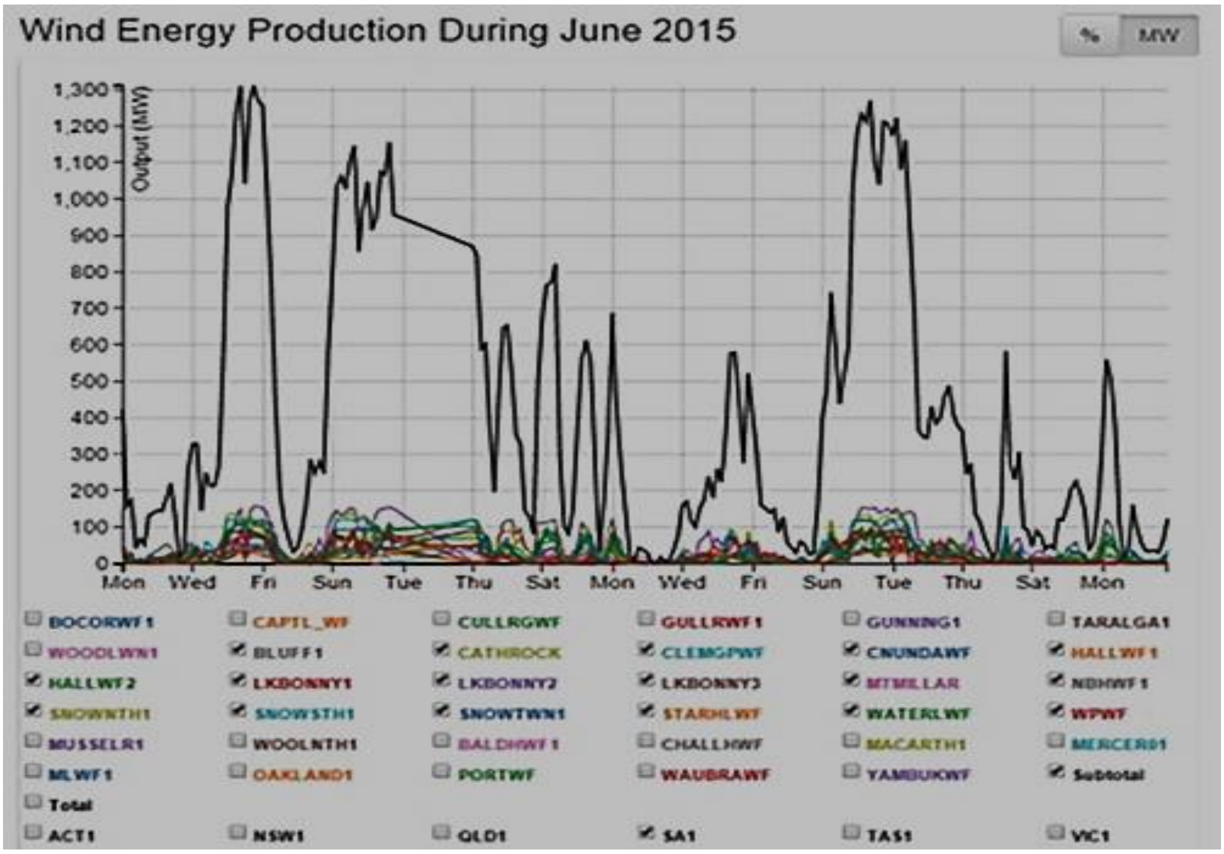



**Figure 43: Wind energy production in South Australia 2015**

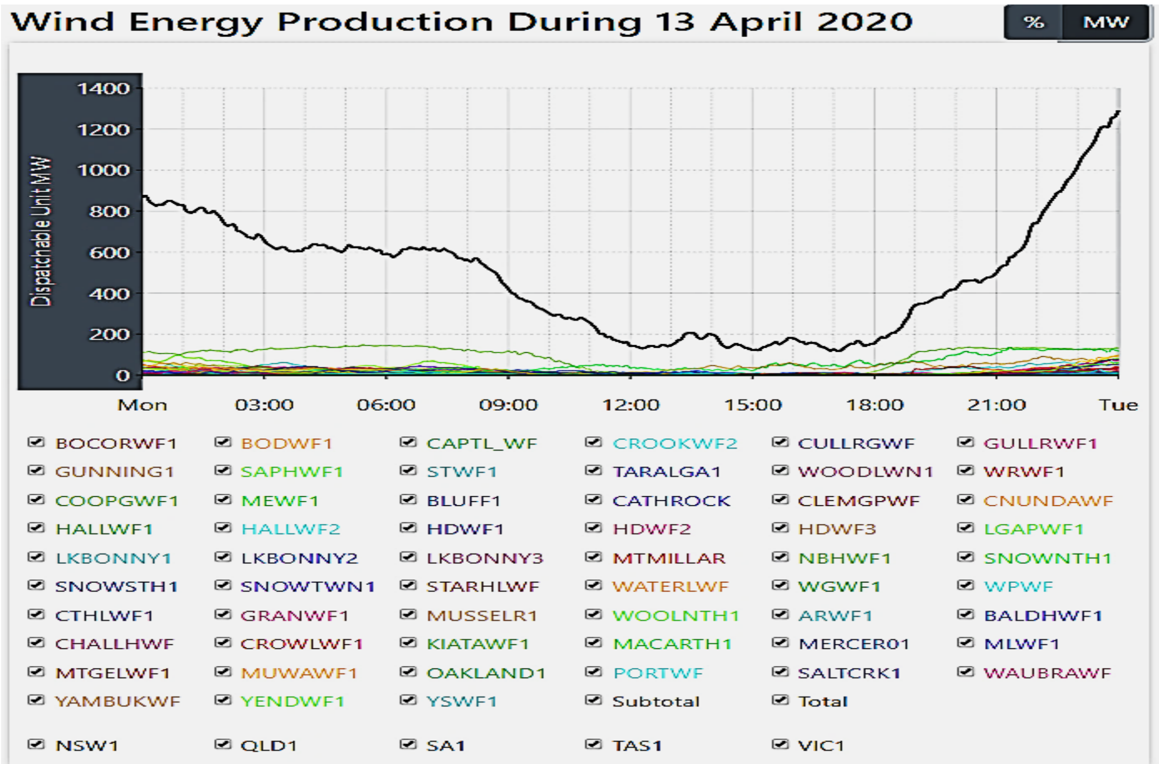



**Figure 44: Wind energy production 13 April 2020**

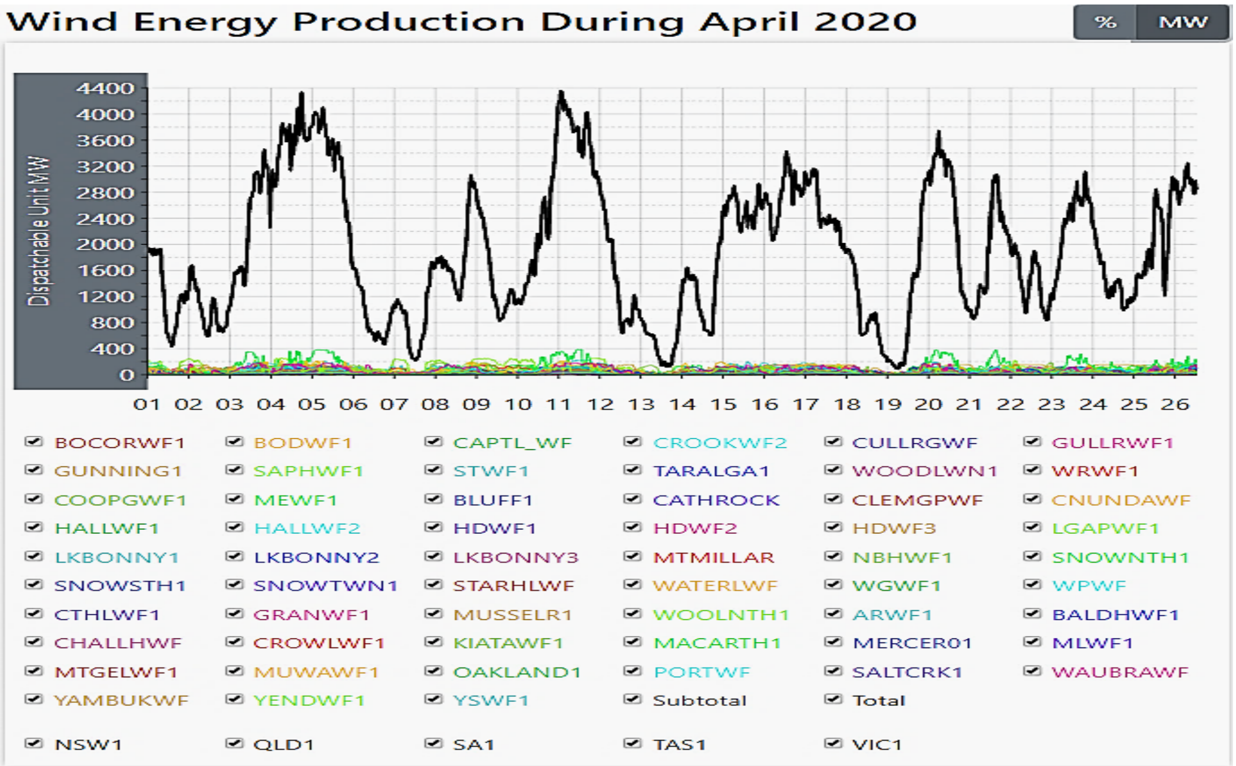



**Figure 45: Wind energy production in South Australia 2020**

The graphs above show that little has changed regarding the consistency of power produced by windfarms in the five-year period from 2015 to 2020. The fact is power remains highly variable and unpredictable. Whatever path is selected, the truth remains that Australian electricity prices have increased dramatically over the past few years due to the variability and associated costs inherent in unreliable wind and solar generation. Australian electricity prices have risen significantly, and from being amongst the cheapest in the world, they are now very high as measured globally. Australia has a significant debate between those favouring fossil fuels and those favouring renewables.

### 3.7 SA COAL’S IMPACT ON GLOBAL TEMPERATURES

South Africa is known to use more coal than other countries on average and per head of capita. If calculations were based on global averages, South Africa’s contribution could be calculated as follows. South Africa contributes 1.1% of global Greenhouse Gas (GHG) emissions. Based on the same assumptions as set out above, the impact on South Africa's total emissions from their coal production is 1.1% of 0.29 Degrees Centigrade, i.e., 0.0032 degrees. In other words, by eliminating coal from its electricity generation mix, SA will reduce global temperatures by 0.0032 Degrees Centigrade by 2100. This is an unmeasurably small number and comes at an enormous economic cost of over R1 trillion by 2035. Nevertheless, this is what the world's climate change experts, supported by the idealists and vested financial and other interests, expect South Africans to sacrifice.

The above figures are based on international averages. However, South Africa is coal-intensive; hence, its primary usage and impact figures would be higher than average world numbers. After using these revised, more intensive assumptions, a more accurate value can be assigned to South Africa's impact on GHG gases. The total contribution that SA makes to total global emissions is estimated to be 1.1%. Therefore, South Africa's overall contribution to the 6 degrees warming would work out at 1.1% multiplied by 6 degrees Centigrade, i.e., 0.066 degrees Centigrade by 2100. In South Africa, approximately 85.1% of energy is supplied by oil, coal and gas. If the total amount of the assumed contribution to global warming is attributable to South Africa's high fossil fuel usage, one can expect the contribution to global warming by South African fossil fuels would be 85.1% of 0.066 degrees Centigrade. This calculation works out as approximately 0.056 degrees Centigrade by 2100. This temperature change works out at 0.007 degrees Centigrade per decade. The GHG emission figures and their impact on temperature are small and insignificant. For all practical purposes, they are meaningless.

However, coal only accounts for 87.9% of the fossil fuel figure. This figure means that coal contributes only 0.0494 degrees Centigrade to reducing global warming by 2100 or 0.006 degrees Centigrade per decade. The economic cost, however, is severe. In effect, South Africa is expected to pay R40 trillion for every one degree C to reduce its impact on its contribution to global warming. As derived from Lomborg's work (Lomborg 2016)

The economic and social sacrifice in terms of reduced economic growth means a reduced standard of living and a poverty increase. It is a prohibitive feel-good factor for the wealthy and those with vested financial and ideological interests who will not be affected by the sacrifices. Many of these costs will be borne by the poor, as stated by Stephen or Prasad (Stephen, 2018; Prasad, 2008).

It is estimated that China, India and the ASEAN countries will considerably increase their emissions over the next 30 years from increased fossil fuel and coal usage (Martin, 2016; Suryadi, 2016b). Anthropogenic CO2, as the primary driver of modern global warming, is an assumption that many renowned scientists question (Kauppinen and Malmi, 2019). The potential adverse economic, social and political consequences for South Africa of making the planned sacrifices in electricity generation from coal are enormous and will substantially increase unemployment. India, China, ASEAN countries, Poland, Russia, and Eastern European countries are all countries that favour High-Efficiency Low Emission (HELE), or "clean-coal", and nuclear power for electricity generation. They consider these as the most efficient energy sources for generating secure sustainable, stable dispatchable electricity for their economies. This fact is particularly true for emerging and industrialising countries, which includes South Africa (Endfield, 2019). This finding is supported by reality on the ground in these countries.

### 3.8 ENVIRONMENTAL IMPACTS AND COSTS

The ecological damage from solar and wind is considerable because of the size of the installations.

- In the case of wind, according to the Council for Scientific and Industrial Research (CSIR), the space requirements are 0.1 square Km/Mw or 10 MW per square Km. On this assumption, the IRP 2019 puts forward 17000 MW as planned by 2030 would cover 1700 square Km. A more realistic figure of 1MW per 0.625 square Km would require about 10625 square Km. The environmental damage would be substantial for South Africa as their locations will primarily be near the coast or on mountain ranges behind. Environmentalists in all parts of the world are opposed to wind farms, let alone wind farms on this scale (Centre for Environmental Rights (CER), 2017).
- The above CSIR figures are an exceptionally dense level of packing wind turbines. Access roads and other land irregularities increase land use substantially. It is unlikely to be much better than 10 MW per 6.25 square Km. The unconstrained recommendation of the IRP 2016 estimates that 106000 MW of wind farms will be required by 2050. Windfarms generating this electricity will cover an area of 66250 square Km. These numbers leave out powerlines of the grid that require approximately a further 11000 square Km. This quantum's visual perspective suggests an area covering approximately 6000 Km of coastline and mountain range to a depth of 11 Km. The potential environmental damage is massive.

The impact on the environment, particularly, cannot be overemphasised. Various studies confirm that the renewables, wind and solar, have a markedly detrimental impact affecting birds, bats, insects and animals. Even man is not unaffected. Infrasound is known to impact humans, animals, and even insects adversely. In some countries, there are bans on wind turbines closer to 10 Km from human habitation. The harmful environmental effects are a huge issue and are subjects in themselves. Research in Norway on an eagle species serves as an example (Dahl et al., 2012). The conclusions here are vital as they serve as an example of the general difficulties with wind farms, particularly bird species.

> "The results emphasise the importance of thorough pre-construction studies identifying important breeding areas for sensitive species. The cumulative impacts from several wind-power plants along the Norwegian coast and elsewhere could negatively affect the white-tailed eagle breeding population if they are located in important breeding areas, turning them from sources to sinks. Moreover, the results underline the need for more Bird and Small Mammal BACI and IG Design Studies in Wind Farm studies to assess the impact of wind-power plants on bird populations properly. Increased knowledge and understanding of wind farms' impacts on birds and other wildlife is essential for sustainable future wind-energy development in Norway and elsewhere".

Wind energy suffers from extremely low energy density. As a result, vast land areas are required to generate very little electricity. Wind farms ' land area usage to generate electricity becomes even more prominent when wind's low load capacity of less than 35% is considered. This figure works out as 10 MW occupying 6.25 square Km.

As Posma notes

> "Jeffreys Bay Wind farm's annual electric energy supplied to ESKOM is claimed to be 460,000 MWh. The combined nameplate rating of the 60 wind turbines is 138 MW; if these ran at that output for an entire year, it would amount to 1,208,00 MWh. The "Capacity Factor" (CF) (Load factor) of the Jeffreys Bay Wind Farms is, therefore, 0.38, and the average or productive output is only 52.4 MW. These 60 turbines are located on 3 700 ha (37 square Km) of land. 71.1 ha land is therefore required for every MW of electric power". (Posma, 2018)

The IRP 2019 proposes wind-generated electricity totalling 17GW or 17000 MW. The land area required will be 10625 square Km. The domain involved is likely to be equivalent to 2000 Km of coastline to a depth of 5.3 Km. This is a large area of land which such building operations will damage. These figures exclude the grid area needed of an estimated more than 11000 square Km, which would mark the landscape and cause further damage to animal, bird and bat life.

Over the years, many articles, reports, and books have been written, giving the perceived considerable benefits of renewable energy use. However, there are substantial views that fossil fuels—coal, oil, and natural gas—do substantially more harm than renewable energy sources by most measures. These include a wide-ranging group of factors, including air and water pollution, damage to public health, wildlife and habitat loss, water use, and global warming emissions (Jaber et al., 2013). These are strongly supported by a global majority of the media and experts. Notwithstanding that, there is steadily increasing support for the contrarian views. This thesis does not take a stand on this issue but believes the case supporting Fossil Fuels must be heard.

The wildlife, bird and nature groups in South Africa seem unaware of the extent of the future economic and environmental damage this country faces if renewables are used excessively. These groups are doing a splendid job of objecting to single projects, as set out in the appeal letter from Van Der Spuy opposing the (Plan, 2019) 11 wind farm. As Van der Spuy notes

> "It is my professional opinion, based on the facts, that this wind farm is clearly environmentally unsustainable, and it most certainly does not comply with environmental standards set by the World Bank Group "Environmental, Health, and Safety Guidelines" (Appeal, Section 4). The held environmental Authorisations lack credibility and are merely and solely the products of government policy implementation acting in unison with the profiteering of the Applicant and others."

A set of appeal documents are contained in the references (van der Spuy, 2019a; Jenkins and Consulting, 2018;  Group, 2015; van der Spuy, 2019b; Vulpro, 2017; Department of Environmental Affairs, 2019 ).

The findings in the USA are equally disturbing: Bryce, In Written Remarks for a Hearing of the Senate Committee on the Environment and Public Works, in 2014, in a paper entitled "Killing Wildlife In the Name of Climate Change"(Bryce, 2014), said that

> "A July 2008 study of bird kills by wind turbines at Altamont Pass, California, estimated that the massive wind farm was killing 80 golden eagles *per year*.  Those birds are protected by the Bald and Golden Eagle Protection Act.  In addition to the eagle kills, it estimated that about 2,400 other raptors, including burrowing owls, American kestrels, and red-tailed hawks – as well as about 7,500 other birds, nearly all of which are protected under the Migratory Bird Treaty Act – were being killed every year at Altamont.  The study was funded by the Alameda County Community Development Agency.  In 2009, a biologist with the Fish and Wildlife Service estimated wind turbines were killing some 440,000 birds per year".

Notwithstanding, the IRP 2016 unconstrained plan talks of 106000 MW being installed by 2050. At a rate of 4.12 birds killed per MW, one is talking about killing 436000 birds per year or 8.7 million over the life of windfarms.  South Africa is rich in rare bird species, and the impact on these species is likely to be severe.  Wildlife and bird associations need to be fully aware of the looming disaster that South Africa's energy plans are taking it towards.  It is incorrect and irresponsible to consider the problem on a windfarm-by-windfarm basis.  The ultimate completed big picture is what needs to be considered.

Many local and overseas environmental experts are vehemently opposed to wind farms. Therefore, various articles have been included as references for further study and reading (Duchamp, 2017; Duchamp, 2007).

It should be noted that all power stations require powerlines.  However, this country's nuclear and coal-fired power stations are 600 MW or more.  Some power stations are 3600MW or more. Windfarms and solar farms are 200MW, and many are less.  In addition, many windfarms and solar farms only generate power 30% of the time or less.  Therefore, many more Km of powerlines are often not fully used.  In some parts of Europe, authorities insist that these are placed underground. Costs are increased significantly.  The distances involved mean that this solution is unworkable in South Africa.

Finally, environmental damage or costs have not been discussed.  These are far higher than generally realised.  They are not limited to environmental or ecological damage only.  They involve health factors and lower values of vast tracts of surrounding property.  It is difficult to place a financial value on these costs.  The value of 29 million hectares could be affected.  Even with an average reduction in an estimated price of R500 per hectare, the market value of surrounding land could fall by R14 billion. It is not suggested that this is the likely fall in all the surrounding land prices. Overseas research is mixed on land prices, with some studies suggesting no decline in real estate values and other studies indicating reductions of up to 25%. Therefore, there is a strong indication of a decline in value. The evidence suggests that planners and adjudicators must seriously consider the ramifications of windfarms' ecological impacts on environmental, financial, and economic issues.

### 3.8.1 CONCLUSION

This section has shown there is sufficient expert evidence to support the view that Anthropogenic Global Warming (AGW) may not be the critical issue made out by the IPCC. In addition, carbon dioxide is not the damaging gas it is often accused of ( Climate Depot, 2010; Kauppinen and Malmi, 2019). This evidence is sufficient to support the hypothesis of this thesis. Emerging economies with a comparative advantage in fossil fuels and countries such as South Africa should explore all the options for alternative electricity generation and not exclude coal and fossil fuels because of potentially damaging environmental impacts. The chapter shows that the potential costs of moving away from coal far exceed the potential benefits South Africa may gain from stopping the use of coal. By being aware of potential negative consequences, the authorities can mitigate any possible harmful effects by utilising technical advances that have been made in these electricity generating technologies

The many experts referenced in this document strongly support the critical references regarding the issues raised in this chapter. Their names appear in the bibliography. Notably, the literature refers to lists of eminent scientists and experts. These experts strongly believe that Anthropogenic Global Warming (AGW) is not the critical issue made out by the IPCC and that carbon dioxide is not the damaging gas it is made out to be. Instead, it is an odourless, colourless, non-toxic gas essential for life on this planet. The works of these eminent scientists, and the reasons why they have come to the conclusions they have, form part of the essential reading of those involved in the debate regarding climate change and the discussion concerning “clean-coal” energy and the use of renewables (Climate Depot, 2010; Gosselin, 2019; Scientists, 2019).

## 3.9 THE IMPORTANCE OF COAL AND POTENTIALLY GAS IN SA

### 3.9.1 INTRODUCTION

This section carefully examines the country's fossil fuel resources, emphasising the role of coal and the potential uses of gas. It discusses the importance of coal in South Africa’s economic development with specific regard to the mining and industry and the industrial heartland of South Africa in Gauteng. Examining the importance of South Africa’s mineral resources and commodities in the economy, job creation and the balance of payments are considered. It scrutinises the potential for developing a gas industry and its role in creating a new industry in South Africa.

Importantly it highlights the need to find local deposits to contribute substantially to South Africa's energy requirement. A report by Falcon et al. entitled "The benefits and Challenges of Coal in South Africa " published in Cornerstone gives background to the subject (Falcon et al., 2013).

Coal is a critical component of South Africa's mining and industrial mix (Manuel, 2017). An article in Engineering News by Creamer stated:

> "For the last 150 years, mining has been the driving force of South African industry and economic development. Even though the dislike of mining is expressed in diverse ways, that does not take away from the fact that mining has shaped South Africa and influenced the interactions of its people. Mining has also compelled South Africans to innovate to create an ongoing future for the industry." (Creamer, Engineering News, 2017)

These facts have not changed, and South Africa needs to restore mining to its former glory.

> "The mining space is a cruel place, and part of what the South African economy lives through because of its mining background is the enormous vagaries of external determinants. But notwithstanding that, mining remains core to defining our economy,"

said former Finance Minister Trevor Manuel at the JSS Empowerment Mining Fund launch, which ENS Africa hosted. Chief Operating Officer (COO) Otsile Matlou emphasised the significant task ahead for South Africa to continue to use mining as a catalyst for developmental growth. It remains a massive industry and is an essential vehicle for developing the economy and emerging miners. The former minister noted that it provides 25% of South Africa's merchandise exports, a figure that rises to 40% if beneficiated minerals are included. The importance of the mining sector, including coal and the industrial and manufacturing industries, Agri-processing and other goods-producing industries, are reinforced by the above statements, and they form a vital component in the development of the country as set out in the National Development Plan (NDP) (National Development Commission, 2011). Gas on its own can be developed as an industrial development sector (Jeffrey and Jordaan, 2015). It must be emphasised that this can only be done if gas in natural gas, shale gas or coal bed methane is found in significant quantities in South Africa. The argument for developing and focusing on gas depends on the above being domestically available and commercially exploitable. It does not in any way detract from the evidence that coal must continue to be developed and used as a critical resource for electricity and energy supply in South Africa. Gas can be used as an industrial development base for the country and support coal and other electricity generation sources.

These facts are supported by many experts who know and understand the problems of South Africa and developing economies in Africa. In this context, apart from the work of Jordaan, there has recently been work published by Lawton PD (2022), "Putting Coal into the African Perspective". Nuclear and coal are critical in Africa if the continent is to develop, grow economically, and eliminate poverty.

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### 3.9.2 THE ROLE OF NATURAL RESOURCES

Countries use those natural resources that give them a competitive or, in economic terms, comparative advantage (Sporton, 2017). South Africa is blessed with many natural resources, particularly fossil fuels. Currently, these include coal and, more recently, potentially offshore gas and shale gas. South Africa must exploit these to gain a comparative advantage over its trading partners and competitors. To do otherwise is not serving the interests of its country or citizens.

- The all-embracing condemnation of fossil fuels does not stand up to scrutiny. Fossil fuels will be a significant source of energy for a long time. According to some experts, the impact of human-produced fossil fuels on climate change is not as high as has been made out and, according to some experts, is very small ( Berkhout, 2019; Hertzberg, 2015). More importantly, thanks to fossil fuels, billions of people have been brought out of the abject poverty their ancestors toiled in for previous millennia (Anielski, 2016). These fuels have a meaningful and continuing role in assisting in this process in the decades to come in developing economies and countries such as South Africa. Epstein says it best in his book *The Moral Case for fossil fuels*: (Epstein, 2015; Jeffrey, 2017d).
- "Climate is no longer a significant cause of deaths, largely due to fossil fuels. Not only are we ignoring the big picture by making the fight against climate danger the fixation of our culture, we are "fighting" climate change by opposing the weapon that has made it dozens of times less dangerous (Burnett, 2017). The widespread climate discussion has the issue backwards. It considers humans a destructive force on climate life, making it dangerous because humans use fossil fuels.
- Higher economic growth rates promote higher employment levels and improved standards of living. High growth is how to fight poverty and inequality. Higher economic growth rates support enhanced social grants, improved education and better medical care (Stats SA, 2016; Childs, 2006). These factors achieve better health, better health care and genuine transformation.

All these statements are controversial and will be a cause of a healthy and long-overdue debate

### 3.9.3 KEY ECONOMIC OBJECTIVES

Research shows that:

- The mining and manufacturing sectors are more energy-intensive than sectors such as trade and finance.
- The growth rate of electricity consumed in South Africa from 1990 to 2008 was 2.6% per annum. The GDP growth rate over the same period was 2.5%. However, correlation does not imply causation.

During this period, there were significant changes in the structure of the economy, which also impacted reducing energy intensity in the economy. There are many causes of increasing electricity usage, but economic growth remains a significant factor.

It would be easy to argue that electricity should be redirected towards less energy-intensive industries and economic activities during a prolonged shortage of electricity generating capacity or limited capital for expansion. In effect, it would result in energy being redirected towards service-orientated industries at a broad sectoral level, where there has been an apparent high growth rate. This argument is fallacious and would negatively impact the economy's potential growth rate and employment in the long term. This situation has prevailed in recent years in South Africa. The facts remain:

- Most services are a derived demand. They exist to support trade in mining, manufacturing and other goods-producing industries. Therefore, it is crucial both domestically and internationally to achieve balanced growth of trade in goods and services. The service sectors must be sufficient and efficient but are commonly not sources of growth in their own right unless they result in exports or foreign exchange such as tourism, top-class medical services and a few other industries.
- Developing export-orientated and import-replacement industries and strengthening the current balance of payments account are central to enhancing economic growth, increasing employment, and raising the standard of living. In South Africa, mining and goods-producing industries are better placed to achieve this objective than services. Developing countries like Singapore and Malaysia have different comparative advantages and needs.
- Expanding the goods-producing sectors of agriculture, mining and manufacturing will more effectively address unemployment. They are more labour-intensive, particularly amongst the less skilled population, than increases in the services sector, which are more skills-intensive and, as a group, remain capital-intensive.

### 3.9.4 COAL IS A NATIONAL TREASURE AND INVALUABLE ASSET

South Africa has an abundance of coal. Coal is the country's primary energy source and will continue for the near and medium-term future, provided correct economic and energy policies are followed. Coal is also in demand internationally, and South Africa is one of the leading coal export nations in the world. This thesis does not intend to enter a discussion of coal grades, but in general terms, ESKOM and Sasol have used lower-grade coal with a more moderate energy content, which has not been exported in the past. At present, the export market requirements are for higher-grade coal. The situation is changing as demand for coal of lower grades increases in the international market. The worldwide market has also changed with the decline in the use of coal in Western Europe. However, demand in China, India and other Eastern countries remains high as they have not bought into the climate change issues. They also exploit the loopholes that exist in the Paris

Accord. Vast quantities of lower-grade coal are available in South Africa, sufficient to meet South Africa's demand for over 100 years. One hundred years gives SA time to assess cheaper sources of dispatchable energy. Renewables, wind and solar do not produce dispatchable electricity. A significant proportion of the coal exported is primarily used for power generation. Coal for energy generation in South Africa, whether for electricity or liquid fuels, should enjoy considerable cost advantages for energy production over coal exported overseas (Fossil Fuel Foundation, 2016). This situation should continue to be the case, although again, this is changing. South Africa must accept this and change its contract pricing towards the export parity prices, ensuring continuity of investment and supply in the future local coal industry. It should also be assumed that its price will increase with international energy and resource cost trends and increased costs from reducing pollution.

Notwithstanding that, the local purchase price of coal and power station operating costs should, in theory, remain lower than comparative international plants. As a result, the electricity generated by coal in this country should remain cheaper than electricity generated in many other parts of the world (Stats SA, 2015; Stats SA, 2019). South Africa holds the keys to long-term sustainable economic, industrial, mining, and economic growth between coal and labour costs. However, much depends on how the government addresses the structural problem of South Africa, Eskom and SOE returning to profitability mainly through public-private partnership and privatisation and labour, improving its productivity. Notwithstanding that, the Rand's value will need to be allowed to adjust to its correct levels.

Where possible, it is worth exporting or using its products and commodities to reduce imports, thereby supporting a value-added process in South Africa. Such economic enhancement of products increases export revenues, reduces import costs and reduces the deficit on the current account of the balance of payments (Jeffrey, 2015). Such value-added processing results in additional inputs and creates employment within a range of industries and their suppliers through the multiplier effect. It seems inconceivable to have an energy policy that curbs its use for beneficiation purposes. If not irresponsible, it is illogical not to utilise our national treasure to the best effect. Yet, South Africa exports this commodity to other countries while not using it in South Africa to its economic advantage. Other countries use this resource to their advantage, generate electricity at a lower cost, manufacture value-added goods and then, in many cases, export these goods back to South Africa. These activities can occur at more competitive prices because South Africa has not used its natural resource, coal, to its advantage and best effect.

### 3.9.5 THE IMPORTANCE OF COAL

A comprehensive study needs to be made of the coal industry before South Africa embarks on a plan that radically restructures its energy supplies and ESKOM (Falcon, 2018; CRO Advisors., 2019) and effectively destroys its coal industry. A few facts about the coal industry in South

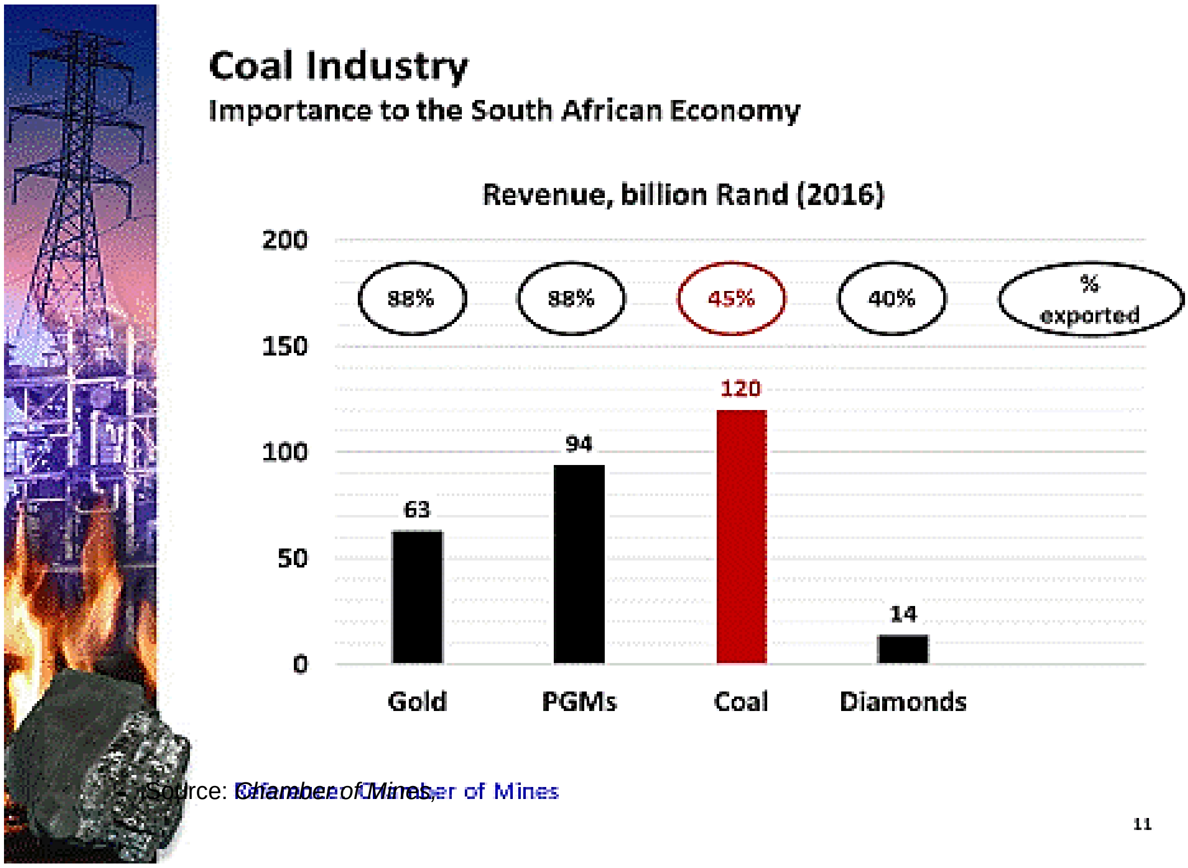



**Figure 46: Importance of coal Revenue & exports**

Africa from the Fossil Fuel Foundation is pertinent (Fossil Fuel Foundation, 2016).

They include:

- SA is the 7th largest producer of coal in the world.
- SA is the 7th largest exporter of coal.
- Coal is a substantial foreign exchange earner.
- Coal is the highest minerals income earner, beating gold, PGM's.

SA produces;

- >30% of petrol and diesel requirements
- >93% of SA's energy production and 81% of the region's energy (Terbrugge and Collins, 2017).
- >98% of carbon reductants in the metallurgical industry - iron, steel, ferrochrome.
- >200 major chemicals and over 7 000 carbon-based products, including paints, plastics, fertilisers, explosives, food and many other carbon-based products.

The coal industry is varied and consists of a wide diversity of downstream users Fossil Fuel Foundation, 2016)

- Local markets are incredibly diverse - ESKOM, Sasol, export industries and local industries dependent on coal. It has ±6,000 local users – including metallurgical, brick and tile, pulp and paper, sugar, cement, hospitals, mines, transport, food, textile, chemicals and other product manufacturers (ESKOM, 2016).
- Advanced products derived from coal include paint, plastic, explosives, petrol, diesel, carbon materials, coke, char, semi-coke, and anthracite for smelters and the metallurgical industry across the board.

Failure to mine coal will result in the need to import some products derived from coal or produced from coal-based processes – the overall cost could rise as high as R500 billion.

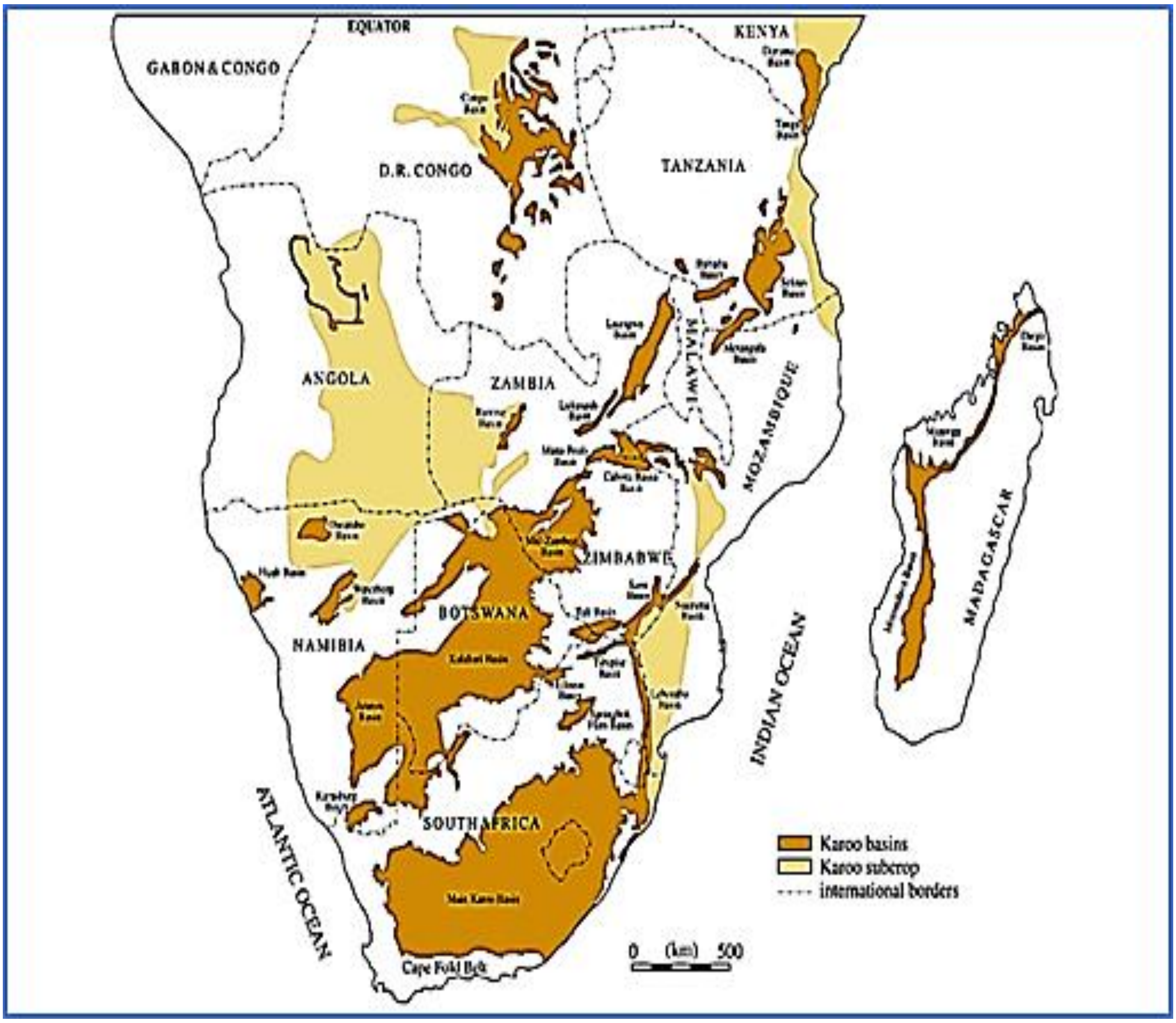



**Figure 47: Coalfields in Southern Africa**

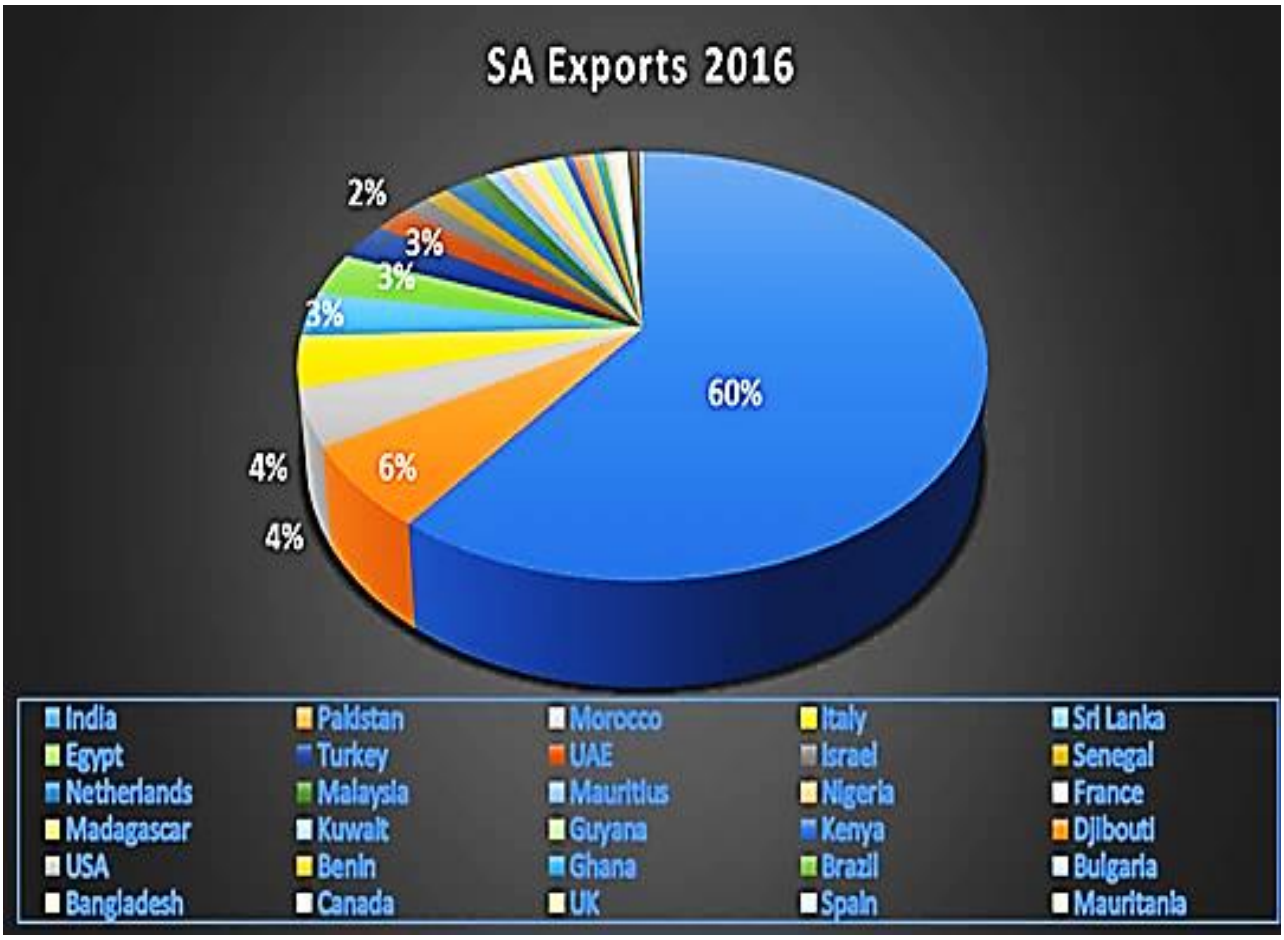
The map above shows the areas in Southern Africa with a significantly higher probability of finding coal.

### 3.9.6 COAL EXPORTS AND EMPLOYMENT

What is often not sufficiently discussed is that the major cost to the South African economy is poverty. Higher unemployment leads to higher levels of poverty. Emerging and developing countries all have their major objectives of reducing poverty and reducing unemployment. This can only come about by increasing their economic growth rates. South Africa needs to reindustrialise and redevelop its mining sectors. These two sectors are more energy-intensive. Their economic redevelopment requires abundant, secure baseload electricity at competitive rates. Mining exports and mineral beneficiation exports account for over 60% of South Africa's exports by value. Hence the importance of mining, mineral beneficiation, coal mining and coal exports to employment and economic growth in South Africa. It could be said that converting coal to electricity is the essential starting value-added mineral beneficiation process. All value-added processing follows after that. It is for these reasons that this thesis focuses on this aspect. Failure to attend to their importance becomes a significant cost to this economy.

The export of SA coal is financially vital for the SA economy, but this regularly requires processing, which leads to the production of secondary, lower-grade coal products for power stations and other uses. Major coal exports can often not happen without a domestic power station for the take-off use of derivative products. This synergistic balance is essential. Otherwise, exports will decline rapidly. Exports totalled more than R50 billion (Fossil Fuel Foundation, 2016).

Coal provides considerable value regarding its footprint on society and the economy. The revenues amount to about R120 billion, and the sector employs roughly 77,000 persons, and their associated dependents comprise more than 300,000 people. In addition, the industry provides many additional indirect jobs ranging from subcontractors in many fields, including engineering, scientific and technical users, consultants, equipment and service providers, health officials, Transnet employees, the road transport sector and environmentalists. Significantly many of these are skilled jobs.




Source: *Chamber of Mines, FFF*

**Figure 48: SA coal exports 2016**

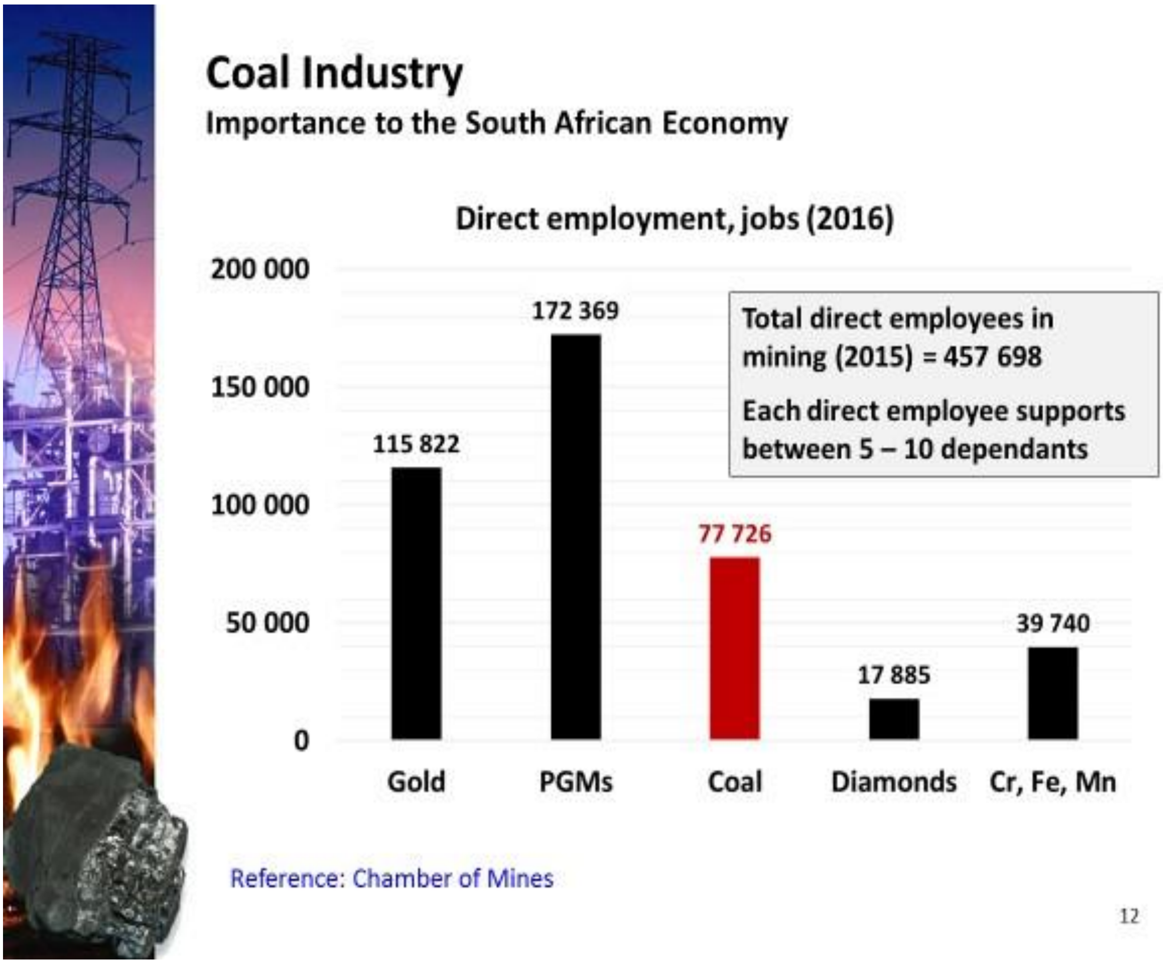



**Figure 49: Importance of coal Employment**

Because mining is an ongoing operation, it lays down a support infrastructure for the local economy. The mines assist these communities' socio-economic development through their economic development plans, supporting hospitals, clinics, health programmes, and general infrastructure.

Any significant decline in the coal and associated industries will profoundly negatively impact the economy. For example, it is estimated that if the coal sector shrinks by 50% on a relative scale, it will reduce South Africa's GDP by over 2.5% (R75 billion) and reduce employment by over 200,000 people, affecting almost one million dependents. The reduction in employment indicated includes those employed directly in the coal mining industry and the indirect employees losing their jobs. This is the likely outcome of implementing the IRP and the Carbon Tax (Jeffrey, 2015a).

### 3.9.7 COAL AND ECONOMIC GROWTH POLICIES IN OTHER COUNTRIES

The cost of doing business in South Africa must be kept competitive internationally. The cost of its power and likely trends in this sector internationally is, therefore, essential. Significantly, it is primarily Western nations that are following the renewable route. However, many nations in

Eastern Europe and Asia are not doing this. Comparing the figures and forecasts suggests they are paying more attention to facilitating higher growth in the energy provided by coal, gas, and nuclear energy sources. A close study reveals there are two major reasons for this. The first reason is that their economic, social and political priorities differ from those of the Western Industrialised World. The second reason is that, in their opinion and according to their analyses, renewables' cost structure is not economical, and their alternative generation policies and plans offer lower costs and greater efficiencies. These trends and the reasons for the trends must be investigated and analysed carefully.

Emerging economies globally include South Africa, the ASEAN countries, China, Russia, India, Vietnam, Korea, and Poland (Jeffrey, 2016c). Many countries continue developing coal and fossil fuels (Vishwanathan, Garg and Tiwari, 2018; WCA, 2016). They have determined that HELE or "clean-coal" and gas are the cheapest, most efficient, and reliable electricity sources to achieve their economic growth objectives and industrialisation programmes. In turn, they achieve higher employment and poverty reduction. Replacement of ageing inefficient power stations is a crucial objective. HELE, or "clean-coal", is globally recognised as a cost-effective and efficient method of reducing emissions and other pollution (AssociationWC, 2017; Sandor, 2017). These countries have made economic growth their priority.

The 10 ASEAN countries are prime examples of governments using "clean-coal" technologies (Suryadi, 2016b). In these countries, electricity generation increased by an average of 7.5% per year, from 155.3 Terawatt hours (TWh) in 1990 to 821.1 TWh in 2013. Fossil fuels generated 79.4% of The Association of Southeast Asian Nations (ASEAN) electricity in 2013. Coal-based electricity capacity is projected to increase from about 47 GW in 2013 to 261 GW in 2035, with an average growth rate of 8.1%. In Vietnam, GDP growth is expected to average 6.0% per annum between 2015 and 2035 (WCA, 2016; Jeffrey, 2016c). Coal generation will increase from 36% of electricity generation to 56%, rising at 7.2% per annum. These countries expect annual growth of over 5% for the next 15 years. South Korea is growing its nuclear-based generation. Growth in its power sector is expected to be 3.6% per annum, but a significant proportion of its power generation will remain in coal and gas (Jeffrey and Jordaan, 2015). In Poland, electricity growth is also expected to be primarily coal-based generation. Certainly, it must be stated that, given the current public debate on climate change, these countries have many discussions concerning the future role of coal and fossil fuels. At this stage, they remain firmly committed to their long-term plans regarding coal and fossil fuels, but they also plan to increase their selective renewable use. Piyush Goyal, Minister of State with Independent Charge for Power, Coal, New and Renewable Energy in the Government of India, has stated:

> "We will be expanding our coal-based thermal power. That is our baseload power. All renewables are intermittent. Renewables have not provided baseload power for anyone in the world." (Vishwanathan, Garg and Tiwari, 2018; Martin, 2016).

Unsurprisingly, India's annual average electricity demand between 2000 and 2013 grew from 376 TWh to 897 TWh, mostly coal-based. Moreover, coal-fired electricity is forecast to grow at over 4% per annum, from approximately 166 GW to 500 GW, by 2040 (WCA, 2015; WCA, 2018; WCA, 2016). In summary, renewable energy has severe limitations (Smith and Electrical, 2012).

In comparison, the average growth in "electricity available for distribution in South Africa", as measured by Statistics South Africa, grew an average of only 1.7% during 1990–2015 (Stats SA, 2015; StatsSA, 2019). The average GDP growth was 2.5% during the same period. Even worse, electricity demand growth from 2000 to 2015 averaged only 1.3% per annum. Over this period, the average GDP was 3.1% per annum (South African Reserve Bank, 2018). This higher economic growth was due to an excessive increase in the services sector, primarily in the public and government sectors, not the mining and manufacturing sectors, where growth was weak. The equivalent figures for 2008–2015 indicate that electricity supply growth grew by approximately 1.1% per annum and GDP grew by only 1.9% per annum. It is little wonder that South African GDP growth does not parallel other high-growth emerging economies. In terms of the Integrated Resource Plan (IRP), electricity growth between 2015 and 2035 appears to be approximately 3.9% (Centre for Environmental Rights (CER), 2017; (Department of Energy (DoE), 2017; (Department of Energy (DoE), 2016). However, because of the low load factors of renewables, real deliverable baseload electricity growth could be only 2.5% per annum. Thus, future average growth to 2035 is unlikely to average more than 2.8% per annum.

There have been reports that Japan plans to build 45 new coal-fired power stations (Follet, 2017). Prime Minister Abe is firmly behind plans to build coal plants, despite repeated pressure from environmentalists to stop the construction of new coal plants. His successor is likely to follow the same path. *Japan Infuriating Enviros By Building 45 New Coal Power Plants* (Follet, 2017) The Prime Minister wants more new coal plants to ensure the island nation is not too reliant on any one source of electricity. "Japan needs to import 95 per cent of all its energy sources," O'Sullivan, an energy analyst with Mathyos Global Advisory in Tokyo, told the Australian Broadcasting Corporation. "So, it is trying to diversify its fuel sources, and it does not want to be too reliant on any one market." Most of the coal Japan plans to burn in these plants will be imported from the U.S. or Australia. The country is also building additional natural gas power plants.

It should be noted that if South Africa does not find its own gas shale gas deposits and reduces the size and scope of its coal industry and coal exports, South Africa will become an energy importing country. Currently, SA is a net energy exporter. As a result, there will be a dramatic adverse swing in its balance of payments, and effectively South Africa will lose its energy sovereignty. Like Japan, most countries attempt to reduce their negative energy imbalance and maintain or improve their energy sovereignty.

### 3.9.8 THE POTENTIAL FOR GAS IN SOUTH AFRICA

Renewables that are recommended by the renewable lobby are solar and wind. This is because South Africa has very little hydro or geothermal potential. The recommended renewables, namely solar and wind, require 100% dispatchable electricity backup as they are unpredictable and subject to frequent and unexpected or planned interruptions. The recommended backup is gas, yet South Africa has no substantial long-term gas supply. Gas may become available in the longer term, as seen in the following discussion. In the past, South Africa was virtually self-sufficient in terms of its electricity-generating requirements. In fact, it is an energy exporter through its coal exports. These would decline as coal production and exports decline. It would now become necessary to import gas. The country would become a net energy importer with a substantial negative impact on its balance of payments and loss of energy sovereignty. This is precisely what has happened in Europe. It is a major contributory cause of the economic downturn and rising energy prices.

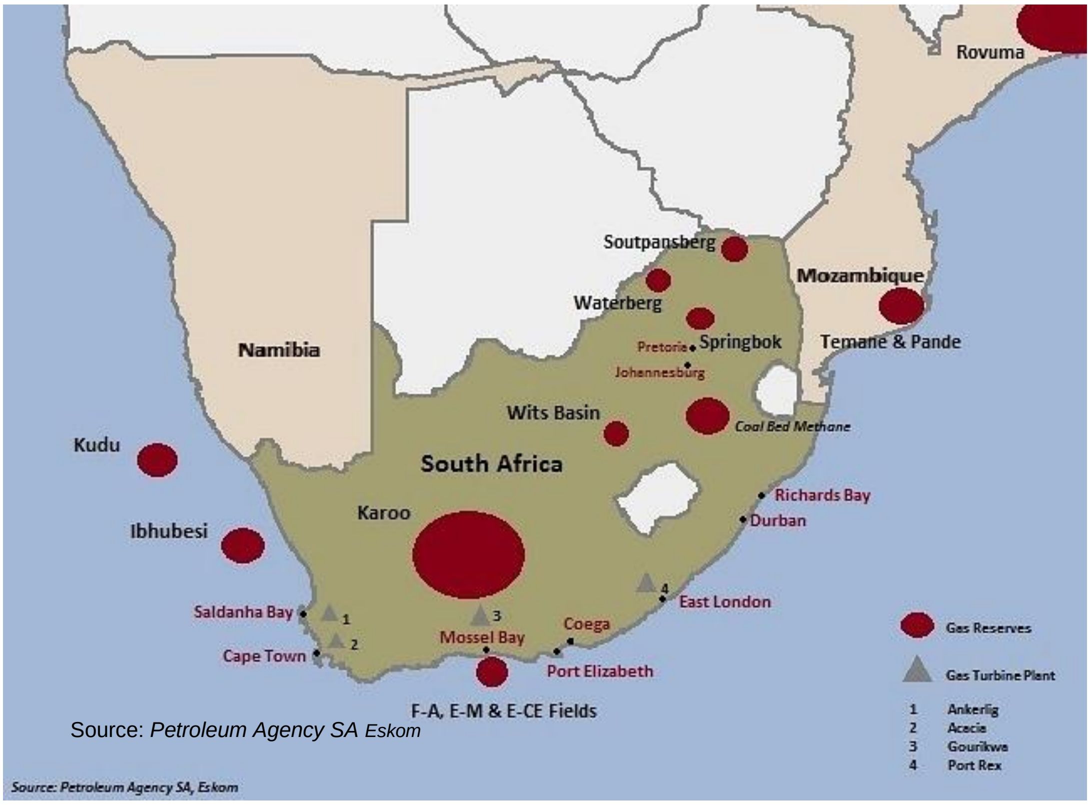
The immediate result would be that South Africa would become short of energy at critical moments because renewables are not dispatchable. The recommended backup in South Africa is gas. However, this can only occur if sufficient domestic natural gas resources are discovered. Unconventional gases such as shale gas, Deep Biogenic Gas (DBG) and Coal Bed Methane (CBM) could well become the most significant contributor to gas. There could also be the opportunity to exploit Underground Coal Gasification (UCG) ( Jeffrey, 2015).

Hydraulic fracturing, or fracking, to utilise shale gas resources is contentious and has made limited progress. Originally, the low oil price has also slowed development. Initially, South Africa's shale gas reserves appeared to be as vast as 110435 trillion cubic metres (TCM) in the Karoo Basin, of which about 10% could represent extractable reserves. However, it would appear that this original estimate may have been excessively optimistic.

Sasol supplies approximately 40% of the country's oil requirements. The balance is imported. Increased domestic production would decrease import reliance, improve the country's trade balance, and reduce international oil price fluctuations on domestic fuel prices. However, a significant investment in infrastructure would be required to exploit local gas supplies.

### 3.9.9 SOUTH AFRICA'S POTENTIAL GAS RESERVES

Besides shale gas, the country's conventional gas reserves are mainly offshore. Because of various constraints, there are limited plans to utilise domestic gas at present. However, the IRP has a policy position to support the development of gas infrastructure and convert all diesel-fired power plants (Peakers) to gas (IRP2019; Jeffrey, 2015b)




Source: *Petroleum Agency SA* *Eskom*

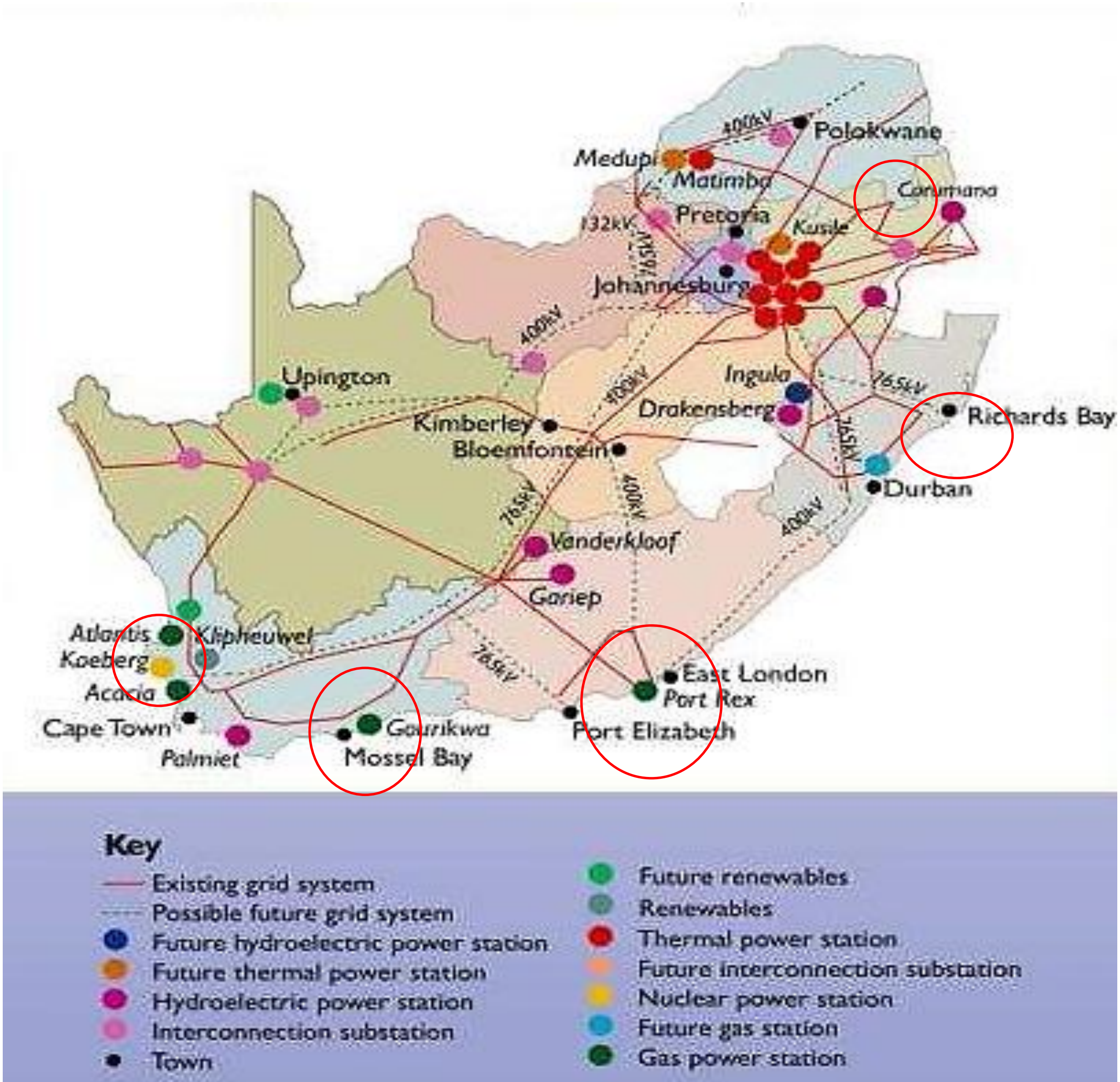
**Figure 50: Significant Gas Prospects in Southern Africa**

South Africa has several production and exploration projects underway as the government seeks to exploit natural gas reserves. While shale gas and coal bed methane represent the most substantial proportion of potential reserves, the process to begin utilising them will require coordinated efforts between the government, the private sector and environmental groups, which, for the time being, will limit activity to exploration. However, conventional gas production offers a buffer and time to develop regulatory and environmental preservation and protection framework.

The Orange Basin is the country's most extensive offshore area for natural gas and is underexplored. The same applies to fields off the coast near Mossel Bay. They represent significant gas reserve potential. A proven field exists at the Ibhubesi gas field development located in the Orange River Basin off the West Coast of the Northern Cape, approximately 60Km offshore. The Ibhubesi Project explores future production capabilities and represents the most significant conventional offshore gas field. It is scheduled to supply the Ankerlig power plant, which can generate 1338 MW of electricity. The Ibhubesi gas field could supply the Ankerlig power plant for up to 15 years.

### 3.9.10 POTENTIAL LOCATIONS FOR GAS-FIRED POWER STATIONS AND INDUSTRIES

Should South Africa discover substantial gas quantities, there are at least five possible gas-fired power stations. The growth and development of upstream and downstream gas-related suppliers and industrial users at these locations would be enabled. Furthermore, since electricity generated by gas is dispatchable, this would be preferable to utilising non-dispatchable renewables such as solar and wind (Jeffrey, 2015b. Jordaan, 2015).




Source: *ESKOM,* EconomicRisk

**Figure 51: South African Power Network (grid map)**

The possible locations indicated in the chart above are:

- Western Cape in the Saldanha Bay/Cape Town areas;
- Western Cape near Mossel Bay;

- Eastern Cape in the Port Elizabeth/Coega economic zone;
- KwaZulu Natal near Durban/Richards Bay;
- Near Nelspruit using imported gas from Mozambique.

The first four locations are better than others for imported or local shale or offshore sources of gas and the latter for imported gas by pipeline from Mozambique. Longer-term, Saldanha, Mossel Bay and Coega could use shale gas should the shale gas deposits prove economically and technically viable. Other nodes for longer-term gas development include Sishen, which supplies the mining industry in the Sishen and Kimberly areas. The suggested locations are close to larger populations and industrial centres serving domestic and industrial electricity demand. Importantly, they offer the elements of a skills base and basic support infrastructure necessary as a power station location and develop upstream suppliers and potential downstream gas users (Budget Review, 2019). This is in contrast to solar and wind development, which would essentially down-skill South Africa's employment opportunities

The local economies have large young populations and access to essential services, including energy, water, refuse removal, telephone services and sanitation. They offer better-than-average health, education, income and infrastructure and provide better supporting infrastructure, including transport and communication, while the ports offer harbour and railway nodes. Simultaneously, each location and the surrounding area have relatively high unemployment levels of more than 25% and growing populations (Jeffrey and Jordaan, 2015).

Additional investment in the chosen regions' economic and physical infrastructure would be required to maximise the full gas development potential. Although the present infrastructure in each area is quite developed and includes roads, railways, and three cases, the essential deep-water harbours, more extensive road networks running through the municipal areas, and additional or expanded rail linkages would be required. Such expanded facilities for Agri-processing and, in Coega and Saldanha Bay, minerals beneficiation would almost certainly become part of the potential industry development mix.

Deep-sea harbours are available to expand and cater to export-orientated industries at Saldanha Bay, Coega and Richards Bay, and possible space to handle imported liquid natural gas until local sources are developed.

## 3.10 THE BENEFITS OF MEGAPROJECTS

Megaprojects, such as substantial power station build projects, which includes national gas projects, nuclear and coal, meet many of the economic development policy needs of South Africa and southern Africa. While a national gas project and power station build programme are capital intensive, with a high capital cost per job created, such developments offer South Africa considerable benefits.

Fundamentally, capital-intensive megaprojects will not solve Southern Africa's under-employment problem. An essential part of the solution is that upstream and downstream development promotes labour-intensive manufactured supply and exports. Ultimately, South Africa's economic, agricultural and industrial growth would increase, positively impacting living standards and long-term employment growth. The country's economic development is enhanced by increasing electricity supply and various associated socio-economic programmes (Prinsloo et al., 2019).

The development of power station projects can support a wide range of South African business segments, upstream and downstream, and adjacent industries. New investment opportunities are bound to arise from medium to large-scale commercially viable natural gas production levels and power station project developments, attracting foreign direct investment into upstream and downstream opportunities.

A rough estimated forecast has been prepared to assess the upstream and downstream economic impact of developing a natural gas industry in South Africa.

Based on a single project at a single location, an estimated gas turnover of R15 billion per annum, upstream and downstream turnover could total as much as R50 billion per annum. The total value added to the economy is estimated at R26 billion per annum of this production value. Average upstream and potential downstream employment created could peak at an estimated 70,000, that level being achieved during the mature phase of the project's production life. Thus, the potential economic impact of such vast gas resource finds, such as the Karoo shale gas, supported by other local finds, should exist and is very significant for the South African economy.

Its impact is substantial if sufficient domestic gas and all five regional projects are fully developed. It could exceed a value add of R100 billion and create over 200,000 jobs. A national gas project would help restore South Africa's confidence and significantly enhance its geopolitical and economic standing as a hub for energy and resource development in Southern Africa.

The table below indicates the potential impact of new electricity generation.

**Table 6: Economic impact of potential electricity generation**

| Electricity | 4,000MW | 8,600MW |
|---|---|---|
| **GDP** | R300 bn | 645 bn |
| **Employment** | 800,000 | 1,720,000 |
| **Dependents** | 3,200,000 | 6,880,000 |

Source: *SARB, Stats SA,* EconomicRisk

The figures above estimate the potential beneficial economic impacts of approximately 4,000MW of electricity and 8,600MW generated by several power stations. The data are rough estimates but give a reasonable idea of the tremendous potential impact of coal and nuclear electricity-generating power stations on South Africa's economy and future growth.

### 3.11 CONCLUSION

The chapter examined the coal and possible gas resources of South Africa. It highlighted the importance of coal in the country's economic development and its relevance to mining and industry and the industrial heartland of South Africa in Gauteng. Examining the importance of South Africa's natural mineral resources and commodities in the economy and the balance of payments is reviewed. It established that any reduction and ultimate destruction of coal mining and coal for electricity generation could significantly affect the coal industry, industries dependent on it, and the entire mining industry. These, in turn, will severely impact the whole of the economy. It scrutinised the potential for developing a gas industry and its role in creating a new industry in South Africa. Importantly, it highlights the need to find local deposits for gas to make any substantial contribution to South Africa's energy requirements and economy

It should be noted that the above economic impacts can only be delivered by dispatchable electricity generating sources such as gas, nuclear and "clean-coal" (Minchener, 2016). The economic benefits above cannot be provided by non-dispatchable electricity-generating solar and wind sources. Wind and solar deliver electricity less than 30% of the time, and not only that, the supply is variable, unpredictable and interruptible. In other words, there is a high risk of non-supply of electricity which is unsuitable for business and industrial development. In summary, it suggests substantial economic advantages in installing dispatchable electricity generating sources such as gas, coal and nuclear. A thorough investigation into gas use should be done before considering any investment in variable, unpredictable, interruptible non-dispatchable renewables such as solar and wind. Solar does have an important role in domestic use and office development as long as its costs are fairly and equitably implemented. These additional costs are a major exercise in their own right. This and the previous chapters have shown that environmental arguments against coal and fossil fuels are not sufficiently proven for an emerging country such as South Africa to forego the long-proven benefits of utilising fossil fuels to generate electricity.

# 4 ELECTRICITY GROWTH REQUIRED AND MODEL DEVELOPMENT

## 4.1 INTRODUCTION

This chapter introduces the concepts used to develop the final built model. The priority is to determine the economic growth needs of the country. It will set out the growth rate potential and the GDP growth required to achieve its primary objectives of reducing poverty, inequality and unemployment. It will examine the structural and sectoral industrial and economic growth requirements for South Africa to meet its critical primary goals. The model must also forecast the likely electricity-generating demand for alternative sectoral growth strategies utilising a model developed for this purpose. These steps are essential in maximising a country or a region's prospect of meeting its primary objectives.

## 4.2 ENERGY THE KEY TO THE VALUE-ADDING PROCESS

A power station is the first step in the value-adding chain. In South Africa, this primarily has been a coal beneficiation process. Coal fuelled power stations effectively convert the energy available in coal into heat energy. The heat is then used to generate a more transportable and helpful form, electricity, used by industry and citizens. This is also the fundamental process driving the electricity generation derived from nuclear processes. In many instances, heat energy produced by both methods is used directly.

Work done by Prinsloo et al. in their paper on "The significance of electricity supply sustainability to industrial growth in South Africa" noted the following.

> "The South African business environment is characterised by supply uncertainties, which have large economic implications on the country's capacity to achieve its industrial goals. South Africa's industrial decline and falling economic growth are directly associated with decreasing electricity sustainability, as the industrial sector is the main economic contributor to South Africa's GDP.
>
> The public sector should apply the good governance framework to ensure policies prioritising electricity supply sustainability to industries. Enterprises are also advised to institute mitigation mechanisms.
>
> The study has critically examined the significance of electricity supply to industrial growth. The objectives were to determine the importance of electricity and the current competence of electricity supply for industries, assessing the effects of ineffective supply on organisations' potential to meet new business pressures and demands, and to recommend reliable and applicable measures with capabilities for ensuring electricity supply sustainability for industries." (Prinsloo et al., 2019)

Most industrial, mining or manufacturing value-adding processes require energy to beneficiate or add value, to essential commodities or input products, mainly in electricity but often direct or indirect heat. Reliable, efficient, dispatchable low-cost power is critical to all businesses. Such power is essential for most businesses. These extend from the more energy-intensive iron, steel, ferrochrome and beneficiation industries to a wide range of less energy-intensive industries such as textiles, paper, cement, and chemicals. Different manufacturing processes depend on electricity to add value to labour and other inputs. These include many services, including businesses such as restaurants and many service-orientated industries. It is vital economically and socially that dispatchable electricity is secure, stable and supplied at the lowest economical price possible when customers require and need it, not when suppliers choose to send it. In other words, it should be dispatchable.

ESKOM has been a value-added processor of South Africa's key and most valuable commodities, namely the national resource coal. It effectively converts the energy available in coal into a more transportable and useful form, namely electricity. It adds value to the coal and sells it as electricity — further value is added to downstream industries. Unfortunately, South Africa is not located geographically where ESKOM can export vast quantities of its value-added product, namely electricity, except in limited amounts to its neighbouring territories. With its natural resources of coal, were South Africa located next door to an industrial region such as Europe, Japan or China, South Africa could have become a significant exporter of electricity, almost certainly with dedicated power stations for this purpose. Poland, an electricity producer utilising coal, is a neighbour to Germany and exports a significant quantity of electricity to Germany and other neighbours when short of power. In addition, South Africa is not able to import electricity when it has electricity shortages (Primary Research, 2019).

Notwithstanding these shortcomings, South Africa is regionally well located between four significant markets, North America, South America, Europe, and Asia and contains a treasure chest of minerals exported directly. In many instances, adding value to the mined raw material is preferable by beneficiating the commodity before export examples include chrome, manganese and coal. In the ideal world, South Africa should use its considerable labour resources to add value to any unbeneficiated or beneficiated commodity or product and, where possible, export finished goods. Furthermore, in the ideal world, such export products should be manufactured at the coast to be more quickly and cheaply exported. This point also applies to other products, many of which can become import substitutes.

## 4.3 ALTERNATIVE ELECTRICITY GROWTH EXPANSION STRATEGIES

Economic growth is the critical overriding goal to achieve South Africa's objectives. It is necessary to have a sufficient, reliable and cost-effective electricity supply. A successful electricity generation and distribution infrastructure are central to achieving this. As stated elsewhere, electricity is a necessary condition for economic growth.  It is not a sufficient condition.  It must also have the right macroeconomic, industrial, and political policies (EIA, 2019; Jeffrey, 2020).

This section summarises certain aspects of this and uses a model developed to consider the economic impact of alternative electricity growth that would be the best for improving the long-term economic potential of South Africa.  It should be noted that the investment and growth in output in the economy and various sectors drive the electricity demand, not the opposite.  Increased energy or electricity supply does not lead to increased energy or electricity demand, GDP, employment and export growth.  Increased energy or electricity supply only creates the potential for economic growth.  Economic growth increases energy and electricity demand, dependent on domestic and foreign investment growth directly in goods-producing industries and businesses (Jeffrey, 2016c), confidence, policies, and many other factors.  Not in investment portfolio flows of financial institutions.  However, having adequate or excess energy or electricity generating capacity is essential for fostering growth.  The higher the electricity supply, the higher the economy's growth potential, and vice versa.  However, economic and employment growth depends on the industries and sectors towards which this growth was extended.  A summary of the economic impact of alternative power generation growth strategies is set out below.

**Table 7: Electricity, GDP and employment growth**

| **Electricity, GDP and employment growth** | | | |
|---|---|---|---|
| Assumed Growth of Electricity Sales | 2.0 % | 3.0% | 4.0% |
| Associated GDP Growth | 2.7% | 3.8% | 5.0% |
| Balance of payments | | | |
| Associated Real Exports | 2.6 | 3.8 | 4.8 |
| Associated Real Imports | 2.9 | 4.0 | 5.1 |
| *Associated Employment Growth | 2.3 | 3.4 | 4.5 |
| Additional jobs created by 2035 million | 6 | 11 | 16 |
| Additional jobs created by 2050 million | 20 | 36 | 59 |
| Effective MW required by 2035 | 47000 | 54000 | 62000 |
| Effective MW required by 2050 | 69000 | 98000 | 137000 |

Source: *Stats SA,* Economic Modelling Solutions, EconomicRisk    ** Non-Agricultural Sector*

The table above shows the GDP growth achievable in each sector given the electricity supply available to those sectors (If the correct policies are in place to achieve economic growth).  The table developed from the model shows clearly that:

- Firstly, the higher the availability of electricity, the higher the economic growth rate.
- Secondly, the GDP growth rate will vary depending on the demand or availability of electricity in each sector

- Thirdly, employment growth will depend on GDP and sectoral growth rates.

A growth rate in electricity of an estimated 3.0% per annum is recommended as a minimum policy goal. It is based on the demand determined by policy growth targets for each sector. These can only be determined by growth policies or policies conducive to growth in each sector. These parameters give a potential GDP growth of approximately 3.8% per annum. 3.8% per annum is probably, at present, the maximum long-term sustainable target economic growth achievable for the country at this stage. This growth rate assumes a high mining growth rate of about 2.7% per annum. This growth rate has not been achieved for many years. The same can be said for the target industrial growth rate of 3.3%. Any decrease in these potential growth rates will have a dire impact on the economy, employment, particularly unskilled jobs, and electricity, as seen in the final column.

The impact on the economy of a lower GDP growth rate of only 2.7% or less on employment, particularly unskilled employment, is disastrous. This scenario and potentially more moderate growth are what many commentators at present are anticipating. Unfortunately, it is now the reality the country faces. Jobs created by 2035 will be less than 6 million, while it is expected that some 16 million new job entrants or more will enter the market. It will plunge South Africa into a severe economic, political and social quagmire with fast-rising unemployment and poverty. Any build programme must have the flexibility to be rapidly increased to cater for the 3.0% growth in electricity demand and GDP growth of more than 3.8%, which should be the target. In studying the above, it is vital to bear in mind the consequences of compound growth. Not only does the absolute value of electricity demand increase rapidly, but more importantly, the total amount of the annual and cumulative increase in employment rises quickly.

According to the Quarterly Labour Force Survey (QLFS), there are 15,788 million workers in the economy, of whom 15,050 million work in the non-agricultural sector. The average annual increase in employment has an average of 3.0% over the period 2001 to 2009. It should be noted that these figures have been affected by structural adjustments and changes in the method of recording employment. The real employment growth is probably considerably less than this. The average annual GDP growth rate over the same period was 4.3%. The low employment growth rate has resulted from high service sector growth and weak growth in the more labour-intensive mining and manufacturing sectors. It must be repeated that this mainly affects unskilled labour.

The return to higher GDP growth in the critical mining and manufacturing sectors will result in a return to higher electricity demand growth and higher employment growth, particularly for the unskilled and those in the lower-income groups. The recommended electricity demand growth of 3.0% per annum results in a GDP growth potential of about 3.8% per annum and results in sustainable employment growth of approximately 3.4% per annum. Initially, this creates the possibility of generating job opportunities for 11 million additional workers by 2035. It is estimated that nearly 16 million new workers will enter the job market over the same period. There will also be persons retiring and leaving the market. Therefore, there is a reasonable chance that unemployment will not increase under this scenario, but it is also unlikely to reduce the unemployment rate (Publishing, 2019) significantly. Unfortunately, the COVID-19 virus will make a tremendous difference which will be discussed separately.

It should be noted that the increase in employment growth from 2.3% per annum to 3.4% because of higher growth, particularly in the goods-producing sectors, results in increases in the number of jobs created from approximately 6 million to 11 million by 2035. These are highly significant numbers and underline the importance of achieving higher economic growth rates and realising a thriving mining and manufacturing policy growth strategy.

The most potent employment-generating investment the government can make is increasing South Africa’s secure, dispatchable baseload electricity generating capacity. Without this, economic and employment growth will stagnate. Increases in electricity generating capacity are necessary for creating potential economic and employment growth. It is also essential to have a climate conducive to fostering the investment growth required in the sectors that generate economic growth and maximises employment growth. In South Africa's case, these are mining, minerals beneficiation, manufacturing, and other goods-producing industries such as Agri-processing and agriculture. The correct political, economic, employment and enterprise development policies are the building blocks for creating the necessary environment for increasing domestic and foreign investment to support this growth.

## 4.4 THE IRP 2016 AND IRP 2019 FORECASTS

It is interesting to consider the recommendations for the new build programmes in the IRP 2016 and the IRP 2019 and compare them with the recommendations regarding electricity growth provided in this section. The recommended growth for electricity contained in that section was 3.0% per annum. It was estimated that this would give an estimated GDP growth rate of 3.8% per annum. This was believed to be the minimum growth objective that the state should have.

The various plans have the following estimates for electricity growth and GDP growth. In each case, it has been assumed that South Africa in 2018 installed 35000 MW electricity generating capacity, which is working effectively. This is considered to be the effective or real capacity.

- The IRP base case recommendation was that by 2050 the total installed electricity capacity should be 128177 MW. This nameplate capacity generated a practical or real 62343 MW for use in the country. This is an effective electricity growth of 1.8% per annum. According to the model, South Africa’s economic GDP growth rate will be limited to 2.5% per annum.
- The recommended plan envisages the country's installed nameplate capacity of 98375 MW by 2050, generated by more coal and nuclear power but less wind. This would generate the same real power of 62343 MW because of the higher load factors of nuclear and coal.

The analysis shows it will, in the long run, be cheaper and more efficient and more effective than the IRP base case plan based on renewable electricity generating capacity.

- The IRP unconstrained plan was that by 2050 the total installed electricity capacity should be 212299 MW, primarily comprised of renewables, wind and solar. This nameplate capacity generated an effective or real 75645 MW for use in the country. This is an electricity growth of only 2.4% per annum. According to the model, South Africa's economic GDP growth rate will be limited to 3.2% per annum. This is still less than the recommended growth rate of 3.8%, which should be set as an objective.
- The unconstrained alternative plan envisages the country's installed nameplate capacity of 129043 MW by 2050, generated by more coal and nuclear power but less wind. This would generate real power of 83686 MW because of the higher load factors of nuclear and coal. This is an electricity growth of 2.8% per annum. According to the model, this will give South Africa an economic GDP growth rate of approximately 3.6% per annum. The analysis shows that this will be considerably cheaper, more efficient and more effective in the long run than the IRP unconstrained plan based primarily on renewable electricity generating capacity.
- The IRP 2019 is an extremely worrying document as it does not seem to be based on having any realistic economic objectives for the country. The IRP 2019 plan takes South Africa to 2030. The total installed electricity capacity excluding storage is 72834 MW, made up primarily of wind and solar. This was nameplate capacity generating an effective or real 41964 MW for use in the country. This is an electricity growth of only 1.5% per annum. This effectively limits economic growth in SA to an average of only 2.0% per annum to 2030. This is almost half the economic growth required, 3.8%. It is substantially less than the targets set in the NDP. It will have disastrous economic consequences and exacerbate poverty and unemployment levels. South Africa is heading for a period of dangerous and extreme economic, social, and political change.

### 4.5 THE MINIMUM GROWTH OBJECTIVE

This section has reviewed the economic growth needs of the country. It has set out a forecast of the GDP growth potential required to achieve its primary objectives of reducing poverty, inequality and unemployment. It has examined the structural and sectoral industrial and economic growth requirements for South Africa to meet its critical primary goals. These require growth in the economy's more electricity-intensive industrial, manufacturing and mining sectors. It has reviewed and forecasts the likely electricity-generating demand for alternative sectoral growth strategies utilising a model developed for this purpose. At this stage, the selected long-term sustainable growth rate of 3.8% is considered the country's achievable long-term sustainable economic growth.

These GDP growth numbers are considerably less than the original Accelerated and Shared Growth Initiative for South Africa (ASGISA) economic growth targets of 6.5% and are also less than the National Development Plan (NDP) target of 5.5% per annum (National Planning Commission, 2011). An alternative objective would be to increase this target growth rate to closer to 5% per annum. In this document, the lower rate of 3.8% per annum has been used, as even at this level, it has important implications for the electricity generating capacity build programme. Currently, given the state of the economy, it will be challenging to achieve these targets. Higher growth at these levels would release the South African economy's growth potential, given its resource richness. The country will become a magnet for domestic and foreign direct investment (Jeffrey, 2016c). These higher growth figures could become a realistic, achievable and sustainable long-term objective if there were the political-economic and social determination and will to achieve them. The required energy growth, in this case, electricity growth, needed to make the 3.8% rate of economic growth, needs to be approximately 3.0% per annum, given the selected sectoral growth targets and assumptions utilised in the model above.

The growth in electricity generation of 3.0% per annum and the resulting higher generation capacity creates the potential for higher GDP growth, higher employment, lower unemployment and a higher standard of living. This growth target assumes that policies are implemented to encourage more industry and mining-related activities. Employment growth would be roughly 3.4% per annum. It can be anticipated that there could be consistent growth in exports at 3.8% per annum. If there is a weaker Rand, combined with more bias towards mining and manufacturing, it can be predicted that there would be higher exports, lower imports and more unskilled persons being employed than is shown. Similarly, the electricity growth required would increase above 3.0% per annum to support this growth.

Electricity capacity growth should be planned to maintain an adequate reserve margin to sustain these economic growth levels. There will, therefore, be time to increase the electricity generating capacity growth programme to cater for periods of higher sustained growth. Similarly, it would be possible to slow the building programme with lengthy periods of slower growth. Inherently, planning for fully developing South African raw material and human resources richness is necessary. Any growth that is less than that would not be doing justice to the people of South Africa. Notably, ongoing electricity shortages would reduce investment and ensure the economy does not achieve the economic growth rates it can produce.

In summary, small electricity generating capacity increases would ensure lower economic growth. It becomes a self-fulfilling prophecy. It would justify the inadequate planning and capacity decisions made previously. The resulting outcomes are detrimental to South Africa as it would reduce employment growth, increase levels of unemployment, increase poverty levels, grow inequity and would lower the standard of living.

## 4.6 COMPARISON OF THE COST OF GENERATING ELECTRICITY

### 4.6.1 DISPATCHABLE AND NON-DISPATCHABLE ELECTRICITY GENERATING SYSTEMS

This section evaluates the real cost of generating electricity for each technology to determine the least-cost energy mixture. The section will examine the strengths and weaknesses of the methodology currently favoured by renewable lobby groups and energy planners in South Africa. The least-cost mix is determined by utilising the Levelised Cost of Energy. The literature is replete with articles focusing on the weaknesses of the LCOE methodology. Therefore, this section examines these weaknesses and particularly centres on the fact that all electricity delivered is not equal. It distinguishes between dispatchable and non-dispatchable electricity. It also distinguishes between the price or cost at the "gate of the supplier', and the cost of electricity supplied to the user, i.e., at the 'gate of the user'. The impact of the load factor and the technology's life are considered. Finally, the section discusses the role risk and uncertainty play in costs. It builds a model based on the introduction of these concepts to the electricity generating costs of these technologies.

The commonly presented view is that non-dispatchable electricity generated by renewable energy resources, particularly wind, is significantly cheaper than dispatchable coal and nuclear-based electricity generation (Solomon Oyewo *et al.*, 2019). This conclusion must be based on the assumption that the product delivered by each technology is the same and equal in value in every respect. Furthermore, the cost of generating and delivering the product produced by renewables is significantly cheaper than those produced and delivered by coal or nuclear power stations.

Therefore, it is essential to understand the difference between dispatchable and non-dispatchable electricity. As noted by Wikipedia

> "Dispatchable electricity generation is capable of being dispatched. According to market needs, it refers to sources of electricity that can be used on-demand and dispatched at the request of power grid operators.
>
> The main reasons why dispatchable power plants are needed are to: provide spinning reserves (frequency control); balance the electric power system (load following); optimize the economic generation dispatch (merit order), and contribute to clear grid congestion (redispatch)."
>
> "Non-dispatchable electricity generation but cannot be turned on or off to meet societies fluctuating electricity needs. It is the opposite of dispatchable electricity sources that are very flexible, changing their output reasonably quickly to meet electricity demands. Non-dispatchable electricity sources are often highly intermittent, which means they are not continuously available due to factors that cannot be controlled (e.g., the weather).
>
> Dispatchable is in contrast to non-dispatchable renewable energy sources such as wind power and solar PV power, which operators cannot control. [ The only types of renewable energy

that are dispatchable without separate energy storage are hydroelectric, biomass, geothermal and ocean thermal energy conversion." (Wikipedia)

There is, therefore, a considerable difference between the product provided by wind and solar and that provided by most fossil fuels, in this case, gas, HELE clean coal and nuclear. The system requirements are, therefore, totally different, and these are illustrated graphically in the following two figures.

## DELIVERING DISPATCHABLE ELECTRICITY TO CUSTOMERS

**System for Non-dispatchable Electricity Generating Sources**
**Mainly Wind and solar**

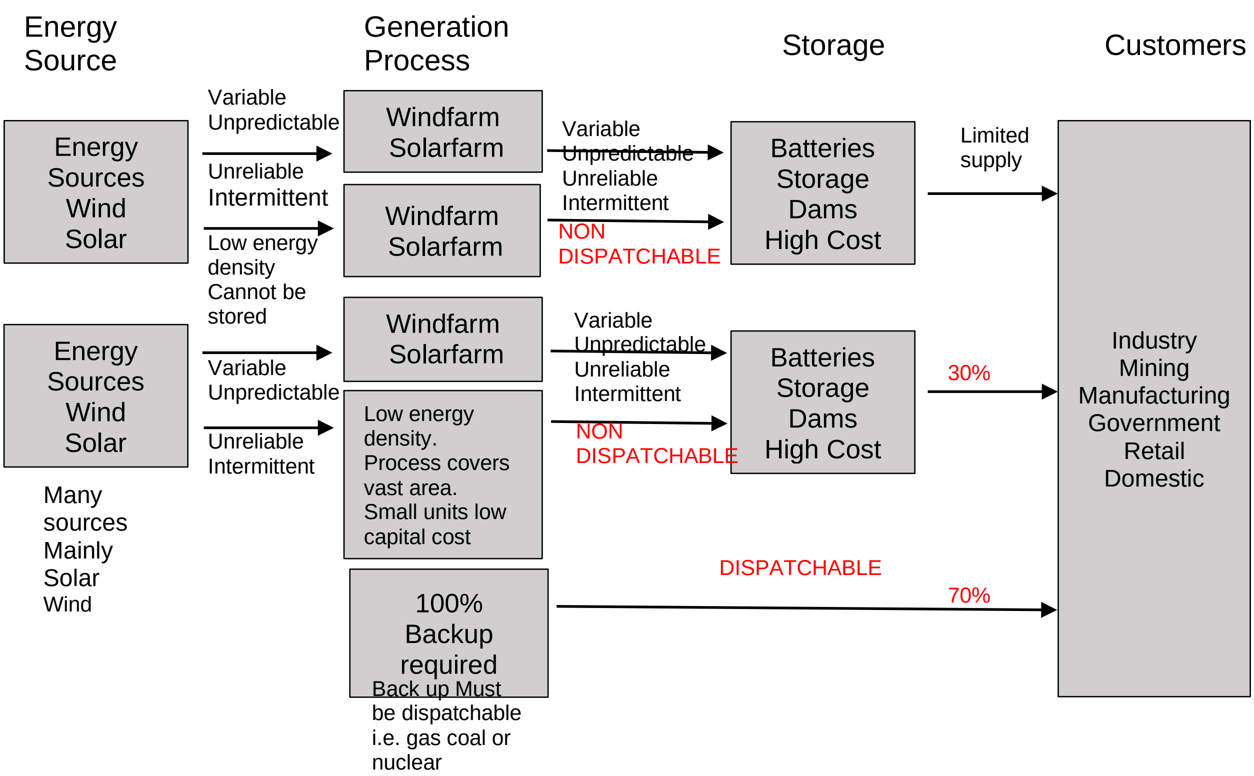



**Figure 52: System for non-dispatchable technologies**

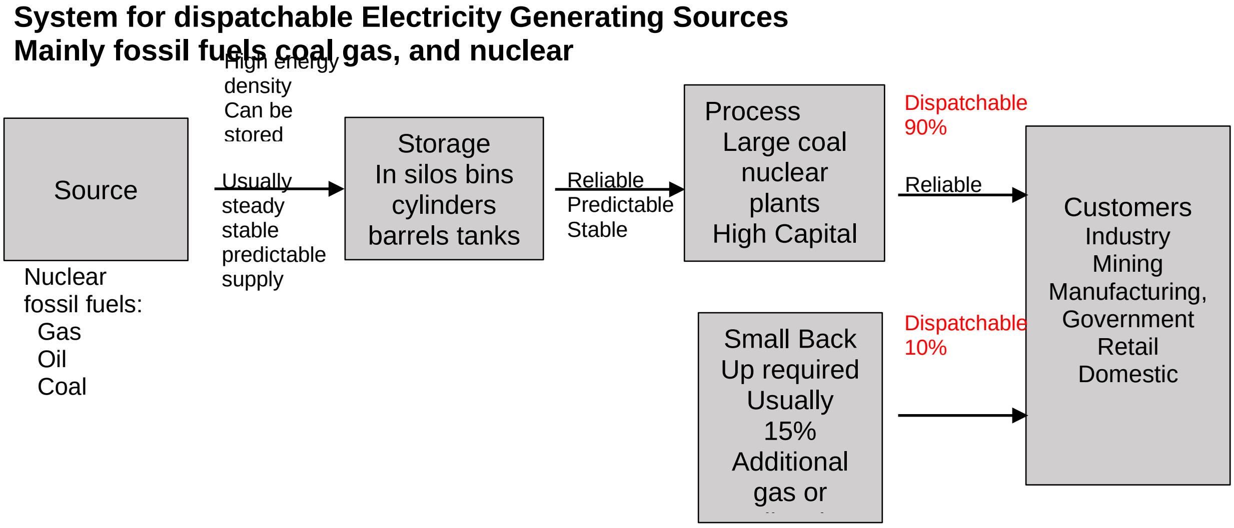



**Figure 53: System for dispatchable electricity technologies**

Only a brief assessment of critical points can be made in this thesis regarding the two systems. The system requirements of the non-dispatchable energy sources are far more extensive than those for the dispatchable system. There is a plentiful supply of the ultimate energy source, namely wind or sun. However, it has a very low energy density and is highly variable unreliable, intermittent and unpredictable. As a result, the technical process is widespread geographically, and there are many of them. They produce electricity with the same characteristics as the source energy, often called the capacity factor, which is low. In the case of wind, the load factor is, on average, approximately 35% of the nameplate or installed capacity. In the case of solar, the load factor is only, on average, approximately 26%. The windfarms or solar farms are relatively small, with a nameplate capacity generally of 75 MW to 150MW. The actual production output is, therefore, between 37MW and 53MW. The grid and management systems are more costly as they operate below optimal efficiency levels. Each solar-farm or windfarm process unit must be fully 100% backed up by a dispatchable power source, usually gas or coal.

The dispatchable system is relatively simple. The energy is obtained from high-density energy sources, namely gas, oil, coal or nuclear material. The storage process is relatively simple as it is taken before the technical process by stockpiling high energy density coal gas and oil. These energy sources provide steady, secure supplies of energy. Therefore, process units can be far more extensive, and power stations typically provide between 600 MW and 4000MW, be far higher. Under normal circumstances, nuclear has a load factor of 90% and coal power stations 80%, delivering secure steady dispatchable power. Backup systems are, therefore, relatively small. The grid and systems management are less costly and not as challenging to manage.

A non-dispatchable electricity generation supply and distribution system are significantly more complex and costly. The electricity product it initially generates is not equivalent to dispatchable electricity and is significantly less valuable. Finally, the dispatchable fossil fuel backup system will run more than 60% of the time. It will not reduce carbon emissions but could lead to an increase in carbon emissions compared to a well-run HELE coal and nuclear system.

This analysis uses figures approximately the same as in late 2016 in the Council for Scientific and Industrial Research (CSIR) proposal regarding renewable electricity generation. This section will show that electricity generated and delivered by wind and solar is significantly more expensive than electricity generated and delivered by coal and nuclear. It also utilises or develops methodologies different from other methods and considers risk and uncertainty. The revised methodologies allow a more accurate comparison of costs, which considers the real world where risk and uncertainties are realities and form part of the expenses that need to be factored into the calculations of the cost of power developed by each technology.

This thesis then compares these directly with the costs of electricity generated from nuclear and coal. The paper does not consider the externalities involved, such as medical and environmental costs associated with each alternative energy generation system. Nor does it consider the actual costs of poverty which probably overshadow all other expenses (Roodt, 2020) but usually are excluded from studies on externalities. Most studies focus on the externalities caused or purported to be caused directly by the technology. These methodologies do not consider more expensive or inefficient technologies that cause energy poverty (Metcalf, 2012). As Cilliers points out, renewables' inefficiencies are associated with their low energy densities. (Cilliers, 2020). This weakness can never be overcome; hence, their high cost and inherent financial and economic efficiency relative to technologies with higher energy density are permanent features.

This study does not estimate the macroeconomic and socio-economic costs of alternative energy generation systems. As far as is known, no in-depth investigation has taken place on the total long-term macro- and socio-economic implications for the economy of switching electricity-generating technologies. The impact on the critical goods-producing industries, namely mining, manufacturing, Agri-processing and agricultural sectors, and coal, must be carefully considered. The impacts of substantive choices between energy sources will have far-reaching implications and consequential effects on individual economic sectors, economy, employment, industry development, and balance payments. It would appear that the IRP 2019 recently gazetted does not go into this detail either (IRP2019; DOE, 2019).

### 4.6.2 ASSUMPTIONS OF POWER SOURCES

The total cost of supplying electricity is a vast and challenging subject. A proper evaluation of power's cost involves the benefits, value, price, and impact of each generation source's different factors plus their costs.

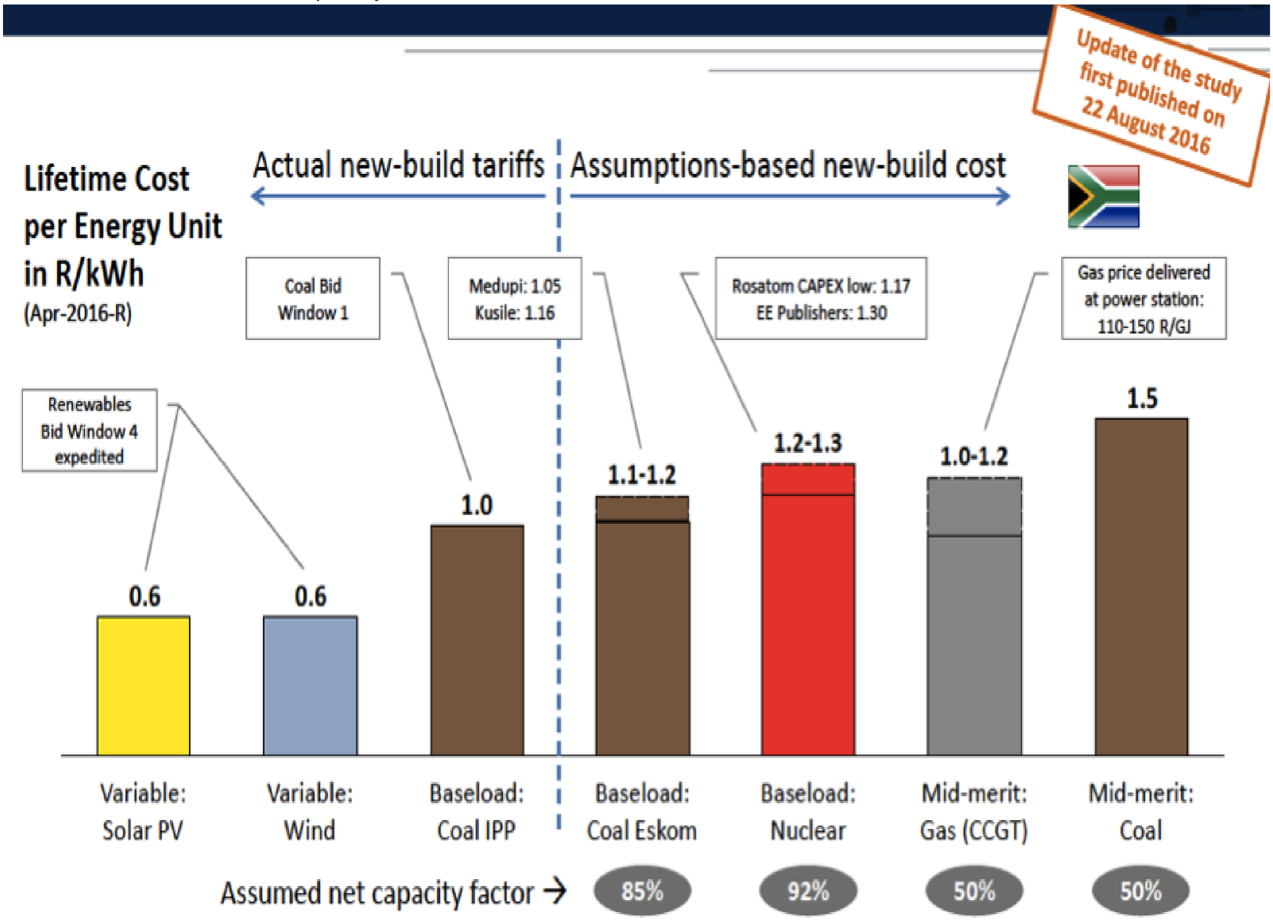
A complete socio-economic impact study must be conducted before decision-making based on any new energy technologies can be made. Historically, past decisions were often made without considering all these factors. It is necessary to work through known unknowns, unknown knowns, and unknown knowns, and there will always be unknown unknowns. Each has different risks, costs and benefits. Unfortunately, with electricity generation, because of such projects' long time-horizon, the probability and risks associated with unintended consequences are high. The costly unintended consequences of the German *Energiewende* programme are only now being felt by Germany (Horgan, 2016; Sopher, 2015; Sopher, 2016a). *Energiewende* was the energy programme to replace nuclear and coal with wind and solar and become a green economy. Many reports suggest that this programme is proving to be a near-disastrous failure at this stage (Andrews, 2016; Vahrenholt, 2017; Lning and Vahrenholt, 2016). Other reports indicate that the wind programme in Germany is in terminal decline (Gosselin, 2019). These are vehemently denied by the industry itself and its supporters. Their view is that propaganda appears on various blogs and sites on the internet. They may view that they are written mainly by ill-informed, biased authors who are not business experts. A review of them reveals that many are knowledgeable respectable authors and experts.

This section will only summarise specific findings arising from an analysis of the claimed assumptions for each technology regarding their overnight costs, the Levelised Costs of Electricity (LCOE), the Load Factors (LF) and the standard deviation ((SD) involved (Yelland, 2016). The assumptions that have been assumed in this thesis have been derived from the IRP 2016 and the CSIR estimates dated 14 October 2016. These have been slightly amended where applicable and relevant. The costs used in specific instances are higher than those used in the IRP 2016. They are more in line with the table below and those published by the CSIR in the figure below.

**Table 8: Assumptions regarding electricity generation sources**

| | Nuclear | New coal | Wind | Solar PV | Solar CSP | CCGT Gas | OCGT |
|---|---|---|---|---|---|---|---|
| **Life of plant years** | 60 | 30 | 20 | 25 | 25 | 30 | 30 |
| **Average capacity Load factor** | 90% | 82% | 35% | 26% | 26% | 50% | 6% |
| **Number of hours over the life** | 525600 | 262800 | 175200 | 219000 | 219000 | 262800 | 262800 |
| **LCOE R/kWh** | **R1.30** | **R 1.05** | **R 0.62** | **R 0.62** | **R3.09** | **R1.24** | **R3.0** |
| **interest rate** | 8% | 8% | 8% | 8% | 8% | 8% | 8% |
| **Construction period years** | 6 | 6 | 3 | 3 | 3 | 2 | 2 |
| **Overnight capital cost R/kW** | **80864** | **40512** | **19104** | **17910** | **44866** | **10421** | **10421** |

Source: IRP 2016,CSIR adapted by Economicrisk




Source: CSIR

**Figure 54: CSIR Assumptions and LCOE**

A review of these figures indicates that the LCOE for wind and solar is 40% cheaper than coal and more than 50% cheaper than nuclear. A more in-depth analysis completed later reveals that these estimates and opinions are almost certainly severely flawed. They do not consider fundamental realities, risks, and theories concerning the pricing and cost of dispatchable electricity, the cost of unserved electricity, and the difficulties and costs of managing a more complex and extended grid. Integrating and managing fluctuating short-term, unpredictable supply-generating units widely spread geographically is a complicated task. Analysis of real-world data from those countries or states with significant wind and solar reveals their electricity prices are significantly higher than other countries reliant on coal, nuclear and gas. These findings are supported by careful analysis of the industrial chart prices found in the various figures. Many other studies also support the findings where the methodology is criticised by several experts, as set out in the next chapter. (Mount *et al.*, 2012; Sklar-Chik, Brent and de Kock, 2016; Pentland, 2014) (Pentland, 2014; Greenstone *et al.*, 2019).

The methodology used in this thesis shows that wind and solar PV are substantially more expensive than the figures presented above. The methodology used may be questioned, but the results are closely similar to the real world and offer a better proxy for the unknowns that are not factored into a simplistic LCOE comparison or other costing methodologies. The fact is that wind and solar do not meet the fundamental stability requirements of an emerging and industrialising economy. The simplistic LCOE comparison of the relative costs is imperfect as they do not consider the variability, interruptibility and unpredictability of most forms of renewable energy, primarily solar and wind (Pentland, 2014). The cost of fluctuating, interruptible, unpredictable, non-dispatchable energy significantly increases the probability of power failures, affecting production and turnover in the economy. All these variabilities, in turn, reduce GDP and employment, and the knock-on effect is that it reduces confidence and investment. Investment is a critical issue, as any reduction has a long-term negative impact on the economy, far exceeding the initial GDP impact.

In summary, this document has a high cost to the economy termed the economic Cost of Unserved Electricity (COUE). A particular methodology has been used to calculate these figures that are open to debate and discussion. The methods used real statistics that have been achieved and the economic effects and prices in other economies with significant renewable programmes, such as Germany, Denmark, Spain, South Australia and Ireland (Sloan, 2016).

In 2010, the cost of unserved electricity (COUE) used in the IRP document was R75/kWh. (Department of Energy, 2010). The price released by the Department of Energy for the IRP 2016 was R77.30/ kWh. This figure has been used in the analysis. The GDP loss due to failure to deliver dispatchable electricity is estimated to be R19.9/kWh.

There is no shortage of literature on why the cost of generating electricity by intermittent renewables, primarily wind and solar, are far more expensive than conventional fossil fuels, namely coal and gas (Hughes and Barnett, 2012; Smith and Electrical, 2012). Other experts and papers report the increased costs and the limited impact wind and solar will have on temperature and climate change (Lomborg, 2016; Curry, 2015).

Recent research entitled 'Do Renewable Portfolio Standards Deliver?' Greenstone et al. summarised specific critical issues as follows:

> "First, renewables by nature are intermittent sources of electricity. Solar plants cannot provide power when the sun does not shine, and wind plants cannot provide power when the wind is not blowing. As a result, any calculation of the costs associated with these sources must take into account the cost of constructing and running backup power. In essence, natural gas plants can often be quickly and relatively inexpensively switched on and off as needed (Greenstone et al., 2019).
>
> Second, renewable sources—solar and wind power in particular—take up much physical space, are geographically dispersed, and are frequently located away from population and industrial centres. According to one study by the Lawrence Berkeley National Laboratory, these factors raise transmission costs—possibly by about $300 per kW, according to one study by the Lawrence Berkeley National Laboratory, or 1.5 cents per kWh. Further, a 2011 analysis by the Edison Electric Institute found that 65 per cent of planned transmission investments over a ten-year period, totalling almost $40 billion for 11,400 miles of new transmission lines, were primarily directed toward integrating renewable generation.
>
> Third, an RPS program can prematurely displace existing baseload generation forcing an increase in renewable power. Though this is an intended effect of RPS policies in that it 'replaces dirtier fuels with cleaner ones, the costs of these early retirements or decreased utilisation—so-called "stranded assets"— do not disappear and are borne by some combination; of ratepayers and owners of capital." (Greenstone et al., 2019; )

The detailed research of data relating to the impact of such renewables on costs confirms that intermittent renewables raise electricity costs and prices in the States they have been introduced (Greenstone et al., 2019; ).

### 4.6.3 COSTS AND ENVIRONMENTAL IMPACT OF WIND

The claim is that wind is cheaper and the lowest-cost energy source. The matter will be investigated further. It is based on false arguments that;

- It produces electricity at the lowest cost. It assumes that the cost of producing electrons and putting these into the grid is the only thing that matters.
- Utilising modern management and electronic techniques, the problem can be solved by sound grid management. The argument is that this is the contemporary way of observing and running an electricity grid.
- It is environmentally friendly and helps reduce the carbon footprint in the economy.

These statements fly in the face of facts and practical experience in every major country, introducing wind as a significant component of their electricity energy source mix. The effect of the matter is that:

- Wind does not produce electricity when it is required most of the time. It only produces power less than 35% of the time. Solar provides heat and energy approximately 26% of the time. Even then, they are highly variable, interruptible and unpredictable. In statistical terms, their standard deviation on delivery (SD) is high. This, in turn, leads to the high risk of loss of production and high Costs of Unserved Energy (COUE).
- Importantly it often generates electricity when it is not required. Yet, in most management contracts, the electricity supply has to be paid for whether it is needed or not. This is one of the essential features highlighting the differences and advantages of dispatchable power over non-dispatchable power generation. There is an argument that when not available for baseload, it can be used for pump storage. However, there is insufficient water for efficient utilisation of pump storage.
- Practical experience in Germany, South Australia and the United Kingdom appears to prove t that wind is difficult to manage and that the experience is proving to be far costlier than anticipated (Sloan, 2016; Vahrenholt, 2017), although there are contrary views to this held by other experts

It is interesting to note the second point above makes a material difference to the useable load factor. It is repeatedly given out that the load factor of wind is, on average, a maximum of 35%. This means that electricity is not supplied on average more than 65% of the time. In the case of Solar PV, the load factors, on average, are a maximum of 26%. In other words, it does not deliver electricity supply more than 74% of the time.

However, sometimes, power is provided when it is not required. Yet payment for such power must still be made.

One would need to adjust all the figures for the above estimates. Energy planners and experts need to ask serious questions about why one should invest in windfarms that fail to deliver useable electricity 65% of the time. Similarly, in solar PV, should one be investing in a system that does not produce useable electricity 74 % of the time. Wind and solar are costly when cost factors are calculated on these numbers. Solar, during daylight hours, averages a load factor of over 50% and the standard deviation is lower than for a 24-hr period. These arguments alone strongly support the findings of the thesis.

It is known that sea-based windfarms have higher outputs. However, they also come with higher risks. These would also need to be taken into account.

Some further factors that need to be considered, which will either increase the land area required for wind, reduce their efficiency or reduce their nameplate output or raise the costs involved are the following (Wilkinson, 2014; Ashuri et al., 2016):

- Wind turbines have a wake effect, which removes the multiplying number of turbines by each energy capability (Diamond and Crivella, 2011). The back turbines sometimes receive less wind energy due to this diminishing impact source, reducing efficiency between 10% to 30%. Random spacing and optimal placing lead to a substantial increase in the land area required above the claimed packed area of 10 MW per square kilometre.
- Blade abrasion takes between 1 and 2 % off the blade efficiency annually, and after ten years, one has less than 90% of the nameplate rating left as operational (Olauson and Bergkvist, 2018; Olauson, Edström and Rydén, 2017; Wilkinson, 2014).
- Grid demands are variable and extensive. The transient impact on the grid demands increased grid costs and management costs (Greenstone et al., 2019).
- A full backup is required. Apart from this, there needs to be a "spinning reserve" or "alternative storage system", which is expensive (Safaei and Keith, 2015; Greenstone et al., 2019).
- Each more flexible technology suffers from efficiency factors, whether battery, salt storage, or pump storage systems (Safaei and Keith, 2015).
- A wind turbine cannot be used to supply customer demand and supply storage at the same time. Effectively this requires more than double the capacity required.
- Weather-related technologies, such as wind and solar, result in individual units, although they are spread geographically, varying together. Therefore, they are not independent and cannot be considered independent risks. Often, the wind does not blow, and the sun does not shine over a wide area. This results in many units being affected simultaneously. Statistically, there is a higher correlation between units and groups of units than for other dispatchable technologies such as nuclear and coal power generation.
- The additional risks and costs associated with the variability, intermittency and unpredictability of supply increase outages' probability. These outages result in economic losses in the form of Costs of Unserved Energy (COUE) far more frequently than dispatchable electricity-generating technologies.

Some people note that one needs to consider windfarms at sea. This opportunity will inevitably be looked at in due course. It is far more expensive and has not been considered in this paper.

As noted previously, there is no doubt that environmentalists and many landowners oppose these developments. The country subsidises a few, prepared to allow their land to be used for such schemes. This is to the detriment of all the people of the country. Mainly, it is at the expense of some of their neighbours whose property is devalued due to windfarm development.

Effectively, it is an additional tax to support the windfarm developers and their financial backers. Besides, it is a highly regressive form of taxation as the poor inevitably suffer more because of the higher prices (Stephen, 2018). In economic terms, which are hard to calculate, the country's economic and social cost almost certainly far exceeds any so-called benefits in terms of climate change that are not proven and themselves are questioned by experts. Many studies support this view (Berkhout et al., 2019; Hertzberg, 2015; Lamar Smith et al., 2017; Greenstone et al., 2019). The renewable lobbies' ideas are driven internationally and locally by *vested financial and idealistic interests*. The government should take the most robust line possible against them.
Many countries with a high penetration quantum solar and wind are reducing subsidies, their markets for solar and wind are shrinking, and their growth is slowing. Suppliers to these markets have a financial interest in finding new markets for wind technology. Germany appears to be questioning the policy and having a total rethink on its *Energiewende* programme. By the latest 2021, all subsidies will have been withdrawn or suspended. A ceiling or cap on such power has been introduced or proposed. At best, it has not been a success in Germany. The German government temporarily or permanently is withdrawing or constraining subsidies and limiting or possibly eliminating further wind farm expansion. South Australia is taking emergency action to rectify the problems it has encountered. The same is now true of Texas. It must be said that the energy mix is in a state of flux worldwide and the transformation of the electricity generating industry is the subject of intense debate between various parties. In the meantime, overseas solar and wind suppliers are seeking new markets in Africa, particularly South Africa (Sloan, 2016).

The following points are controversial but need to be seriously considered by those making important decisions that could significantly drive the country towards energy poverty and increasing poverty (Anielski, 2016; McGee and Greiner, 2019; Nicolson, 2015).

- The fact is that poverty is one of the biggest problems the world faces (Roodt, 2020). As stated elsewhere, it remains a critical problem in South Africa. Coal and fossil fuels have been the economic growth drivers in industrialised countries, allowing them to overcome this poverty (Epstein, 2015). In effect, the IPCC and the environmentalists recommend stopping using these technologies that can best assist them in overcoming poverty in Asia, Africa, and elsewhere.
- The wealthy few are denying the poor the same energy and technology that helped them raise their living standards. Fossil fuel-derived power allowed these countries to raise their living standards to overcome poverty's misery (Epstein, 2015).
- More than 1.0 billion people in Asia and Africa remain impoverished. The mental and physical medical costs far exceed any such costs associated with modern, "clean-coal" power stations.

- ASEAN countries are not following the COP 21 guidelines because it is not in their economic interest. South Africa should follow that lead.

### 4.6.4 COMPARISON OF IRP BASE CASE AND A RECOMMENDED MIX

This section summarises specific key statistics comparing two electricity generation systems. The first is the IRP 2016 Base case system. The second is a recommended system based on the assumptions made above and the assessments of South Africa's economic and electricity stability requirements over the period to 2050.

- The discussion at this stage is limited to meeting the anticipated electricity demand targets as set out in the IRP 2016 document
- The detailed analysis of costs will primarily focus on the significant components of potential energy sources of supply, namely wind, nuclear, coal, solar and gas.

The estimated outputs of various energy sources are set out below

**Table 9: Electricity generation output by Source**

| | Nuclear | Coal | Wind | Solar PV | Gas | OCGT | Total |
|---|---|---|---|---|---|---|---|
| **IRP Base Case** | | | | | | | |
| **IRP Base Case MW** | 20 385 | 15 000 | 37 400 | 17 600 | 21 960 | 13 332 | **125 677** |
| **Percentage MW** | 16.2% | 11.9% | 29.8% | 14.0% | 17.4% | 10.7% | **100.0%** |
| **IRP MWh per day** | 440 316 | 295 200 | 314 160 | 109 824 | 263 520 | 19 198 | **1 442 218** |
| **Percentage MWh** | 30.4% | 20.3% | 21.8% | 7.5% | 18.2% | 1.8% | **100.0%** |
| **Recommended** | | | | | | | |
| **Mixed System MW** | 20 385 | 37 390 | 0 | 17 600 | 12 000 | 8 500 | **95 875** |
| **Percentage MW** | 21.3% | 39.0% | 0% | 18.4% | 12.5% | 8.8% | **100.0%** |
| **Mixed MWh per day** | 440 316 | 735 838 | 0 | 109 824 | 144 000 | 12 240 | **1 442 218** |
| **Percentage MWh** | 30.5% | 51.0% | 0% | 7.6% | 9.9% | 1.0% | **100.0%** |

Source: IRP 2016, Economicrisk

The IRP Base case consists of an apparent or nominal nameplate 125677 MW, excluding Inga. It can only deliver 14422218 MWh on any day because of the low load factors of renewables.

The recommended mixed system totalling only an apparent or nominal nameplate 95871 MW can deliver 1422218 MWh in any one day because of the higher load factors of nuclear and coal.

Solar PV is selected as renewable in the recommended system. Although it is variable, it can provide more power during the higher daylight demand and with limited storage peak demand periods. Importantly, it has a far higher load factor at 52% during higher demand daylight periods, compared to less than 35% for wind. It is also easily installed and useable domestically for houses, flats, and business offices in the urban environment. Solar can have an adequate current storage capability of delivering power during the evening peak period between 5 pm and 9 pm and, possibly, in the early morning between 5 am and 9 am.

A comparison of the two systems is set out below in greater detail.

**Table 10: Summary of costs of the two systems**

| System | IRP Base case system | Recommended mixed system |
|---|---|---|
| System total nominal MW | 125 677 | 95 875 |
| System total real MW | 60 092 | 60 092 |
| PV Payment over Life of nuclear plant 60 years Rbn | R 6 909 878 | R 7 356 255 |
| System MWh per day | 1 442 218 | 1 442 218 |
| PV per productive MWh | 0.22 | 0.25 |
| PV per productive MW | R114 988 | R122 416 |
| PV over life nuclear plant | **R 1,31** | **R 1,40** |

Source: IRP 2016, Economicrisk PV Present Value

The IRP Base Case system is less expensive than the alternative mixed system. However, the recommended system is more stable and allows for greater flexibility. As will be seen in a later section, renewables' cost and, therefore, a system based on more renewables (higher penetration renewable system) is far greater than indicated (Jeffrey, 2019). Substantial increased Costs are incurred when risk, additional grid costs, other associated system costs and the risk of incurring the Cost of Unserved Energy (COUE) are calculated and included in the PV and LCOE over the life of a nuclear plant (Department of Energy, 2010).

### 4.6.5 SUMMARY OF THE MIX OF THE SYSTEMS

The tables below summarise each system's nominal or nameplate output and compare this to the real output. The IRP base case system excludes Inga.

**Table 11: The IRP base case mix**

| IRP BASE CASE 2050 | | | | | |
|---|---|---|---|---|---|
| Energy Source | Quantity Nominal MW | % Total | Quantity Real MW | % Total | % Real to Nominal |
| Nuclear | **20 385** | 16.2% | **18 347** | 30.5% | 90,0% |
| Coal | **15 000** | 11,9% | **12 300** | 20.5% | 82,0% |
| Wind | **37 400** | 29,8% | **13 090** | 21.8% | 35,0% |
| SolarPV | **17 600** | 14.0% | **4 576** | 7.6% | 26.0% |
| Gas | **21 960** | 17,5% | **10 980** | 18.3% | 50,0% |
| OCGT | **13 332** | 10,6% | **800** | 1,3% | 6,0% |
| Total | **125 677** | **100,0%** | **60 092** | **100,0%** | **47.8%** |

Source: IRP 2016, Economicrisk Note excludes Inga and minor technologies

In the IRP base case, nuclear and coal are rated on installed nameplate output to supply only 28.1% of the total nameplate 125677 MW installed over 2020 to 2050. However, they supply 51.0% of the average 'real' MW available at any time, namely 60092 MW. Wind theoretically totals 29.8% of installed nameplate supply, and only supplies 21.8% of the average real 60092 MW available. The above should be compared with the recommended mixed system below

**Table 12: Mix of recommended system**

| RECOMMENDED SYSTEM | | | | | |
|---|---|---|---|---|---|
| **Energy Source** | **Quantity Nominal MW** | **% Total** | **Quantity Real MW** | **% Total** | **% Real to Nameplate** |
| **Nuclear** | 20 385 | 20,7% | 18 347 | 30,5% | 90,0% |
| **Coal** | 37 390 | 38,0% | 30 660 | 51.0% | 82,0% |
| **Wind** | 0 | 0,0% | 0 | 0,0% | n/a |
| **Solar PV** | 17 600 | 17,9% | 4 576 | 7.6% | 26,0% |
| **Gas** | 12 000 | 12,2% | 6 000 | 10.0% | 50,0% |
| **OCGT** | 8 500 | 8,6% | 510 | 0,8% | 6,0% |
| **Total** | **98 375** | **100,0%** | **60 092** | **100,0%** | **61.1%** |

Source: IRP 2016, Economicrisk Note excludes Inga and minor technologies

Nuclear and coal are rated on the nameplate or installed output in the recommended system to supply 58.7% of the total nameplate 98375 MW installed. However, on average, they provide 81.5% of the 'real' MW available at any one time, namely 60 092 MW. It should be noted that it is recommended that little or no wind is installed after 2020. Wind can be helpful in particular situations, but its variability, interruptibility and unpredictability make it non-dispatchable. This results in its excessively high COUE and makes it unsuitable for baseload industrial or domestic use. These unreliability problems apply particularly to South Africa, where the country has massive coal reserves, is industrialising, and has high levels of poverty and unemployment. Because of this and changing the mix from excessive renewables, the total MW installed drops from 128177 MW to 98375 MW. The % real to installed capacity increases from 47.8% to 61.1%.

**The overnight cost of the system**

The IRP 2016 base case overnight costs were:

**Table 13: Overnight costs of base case system**

| IRP BASE CASE 2050 | | | | |
|---|---|---|---|---|
| Energy Source | Total Overnight Capital Cost Rbns | % | Cost R/nameplate kWh | Cost R/Real kWh |
| **Nuclear** | R 1 648,413 | 45,1% | 0,15 | 0,17 |
| **Coal** | R 607,681 | 16,6% | 0,15 | 0,19 |
| **Wind** | R 714,490 | 19,6% | 0,11 | 0,31 |
| **Solar PV** | R 315,212 | 8,6% | 0,08 | 0,04 |
| **Gas** | R 228,845 | 6,3% | 0,02 | 0,08 |
| **OCGT** | R 138,935 | 3,8% | 0,04 | 0,66 |
| **Total** | **R 3 653,576** | **100,0%** | **0,09** | **0,16** |

Source: IRP 2016, Economicrisk

The IRP system's overnight cost is an average of R0.09/kWh based on the nameplate or installed nameplate capacity. The overnight cost of the real output of the system works out at R0.16/kWh.

The actual overnight costs are:

**Table 14: Overnight cost of recommended system**

| RECOMMENDED SYSTEM | | | | |
|---|---|---|---|---|
| Energy Source | Total Overnight Capital Cost Rbns | % | Cost R/nameplate kWh | Cost R/Real kWh |
| **Nuclear** | R 1 648,413 | 44,6% | 0,15 | 0,17 |
| **Coal** | R 1 514,746 | 41,0% | 0,15 | 0,19 |
| **Wind** | R 0,000 | 0,0% | 0,11 | 0,31 |
| **Solar PV** | R 315,212 | 8,5% | 0,08 | 0,16 |
| **Gas** | R 125,052 | 3,4% | 0,02 | 0,04 |
| **OCGT** | R 88,579 | 2,4% | 0,04 | 0,66 |
| **Total** | **R 3 692,001** | **100,0%** | **0,11** | **0,16** |

Source: IRP 2016, Economicrisk

The total cost of the recommended system appears to be slightly higher. The nameplate costs in R/kWh are marginally higher at R0.11/kWh than the base case system of R0.09/kWh. However, the real costs per kWh delivered are the same at R0.16/kWh. In other words, a renewable-dominated system in terms of capital spent is no cheaper than the equivalent nuclear or coal-dominated system when measured on an actual LCOE basis. The renewable system comes with substantial cost additions because of its instability, interruptibility and additional costs associated with the grid, management of the system and COUE (Pentland, 2014; Greenstone et al., 2019).

## 4.7 DEVELOPMENT OF THE MODEL

### 4.7.1 EXPLANATION OF INCLUDING RISK AND COUE INTO LCOE

There are always periods when electricity is not available. This represents a cost to the economy. There is uncertainty hence a risk and a cost associated with that risk. Any downtime leads to a loss of economic activity measured in terms of turnover, ultimately resulting in a loss of GDP and jobs. Another aspect that needs to be considered is that baseload power during the daytime period is used more than during the night, other than peak periods in the early morning and evening. In other words, more electricity is used during daylight, and more GDP is produced than at night. Most people and businesses work during daylight hours. Thus, there is a higher demand for baseload dispatchable power during daylight than during night-time hours. However, many industries require a constant secure electricity supply at competitive prices 24 hours per day (Nicholls, 2019). Value-added creation during daylight far exceeds that produced during the evening, although value-added per unit of electricity remains reasonably constant. Finally, for several reasons, domestic electricity demand increases during the early evening and morning hours.

- Considering the value of secure dispatchable electricity during a maximum business period and productive GDP creating operating hours is necessary.
- The COUE is the value (in Rands per kWh) placed on a unit of energy not supplied due to an unplanned outage of short or long duration. Optimal planning results from the power system planner balancing the total COUE against the incremental cost to supply the energy not served (Department of Energy, 2010).
- The low reliability of South Africa's generation, transmission and distribution system may lead to interruptions of electricity supply to customers, either randomly selected or selected explicitly because of their load management contracts with the System Operator or the area from which they happen to operate.
- Reserve, redundancy and reliability standards, criteria and targets will be selected primarily to minimise the sum of the cost to the country of the energy supplied and the damage to the customer of the power unsupplied by equipment failure or system inadequacies.
- The economic evaluation of investments affecting the reliability of supply will consider the cost to the customer of unsupplied energy, and its probability of occurrence
- The Cost of Unserved Energy is usually measured in terms of activity and other factors and is far higher than GDP lost. The figure used for COUE by the IRP in 2010 was assumed to be R 75/ kW (Department of Energy, 2010). The IRP 2016 has used assumptions that the COUE was R77.30/kWh.

- The SA economy generated a GDP of some R3991 billion in 2015, resulting in a potential GDP loss of R19.851/kWh.

The COUE estimate is a number that will vary significantly amongst different customer sectors. COUE is not a number that can be measured directly. Instead, it is typically derived from customer research. Assigning a monetary value to COUE puts a shadow cost on the failure to serve energy. There is no price for having the lights out for some customers, e.g., critical health and safety facilities. The COUE is challenging to estimate since it varies significantly among customer load segments and the actual timing of unexpected interruptions.

A specific reserve margin can be chosen by applying various methodologies considered a constraint in planning. Alternatively, it is possible to use different methodologies to decide the optimum level and mix of plant required for investment. Certain technologies offer significantly less risk in their variability and unpredictability than others.

It is submitted that insufficient attention has been paid to these risk factors in recommending the dominant use of renewables, particularly wind and solar, in all the Integrated Resource Plans, including the IRP 2016 and the latest plan, namely the IRP 2019.

When comparing various energy technologies, the vital fact underestimated is the risk factor associated with non-dispatchable power. It can be estimated that almost 60% of economic activity and Gross Domestic Product (GDP) value creation occurs during the day. Therefore, the highest priority needs to be put on dispatchable electricity during peak hour baseload electricity demand periods during the daytime, evening, and early morning.

However, one must remember that many industrial processes require power 24 hours a day. There is equal value to its electricity lost during any period. The cost of not receiving secure cheap dispatchable electricity is difficult to quantify, but it is enormous. African Rainbow Minerals (ARM) and Assore recently built an R3 billion manganese smelter in Malaysia because of the high prices and insufficiently secured electricity supply offered by South Africa. Based on a 10% profit, the country has lost R10 billion in profit each year. Revenue dropped would exceed R3 billion per annum. Rio Tinto scrapped a smelter at Coega some years ago due to uncertainty about electricity supply. Reversal of beneficiation decisions contradicts a critical South African policy goal: to mine and beneficiate its domestic minerals. This is an objective in all National economic plans, including the New Growth Path and the National Development Plan (Department of Economic Development, 2011; National Planning Commission, 2010; Meyer, 2013). Domestic and foreign investment in real economic activity is the largest creator of jobs and long-term economic growth in an economy.

### 4.7.2 DELIVERY COSTS OVER 24 HOURS

The underlying assumptions for each energy source used are set out below. It should be noted here that the methodology used later uses standard deviation (SD) that has been assumed or calculated for each power source. These are based on assumptions and figures that have been made available. A normal distribution has been used as the basis for the calculations. The premises can be changed, particularly the assumptions regarding the standard deviation. However, these are based on available best estimates.

Notwithstanding that, they remain consistent and give a reasonably accurate estimate for the figures that will ultimately be the reality for each system. They appear to be confirmed by real-life experience elsewhere in the world. Wind and solar in South Africa have been grouped into regional areas, namely six regions in the wind and ten regions in solar, respectively. In the instance of nuclear and coal, there were 22 and 18 units respectively. Catastrophic events are excluded from the calculations.

**Table 15: Comparison between technologies**

| Power Source | *Nuclear* | Coal | Wind | Solar PV | Gas |
|---|---|---|---|---|---|
| **Delivery probability** | 90% | 82% | 35% | 26% | 50% |
| **Standard deviation per unit %** | 3% | 4% | 32% | 32% | 5% |
| **Price R/kWh** | R 1.30 | R 1.05 | R 0.62 | R 0.62 | R 1.24 |
| **Nominal nameplate MWh per day** | 489240 | 360 000 | 897 600 | **211197** | **527 040** |
| **Real MWh per 24 hrs MWh** | **440316** | **295201** | **314160** | **109822** | **263520** |
| **Total Name Plate Supply MW** | 20 385 | 15 000 | 37 400 | 17 600 | 21960 |
| **Total average actual supply across all units MW** | 18347 | 12300 | 13090 | 9152 | 10980 |
| **SD (assuming all units & sources operate independently)** | 3129 | 3394 | 117262 | 42744 | 11236 |
| **10th Percentile Real output (Normal Distribution)** | 436364 | 290808 | 163863 | 82435 | 256320 |

Source: IRP 2016, Economicrisk

**Table 16: Comparison between the base case and recommended system**

| | IRP Base | % | Mixed | % |
|---|---|---|---|---|
| **Nameplate MW available** | 128177 | | 98375 | |
| Real Megawatts available | 62342 | 48.6% | 62342 | 63.4% |
| Nameplate MWh per day 24hrs | 2865053 | | 2149798 | |
| Real MWh per day 24 hrs | 1496218 | 52.2% | 1441304 | 69.6% |
| SD (assuming all units & sources operate independently) | 181468 | | 63068 | |
| 10$^{th}$ percentile | 1263664 | 84.5% | 1360478 | 94.6% |
| % Nameplate MWh | | 44.1% | | 65.8% |

Source: IRP 2016, Economicrisk

The above shows that real MWh delivered and MW generated per day can remain at the same level even though the nameplate MW and nameplate MWh have been reduced by approximately 24%, from 2865053 MWh to 2149798 MWh per day. The real capital cost per kWh remains the same at R0.16/kWh.

### 4.7.3 METHODOLOGY 1: ENERGY SOURCE INCREASED FOR LOAD FACTOR

A method that can be used to calculate the actual and more realistic electricity-generating costs of a specific technology is to assume that by increasing the number of units involved from one energy source, it will be possible to generate electricity all the time. Increasing the number of units means theoretically providing power 24 hours a day at the technology's normal LCOE. It is a logical assumption that works in the case of dispatchable technologies. This is not the situation for non-dispatchable high variability, interruptible and unpredictable technologies with low load factors like wind and solar. Therefore, it is not an impartial method, nor does it provide the correct answer. A unit cannot both supply electricity and store it at the same time. Besides, it needs a supply source of power to generate electricity should there be no electricity supply during its allotted time slot. Additional units are required.

In summary, this price comparison method consists of a straight comparison of the generating sources. It is possible to generate the total electricity requirement by increasing the energy source sufficiently to compensate for the variability and efficiency reductions due to the published load factors. It assumes that if the energy sources' volume is increased sufficiently, it will fully compensate for the variability experienced due to low load factors. It is a false and optimistic assumption as there are many periods when the wind does not blow. There are many periods and many days in extent when the sun does not shine. There are also periods when the sun does not shine and the wind does not blow. It also assumes certainty in an uncertain environment. It takes no account of increased grid costs, management costs, system costs and many other factors which can be looked up in the literature. For this reason, an intermittent electricity supply system requires full backup from a dispatchable source of electricity. For all these reasons, it significantly underestimates the actual cost of renewables (Metcalf, 2012; Greenstone et al., 2019).

#### Effective baseload dispatchable costs

The claim is that wind is cheaper and the lowest-cost energy source.

- It sometimes does not produce electricity when required, which is most of the time. In the case of wind, it only provides power on average less than 35% of the time or any given period. Even in this instance, it is variable and unpredictable. Therefore, the probability of not producing electricity is 65% of the time or more. The load factor of 35% is a probability factor. Even when providing power, it is often accompanied by high variability, interruptibility and unpredictability.
- Practical experience in Germany, South Australia, California, Texas and the United Kingdom proves that wind is difficult to manage and that the experience is far costlier than anticipated (Greenstone et al., 2019; Vahrenholt, 2017).

A further argument is made to meet its requirements provided there is dispatchable electricity from other sources. However, this does not consider the backup needs and the difficulties associated with managing this. It assumes certainty of supply management, grid operations and many other details, whereas, in reality, it is a world full of risk and uncertainty. It is impossible to compare electricity prices generated from stable, secure supply sources with high load factors with electricity supplied by highly variable interruptible and unpredictable energy sources with low and variable load factors (Nicholls, 2019; Sklar-Chik, Brent and de Kock, 2016). Overseas research and real-life experience bear testimony to this.

#### 4.7.4 METHODOLOGY 2: PROXY METHOD BY ONLY USING THE APPARENT LCOE AND THE LOAD FACTOR

As a proxy for the real-life comparison of the delivery cost of dispatchable and non-dispatchable power, a methodology that compares these costs and closely resembles real-world cost structures is to divide the LCOE by the load factor.

**Table 17: Methodology 2: Price comparison by load factor between systems**

| Methodology 1 | Nuclear | New Coal | Wind | Solar PV |
|---|---|---|---|---|
| **Load factor** | 90% | 82% | 35% | 26% |
| **LCOE R/kWh** | R1.30 | R 1.05 | R 0.62 | R 0.62 |
| **Effective price R/kWh using load factor** | **R1.44** | **R1.28** | **R1.77** | **R2.38** |
| **Effective price with extra unit R/kWh** | **R1.57** | **R1.47** | **R2.17** | **R2.83** |

Source: IRP 2016, Economicrisk

There is a logical and statistical basis for this methodology. Each technologically should stand on its own regarding dispatchable power during any given period. This methodology does resemble real-world cost structures in several countries. It should be noted that using this estimating technique based on these assumptions, the wind price will be 38% greater than coal and some 23% higher than nuclear. These are underestimates. The technique only calculates for generation during periods when the original unit is not generating. However, it is necessary to have an extra unit to generate and save electricity when the original unit is unavailable and should be produced. This increases wind generating costs so that they are 38% higher than nuclear and 48% higher than coal. Solar costs are significantly higher than nuclear or coal.

The argument is perfectly valid and would increase costs. This gets to the heart of directly comparing dispatchable and non-dispatchable technologies. Many authors, such as Sklar-Chik, noted that it is impossible to compare the two technologies (Sklar-Chik, Brent and de Kock, 2016). Essentially, they do not deliver equivalent products. One is provided and usable on demand. The other does not have this flexibility of meeting demand. The result is that there are marginal changes to the price for dispatchable technologies such as nuclear and coal but a major difference in price or cost for non-dispatchable power sources such as wind and solar.

It should be noted that solar offers a superior load factor during the day than wind at 46% during the daylight period compared to wind at 35%. Therefore, it is more easily managed and predictable than wind, which remains only 35% or less of the time during any specific period. Besides, each does vary per season and time of day. Solar systems only work during daylight hours, so their efficiency, when combined with gas, is higher than wind during this high baseload power demand. Baseload requirements fall off during the night allowing the nuclear and coal-based electricity generating sources their task of supplying 24-hour baseload supply. Effectively they are the only sources that offer the security of dispatchable electricity supply at the lowest cost in many countries such as South Africa.

Some consider this to be an unrealistically simple method. However, each technologically should be able to stand on its own regarding dispatchable power. Wind and solar require backup in the form of storage or other sources. The problem is that no technology can simultaneously generate power for electricity use and storage. Wind delivers electricity on average for 35% for any eight hours per day and during any period during a 24- hour day.

Furthermore, large groups of wind turbines spread geographically widely in one region are not independent. The wind is either blowing or not blowing over a wide area. Indeed, many widely spread areas are not independent and separate. There are a lot of co-dependencies as weather systems move through the country. The argument can go even further. Because of its inconsistency, it needs a backup for itself. Its costs rise further for the need to store and the storage costs involved (Safaei and Keith, 2015). Finally, there are efficiency losses associated with storage systems. All these costs are carried by the power utility or grid operator, in this case, ESKOM. The operator needs to have these power sources online and available on-demand. In other words, it must hold dispatchable electricity in reserve not only as a “spinning reserve”, i.e., immediate supply, but also when notice can be given to start generating. No wonder it is expensive and, therefore, additional costs for the operator, in this case, ESKOM. These additional costs are ultimately passed on to the customer. When electricity is generated and is not required, then once again, it costs grid managers money. These additional costs also occur in the USA (Greenstone et al., 2019). On the relatively few occasions when they are all running, there is excess power, which also causes losses for the grid operators. Ultimately these costs are passed on to users. In Europe, there is the ability to purchase from the grid and sell surpluses back to the grid network (Rentier et al., 2019). Germany has now recognised this failure of its *Energiewende* programme. On a worldwide basis, it is understood that these are hidden additional costs and effectively amount to a tax on consumers, particularly on the poor. It has been found that energy poverty is rising in most countries where wind and solar have been used on a significant scale (Andrews, 2016; Vahrenholt, 2017; Horgan, 2016; McGee and Greiner, 2019).

### 4.7.5 METHODOLOGY 3: RISK ASSESSMENT AND THE COST OF UNSERVED ENERGY

The Cost Of Unserved Energy (COUE) is based on the standard deviation of the various technologies and their combinations. These remain estimates and are subject to multiple assumptions. These have been set out previously. Discussion is essential around these assumptions, but they reasonably compare each technology's actual electricity costs.

#### IRP Base Case

**Table 18: Risk related LCOE**

| Potential Dispatchable Cost | Nuclear | New Coal | Wind | Solar PV |
|---|---|---|---|---|
| **System MW** | 20385 | 15000 | 37400 | 17600 |
| **Nominal MWh** | 489 240 | 360 000 | 897 600 | 422 400 |
| **Real MWh** | 440316 | 295200 | 314160 | 109824 |
| **LCOE Rand** | **R1.30** | **R 1.05** | **R 0.62** | **R 0.62** |
| **Average capacity Load factor** | 90% | 82% | 35% | 26% |
| **Potential GDP lost Rm per annum 10% probability** | R 29.0 | R 31.5 | R 1088.8 | 198.4 |
| **Levelised COUE IRP rates R77.30/kWh R/kWh** | **1.33** | **1.10** | **2.52** | **3.83** |
| **Levelised cost during 12-hour daylight period R/kWh** | **1.33** | **1.10** | **2.52** | **1.91** |

Source: IRP 2016, ESKOM, SARB, EconomicRisk *Prob: Probability

Such a model allows alternative assumptions to be used as more data becomes available. The above table shows that the potential opportunity cost lost due to the variability of wind is high. In summary, it illustrates the unacceptable risk to the economy of having unreliable electricity-generating sources. It is interesting to note that wind is riskier than solar power during daylight periods because solar energy is more predictable during daylight hours. A risk assessment based on these numbers would automatically exclude wind. The risk to the economy of using these power sources, namely wind and solar, on a significant scale is excessive and irresponsible. The factual evidence in the real world where they have been tried substantially, primarily the German *Energiewende* and South Australia, and elsewhere bears this out (Sloan, 2016). In all instances where they are used on a major scale, they have significantly raised electricity prices as they are more expensive and unreliable than anticipated.

It must be stressed that the methodologies used only offer a corrected LCOE giving a proxy for the economic cost associated with the technology. The only correct way is to use a complex model with estimates for all the additional costs that need to be considered for each technology. However, it should be noted that these also do not generally cost all the relevant factors and the mix of selected technologies associated with each technology. They also usually do not charge for their impacts on investment and numerous socio-economic impacts associated with their use, such as the cost of poverty or energy poverty resulting from expensive electricity or failure to supply

(Anielski, 2016). There are always the unknown-unknowns giving rise to sometimes unforeseen severe consequences and costs.

## 4.8 COUNTER ARGUMENTS TO ADDITIONAL COSTS OF RENEWABLES

There is considerable literature available countering the arguments that renewables have high risks and additional costs. This is true internationally and in South Africa. It is also a fact that renewables have been introduced globally in some instances on a significant scale. However, it is also true that, where there has been a significant increase in renewables in wind and solar, there have often been detrimental consequences. Firstly, costs and electricity prices have increased substantially unless they have been heavily subsidised. Secondly, increased extended power shortages have significantly damaged the local economy. Thirdly there has been rising energy poverty, and in some cases, increasing public resentment of renewables has been the consequence once the real impact of renewables has been fully felt. This has been true in Germany, California, Ontario and Australia. In two instances, it has resulted in political leadership changes, namely in Australia and the state of Ontario in Canada.

It is also true that in some cases, while the renewables have failed and would have caused substantial collateral damage, the countries or States have been able to call in significant additional supplies of electricity from neighbouring independent grids. These extra supplies have ameliorated and even prevented economic losses. Invariably this has been because the country or State within a country are part of a larger integrated grid. In Germany, they can sell surplus electricity or call-in extra electricity supply from other countries, in this case, France, which is predominantly nuclear and Poland, where electricity generation is primarily based on coal. In addition, they have increased their dependency on Russian gas. There has been political condemnation that Germany has, in effect, lost its energy sovereignty to Russia. It can also obtain electricity from Scandinavia or Switzerland, which are based on hydroelectricity. In the case of States and cities in the United States that have significantly increased their solar and wind capacity, their electricity variations caused by wind and solar intermittency are cushioned by the inter-state grid available to them. The fact remains that the South African electricity grid is isolated, and support from neighbouring countries does not exist on any scale. Therefore, economic, social and political risks for South Africa are far higher, and hence potential additional costs are substantially higher.

There have been extensive studies of wind and solar potential globally and in South Africa. The Energy Centre at the CSIR has done wide-ranging work in this field. The CSIR is South Africa's national research organisation established in terms of the Scientific Research Council Act of the Parliament of the Union of South Africa.

The CSIR, the South African National Energy Development Institute (Sanedi), ESKOM and Fraunhofer IWES did an extensive study in 2016 on the Wind and Solar PV Resource Aggregation

Study for South Africa (Knorr, 2016). "This study was carried out to increase the fact base and understanding of aggregated wind and solar photovoltaics (PV) power profiles for different spatial distributions of these renewable energy sources throughout the whole country."

In summary, some of the primary findings of the study included:

- "The wind resource potential is as good as the solar resource. Almost the entire country has sufficient resources with potential for very high load factors and, thus, profitable wind projects;
- While the solar irradiation and electricity generation from solar PV shows nearly no seasonality, wind speeds and generation from wind closely follows the demand over the year;
- Gradients of the electricity feed-in from wind generation can be reduced noticeably through aggregation effects (more distributed wind turbines result in reduced fluctuations). A wider distribution of turbines also leads to a significant reduction in forecast errors;
- The low seasonality in wind conditions and solar irradiation allows a steady electricity supply from renewable energies than the rest of the world. This makes integration of wind and solar PV easier; no seasonal storage is required in particular;
- Finally, up to 20 to 30% energy share of variable renewable energies (wind and solar PV) for the whole country will not increase short-term (15 min) gradients or ramps significantly if there is a balanced combination of wind and solar PV in the electricity system."

The report concluded that "South Africa has perfect conditions to introduce a huge number of variable renewables into the electricity system in a cost-effective way."(Knorr, 2016)

The report accepts the vital and faulty assumption that wind and solar are suitable alternative energy sources. This assumption is incorrect and severely flawed. There are many points of view on this subject (Söder et al., 2019).

It is not intended to counter these findings. They could be debated when considering other technologies' strengths and weaknesses and the defects that renewables, particularly wind and solar, have. Several crucial issues are addressed in this thesis, including:

- The environmental requirements to introduce such energy sources and the ecological impacts of their introduction
- The additional costs associated with wind and solar
- The comparative costs of alternative technologies
- The risks and the costs associated with non-performance when utilising wind and solar
- The economic benefits and losses associated with significant changes in energy technology in a country that is already richly endowed with fossil fuels

These considerations are critical in making any decision about renewable and substantial changes in energy and electricity-generating technologies in the South African environment

### 4.9 SYSTEM COMPARISON OF RISK-RELATED LCOE

The recommended mix has the same nuclear and solar PV quantity as the IRP 2016 base case. Coal has been increased substantially, and considers new build and refurbishment of old coal-fired power stations. Wind has been excluded from the mix. Gas has been dramatically reduced in electricity generation requirements due to increasing dispatchable electricity generated by coal and nuclear. If gas is discovered domestically, gas will be used for industrial development or, more significant, power generation. Such alternatives should only be considered if competitive South African gas exists. Otherwise, South African imports could increase dramatically, and the balance of payments would be adversely affected.

Comparing the two systems, the IRP 2016 base case mix and the recommended mix are revealing.

**Table 19: System Comparison of risk related LCOE**

| Potential Dispatchable Cost | Base IRP | Recommended |
|---|---|---|
| **System MW** | 125677 | 95875 |
| **Real MW available** | 60092 | 60092 |
| **Nominal MWh** | 3 016 248 | 2 301 004 |
| **Real MWh** | 1 442 218 | 1 442 218 |
| **LCOE R/kWh** | **1.09** | **1.17** |
| **Average capacity Load factor** | 47.8% | 62.7% |
| **IRP Activity Loss Rm per annum COUE** | R5 012 | R2 280 |
| **Levelised cost including IRP rates COUE R/kWh** | **1,45** | **1,22** |

Source: IRP 2016, EconomicRisk

It can be deduced from the above that the LCOE for the IRP 2016 appears to be slightly cheaper than the recommended mixed system at R1.09/kWh compared to R1.17kWh for the recommended mixed system. The outcomes assume no variability and perfect transitions from one power source to another power source. In other words, the underlying assumption is certainty and no periods of non-supply of electricity. Hence no estimate is made of COUE. These conditions do not exist in the real world.

The assumptions of the model utilise standard deviation and a normal distribution, the economic Levelised Cost for Electricity for each of the two-generation mixes and adjust these costs for the potential economic costs associated with the risk of non-performance (Vavi, 2019; Jeffrey, 2019)

The model adjusting for economic risk uses the potential economic activity losses as measured by the COUE. The IRP 2016 assumption for the Cost Of Unserved Energy (COUE) is R77.30/kWh. As a result, the IRP 2016 base case economic LCOE becomes considerably higher than the recommended mix.  Using this methodology, the base case figure is approximately R1.45/kWh or 19% higher than the LCOE for the recommended mixture of R1.22/kWh.  It should be noted that these figures are lower than the actual increases in prices of electricity associated with other countries using wind as a significant electricity-generating source, such as Germany, Denmark, Spain, Texas and South Australia.  It is closer to the figure for Ireland.  The land area of Ireland is tiny in comparison to South Africa.  The grid network is only 4700 MW compared to South Africa's more than 30000 MW network.  Therefore, the values calculated are probably conservative and do not consider other grid management and system costs.  It also should be noted that the higher the use of wind in the different scenarios laid out in the IRP 2016 scenarios, the worse the situation becomes, resulting in even higher costs for delivering unreliable electricity.  These, therefore, have not been considered and would not be recommended

Various assumptions have been used.  These could be improved with possibly more accurate assumptions if and when such data is available.  However, it is believed that these figures are conservative estimates and give a close approximation to reality.  The figures are also supported by the findings of other reports showing significant additional costs associated with non-dispatchable intermittent renewable energy sources.  They tend to prove the situation that exists in the real world, namely that renewables, in the form of wind and solar, are not cheaper than coal and nuclear and that the figures often bandied about are incorrect in terms of the technique used and the reality that exists in the real world.  There are numerous reports on this subject, and some of them are cited here for convenience of reference (Joskow, 2010; Mount et al., 2012; Hughes and Barnett, 2012; Foundation, 2013; Pentland, 2014; Bryce, 2015; Peacock, 2016; Koko, 2016; May, 2017; Heard et al., 2017; Greenstone S et al., 2019; McGee and Greiner, 2019).

### 4.9.1 RISK-RELATED LCOE OF THE UNCONSTRAINED PLAN

This section examines the unconstrained plan put forward by the CSIR.  This must be considered the ultimate plan that the renewable lobby and the green party planners envisage for the future energy plan in South Africa.  This section illustrates that the greater the use of unreliable renewables, the higher the risks and the country's economic cost.

### Table 20: Base case and recommended generating capacity to 2050

| Comparison of the IRP 2016 Base case and Recommended Systems mix | | | | |
|---|---|---|---|---|
| | IRP Base case | Recommended | IRP Base Case | Recommended |
| Energy Source | Nominal MW | Nominal MW | Real MW | Real MW |
| Nuclear | 20 385 | 20 385 | 18 347 | 18 347 |
| Coal | 15 000 | 37 390 | 12 300 | 30 660 |
| Wind | 37 400 | 0 | 13 090 | 0 |
| Solar PV | 17 600 | 17 600 | 4 576 | 4 576 |
| Gas | 21 960 | 12 000 | 10 980 | 6 000 |
| OCGT | 13 332 | 8 500 | 800 | 510 |
| Inga | 2 500 | 2 500 | 2 250 | 2 250 |
| **Total** | **128 177** | **98 375** | **62 343** | **62 343** |

Source: IRP 2016, EconomicRisk

### Table 21: No constraints and revised recommended systems mix

| Comparison of the IRP 2016 No constraints and Revised Recommended Systems mix | | | | |
|---|---|---|---|---|
| | IRP No Constraints | Revised Recommended | IRP No constraint s | Revised Recommende d |
| Energy Source | Nominal MW | Nominal MW | Real MW | Real MW |
| Nuclear | 5 436 | 23 400 | 4 892 | 21 060 |
| Coal | 0 | 53 550 | 0 | 43 911 |
| Wind | 106 100 | 0 | 37 135 | 0 |
| Solar PV | 50 060 | 19 133 | 13 016 | 4 975 |
| Gas | 35 136 | 21 960 | 17 568 | 10 980 |
| Solar CSP | 0 | 0 | 0 | 0 |
| CCGT | 13 068 | 8 500 | 784 | 510 |
| Inga | 2 500 | 2 500 | 2 250 | 2 250 |
| **Total** | **212 299** | **129 043** | **75 645** | **83 686** |

Source: IRP 2016, EconomicRisk

### Table 22: System Comparison of risk related LCOE

| Potential Dispatchable Cost | Base No constraints | Revised Recommended |
|---|---|---|
| System MW | 212 299 | 129 043 |
| Real MW d available | 75 645 | 83 686 |
| Nominal MWh | 4 072 835 | 2 603 913 |
| Real MWh | 1 815 478 | 2 140 212 |
| LCOE R/kWh | **0.87** | **1.15** |
| Average capacity Load factor | 35.6% | 64.9% |
| IRP Activity Loss Rm per annum COUE | R12 727 | R2 956 |
| Levelised cost including IRP rates COUE R/kWh | **1.74** | **1,18** |

Source: IRP 2016, EconomicRisk

It can be seen from the above that the real economic LCOE using the IRP 2016 rate for COUE of R77.30/kWh has increased 20% from R1.45/kWh to R1.74/kWh. The result is a substantial increase in highly variable, interruptible and unpredictable wind. The scenario No Constraints in the IRP using this methodology is 47% higher than the alternative recommended generation mix. This is the planned future of this country. The economic, social and political impacts on this country will be catastrophic.

### 4.10 CONCLUSION

This chapter evaluated the real cost of generating electricity for the primary technologies used in South Africa to determine the least-cost energy mixture. The study was limited to Coal, Solar, Wind and gas. The strengths and weaknesses of the methodology currently favoured by renewable lobby groups and energy planners in South Africa, where the least-cost mix is determined by utilising the Levelised Cost of Energy, were examined. The literature is replete with articles focusing on the weaknesses of the LCOE methodology. These weaknesses emphasise that all electricity delivered is not equal, and there is a distinct difference between dispatchable and non-dispatchable electricity. In particular, the price or cost at the gate of the supplier and the cost of electricity supplied to the user, i.e., ‘supply at the gate of the user’. The impact of the load factor and the life of the technology were discussed. The role risk and uncertainty play in economic activity losses and costs were considered. A model based on the introduction of these concepts to the electricity generating costs of these technologies was utilised to calculate the real costs of electricity supplied by each technology and the least-cost mix. The chapter concluded that the value of wind and solar as a source of power for an industrialising economy such as South Africa is significantly higher than that of coal and nuclear.

# 5 ADDITIONAL COSTS MODEL DEVELOPMENT REVIEW AND ANALYSIS

## 5.1 THE REALITY OF ADDITIONAL COSTS OF WIND AND SOLAR

This chapter examines the additional cost that wind and solar add or impose on a system in greater detail. It is claimed that wind and solar are far the cheapest electricity source, and these sources should dominate the future electricity supply. There are many complex issues that are involved. These include environmental issues and many other externalities. This section focuses on known costs and subsidies and excludes these other issues. That is not to say these other issues are unimportant or that no additional costs are involved. All energy sources and associated technologies are subject to similar problems and additional charges to varying degrees. Still, those imposed by wind and solar are often hidden and subsidised by others. They are significant but are left out of costing information. They are not taken into account the LCOE calculated, which only measures the costs at the gate of the supplier, not those at the demand user's door. Let alone including those costs imposed on the economy and the user because of their unreliability, variability, interruptibility and unpredictability.

Wind and solar claim a cost of 62 cents/kWh. This is the price at the gate of the supplier. It does not include all the charges of supply necessary to convert this electricity from a non-dispatchable electricity supply at the gate to a dispatchable electricity supply at the point of supply to the customer. These costs are paid either by the utility, ESKOM, or other suppliers to achieve this result. Either way, customers pay directly or indirectly via additional charges or taxation. These are, in effect, direct subsidies to solar and wind suppliers, whereas they should be added as a cost to the renewable energy suppliers.

The following basic facts concerning energy sources considered, namely solar, wind, coal, and nuclear are critical to the debate. Hydro, biomass and thermal have different qualities and are not discussed here. Hydro and Thermal are unavailable in quantity in South Africa and hence are not options. At this stage, gas is another fossil fuel not found in sufficient economic quantities in South Africa. They receive substantial subsidies paid by other energy suppliers and the electricity utility, in this case, ESKOM or other customers. Critical issues are that solar and wind have very low load factors. Wind’s load factor averages only 35% or less, and solar 26% or less. Their supply being weather dependent, is highly variable, intermittent, interruptible, unpredictable and unreliable. Since, on average, wind supply from these sources is not available more than 65% of the time, electricity supplied from these sources needs substantial backup. This back- up must be available 100% of the time, 24/7.

In summary, the availability of a backup supply must be 100% of the time, and its utilisation is usually 65% of the time or higher at various times. This supply backup must be available directly or by way of storage. There are claims that these facilities are only required for limited periods. Superficially, this appears to be correct, but closer examination reveals the full extent of the backup needed. Risk and probability theory discloses that there will be prolonged periods of shortages in supply at intervals. Most reports from renewable lobbyists suggest that only limited gas reserves must be stored. In practice, these supplies have to be extensive, and they require distribution and storage on a countrywide basis. These risks and costs are not taken into account. Nor is the significant negative impact on the balance of payments mentioned or considered.

Coal usually has a load factor of approximately 80% and nuclear an average of 90% when operating efficiently. The load factors here are affected by predictable maintenance requirements and, generally, to a lesser extent, by unpredictable repair requirements. A reserve margin (or backup) of 20% has traditionally been considered sufficient to cover both these events.

Attention must be drawn to the work of Joskow of the Massachusetts Institute of Technology published in February 2011. He demonstrated that

> "Levelised cost comparisons are a misleading metric for comparing intermittent and dispatchable generating technologies. The reason is that they fail to take into account differences in the production profiles of intermittent and dispatchable generating technologies and the associated large variations in the market value of the electricity they supply. Levelised cost comparisons overvalue intermittent generating technologies compared to dispatchable baseload generating technologies" (Joskow, 2010; NEA OECD, 2018).

Work by Sklar-Chik et al. supports these findings (Sklar-Chik, Brent and de Kock, 2016). Other commentaries on the subject are available (Koko, 2016; Partridge, 2018; Aldersey-Williams et al., 2018; America's Power, 2019).

Joskow uses a simple set of numerical examples representing actual variations in production and market value profiles. These examples show intermittent and dispatchable generating technologies with the same Levelised total costs per kWh supplied can have different economic values. Due to differences in the economic value of the electricity they produce, they do not consider differences in the production profiles of intermittent non-dispatchable and dispatchable generating technologies. In essence, there are significant variations in the market value of the electricity they supply, resulting in an overvalue of intermittent generating technologies. The benefits of the power provided are flawed because all MWhs supplied are treated as a similar product governed by one price law (Pentland, 2014). The quantum involved can be up to four orders of magnitude. There should be a focus on the short-term network operating challenges and associated costs. Additional costs are created by rapid swings in output, wide variations in output from one day to the next, and the difficulties of controlling output consistent with balancing supply and demand efficiently and meeting network requirements.

Another scholar, Tim Mount, brings an interesting angle to this discourse. In his paper of January 2011, he deals with the hidden system costs of wind generation. These hidden costs are ignored (Mount et al., 2012). Further comments are made by other experts (Koko, 2016; Lamar Smith et al., 2017; NEA OECD, 2018).

Finally, attention must be drawn to the value of electricity to the power delivered to the consumer. One of the most significant differences lies between variable intermittent non-dispatchable electricity to secure, reliable dispatchable electricity. Each customer has different needs and places different values on the electricity delivered. A specialist in an operating room in a hospital about to undertake heart or brain surgery places a substantial premium on receiving reliable electricity supplies. A business running a continuing process or beneficiation process puts a premium on getting a secure electricity supply. A restaurant places a premium on electricity supplies at breakfast, lunch and dinner times. Households and families also have differing needs and place a premium value on reliable supplies. Research in South Africa and elsewhere confirms this, and the research by Nkosi et al. (Nkosi and Dikgang, 2018) emphasises this.

> "The picture that emerges is that 'Overall, South African households place a significant value towards avoiding the interruption' … The massive blackout has left millions of people without power. South Africa's power crisis has widespread effects on both social and economic development. South African households would like more investment in electricity infrastructure, and their willingness to pay (WTP) to avoid blackouts implies that they would not want to leave the future of the electricity grid to chance" (Musango, 2014. Nkosi and Dikgang, 2018)

Research has shown that the risk of outages rises with higher penetration of renewables such as wind and solar. These costs are not borne directly by renewable energy sources (Quezada, 2006; Metcalf, 2012). They are effectively passed on to consumers and customers. They, in turn, are willing to spend additional sums of money on alternative sources of power band backup systems in the form of storage through batteries or backup generators. These are hidden subsidies to the renewable industry.

These flaws have both a cost and a value implication. Summarising these effects, it can be said that the cost or price of electricity at the supplier's gate is very different from the cost or price of electricity delivered to the customer, i.e., 'at the gate of the user'. The LCOE of electricity is the electricity cost at the generating source's gate. The above findings strongly argue that the difficulties and risks involved in delivering and managing this electricity supply need to increase these costs or prices. In the case of intermittent electricity, these additional costs will be substantial.

## 5.2 DEFINING THE ADDITIONAL COSTS OF SOLAR AND WIND

The additional costs that should be added to the claimed expenses of 62 cents/kWh for solar and wind include the following items, as at this stage, it is apparent that these costs are not included in the claimed expenses. Ultimately, these additional costs must be quantified in cents/kWh. The additional costs to ESKOM, other suppliers or directly by customers can be quantified in R millions /annum (ESKOM, 2016; PeacockB, 2016; Metcalf, 2012). The point must be made that additional costs are attributable to all systems. These costs can fluctuate substantially with fluctuations in the efficiency of the system. This will also depend on efficient maintenance and management of the grid and system. This is something that is bedevilling South Africa's power system at present. They include:

1. *Additional grid costs:* Most wind farms are far from the existing grid and customers. Not only do transmission lines have to be built, but they will only be used less than 35% of the time. More significant inefficiencies cause losses in the grid because of the greater distances involved and, in many cases, lower voltages utilised. This suggests that the grid costs of wind will almost certainly be higher than the grid costs of dispatchable power units.
2. *Backup costs:* 100% backup must be available 100% of the time. Backup is utilised on average 65% of the time or more. But for some periods, for a very limited period. Assuming coal or nuclear compared with load factors of about 80% and 90%, respectively, only 20% of backup power needs to be kept, and this will only be used on average 20% of the time or less. The backup capital costs of wind would be approximately 5X (5 times) higher per kWh (100/20) than, say, coal, with running costs about 3.25X (i.e., 65/25) that of reliable dispatchable power supply such as coal.
3. *Efficiency loss of backup and alternative electricity supply:* Backup power or other power supplies would only be used where necessary. As a result, due to low utilisation, backup facilities would typically be running well below their optimal efficiency. In effect, their efficiency loss is a direct subsidy of solar and wind, in this example, wind. The efficiency loss and costs incurred by backup or alternative electricity suppliers would need to increase the wind electricity price. This would suggest the efficiency loss could be approximately 54% [(100-65)/65]. There would need to be a price increase of the backup or alternative electricity supplier of the same amount, 54%. This estimate is based on solar and wind used only 65% of the time, i.e., it runs at only 65% efficiency.
4. *Excess supply of electricity:* Because electricity supply from solar and wind is variable, unreliable, intermittent and unpredictable, there will be periods where a surplus of electricity will be generated. Regarding the Power Purchase Agreements (PPA), ESKOM must pay the renewable producers for the excess power. There are periods when other electricity producers producing secure dispatchable power cannot close the plant or reduce the electricity generated. All these are additional costs that, at present, are paid by the utility (ESKOM) or other electricity producers. These additional costs will ultimately be paid by consumers. Usage, where for coal the load factor is about 80% of the time, nuclear approximately 90% and only 35% for wind suggests that surplus electricity occurs at least about 2.3X [80/35] more frequently using wind energy. European countries, e.g.,

Germany, have regular large-scale exports available because they are on an integrated grid. SA does export to its neighbouring countries in terms of various agreements that it has. However, ad hoc sales due to sudden excess supply are more difficult to handle. Such sales are usually on a limited scale. States in the USA can also sell this surplus capacity or supply it to another state in the vicinity.

5. *Insufficient electricity supply due to technology being unable immediately to close the gap between supply and demand:* Because electricity supply from solar and wind is variable, unreliable, unpredictable and intermittent, there will be periods where a shortage of electricity supply will exist. Even though they require substantial backup, there will be periods when the backup will not be available. This will arise because models indicate certainty of supply, the real world is governed by uncertainty, and backup will not be immediately available. There will, for a period, be no supply before supply increases sufficiently to cover the deficit. Such a shortfall could arise because the system will not adjust immediately to meet the supply-demand imbalance. The potential electricity supply gaps from such situations can be estimated using statistical techniques utilising the different electricity technology sources' statistical variability. The economy would suffer as a result of a lack of economic activity. This would result in an economic and financial cost measured by the Cost Of Unserved Energy (COUE); Department of Energy, 2019). Inefficiency at coal-fired power stations is currently having a severe economic impact on the economy.
6. *High Economic Cost of Unserved Energy:* The economic cost of Unserved Energy (COUE) can be measured, and these costs are high. The 2016 IRP estimates the COUE at R77.30/kWh. This COUE of R77.30/kWh is per the National Energy Regulator of South Africa (NERSA) study. This has increased from the R75.00/kWh previously estimated in 2010 by NERSA. In 2019 it was increased further to R87.85/kWh in the IRP. In December, a senior energy expert estimated that load shedding had cost South Africa over R1.0 trillion over the previous decade or about 1.5% GDP growth per annum.
7. *Insufficient electricity supply due to extended periods of weather-related conditions:* Solar and wind depend on unpredictable and highly variable weather-related conditions. There will be extended periods when the electricity supply could fall well below average. As a result, supply would not be available at all for extended or unexpected periods. This lack of supply could involve long periods of excessive cloud, no wind or extreme wind making electricity generation impossible. The country or parts of the country could be entirely dependent on backup-generated electricity, which cannot immediately be supplied to meet demand. Gas backup supply may not be available during the period, and the market may exceed the gas supply storage for gas generators. Gas storage has to be countrywide and has to be substantial. The risks and costs for this have never been estimated or calculated.

8. *The higher the penetration of low load, high variable intermittent technologies, the higher the Cost of Unserved Energy:* Models are invariable only as good as the assumptions used. Most models assume certainty of output and do not consider risk and uncertainty. The fact is that the real world is subject to risk and uncertainty. Several uncertainties and risks are not considered in the current set of models. Firstly, there is a pause and delay before new generation technologies come online when a technology closes down. Secondly, as set out, the outage period can increase and exceed the average planned for such outages. Under such circumstances, backup supplies become inadequate.
9. *Reduction in ESKOM sales due to artificially low prices offered by renewable suppliers:* Installation of renewable power directly at customers' or potential customers' premises of ESKOM reflects lost demand or sales at ESKOM or lack of growth of the market at ESKOM. A simplistic example would be at a factory or mine or even a solar installation at a customer's shopping centre or residential house.
10. *Cost of backup for installation directly supplied by solar and wind:* If there is a reduction in such customers' electricity supply, ESKOM would be expected to provide immediate backup supply at standard costs. ESKOM must have substantial reserves readily available. This is costly. These costs incurred by ESKOM are not charged or costed into the technology causing the problem. This amounts to a subsidy to the technology and its investors.
11. *Cost of purchasing electricity from customers with their renewable installations:* The trend is that customers can sell their surplus electricity supply to ESKOM. Invariable, there is a commitment to purchase, reducing the perceived backup required. However, this is not the actual situation, as backup is still necessary for standard backup requirements and the complete installation of the renewable supply at the customer’s premises. In reality, such customers are, in effect, receiving hidden subsidies from ESKOM paid for by ESKOM, and these additional costs are inevitably passed on to other ESKOM customers. Unfortunately, coordination and cooperation between the various departments controlling supply are lacking, and efficient economic electricity supply has suffered. Either way, customers are paying for the additional costs involved.
12. *Destruction of industries and political, social-economic impacts:* The move to solar and wind, as set out in the IRP, would result in a major shrinking of South Africa’s coal industry. Coal mining accounted for 26.7% of the total value of mining production in 2015, making it the most valuable in sales of the 14 primary mining commodities ((Fossil Fuel Foundation, 2016; Jeffrey, 2017d; Jeffrey, 2017c). A report by Econometrix prepared in 2018 indicates that the country's coal industry would be adversely affected. The report found that the negative impact on the coal industry would reduce the GDP of South Africa by over 2.5% or R75.2 billion. The compensation of employees would be reduced by R25.1 billion. The investment would be expected to be R3.8 billion lower per year.

Government tax income would be reduced by R16.2 billion. There would be a loss in employment of 29000 jobs in the coal mining industry alone and almost 162000 jobs in the economy (Jeffrey and Jordaan, 2017b). Approximately 1 million dependents would be adversely affected. A number of previously prosperous communities in Gauteng and South Africa would become ghost towns with rising unemployment and increasing poverty levels. Social benefit costs would increase dramatically.

13. *Lack of permanent Job creation:* Renewable energy sources do not give rise to permanent jobs being created. Most jobs created by solar and wind relate only to their construction phase. Most jobs, mainly skilled jobs, are produced overseas in countries supplying equipment. These countries would primarily be Germany for wind-related equipment and China in the case of solar equipment.
14. *Export of jobs and Loss of energy sovereignty:* The move toward solar and wind will mean that South Africa loses its energy sovereignty, primarily to Germany for importing technology and equipment related to wind and China for material related to solar. Substantial gas imports would also be required. South Africa will effectively export its skilled jobs overseas and suffer a loss of skills. Instead of South Africa being an energy exporter, it will become an energy importer due to losing coal exports and becoming dependent on gas imports.
15. *Creation of a current account deficit and not utilising valuable natural assets:* Coal is one of South Africa's most significant commodity products. It is also one of the country's largest exports. It is also the country's largest by value commodity export. (Falcon et al., 2013; Fossil Fuel Foundation, 2016) The importation of gas and coal export loss will result in an increasing and substantial current account deficit. Coal mining accounted for approximately 26% of the total value of mining production in 2015, making it the most valuable in sales. Potential uranium reserves are also substantial. The drive for wind would deprive South African citizens of these benefits. South Africa has 55 billion tons of coal left which would last over 100 years. The discounted value of coal reserves is more than ten trillion Rand. The value of Uranium reserves is probably equal to this. South Africa cannot afford to leave these valuable assets and their value-added buried in the ground. They represent each South African working-age value of over R500000 per working person (R0.5 million/per working person).
16. *Levelised Cost of Electricity (LCOE) is not a sound methodology to compare highly variable and interruptible electricity technologies with electricity supplied by reliable and virtually continuous energy-generating technologies* (Jeffrey, 2017a). A report entitled *'Critical Review of The Levelised Cost of Energy (LCOE) Metric', by Sklar-Chik et al., South African Journal of Industrial Engineering December 2016,* concludes that "LCOE neglects certain key terms such as inflation, integration costs, and system costs." They note, "Many international reports prove that such electricity supply is costly due to

its variability, interruptibility, inefficiency and its requirement of 100% backup" (Sklar-Chik, Brent and de Kock, 2016). Joskow et al. of the Massachusetts Institute of Technology, published in February 2011, wrote a paper entitled Comparing *the Costs of Intermittent and Dispatchable Electricity Generating Technologies*. The paper demonstrated that LCOE comparisons are a misleading metric for comparing intermittent and dispatchable generating technologies. This is because they fail to take into account differences in the production profiles of intermittent and dispatchable generating technologies (Joskow, 2010). The paper uses a simple set of numerical examples representing actual variations in production and market value profiles. These profiles show that intermittent and dispatchable generating technologies with identical Levelised total costs per kWh supplied can have different economic values due to the arrangement and form of electricity they produce.

17. A study entitled *"Nuclear Energy and Solar and wind: System Effects in Low-carbon Electricity Systems investigated" 2012* by the Nuclear Energy Agency (NEA) and Organisation for Economic Co-Operation and Development (OECD) estimated the additional grid costs alone would amount to more than R0.3/kWh (NEA, 2012; WNA, 2019). A similar result and other factors can be found in the study entitled *The Full Costs of Electricity Provision* 2018 by the NEA and the OECD (NEA OECD, 2018; Heard et al., 2017; NEA OECD, 2018). Various in-depth studies by experts around the world substantiate this fact. Such papers and reports include a recent Australian Research study by GHD and *Solstice Development Services entitled "HELE Power Station Cost and Efficiency Report."* (Solstice, 2017) Another study by *B.P. Heard et al. entitled a 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems'* concluded that "there is no empirical or historical evidence that demonstrates that such systems are feasible (Heard et al., 2017). They also reviewed the CSIR proposals. The study concluded,

    > "Both the use of the terms 'technically feasible' and the attempted costing of the proposed system are inappropriate and premature".

18. Naturally, this finding has been refuted by Brown and others (Brown et al., 2018a; Oyewo et al., 2019). This work included Niemz, who led a team at the CSIR advocating this generation mix. The research report aggregation study of wind and solar PV in South Africa by Fraunhofer in conjunction with Sanedi, the CSIR and ESKOM, concluded that

    > "South Africa has perfect conditions to introduce a very large number of variable renewables into the electricity system in a cost-effective way." Their conclusion was, "The magnitude and cost competitiveness of wind power in South Africa is on par with solar PV. Solar and wind energy are very low-cost bulk energy providers in South Africa" (Fraunhofer, 2016).

This is in direct conflict with other reports, the reality on the ground and the results and statistics on the actual performance of windfarms and solar PV provided by ESKOM.

19. A research report by *Weißbach* on Energy Returned from Energy Invested (EROI) in Germany showed that solar and wind are uneconomic and will lead to economic stagnation (Weißbach et al., 2013; Raugei et al., 2015). These hidden costs appear to be ignored in current models (Mount et al., 2012; Koko, 2016)
20. *Methodologies and more realistic estimates of the real costs of solar and wind*: Many calculation methods are trying to prove one side of the argument or the other. The simple or "*simplistic*" approach using the load factor alone uses unpretentious logic. The case is that each technology should be able to support its own electricity supply. The simplistic calculations are that the cost of wind is R1.77/kWh (100/35XR0.62)). The cost of solar is R2.38/kWh (100/26X62) cents. These costs compare to coal, estimated at R1.31/kWh (100/80XR1.05) and nuclear at R1.44/kWh (100/90XR1.30). These are purely guideline estimates and do not consider the additional grid costs or previous costs. More complex methodologies take the risk and uncertainty of outages into account and use variance or standard deviation as the risk estimate, putting the costs of wind at R2.52/kWh, coal at R1.10/kWh and nuclear at R1.33/kWh.

21. *The test of global reality*: There is nothing like the test of global reality. In 2016, the prices paid by industry in Germany were approximately 52% higher than in France (nuclear) and 86% higher than in Poland (coal). The average estimates discussed above result in costs close to this global reality. It is a reality that there is no country in the world with high penetration of solar and wind where electricity prices are lower than coal or nuclear-powered electricity where available. This includes Denmark, Germany, Ireland, and states within South Australia in Australia and California and Texas in the USA. Ontario in Canada found problems with solar and wind renewables there. Political leadership changed, withdrawing and reversing support for this renewable programme. Doubtless, with more political changes, policies will be reversed yet again. Many such countries and states are experiencing energy poverty and deindustrialisation. High-growth emerging economies such as China, India, and the ASEAN countries focus on using fossil fuels and nuclear. This is also true of Russia and countries in Eastern Europe, including countries such as Poland.
22. A further report by Schernikau (Schernikau et al., 2022) entitled Full Cost of Electricity "FCOE" and Energy Returns "EROI" confirms many of the above findings

### 5.3 METHODS TO OVERCOME WEAKNESSES OF LCOE

Wind and solar have been known as energy sources since humans' earliest existence on the planet. They were replaced by coal and fossil fuels, which have brought about incredible increases in production and output, along with a quantum leap in the standard of living of the human species (Mills, 2019). fossil fuels are now the dominant source of energy in the world.

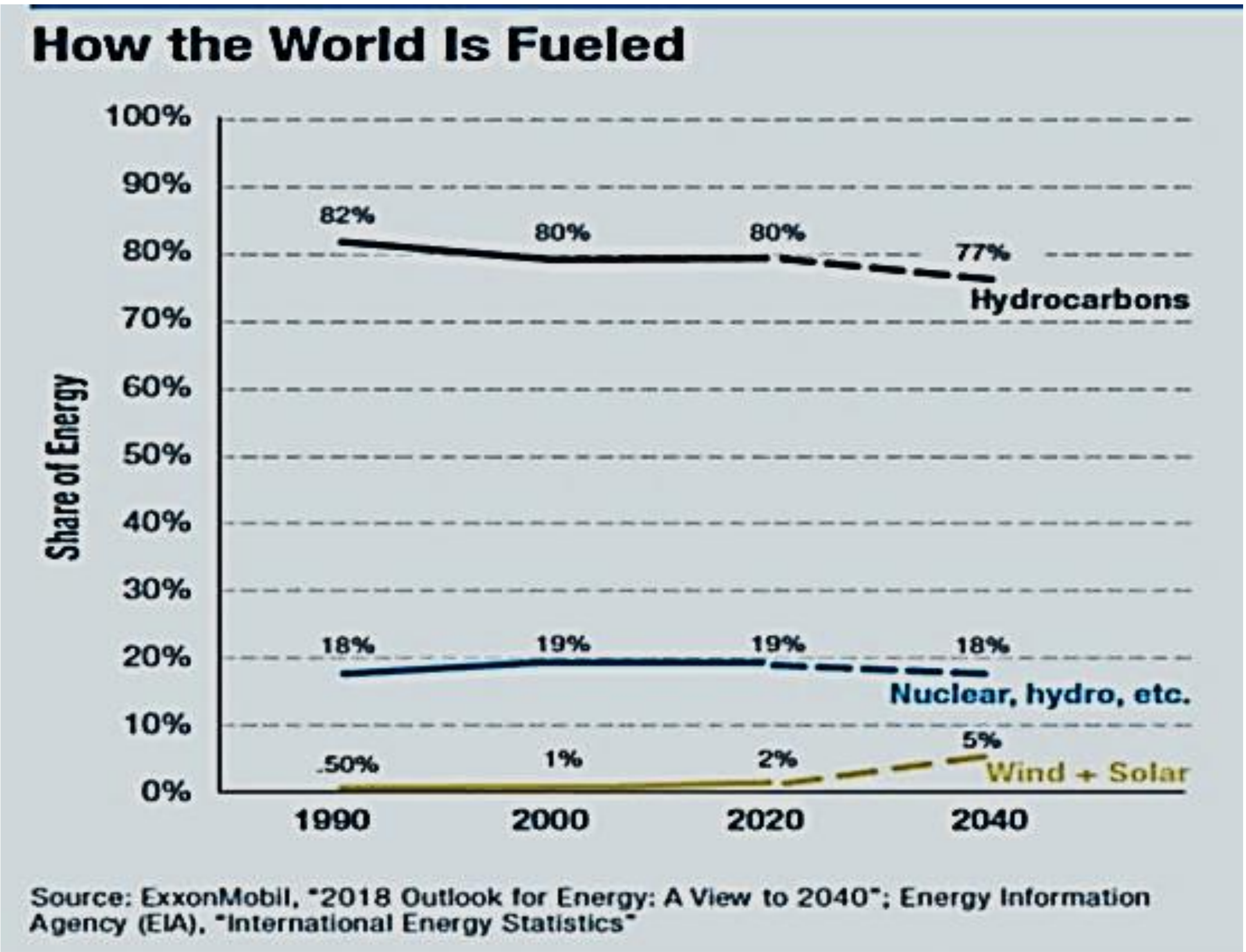



**Figure 55: How the world is Fuelled**

It is difficult to see how wind and solar can dominate world energy, bearing in mind some of these forms of energy's inherent weaknesses.

The first weakness is that the cost of generating electricity from renewables has dropped dramatically over the past decade. But there is no Moore's Law governing energy. The limits for improvement are fast approaching. The Betz limit stipulates that a blade can only recover approximately 60% of the wind's Kinetic energy. The Schockley-Queiseer Limit states that only 33% of incoming photons can be converted to silicon photovoltaic electrons. Modern windmills have already reached a 45% recovery and PV a 26% conversion rate, respectively or roughly 75% efficiency.

Further improvements in efficiency and cost reductions are, therefore, limited. The movement of goods, people, and consumption causes the hardware to increase with volumes and demand. Simultaneously, the energy required to move a ton of people, goods, and heat is set by laws of gravity, inertia, thermodynamics and friction, not by software. Therefore, any improvement in energy efficiency and reduced costs tends to bring about an increase in demand.

The second major weakness is the low energy density of solar and wind compared to fossil fuels. Solar and wind have a very low energy density, safety and stability compared to fossil fuels. In other words, they are highly intermittent and unpredictable. Very few known energy sources are endowed with so many useful features as fossil fuels, coal, oil and gas.

As noted by Lars Schernikau

> "Hydrocarbons are one of the most efficient ways to store energy. Today's most advanced battery technology can only store 1/40 of the energy that coal can store, a figure that already discounts for coal plant efficiency of about 40%. The energy that a 540kgm, 85KWh battery can store equals 30 kg of coal energy. A Tesla battery must still be charged with power (often through the grid) while coal is already charged.
>
> Also, you can calculate that one annual Giga factory production of 50GWh of Tesla batteries would be enough to provide backup for 6 minutes for the total US power consumption. Today's battery technology, unfortunately, cannot be the solution to intermittency" (Schernikau, 2020).

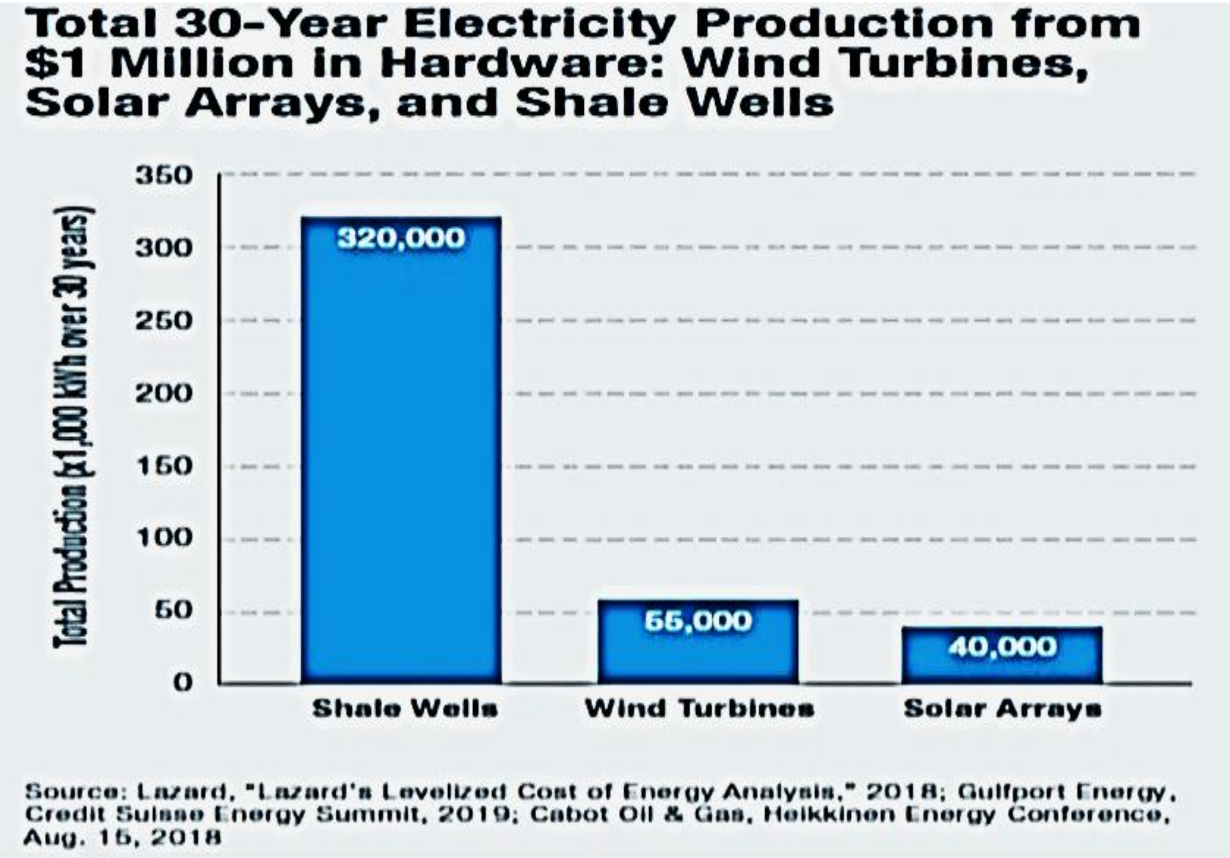


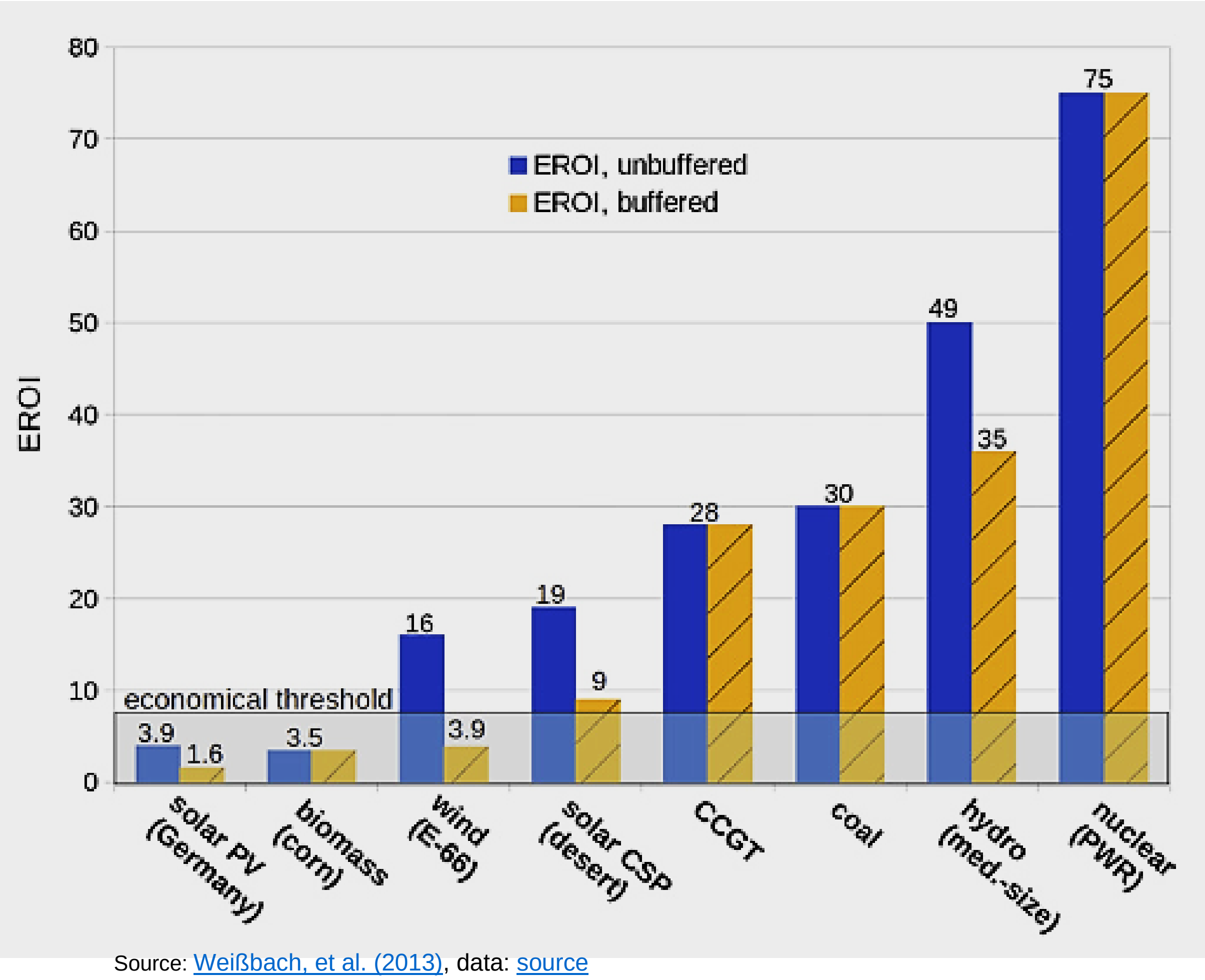

**Figure 56: Total 30-year electricity production from different technologies**

The result is that fossil fuels generate far more than an equal investment in wind or solar sources over the lifetime of an equal investment in each generation. A 1-million-dollar investment in shale oil will produce 300 million kWh over 30 years compared to 55 million and 40 million kWh for wind and solar, respectively (Schernikau, 2020; Mills,2019). The difference shows that the capital cost of solar and wind is roughly 6X that of shale gas. These figures will change materially with changes in the oil price.

The above shows clearly that batteries and renewables cannot provide a cheap alternative to fossil fuels. The mining requirements are enormous. Including the overburden, the requirements for each Tesla battery of 85 kWh requires up to 25 to 50 tons of material to be mined, moved and processed. These materials include copper, nickel, platinum, aluminium rare-earths apart from the energy and electricity needed to process them. Including the overburden required to be processed, solar and wind require 250 to 500 tons of overburden needs to be moved and processed compared to only 0.3 tons for coal, i.e., between 800X and 1600X times the end requirement needs processing. The environmental damage is massive. Not only that, the amount of energy, i.e., electricity, required to process, is equally massive. Therefore, it is easy to deduce that energy return on energy invested must be relatively low for renewables like wind and solar.

Essential reading is a research report by Weißbach et al. on EROI or energy returned from energy invested (Weißbach et al, 2013; Schernikau et al, 2022). Without going into detail, Weißbach et al. have shown that, in Germany, all renewables, except commercial solar installed in the Sahara Desert, are currently uneconomic (May, 2017). It can be assessed that renewables must be subsidised indefinitely unless a significant technical breakthrough in energy storage appears (Safaei and Keith, 2015). It is reported that “because modern society requires so much energy when the overall EROI drops below 7:1, the economy contracts, and we are at risk of recession”. ‘Buffered”, that is “, backed up” wind and solar have orders of magnitude less than 4:1 while nuclear and coal have magnitudes several times higher than that. These figures all were arrived at in the research study conducted in Germany. The Value of 7:1 may drop slightly in less developed economies. However, even poor people like to turn on their lights and use electricity at night (Prasad, 2008). In summary, the economic effects of wind and SolarPV are in economic stagnation areas, while coal and nuclear are in territory that fosters growth. No wonder America and Europe have had 150 years and more of high growth, and India, China and Japan have also enjoyed great prosperity in more recent years.

“The figure below plots EROI. The weighting factor is based on the production cost ratio of electricity to thermal energy. The economic threshold of 7:1 for Germany is shown in grey. The biomass plotted is corn, the wind generation location is in Germany, coal transportation costs are not included, and the type of coal is the German mix (roughly 42% hard coal and 58% lignite). Nuclear is based on 83% centrifuge and 17% diffusion refining. The solar PV values are all rooftop solar values. The commercial solar values are computed as if from the Sahara Desert, but the grid connection to Europe is not included in the cost."




Source: Weißbach, et al. (2013), data: source

**Figure 57: German EROI of various energy sources**

The yellow bars include the cost of backup ("buffered"), and the blue bars do not ("unbuffered") (*Exergy and Power Plants | Watts Up With That?* no date, Weißbach *et al.*, 2013). The data used to compute the values shown in the figures can be downloaded as a spreadsheet.

The third major factor is that the real cost of wind and solar are not correctly depicted by LCOE. This methodology is criticised by several experts as set out in previous chapters and the next chapter (Mount *et al.*, 2012; Sklar-Chik, Brent and de Kock, 2016; Pentland, 2014) (Pentland, 2014; Greenstone *et al.*, 2019). There have been several attempts to overcome and reduce its weaknesses. A review of some of these methodologies has been set out in the paper by Graham, 2018, entitled "*Review of alternative methods for extending LCOE calculation to include Balancing Costs."* This report responded to a broad range of stakeholders requiring easily comparable cost data for electricity generation technologies. The primary concern is finding a solution to the inability of LCOE to capture the balancing costs that variable renewable electricity generation technologies invariably require to ensure the electricity system has a reliable and stable supply.

(Graham, 2018). This would make LCOE more valuable and practical for comparing technologies and measuring the least-cost solution for the best technology mix.

### 5.4 THE IEA METHOD TO OVERCOME WEAKNESSES OF LCOE

This thesis summarises one briefly, namely the Value Adjusted Levelised Cost of Electricity (VALCOE). Its importance is that it was put forward by the International Energy Agency (IEA) 2018, World Energy model:2018 version, IEA OECD Paris to compensate for the known weaknesses of LCOE.

https://www.iea.org/media/weowebsite/energymodel/WEM2018.pdf

The VALCOE is an LCOE that has been adjusted to account for the differences in Value each Technology provides to the electricity system. The VALCOE makes three adjustments to LCOE: Energy, Value and Flexibility. The value adjustments are calculated from the outputs of an hourly electricity market model. The equation for calculating VALCOE is as follows:

VALCOEx=LCOEx + (Ex -E)+(Cx-C)+(Fx-F)

Where:

LCOEx: The Levelised Cost of Energy for that Technology x

- (Ex-E): The energy adjustment E., i.e., the difference between output weighted per MWh received by technology x and the weighted average.
- (Cx-C): The Capacity adjustment C, i.e., the difference between the capacity revenue received by technology x and average system capacity revenue. The capacity revenue is calculated from the capacity payments per kilowatt divided by each Technology's operating hours.
- (Fx-F): The flexibility adjustment F, the difference between the flexibility of Technology x relative to the average flexibility.

The second and third terms of the equation were calculated from model outputs, e.g., prices and technical characteristics. The flexibility value is based on a flexibility value multiplier, which is user-defined and constant over time. The flexibility multiplier is multiplied by a base flexibility value that is assumed to increase with rising variable energy hares up to a maximum equal to a peaking plant's total fixed recovery costs.

The reason for focussing on this is that VALCOE was developed as part of the International Energy Agencies' version of their World Energy Model (WEM). This was to deliver the 2018 World Energy Outlook. The VALCOE is an LCOE that has been adjusted to consider the difference in Value each Technology provides to the electricity system. Its importance is that the IEA stated that “the LCOE for dispatchable and non-dispatchable technologies are listed separately in the table because comparing them must be done carefully.” Graham noted this because “the LCOE calculation does not consider the real if hidden costs. Costs need to operate a 24/7 and 365 days per year energy infrastructure" run. What is required is a simple costing system that can be used to compare technologies that consider the additional balancing costs of renewables, which are not considered in the LCOE calculation. In summary, balancing costs are a system property, whereas conventional LCOEs are a technology property. Ideally, a method should refer to the system costs for a specific technology.

It is known that these costs can be substantial, and they show that there are significant Technology and system costs. These can differ substantially between regions, technologies, technology mixes, and time.

The following indicate the wide variation in prices or costs between countries' technologies and systems.

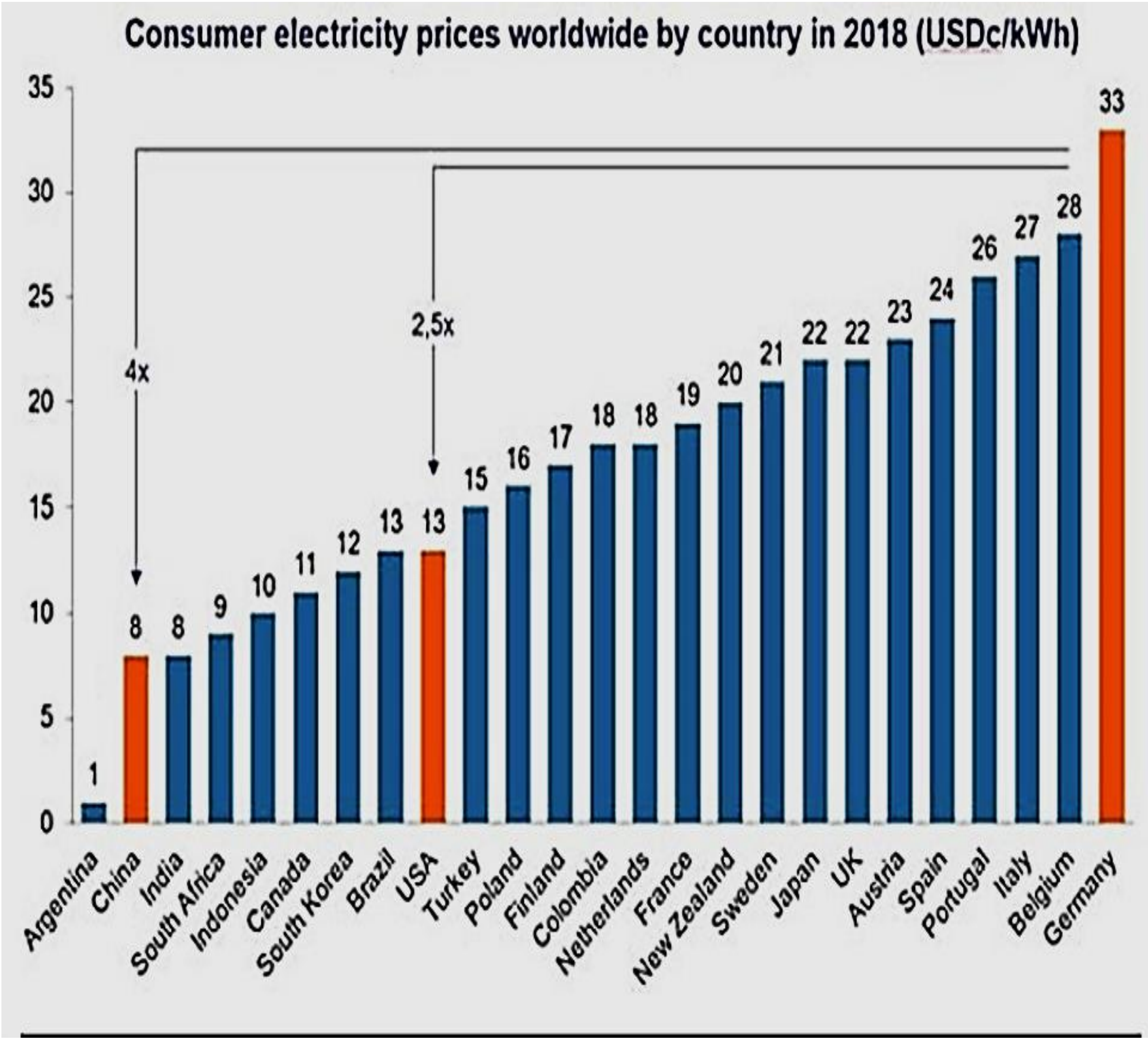



**Figure 58: Consumer Electricity Prices worldwide by country**

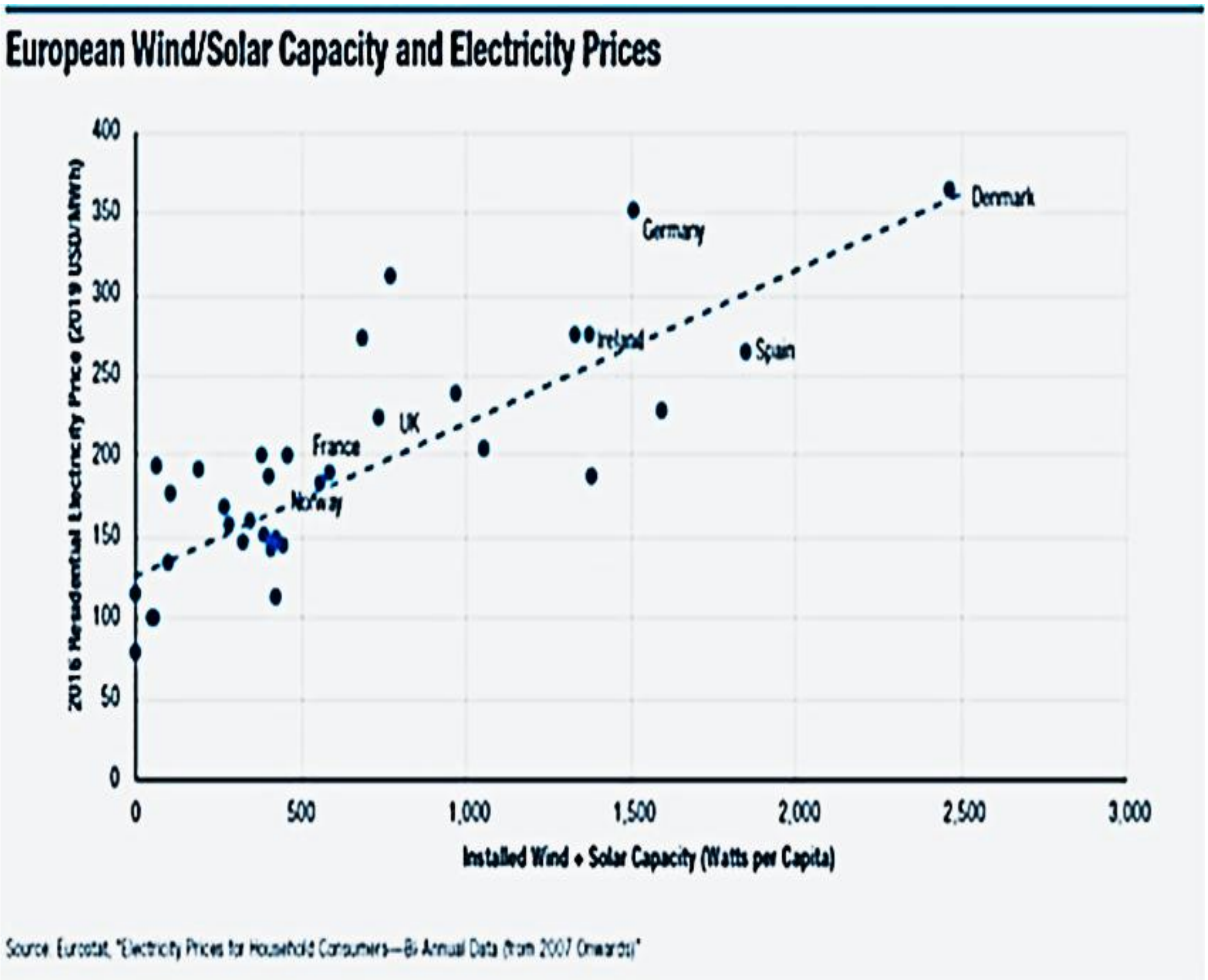
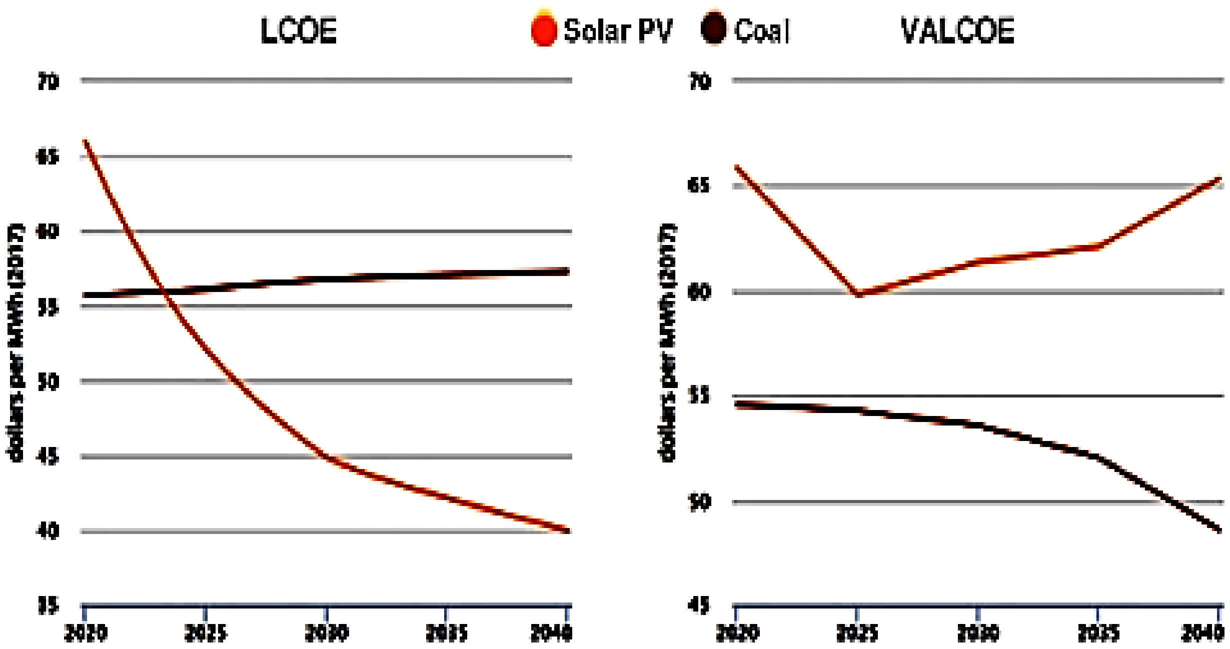



**Figure 59: European Wind/Solar Capacity and Electricity Prices**




Source: IEA; Brent Winner WEO Energy Analyst, 12 February 2019

**Figure 60: LCOE and VALCOE for solar PV and coal-fired power plants in India**

It would appear that the above three figures corroborate the following realities.

- For a variety of reasons, different regions have widely different electricity prices.
- Increased penetration of renewables, wind and solar results in higher electricity prices
- The VALCOE would appear to reflect the price of electricity for solar and coal in India more accurately. Solar shows a VALCOE of $64.5/MWh compared to a price of $48.6/MWh for coal.

## 5.5 METHODOLOGIES FOR COMPARING TECHNOLOGY COSTS

The previous chapter outlined several alternative methodologies for calculating and comparing the relative cost of electricity. As pointed out, most models do not consider risk and uncertainty. They assume the certainty of operations and continuous delivery. The real world operates on the basis that there is uncertainty and that there will be breaks not only in supply from the prime technologies but also from backup or alternative supplies. These gaps in supply lead to production stoppages. These stoppages result in lost production, and Economic Value collectively called the Cost of Unserved Energy (COUE).

A critical problem regarding electricity energy sources is the differences in the product they produce and distribute. Some argue that the product is the same, and they all involve basically the production and delivery of electrons to the grid and transfer down a wire. In practice, the supply characteristics of the electricity produced by each energy source may be different.

Because solar and wind are weather dependent, the production is variable, unreliable, intermittent and unpredictable. Electricity produced by fossil fuels is generally secure, stable, predictable, and dispatchable. The product can usually be instantly provided and is available on demand. The energy provided and electricity produced by Solar and Wind is termed non-dispatchable electricity, i.e., the electricity unavailable on demand. As a result, there is a different value attached to each product.

The model developed analyses and assesses the risks and uncertainties associated with each of the four significant technologies available in South Africa. These are translated into an additional economic cost added to each technology's LCOE to arrive at the correct or real cost. This chapter will summarise the model’s findings for four essential alternative technologies considered to be South Africa’s primary electricity generating sources over the next thirty-year period: wind, solar, nuclear, and HELE coal, all supported by gas.

## 5.6 MATHEMATICAL MODEL DEVELOPMENT

The model can be described in the same format set out for the **VALCOE** used in the previous section.

**RUALCOE**x=LCOEx + f(U)x
**RUALCOEx= Risk and Uncertainty Adjusted Levelised Cost of Electricity;**

LCOEx: The Levelised Cost of Energy for that Technology x;
x=Technology; w=wind, s=solarPV, c=coal, n=nuclear;
R=Risk;
U=Uncertainty;
A=Adjustment;
f(U)x= The uncertainty adjustment function for technology x.

Where f(U)x is defined as
Cost of Unserved Energy= F
F=R87.85 As set out by NERSA and the IRP
Px=Accepted Levelised cost technology x
Lx=Accepted Load factor of technology x
Cx=Nameplate Capacity in MW per production unit
Nx=Number of units of Technology x
Tx=Total Real Capacity deliverable of Technology x
Ta=Total Real Capacity All Technologies in Project Mix
Tx=CxLxNxLx. Total real capacity available technology x
Ta =SumTx i.e., Total real capacity Total wind +Total solar+ Total Nuclear +total coal
Tx/Ta=Proportion of real capacity Technology x in the total deliverable mix of Real Capacity available
Then fU)w= P/
Ta=Sum (Tx)

The True Risk and Uncertainty Adjusted Levelised Cost of Electricity is therefore defined as follows;

The Model
**Final Formula for wind 95% probability**
**RUALCOEw= 0.95*Pw + ((NORM.INV(50%, ΣLw,$Q8)- (NORM.INV(5%, ΣLw,Σ$\sigma$))/ NORM.INV(50%, ΣTw,Σ$\sigma$) *87.85)**

**Final Formula for a mix of technologies with 95% probability for a mix**
**RUALCOEm= 0.95*Pw + ((NORM.INV(50%, ΣLx,$Q8)- (NORM.INV(5%, ΣLw Σ$\sigma$))/ NORM.INV(50%, ΣTx,Σ$\sigma$) *87.85)**
The sum for all technologies

The table below summarises the assumptions and costs utilised in the model and the results obtained from its use. The assumptions are slightly different from those used previously. These have been taken and calculated from figures supplied by Eskom. Individual correlation estimates and assumptions have been made concerning the correlation coefficients between units and technologies. The model is relatively simple in construction, and users can update the various figures as more accurate figures become available. Broadly the standard deviation estimated and used for each Technology has been used to calculate the risk of variation for each Technology. These have been used to calculate the probability of non-supply. In this case, a 5% risk level of non-supply has been used for all technologies. Technologies with a high standard deviation have a high risk and a high economic cost of unserved energy (COUE) which must be added to the technologies calculated LCOE.

Statistically, a normal supply distribution has been assumed to apply to each Technology. Controversially the load factor used for solarPV has been limited to its daytime energy provision. This brings the COUE of solar down dramatically to a reasonable level. The 24-hour load factor of approximately 26% causes the COUE of solar to rise to unacceptable levels. This load factor would result in roughly double the costs calculated in the table below.

**Table 23: Calculation of COUE Model Assumptions**

**Model Assumptions**

| **Correlation Between Sources** | |
|---|---|
| **Wind & CPS** | -0.3 |
| **Wind & PV** | -0.0034 |
| **CPS & PV** | 0.75 |

Source: Eskom, IRP, NERSA, EconomicRisk NERSA

**Cost of unserved energy R/kWh** 87.85

It should be noted that the COUE for each Technology has been calculated based on sufficient units to give a nameplate output of 10000MW for each Technology. Enlarging the minimum nameplate supply helps overcome the inefficiencies caused by having too few units and reduces the impact caused by the correlation between units.

**Table 24: Estimated actual costs generated by different technologies**

| **Estimated True Costs of Independent Energy Technologies** | | | | | | |
|---|---|---|---|---|---|---|
| **Generating Source** | **Wind** | **SolarPV** | **Nuclear** | **Coal** | **Gas** | |
| **Cost of Unserved Energy** | 2.03 | 1.76 | 0.05 | 0.12 | 0.00 | |
| **Adjusted true cost R/kWh** | 2.65 | 2.38 | 1.35 | 1.17 | 1.75 | |
| **Nameplate Production** | 10000 | 10000 | 10000 | 10000 | 10000 | 50000 |
| **Nameplate proportion** | 20% | 20% | 20% | 20% | 20% | |
| **Real production** | 3417.0 | 5545.0 | 9000.0 | 8000.0 | 9500.0 | 35462 |
| **Real Proportion** | **9.6%** | **15.6%** | **25.4%** | **22.6%** | **26.8%** | **100%** |

Source: *Eskom,* Economic Modelling Solutions, EconomicRisk

A theoretical mix of technologies would give each a nameplate share of 20%. 40% is supplied by renewables, wind and solar, 40% by the fossil fuels coal and gas, and 20% by nuclear. The figures for renewables drop dramatically wind and solar proportional share fall from 40%

to 25.2% due to their low load factors in real production. Non-renewables proportional share increases to 74.8%. The nuclear share increases to 25.4% due to its high load factor. Fossil fuels and gas increased to 49.4%. Over a 24-hour period, the proportion of wind and solar would have dropped lower because the 24-hour load factor for solarPV is only 26% compared to the daylight figure of 55.5%. Similarly, non-renewables would increase their share to over 80%.

The table below summarises the four methods of calculating and estimating the actual cost of each Technology used in this thesis. The first two use the load factor only, and the second uses both the load factor and an additional unit to ensure a continuous supply.

The final two methodologies are the most important. They both calculate the COUE for that specific Technology. In the first instance, the COUE utilises the NERSA estimate, namely R87.85/kWh. This calculates the estimated total COUE using the load factor and the standard deviation in the manner set out in the model.

The final estimate calculates the COUE by calculating the total economic activity lost when electricity is not generated. Derived from the electricity supply and use tables, it is possible to derive the table below. This determines that the productive economic activity for 2019 can be calculated at R84.2/kWh. This can be directly compared to the COUE calculated by NERSA of R87.85/kWh. The difference is not significant.

**Table 25: Calculation of total economic activity generated**

| | 2017 | Est 2019 |
|---|---|---|
| Total Industry | 4791222 | 5222431.6 |
| Total gross value added / GDP | 4173328 | 4548927.2 |
| **Total output at basic prices** | **8964549** | **9771358.8** |
| Imports | 1319114 | 1437834.3 |
| Taxes fewer Subsidies | 480251 | 523473.59 |
| **Total Economic Output** | **10763914** | **11732667** |
| | | |
| **Price Increase from 2017 to 2019** | | **9.0%** |
| Electricity distributed | 223017000 | |
| **Economic activity/kWh** | **48.3** | **52.6** |
| Estimated % Productive Electricity | 62.5% | |
| Estimated Productive Electricity | 139385625 | |
| **Productive Economic activity R/kWh** | **77.2** | **84.2** |

Source: Eskom, Supply and use tables, Economic Modelling Solutions EconomicRisk

| | |
|---|---|
| Share Household Electricity | 50% |
| Av Premium paid for electricity | 25% |
| Household share | 37.5% |
| Productive Electricity | 62.5% |

Source: Eskom, Supply and Use tables Economic Modelling Solutions, EconomicRisk

### Table 26: Summary of real costs of technologies using different methodologies

| Generating Source | Wind | Solar PV | Nuclear | Coal | Gas |
|---|---|---|---|---|---|
| Cost R/kWh generally accepted assumption | 0.62 | 0.62 | 1.30 | 1.05 | 1.75 |
| Load factor generally accepted | 35% | 26% | 90% | 82% | 90% |
| **Methodologies for calculating the real cost** | | | | | |
| Cost using load factor | 1.77 | 2.38 | 1.44 | 1.28 | 1.94 |
| Cost using the extra unit | 2.17 | 2.84 | 1.57 | 1.47 | 2.12 |
| LCOE with NERSA COUE R87.85/kWh | 2.65 | 2.38 | 1.35 | 1.17 | 1.75 |
| LCOE by COUE Economic Activity R84.2/kWh | 2.54 | 2.28 | 1.29 | 1.12 | 1.68 |
| **Total Average** | **2.28** | **2.47** | **1.42** | **1.26** | **1.87** |

Source: Eskom, IRP, EconomicRisk

The difference in price between a no constraints system and the recommended system works out at no constraints R1.83/kWh compared to the recommended system of R137/kWh

The system containing more wind and solar is not the least cost system claimed based on numbers presented as the LCOE by the renewable lobby. In practice, the no-constraints system is 33.6% more expensive than the recommended system.

These figures confirm that the higher the penetration of solar and wind, the higher the electricity delivery. This conforms to the real world, as confirmed by the figure below.

The two tables below show the estimated cost of a recommended mix and a mix resembling the unconstrained mix recommended by the CSIR and the IRP.

### Table 27: Estimated True Costs of a recommended technology mix

| Estimated True Costs of a recommended fossil fuel and nuclear-driven technology mix | | | | | | |
|---|---|---|---|---|---|---|
| **Generating Source** | **Wind** | **SolarPV** | **Nuclear** | **Coal** | **Gas** | |
| **Cost of Unserved Energy** | 2.03 | 1.76 | 0.05 | 0.12 | 0.00 | |
| **Adjusted true cost R/kWh** | 2.65 | 2.38 | 1.35 | 1.17 | 1.75 | |
| **Nameplate Production** | 0 | 13000 | 16000 | 29000 | 15500 | **73500** |
| **Nameplate proportion** | 0 | 18% | 22% | 39% | 21% | **100%** |
| **Real production** | **0** | **7208** | **14400** | **23200** | **14725** | **59533** |
| **Real Proportion** | **0** | **12%** | **24%** | **39%** | **25%** | **100%** |

Source: Eskom, IRP, NERSA, EconomicRisk

**Cost of Unserved Energy provided by NERSA: R87.85/kWh**
**The electricity generation cost: R1.23/kWh**
**Cost of Unserved Energy COUE caused by the mix: R0.17/kWh**
**Cost of a recommended technology mix, primarily coal and nuclear: R 1.40/kWh**

**Table 28: Estimated True Costs of a primarily renewable mix**

| Estimated True Costs of a primarily renewable mix | | | | | | |
|---|---|---|---|---|---|---|
| **Generating Source** | **Wind** | **SolarPV** | **Nuclear** | **Coal** | **Gas** | |
| **Cost of Unserved Energy** | 2.03 | 1.76 | 0.05 | 0.12 | 0.00 | |
| **Adjusted true cost R/kWh** | 2.65 | 2.38 | 1.35 | 1.17 | 1.75 | |
| **Nameplate Production** | 57000 | 26500 | 3000 | 0 | 26000 | **112500** |
| **Nameplate proportion** | 51% | 24% | 3% | 0% | 23% | **100%** |
| **Real production** | **19477** | **12060** | **2700** | **0** | **24700** | **58937** |
| **Real Proportion** | **33%** | **20%** | **5%** | **0%** | **42%** | **100%** |

Source: Eskom, IRP, EconomicRisk

**Cost of Unserved Energy provided by NERSA: R87.85/kWh**
**The electricity generation cost: R1.13/kWh**
**Cost of Unserved Energy COUE caused by the mix: R0.74/kWh**
**Cost of an unconstrained technology mix, primarily wind and solar: R 1.87kWh**

An analysis of the two tables above is revealing.

Firstly, the technology mixes result in an actual generation of approximately 59000 MW. It must be noted that the recommended technology mix consisting primarily of fossil fuels and nuclear requires a building programme of the nameplate capacity of approximately 73500MW delivering real production of 59533MW. The average load factor is approximately 81%. The unconstrained build programmes require a nameplate capacity of 112500MW to deliver a similar real production of approximately 58937MW, with an average load factor of only 52%.

Secondly, the real cost of electricity delivered to clients by the recommended mix has an estimated actual cost of R1.40/kWh. The actual cost of electricity delivered by the renewable mix of wind and solar is estimated to be R1.87/kWh. The actual generation costs of the renewable mix of wind and solar appear slightly less than the recommended mix. A least-cost methodology would indicate its generation cost to be R1.13/kWh compared to the fossil fuel and nuclear mix cost of R1.23/kWh. However, the cost of unserved electricity (COUE) is far higher at an estimated R0.74/kWh than only R0.17/kWh for primarily nuclear and fossil fuel-generated electricity.

In reality, the electricity generated by the renewables mix costs some 34% more than that generated by the more traditional baseload supply from the nuclear and coal mix, even though it appears to be cheaper on a least-cost generation basis. Solar and wind are weather-driven energy sources.

Weather-driven energy is highly variable, unreliable, intermittent and unpredictable. These qualities result in statistically measurable low energy density, low load factors and high standard deviations. This increases electricity prices, reducing economic growth and investment in energy-intensive production processes.

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## 5.7 ENVIRONMENTAL, ECONOMIC AND POLITICAL FACTORS

Many other factors need to be taken into account, including the costs of environmental, economic, political and social factors. Other factors that need to be considered include:

*Reduced sales by ESKOM from economic policies:* The government's poor economic policies have effectively reduced economic growth. In particular, they have reduced industry development, mining and generally the goods-producing sector. This has led to a structural change in the economy where the service sectors, particularly government with low electricity intensivity and public sectors, have experienced high growth. In contrast, goods-producing segments with high electricity intensivity have experienced little growth resulting in relatively small electricity demand growth. In the long-term, this is an unsustainable economic growth model for a country such as South Africa, which requires, as set out in the National Development Plan (NDP), high growth in its goods-producing sectors (National Planning Commission, 2011). The below-average electricity growth of ESKOM has resulted from many factors beyond ESKOM's control. If correct policies are followed, electricity growth should increase. Planning must consider this, which will require an increase in reliable baseload power (Mcmillan and Rodrik, 2014).

*Corruption*: It is a separate exercise to ensure that all technologies are, under all circumstances, kept free of corruption at all levels. Corruption has to be stamped out. The correct electricity generating sources must be selected. This must be made based on efficiency, effectiveness, long-term cost, and viability, free of corruption. Corruption is a different exercise in dealing with the economic choice of electricity technologies.

The previous chapter outlined several alternative methodologies for calculating and comparing the relative cost of electricity. As pointed out, most models do not consider risk and uncertainty. They assume the certainty of operations and continuous delivery. The real world operates on the basis that there is uncertainty and that there will be breaks not only in supply from the prime technologies but also from backup or alternative supplies. These gaps in supply lead to production stoppages. These stoppages result in lost production, and economic value collectively called the cost of unserved energy or electricity (COUE).

A critical problem regarding electricity energy sources is the differences in the product they produce and distribute. Some argue that the product is the same, and they all involve basically the production and delivery of electrons to the grid and transfer down a wire. In practice, the supply characteristics of the electricity produced by each energy source may be different. Because solar and wind are weather dependent, the production is variable, unreliable, intermittent and unpredictable. Electricity produced by fossil fuels is generally secure, stable, predictable, and dispatchable. The product can usually be instantly provided and is available on demand. The energy provided and electricity produced by Solar and Wind is termed non-dispatchable electricity, i.e., the electricity that is unavailable on demand. As a result, there is a different value attached to each product. Dispatchable electricity is highly valued for many specific tasks, such as hospital operating theatres or lifts carrying humans in mines or office buildings and for many continuous production processes. Cooking meals at specific times is a requirement for most homes and restaurants.

As discussed in the previous chapter, there are several methods of assessing each technology's correct cost. In practice, each technology's energy cost is usually assessed using actual costs and estimates of relevant costs and calculating each technology's Levelised Cost of Energy (LCOE). As noted previously, there are many problems associated with using this methodology. Several energy experts have set these problems out in papers on the subject. (Mount *et al.*, 2012; Sklar-Chik, Brent and de Kock, 2016; Pentland, 2014) (Pentland, 2014; Greenstone *et al.*, 2019). It would appear that LCOE does not sufficiently consider the economic risk and uncertainty associated with variable, intermittent, unreliable and unpredictable non-dispatchable electricity. (Joskow, 2010; Partridge, 2018; Aldersey-Williams et al., 2018; AmericaPower, 2019).

Calculations for the model assumptions developed are set out below. Clearly, there can be improvements by calculating using a more comprehensive data set.

**Table 29: Calculation of COUE Model Assumptions**

**Model Assumptions**

| **Correlation Between Sources** | |
|---|---|
| **Wind & CPS** | -0.3 |
| **Wind & PV** | -0.0034 |
| **CPS & PV** | 0.75 |

Source: Eskom, EconomicRisk NERSA

Source: IRP, NERSA

**Cost of unserved energy R/kWh** 87.85

This section examined the additional costs that wind and solar add or impose on a system in greater detail. It is claimed that wind and solar are the cheapest electricity source by far, and these sources should dominate the future electricity supply. There is substantial debate regarding this subject. There are many complex issues that are involved. These include environmental issues and many other externalities. This section focuses on known costs and subsidies and excludes these other issues. That is not to say these other issues are unimportant or that no additional costs are involved. All energy sources and associated technologies are subject to similar problems and additional charges to varying degrees.

However, those imposed by wind and solar are often hidden and subsidised by others. They are significant but are left out of costing information. They are not taken into account in the LCOE calculated, which only measures the costs at the gate of the supplier, not those at the demand user's door. These are costs imposed on the economy and the user because of the unreliability, variability, interruptibility and unpredictability of renewables.

Emerging economies need to focus on those technologies which are efficient and effective. In South Africa, mining, manufacturing and industry need the security of electricity supply at competitive prices. The only two electricity generation sources of energy that can achieve these objectives in this country would appear to be High-Efficiency Low-Emissions (HELE) coal, otherwise called “clean-coal”, and nuclear.

The country or state must raise its economic growth rate by ensuring it has a sustainable, secure electricity supply at the lowest financial and economic cost. This must be accompanied by the necessary supporting condition fostering domestic and foreign investment into its economy (Jeffrey R, 2016). The arguments above show clearly that renewables in the form of solar and wind, in particular, almost certainly have substantial additional costs that are not fully accounted for in the current costs. This also means that the so-called least-cost optimum mix is wrong. As a result, this methodology is severely flawed as currently defined and used.

Furthermore, increased penetration of such technologies will automatically lead to a higher cost of the optimum mix. Finally, the risk and uncertainty posed by solar and wind lead to rapidly increasing economic costs measured by the COUE. These are not currently allowed for or measured accurately in current models associated with the least-cost energy mix. The impact and economic COUE set out by the IRP in 2019 is approximately R87.85/kWh. The figure of R77.30 from the IRP 2016 has been used for calculation purposes in this thesis. The technique and methodology recommended using statistical calculations based on variable estimates utilising each technology's variance and calculating the COUE.

The above arguments and assessments lend force to the case that solar and wind, mainly, are unaffordable in the current economic situation in the country. The estimates strongly suggest that the least-cost methodology is severely flawed. In the future, the renewable technologies of wind, in particular, should play a marginal role in any future technology mix for the country despite the views of the CSIR (Centre for Environmental Rights (CER), 2017). Solar could have a more substantial part in office development and the residential market with a more limited role in the industrial market.

The final nail in the coffin for South Africa is that increased wind penetration will lead to a rapidly rising import bill for gas imports, its coal mining industry's demise, and substantial declines in the mining industry (Jeffrey, 2017d). These catastrophes could ensure that South Africa's future moves towards rising unemployment, increasing poverty, and increasing social and political instability. South Africa needs to focus its energy plans on HELE or “clean-coal”, nuclear, domestic solar, and limited gas, apart from limited use of other sustainable energy sources such as biomass, hydro, and pump storage.

## 5.8 JOB CREATION AND GROWTH CREATED BY TECHNOLOGIES

### 5.8.1 INTRODUCTION

This section evaluates each electricity technology's job creation and economic growth capabilities. There has been widespread discussion on this subject. The focus has been on the number of jobs and additional growth each technology creates in its own right regarding its construction and operation. This section shows a severely flawed approach and sets out the correct path to examine job creation and any electricity generation-technology or mix's economic growth potential.

The principal objective of emerging markets is to alleviate poverty. South Africa has high poverty levels and one of the world's highest unemployment rates (Nicolson, 2015). Various unemployment measures put this figure over 29% and, in the case of youth, above 50%. It is estimated that between now and 2035, some 16 million job entrants will be coming into the market. Forecast growth to 2021 is less than 1.5% per annum, potentially rising to 2% per annum in 2022 (Outlook, 2019). With population growth at approximately 1.5% per annum, the standard of living is falling. Less than 5 million new jobs will be created by 2035, and unemployment levels will steadily increase.

The key to the country's economic, social and political future is to increase the growth rate to above 4% per annum and re-industrialise and redevelop its mining sector. To achieve these objectives, South Africa requires a steady development of a secure electricity supply at the lowest financial and economic cost over an extended period, giving investors confidence to return to this country. Without growth in Domestic Investment and Foreign Direct Investment and achieving growth rates above current levels, South Africa will become a failed state and follow Zimbabwe, Venezuela and Somalia (Jeffrey R, 2016). However, this country is potentially one of the richest globally with its people and, importantly, its resources, including coal, uranium and numerous vital commodities such as chrome, manganese, platinum, and sufficient agricultural land. Many are in demand globally, but South Africa needs to be able to compete in these markets. South Africa must use these market opportunities to their fullest extent, including the beneficiation of these commodities, before exporting where possible. The selection of the correct electricity-generating technology must be carefully evaluated, considering the country's economic needs.

This section focuses on some critical factors that must be considered when selecting alternative electricity-generating technologies. Only five technologies have been reviewed, namely HELE “clean-coal”, nuclear and renewables, in the form of wind, solar, and gas. As will be seen, some fundamentally incorrect arguments are used when comparing two critical parameters for analysing these technologies: jobs created and costs.

### 5.8.2 JOB CREATION AND ECONOMIC IMPACT

The first vital element is that the number of jobs involved by the technology itself to generate its electricity is essential. The total number of potential employment and GDP created in the SA economy by the electricity generated by the technology is essential. The upstream and downstream jobs and value of products created by the electricity generated are critically important. This argument holds true unless the export of electricity generation outside the economy becomes a primary export industry in its own right. The second vital element is the overall economic effect of the electricity-generating technology choice on the national economy. Several studies show an undeniable impact that “renewable” energy causes significant job losses elsewhere in the economy. For example, Gabriel Calzada Álvarez, PhD, testified before the US House Select Committee on Energy Independence and Global Warming on September 24, 2009 – “For every green job financed by Spanish taxpayers, 2.2 jobs were lost as an opportunity cost.” Similarly, in South Africa, a study by Econometrix calculated that the development of wind and solar at the expense of coal would result in the coal industry declining by 46%, with a potential loss of 150000 jobs. (Jeffrey, 2017)

The second key issue is that the more resources necessary to construct and generate the required electricity, the less efficient and costly the electricity generation process becomes. In other words, the more workers and time were taken to construct and produce a stipulated real quantity of electricity, the more expensive and inefficient the electricity generation process became. In summary, the higher the ratio of input resources to output, the more inefficient electricity-generating technology is. All the costs and input resources used in construction, including other resources, fuel and maintenance for actual generation, must be included**.** In essence these metrics become a measure of the relative cost of generating electricity utilising this technology. Importantly this must be based on the real output and not nameplate output. The load factor and life of the asset become critical metrics. Equally importantly, it involves the security of supply. Highly variable and interruptible supply further devalues the electricity delivered.

According to the SARB quarterly report 2018, the South African GDP at current prices is R4.874 trillion, and Employment totalled 9.8 million. Electricity generated in the economy averages 33 GW. Using these figures, it can be calculated that, on average, 1000 MW generates approximately R148 billion in GDP and creates about 297000 jobs (Services user information, 2019; South African Reserve Bank, 2018).

Recent figures quoted by various sources regarding technology project costs and output indicate that it has frequently been referred to as job-years created in the renewable lobby and industry in South Africa. Job years have also been calculated for comparison purposes.

- Coal: A project Cost of R195 billion delivers nameplate 4760 MW with a Load factor of 80% and a life of 40 years. The real output would be 3808 MW creating 4000 direct jobs (including coal mining). It is generating 160000 job-years. Alternatively, this means that coal generating an actual electricity output of 1000 MW costs R51 bn creating 1050 jobs or 42016 job-years of employment.
- Nuclear: A project Cost of R361 billion delivers nameplate 5600 MW with a Load factor of 90% and a life of 70 years. This provides real 5040 MW creating 5500 direct jobs and generating 385000 job-years. Alternatively, this means that nuclear generating actual electricity output of 1000 MW costs R72bn, creating 1091 jobs or 76389 job-years of employment.
- Wind & Solar: the project cost was R200 billion, delivering nameplate 3851 MW with a load factor averaging 30% and a life of 20 years. This gives real 1155 MW delivered, creating 2000 direct jobs and generating 40000 job-years. Alternatively, this means renewables generating actual electricity output of 1000 MW costs R173 bn creating 1731 jobs or 34632 job-years of employment.

An analysis of the above figures shows that nuclear and coal easily outperform solar and wind on all metrics and deliver significantly more job-years for the SA economy. These would be substantially lower resource costs than costs per job and about 1/5$^{th}$ of the generated solar and wind costs in job-years. In terms of cost per real MW, coal is approximately 30% cheaper and less costly than nuclear and 12% less expensive per direct job. Both are between 65% and 100% less expensive on these metrics than wind and solar. Once the plant's life comes into play, the cost per job-year nuclear is 36% less costly than coal. Wind and solar are more than 4X (4 times) more expensive.

Naturally, special interest groups will argue over the longer life of nuclear or solar and wind or higher and lower load factors. The solar and wind lobby will naturally say that later rounds showed significant cost reductions. However, they do not consider the numerous additional potential and hidden costs they incur or the substantial subsidies (Koko, 2016). A list of such potential additional and hidden costs appears in the table. The renewable lobby's often minor and debatable points will not be corrected by the above figures' significance.

In reading the following, care must distinguish between jobs created to keep the power station running. These are referred to as direct jobs in this section. The second reference is total employment or jobs created in South Africa by generating electricity at the power station. Thus, nuclear costs approximately R54545 per direct job created while coal costs R48750 per direct job created. I.e., nuclear is 12% more expensive in terms of direct jobs created. Regarding total employment in the country, despite having a higher load factor, the high cost of nuclear construction per MW resulted in the cost of jobs in the country for nuclear being 30% higher than coal.

In this instance, R66667 per job to the coal figure R51208 per job created in the country. Once job-years are considered the long life of nuclear of 70 years to coals' 40 years, the cost per year for nuclear is considerably lower, which can be calculated in two ways. Directly nuclear cost per job-year is R3207 compared to coal, R4311 per job-year in SA or approximately 26% less. Naturally, one can work it out from the ratio of 40 years for coal divided by 70 years for nuclear, i.e., 40/70 multiplied by the 1.30% higher costs for job-years produced by nuclear than coal. This calculation gives the same 26% lower cost per job year than coal. A nuclear plant's long life drives these figures at 70 years compared to a “clean-coal”-fired power station life of 40 years. The figures show that a plant's life is a significant factor in assessing costs. Additional money should be invested in an efficient, reliable, long-life asset rather than a lower cost or relatively cheap, unreliable short-life asset. Both “clean-coal” and nuclear work out as considerably better and more cost-effective investments than erratic and unpredictable wind and solar with lives of 20 years and possibly less. The adage “what you pay is what you get” also holds in the energy field.

Once again, it must be emphasised that each technology's length of life and load factors make a significant difference. However, these differences would need to be substantial to give different results.

### 5.8.3 SUMMARY OF THE RELATIVE COSTS OF GENERATION

The table below summarises the relative performance of technologies. Naturally, discount rates should be applied, which would alter the costs, particularly if different discount rates are applied to technologies. The first figures directly compare the cost of electricity generation by different technologies. All the ratios are measured, taking the factor for coal as 1% or 100%. Doing this allows a direct comparison of the relative cost of each technology.

- Direct jobs/real 1000 MW electricity generated: Nuclear is 16% more expensive than coal. Wind & solar are 65% more expensive than coal
- Cost per direct job: Nuclear is 12% more expensive than coal. Wind & solar are 2.1X more expensive than coal.
- Cost per real MW generated: Nuclear is 30% more expensive than coal. Wind & solar are 3.4X more expensive than coal
- Cost per direct job year: Nuclear is 36% cheaper than coal. Wind & solar are 310% or 4.1X more expensive than coal. Wind & solar are 6.4X more expensive than nuclear

### 5.8.4 SUMMARY IMPACT ON TOTAL SA EMPLOYMENT GENERATION

The second half of the table gives the economic impact or efficiency of the technology's employment creation or jobs created in the total SA economy. This economic efficiency or potential productive employment is measured by the number of years and job-years created by each technology.

- Total SA employment or jobs created: Nuclear creates 18% more jobs in SA than coal. Wind & solar create only 30% of the jobs or employment in SA that coal creates. Wind & solar creates only 25% or one-quarter of the number of jobs created by nuclear.
- Total SA employment years or job-years created: Nuclear creates 2.1X more job-years in SA or slightly more than double the number of job-years created in SA than coal. Wind & solar create only 15% or 1/7$^{th}$ of coal's job-years or employment years generated in SA.

### 5.8.5 SUMMARY OF THE COSTS TO CREATE JOBS OR JOB-YEARS

Cost of each technology for creating employment or job by each technology or the costs of the employment years and job-years created in South Africa by the various technologies

- Cost per job created in SA: Nuclear is 30% more expensive than coal in creating SA jobs. Wind & solar are 3.4X more expensive than coal.
- Cost per job year created in SA: Nuclear is 26% cheaper than coal in creating job-years. Wind & solar are 6.7X more expensive in creating job-years in SA than coal.

### 5.8.6 AREA OR ENERGY DENSITY OF TECHNOLOGIES

Multiple criteria govern the energy density and or efficiency of various technologies. Mills' "New Energy Economic: An Exercise in Magical Thinking" points out the limits for the physics boundary of wind turbines and solar capabilities. According to various papers and work on Land Area Required to Generate Electricity by Bonne Posma, Chairman, Nuclear Africa (Pty) for wind 625 square Km per GW. and Solar 36 square Km per GW. In comparison, Coal, Nuclear and Gas will require less than 2 square Km per GW. Together with associated mining operations this would increase to, say, 20 square Km. It is interesting to note that recently a wind turbine collapsed at Chisholm View windfarm Hunter Oklahoma in the USA. This windfarm was selected purely on an arbitrary random basis.

The wind farm has an area of 51000 acres and generates 300 MW. (One acre =0.004 square Km. i.e., 206.4 square Km). This works out at 1 GW per 688 square Km. This is very close to the figure used in the B Posma report of 625 square Km per GW (Posma, 2018). It also lends credence to the view that the projections in the unconstrained CSIR plan of 100 GW of wind in SA would cover an area approaching 68800 square Km. To put this in perspective, it is 3000 Km of coastline to a depth of 23 Km. This will have a devastating environmental impact on South Africa's land and environment.

Environmental issues concerning land are affected by windfarms and need to be clarified. The jury is out regarding the environmental impact of windfarms. More and more information and data are being found about the land damage caused by windfarms due to roads, cabling, foundations, the vast grid requirements, and infrasound's impact on human and animal life. The growing recognition of the enormous negative impact on birds, bats, insects and animal life is pertinent to the land. Even humans are not immune, and infra-sound implications on humans are a growing concern. Mining for the rare earths and minerals required causes considerable environmental damage. The disposal of the materials is substantial and involves the disposal of toxic waste on a larger scale than most people recognise.

Regarding large birds and birds of prey and migrating bird colonies, it is now recognised that the damage extends far beyond a wind farm's physical boundaries (Plan, 2019). Figures of between 20 to 40 Km are often mentioned. This means the potential environmentally damaged area could easily extend 4X to 10X the area of the windfarms involved. The numbers are influenced by the number and average area of the individual windfarm. For a country such as South Africa, with many large and rare birds the impact could be substantial and negatively impact the critical tourist industry.

This should be compared to the land required for nuclear and coal power generation. Mining would involve less than 2000 square Km or less than 3% of the land involved in wind and solar electricity generation.

### 5.8.7 SUMMARY

The above summary of costs and ratios shows that wind and solar have remained an inferior investment for South Africa. They are significantly more costly in their ability to generate electricity in terms of their real MW produced; this by a factor higher than 3X. Furthermore, they require excessive human resources or jobs to generate this power, more than 2X in terms of the number of permanent jobs created for their continued use compared to coal. When measured in job-years, this figure rises to over 4X the cost. The reason for using this metric highlights the excessively high costs and inefficiency of wind and solar because of their limited lives of 20 years or less.

Wind and solar costs generate real electricity resources for the economy and create jobs, and the job-years in the total SA economy are very high. Costs of creating jobs are more than 3X, and costs per job year are more than 6.5X higher. The first figure arises from wind and solar inefficiency and the high cost of generating electricity measured in a usable dispatchable power format in MW. The second has these costs magnified due to the short life of only 20 years for solar and wind compared to 40 years for coal and more than 70 years for nuclear.

Some will argue that the economic structure of the economy is changing. They will say that heavy industry, industry in general, and mining are declining and that the economy's electricity intensity is declining. The fact is that South Africa, due to incorrect policies and the energy crisis, has been deindustrialising and has almost destroyed its mining industry.

South Africa is a developing and emerging economy. SA must reindustrialise and grow its industrial and mining sectors. Apart from the employment created, these activities increase the country's exports and lead to substantial import-replacement with beneficial results to the balance of payments. The subject is dealt with at length in other sections. However, it leads directly to the question of South Africa's need for secure and competitive baseload electricity. Proponents of solar and wind also highlight the requirements for developing microgrids. The country's economic objectives and strategy point toward secure and competitive baseload power provided by HELE "clean-coal" and nuclear supported by a grid (Minchener, 2016) capable of efficiently delivering the baseload power required for the goods-producing industries. Strategically solar and wind and developing microgrids as a priority are precisely the opposite of South Africa's economic needs at this stage of its economic development.

The wind and solar proponents and lobbyists will claim that the high initial renewables costs for the first round of solar and wind contracts signed in South Africa were expensive. This may be partially true. However, the relative costs of other technologies have also changed. It is noteworthy that wind and solar receive substantial subsidies in backup facilities and other hidden grid and system costs.

Most significantly, the cost difference is so significant that even a major change in the wind and solar relative costs would not change the overall findings in this analysis. Namely, wind and solar are significantly less efficient, and hence electricity generation from them is substantially more costly than electricity generated from coal or nuclear. The selected metrics used confirm this. The parameters used are real MW generated, total jobs created in the SA economy, and job-years over the technologies' lives. The three technologies compared are coal, nuclear and renewables, consisting of only wind and solar.

**Definitions**

- 1 GW=1000 MW
- Nameplate capacity: Also known as the rated capacity, nominal capacity, installed capacity,
- Real capacity output: is the nameplate capacity adjusted for the average load factor
- Direct job: Jobs directly associated with the production of electricity by the technology
- The calculations have been taken to the first decimal point. This is for ease of reference as to the calculation. In practice, all figures are only approximate estimates. They are not indicative that the calculations are accurate to one decimal point (Wikipedia, 2019).

**Table 30: Costs and job-year of generating technologies**

| Annexure 2 | Costs jobs and job years of the main Alternative electricity generating technologies in SA | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| The truth about costs and jobs created: The SA economy | | | | | | | | |
| | | | | | | GDP | Jobs | |
| Assumptions | Cost | GDP Rm | Jobs | MW | GDP/job | /1000 MW | /1000 MW | |
| SA economy | | 4 874 000 | 9 800 000 | 33 000 | 497 347 | 147 696 970 | 296 970 | |
| | | | | | | | | |
| Technology assumptions used and recenly discussed | | | | | | | | |
| | | Nameplate | | | Real | Direct Manuf | Direct job | |
| | Cost Rm | MW | Life Yrs | Load Factor | MW generated | Jobs Created | years created | |
| Coal | 195 000 | 4 760 | 40 | 80% | 3 808 | 4 000 | 160 000 | |
| Nuclear | 300 000 | 5 000 | 70 | 90% | 4 500 | 5 500 | 385 000 | |
| Solar & wind | 200 000 | 3 851 | 20 | 30% | 1 155 | 2 000 | 40 000 | |
| | | | | | | | | |
| Critical for each technology are the following: costs/MW, cost per job and jobs created in the economy | | | | | | | | |
| | Direct jobs/ | Cost Rm/ | Cost Rm/ | Cost Rm/ | Total SA jobs/ | Total SA Job years/ | Cost/Total | Cost/Total |
| | real 1000MW | direct job | real 1000MW | Job year | real 1000 MW | real 1000 MW job years | SA Jobs | SA job years |
| Coal | 1 050 | 48 750 | 51 208 | 1.2 | 1 130 861 | 45 234 424 | 172 435 | 4 311 |
| Nuclear | 1 222 | 54 545 | 66 667 | 0.8 | 1 336 364 | 93 545 455 | 224 490 | 3 207 |
| Solar & wind | 1 731 | 100 000 | 173 115 | 5.0 | 343 089 | 6 861 782 | 582 939 | 29 147 |
| | | | | | | | | |
| Important relative cost comparisons and ratios | | | | | | | | |
| | Direct jobs/ | Cost / | Cost/ | cost/ | Total SA jobs | Total SA job years | Costs/Total | Costs/Total |
| | real 1000MW | Direct job | Real MW | job year | created | created | SA jobs | SA Job years |
| Coal | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Nuclear | 1.16 | 1.12 | 1.30 | 0.64 | 1.18 | 2.07 | 1.30 | 0.74 |
| Solar & wind | 1.65 | 2.05 | 3.38 | 4.10 | 0.30 | 0.15 | 3.38 | 6.76 |

Sources: Economic Modelling Solutions EconomicRisk Estimates based on IRP SARB

The calculations are approximations. The ratios are calculated to the nearest decimal point.
This gives a false sense of accuracy but are used to give guidance as to the source of the calculation

This section re-evaluated each electricity-generating technology's job creation and economic growth capabilities. There has been widespread discussion on this subject, with a particular focus by energy planners and solar and wind lobbyists on the number of jobs and additional growth each technology creates in its own right regarding its own construction and operation of the technology itself. This section has shown that this is severely flawed and has resulted in a total misrepresentation of each technologies contribution to the economy. The section has set the correct evaluation path for job creation and electricity generation technology's economic growth potential.

It is clear from the above that wind and solar are hopelessly unreliable, inefficient, and expensive. Furthermore, wind and solar are unsuitable for developing an emerging economy such as South Africa. This also would hold for any emerging economy with uranium or fossil fuel resources that have objectives and aspirations of developing its goods-producing industries, particularly electricity-intensive industries such as manufacturing, mining and agricultural production and processing.

## 5.9 SOUTH AFRICA CAN AVOID ENERGY CAUSED ECONOMIC DAMAGE

### 5.9.1 INTRODUCTION

This section further breaks down the cost of different electricity-generating technologies. In particular, it analyses more carefully the impact of each electricity-generating technology on employment and economic growth. The figures used are based on information made available by several sources on costs, jobs created by each technology and their economic impact.

The appointment of a new Minister, the honourable Gwede Mantashe, to look after the critical portfolios of mining and energy resulted in the hope that South Africa could avoid the economic damage caused by electricity generation. This was inevitable if SA continued to pursue the highly inefficient and ultimately costly wind and solar technologies for electricity generation being put forward by the powerful renewable lobby and neglecting its extensive and far cheaper coal and nuclear resources. However, what is the truth about this subject? This section offers a different point of view. It deals with the potential reductions in global temperature due to the Paris Agreement, "*The Intended Nationally Determined Contribution"* (INDC) measures and its estimated costs with particular reference to South Africa (Jeffrey, 2019).

The elephant in the room remains specifically Anthropogenic Global Warming (AGW) or human-induced global warming caused primarily by rising carbon dioxide levels. The IPCC claims this is caused by humans burning fossil fuels. Recently, there has been a heightened clamour amongst the intellectual elite, greens and youth supported by media interests. The world is nearing a doomsday scenario with temperatures rising out of control - a "tipping point".

A little recognised fact, known by most experts in the world, is that CO2's heat absorption capacity diminishes logarithmically, so that doubling the CO2 content in the atmosphere from 0.04% to 0.08% (which would take probably 200 years) would add about 1 degree of warming and not more. The concentration of CO2 is so small that it constitutes only 0.038% of the Earth's atmosphere and accounts for only 3.6% of greenhouse gases. As noted by Moore and supported by others' research, Anthropogenic CO2 has one significant benefit that the public is unaware of. It greens the Earth and increases the biomass needed to feed our growing population and animal life (Moore, 2016; Lindzen, 2018). Man-made CO2 has added over 15% to global biomass in the past decades, so fossil power plants add far more biomass (indirectly trees) than activists can plant. Recently, even the Davos World Economic Forum admitted the benefits of CO2.

### 5.9.2 TEMPERATURE REDUCTIONS AND ESTIMATED COSTS

Christina Figueres, the UN climate chief, said about the Paris Accord

> *"The Intended Nationally Determined Contribution" (INDC)s have the capability of limiting the forecast temperature rise to around 2.7 degrees Celsius by 2100, by no means enough but a lot lower than the estimated four, five, or more degrees of warming projected by many prior to the INDCs."*

That was a reduction in the temperature of 2.3 C or more. The selected global target temperature reduction is approximately 2.5C (Leemans and Vellinga, 2017). It is a question of what can be achieved and at what cost.

The IPCC claims that the CO2 increase from 280ppm (parts per million) in 1750 to roughly 410 ppm today has been caused by Human Emissions of CO2. In practice, science suggests that the ratio of human to natural CO2 is about 4.6%. Calculations show that since 1750 human CO2 emissions have added just 18 parts per million to the CO2 levels of 410 ppm. Nature is responsible for the remaining 392 ppm of CO2. If humans stopped all CO2 emissions, this would cause a falloff of only 18ppm from the current level of 410ppm or 4.4%. Human CO2 emissions are not dangerous to the planet and cannot cause runaway global warming. These figures point out that international efforts to curb CO2 emissions will decrease the temperature by a mere 4.4% or 0.11C. These figures are less than Lomborg's estimates of 0.17C.

### 5.9.3 COSTS

Lomborg calculates that the Paris Accord promises will result in a global economic cost of $1 trillion to $2 trillion annually from 2030. The cost is caused by slower gross domestic product (GDP) growth due to higher energy costs. Lomborg says that peer-reviewed estimates show that even if all countries continue their promised reductions from 2031 until 2100, it will reduce global temperatures by just 0.17°C (Lomborg, 2015).

The US climate promise will reduce global temperatures by only 0.031°C by 2100. The US's lost GDP costs are likely between $154 to $172 bn yearly. Wood McKenzie calculates the cost of the US's climate change plan would be approximately $4.7 trillion. Over 30 years to 2050, this would be $157 billion per annum. This figure is very close to the values estimated by Lomborg.

Based on the Lomborg figures above, South Africa's GDP in relationship to the global GDP and South African emissions of 1.1% of global emissions means that Carbon Tax and renewables would cost South Africa between R35bn to R51bn per annum. Secondly, South Africa's sacrifices will reduce temperature increases by only about 0.0026°C by 2100. These figures are less than measurable. This is a measure of the futility of South Africa's efforts to curtail the production of coal-fired power station electricity generation in a country with a treasure chest of coal resources and uranium.

The global situation was put very succinctly in 2018 by Lindzen. The paper has compelling remarks about the benefits to the planet of CO2 and the futility of current efforts to change the climate by limiting CO2. Two of the most informative and convincing statements he made were:

> "An implausible conjecture backed by false evidence and repeated incessantly has become politically correct 'knowledge' and is used to promote the overturn of industrial civilisation. "
>
> "Presumably, the power these people desperately seek includes the power to roll back the status and welfare that the ordinary person has acquired and continues to acquire through the fossil fuel-generated industrial revolution and return them to their presumably more appropriate status as serfs. Many more among the world's poorest will be forbidden the opportunity to improve their condition" (Lindzen, 1994b; Lindzen, 2017; Lindzen, 2018).

These words come from one of the world's most respected meteorologists and climatologists and a member of the US National Academy of Sciences.

South Africa must not be sucked into this pointless exercise pursued by narrow ideological and financial interests. They will destroy the economic, political and social development of South Africa for a generation and ensure that the country enters a new era of deepening poverty. The South African government must have only one objective: to maximise its economic growth rate and reduce unemployment. That means avoiding the flawed arguments regarding climate change and renewables and focusing on generating electricity from High-Efficiency, Low-Emissions HELE "clean-coal" and nuclear.

### 5.9.4 COSTS JOBS AND JOB-YEARS

The previous section analysed the costs, jobs and job-years of the leading alternative electricity generating technologies in SA. Some of the analyses used methodology based on two key reference works.

- *Critical Review of The Levelised Cost Of Energy Metric, M.D. Sklar-Chik, A.C. Brent & I.H de Kock South African Journal of Industrial Engineering December 2016 Vol 27(4), pp 124-133* (Sklar-Chik, Brent and de Kock, 2016).

> "The purpose of this paper is to critically review the 'Levelised Cost of Energy' (LCOE) metric used in electricity project development. This metric is widely used because it is a simple metric to calculate the cost per unit of electricity for a given technology connected to the electricity network. However, it neglects key terms, such as inflation, integration, and system costs. The implications of incorporating these additional costs would provide a more comprehensive metric for evaluating electricity generation projects and the system as a whole."

  It is also the cost at the gate of the supplier. It takes no account of additional expenses that the technology imposes on the system to deliver dispatchable electricity to the ultimate consumer's door.

- *January 2013, Energy intensities, EROI (energy returned on invested), and energy payback times of electricity-generating power plants;* (Weißbach *et al.*, 2013)

> "The economic efficiency and wealth of a society strongly depend on the best choice of energy supply techniques which involves many parameters of quite different significance. The 'energy returned on energy invested', EROI (often also called ERoEI), is the most critical parameter as it describes the overall life-cycle efficiency of a power supply technique, independent from temporary economic fluctuations or politically motivated influence distorting the perception of the real proportions".

  The EROI answers the simple question, 'How much useful energy do we obtain for a certain effort to make this energy available'.

Of course, there is a rebuttal (Rauge*i* et al., 2015).

The primary quantity used in the Weißbach paper was Energy Return over Energy Invested or the EROI, abbreviated with R. Energy intensity and energy payback time are derived by simple relations as shown in the following. The EROI of a power plant, R, is the ratio of usable energy. Er, the plant returns during its l or investment, divided by all the invested energy or Ei needed to make this energy functional. In summary,

Mathematically this is R=Er/Ei.

An examination of the equation shows that either the numerator must increase or the denominator must be reduced. The more real electricity produced, the higher the return and vice-versa. The fewer resources used, defined by the denominator, the higher the return and vice-versa.

The energy intensity is simply the inverse of the EROI. Therefore, it is denoted as $R^{-1}$. It describes the "effort" needed to "generate" a specific energy output. In summary:

Mathematically this is $R^{-1}$ =Ei/Er.

This section estimates costs, jobs, and job-years: it does not pretend to go into the detail required to make accurate calculations. However, it gives sufficient guidance on such complex calculations' extent and likely direction. Three metrics are used to provide output or Er. They estimate the real MW produced in SA, the average number of jobs created in the SA economy and GDP. The underlying assumption is that the real MW produced in South Africa creates the country's employment and GDP figures recorded. If an additional real MW is generated, it can be assumed to create the equivalent number of jobs and GDP. This would be based on the additional MW ratio produced to the existing real MW of electricity produced. Only two metrics measure Ei, representing the energy or resources used to generate electricity. They are costs and direct jobs. In this first part, cost represents the construction costs, while direct jobs measure the resources used. Nowhere is there a measure of both together which is really necessary.

On this basis, the following figures emerge from Table 32.

R nuclear=Rn;

R coal=Rc;

R renewable =Rr.

Using real MW generated and direct jobs necessary:

Rn=4500/5500 i.e., Rn=0.818;

Rc=3808/4000 i.e., Rc= 0.952;

Rr=1155/2000 i.e., Rr=0.578.

The ratios estimate the efficiency for each energy technology produced against the energy used to progenerate it. The proportions are coal 1, nuclear 0.859 and renewables 0.607. Renewable efficiency Rr is a combined figure for wind and solar as the individual costs were unavailable. In summary:

Nuclear is 14% less efficient than coal ((0.952-0.818)/0.952*100), and

Renewables are 39.3% less efficient than coal.

Using real MW generated and costs in billions:

(In this section capital X refers to times. Small x is a variable)

Rn=4500/300, i.e. Rn=15X;

Rc=3808/195, i.e. Rc= 19.5X;

Rr=1155/200, i.e. Rr=5.78.

The ratios determine an estimate of energy efficiency produced against the costs required to provide each technology's power. The proportions are coal 1, nuclear 0.769 and renewables 0.296. In summary:

Nuclear is 23.1% less efficient than coal; and

Renewables are 70.4% less efficient than coal.

These are the same figures appearing previously but inverted.

If the figures were taken over the lifetime of each technology and measured in terms of MWh over the lifetime of each technology, nuclear 70 years, coal 40 years and renewables 25 years, the cost-effectiveness changes dramatically. Nuclear energy has emphatically become the most cost-effective technology.

Nuclear is 34.8% more cost-effective than coal; and

Coal is more than 5X more cost-effective than renewables.

Clearly, the time cost of money would need to be considered. This cost would be affected by the rate assigned to each technology. It also needs to consider that shorter-lived technologies such as renewables need to be replaced. Short lives mean they have to be replaced, and the replacement cost must consider the inflationary impact on its replacement cost.

Each technology's changing relative capital and running costs must be considered a further factor. Recent experience is that renewable costs have been falling whilst costs of fossil fuels have been rising. There are many reasons for these changes, which is a crucial subject.

### 5.9.5 COMPENSATING FOR LOAD FACTOR

As stated at the outset of the paper by Weißbach et al. (2013).

> "The economic efficiency and wealth of a society strongly depend on the best choice of energy supply techniques which involves many parameters of quite different significance."

This thesis has taken only a few metrics to illustrate a point. In most instances, the Levelised Cost of Energy (LCOE) compares electricity-generating technologies as this is the norm used internationally by energy planners. The LCOE metric's limitations must be highlighted, and it must not be used in isolation. A difficulty is when comparing dispatchable and non-dispatchable technologies, as the LCOE merely accounts for the average electricity produced. The claim is that wind is cheaper and the lowest-cost energy source. The fact is that it does not produce electricity when it is required. It only produces power 35% of the time or in any given time period. The load factor of 35% is a probability factor. Therefore, the probability of not producing electricity is 65% of the time, even when it is often accompanied by high variability, interruptibility and unpredictability.

A further argument is made to meet its requirements provided there is dispatchable electricity made available from other more efficient but higher-cost sources. This is true, but it does not consider the backup requirements and the difficulties associated with managing these.

As noted by Sklar-Chik et al (2016)

> "It neglects certain key terms such as inflation, integration costs, and system costs". "Some commentators suggest that network costs (transmission, distribution, and marketing costs) can be as much as 40% of total electricity costs, adding a significant burden to the network operators that must then be recovered through tariffs".

In summary, it is impossible to compare electricity prices generated from stable, secure supply sources with high load factors with electricity supplied by highly variable interruptible and unpredictable energy sources with very low load factors directly with LCOE costing. Overseas research and real-life experience bear testimony to this. Major adjustments need to be made. One methodology is increasing the technology's supply to compensate for the load factor. A fair comparison assumes that by increasing the number of units involved from one energy source, one will always generate electricity. This ratio means that it should theoretically be possible to provide power 24 hours a day. However, even this does not give the correct answer. A unit cannot both supply electricity and store it at the same time. Also, it needs a supply source of power to generate electricity if it cannot supply electricity during its allotted time slot. An additional unit is theoretically also required.

In summary, this price comparison methodology consists of a straight comparison of the generating sources if it is possible to generate the total electricity requirement by increasing the energy source sufficiently to compensate for the variability and efficiency reductions due to the published load factors. It assumes that if the energy sources' volume is increased sufficiently, it will fully compensate for the variability experienced due to low load factors. Again, even this is a false or optimistic assumption. There are many periods when the sun does not shine, nor does the wind blow. It is for this reason that the base case system requires full backup.

**Table 31: Adjusted LCOE for load factor**

| | Nuclear | New coal | Wind | Solar PV |
|---|---|---|---|---|
| **Average capacity Load factor** | 90% | 82% | 35% | 26% |
| **LCOE R/kWh** | R1.30 | R 1.05 | R 0.62 | R 0.62 |
| **Effective price 24-hour day** | **R1.44** | **R1.28** | **R1.77** | **R2.38** |
| **Ratios** | **113** | **100** | **138** | **186** |

Source: IRP 2016, EconomicRisk

Based on these assumptions, it should be noted that using this estimating technique, the wind cost will be 38% greater than coal and some 23% higher than nuclear. On the basis of wind being 80% of the renewable mix and solar being 20% of the mix, the renewable price ratio would be approximately 47.6% higher than coal.

These could be underestimated. The technique only calculates for generation during periods when the original unit is not generating. However, it is necessary to have an extra unit to generate and save electricity when the original unit is unavailable and should be generated. It should be noted that solar offers a superior load factor during the day than wind at approximately 52% during the daylight period compared to wind at 35%. Therefore, it is more easily managed and predictable than wind, which generates electricity on average, only 35% of the time during any specific period. Also, each does vary per season and time of day. This has not been considered.

Solar systems only work during daylight hours, so their efficiency, when combined with gas, is higher than wind during this high baseload power demand. Baseload requirements fall off during the night allowing the nuclear and coal-based electricity generating sources their task of supplying 24-hour baseload supply. Effectively they are the only sources that offer the security of dispatchable electricity supply at the lowest cost.

Some consider this to be an unrealistically simple method. However, each technologically should be able to stand on its own regarding dispatchable power. Wind and solar require backup from storage or other sources (Safaei and Keith, 2015). The problem is that no technology can simultaneously generate power for electricity use and storage. Wind delivers electricity for, on average, only eight hours in any twenty-four-hour time period. These statistics are constantly being examined and adjusted to account for the latest trends.

Furthermore, large groups of wind turbines spread geographically widely in one region are not independent. The wind is either blowing or not blowing over a wide area. The argument can go even further. Because of its inconsistency, it needs a backup for itself. Its cost rises further not only for the ability to store but also for the storage costs involved. These costs at present are born by the power utility or grid operator. The operator needs to have these power sources online and available on-demand. In other words, it must hold dispatchable electricity in reserve not only as a "spinning reserve", i.e., immediate supply, but also when notice can be given to start generating. No wonder it is expensive and costs the operator ESKOM (ESKOM, 2016). When electricity is generated and is not required, then once again, it costs grid managers money. Ultimately these costs are passed on to users. On a worldwide basis, it is recognised that these are hidden additional costs and effectively tax the poor (Stephen, 2018). In effect, they are subsidies to intermittent renewables.

### 5.9.6 EXPERIENCE IN OTHER COUNTRIES

Doubtless, countless people will prove that EROI is not a justifiable measure to use. They will have more difficulty establishing the facts supporting it is valid. In 2016, it was interesting to note that Germany's prices for electricity by industry were 52% higher than France (nuclear) and 86% higher than Poland (coal). In Ireland, often given as an example of wind power's success, the equivalent comparisons were 35% compared to France and 64% compared to Poland. Besides, Ireland is a tiny country with a grid of only 4.7 GW. America would now appear to be about half the comparable German prices. Germany's electricity price seems to be 44% higher than the average electricity price in Europe. The Wall Street Journal estimates that Germany's electricity costs have risen 60% due to its renewable energy subsidies. This has lowered their GDP, standard of living and competitiveness. As a result, several companies, including BASF, SGL Carbon and Siemens, have moved or are considering moving operations from Germany.

A further fact that should hold up the large-scale development of renewables is the land area involved with renewables. For example, onshore windfarms in Germany produce less than 2 $W/m^2$ of land. A new oil field, on average, produces 90 $W/m^2$ of land. Nuclear involves minimal land area. Coal uses more land. It doesn't remain significant compared to the land area used by wind and solar. An idea of this problem's magnitude is that the IRP contains scenarios involving more than 10000 square Km of land in South Africa. This is equivalent to 1500 Km of coastal land 3 Km deep with wind turbines and a similar mountain range, plus numerous other wind farm areas. Those defending windfarms will find it difficult to defend those landowners in the surrounding regions bordering on windfarms, probably an area twice or even three times the areas of windfarms have found their land devalued. Only a few wealthy or unscrupulous owners benefit from the largesse of windfarm interests. Environmentalists are also concerned about the devastation caused to habitats for large birds, bats, migrating birds, insects, and other life forms, including animals and humans. This is the history of windfarms worldwide that are not given sufficient consideration and weight.

### 5.9.7 ENERGY PLANS IN OTHER COUNTRIES

The pro-renewable faction will also find it difficult to argue with the plans for increasing the use of coal and fossil fuels in many countries ( Fossil Fuel Foundation). These difficulties apply to Poland, the United States under the new administration, India, China and the ASEAN countries. Japan is set to build 45 new High-Efficiency Low-Emissions (HELE) coal plants totalling approximately 45 GW (Follet, 2017). The International Energy Agency (IEA) has forecast that 730 GW of these highly efficient plants will be built by 2040. Despite being one of the most richly endowed coal countries globally, South Africa plans to increase its coal output by less than 15 GW. At the same time, it is closing older dirty plants. The output of electricity generated by coal-fired power plants will decline significantly. South Africa exports significant coal quantities to other countries. Therefore, these countries will use one of the most efficient electricity-generating sources globally to improve their manufacturing and industrial sectors more efficiently and effectively, thus exporting lower-priced goods to South Africa. This will ensure South Africa’s structural deficit continues and provides lower economic growth for many years.

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### 5.9.8 THE COMBINED ECONOMIC IMPACT ON GDP AND EMPLOYMENT

South Africa has a relatively high population growth of approximately 1.7% per annum and a steep annual increase in the labour force. It is generally recognised that worldwide youth unemployment is three times higher than adult unemployment. This view is supported by data in South Africa, where unemployment is running at over 25%.

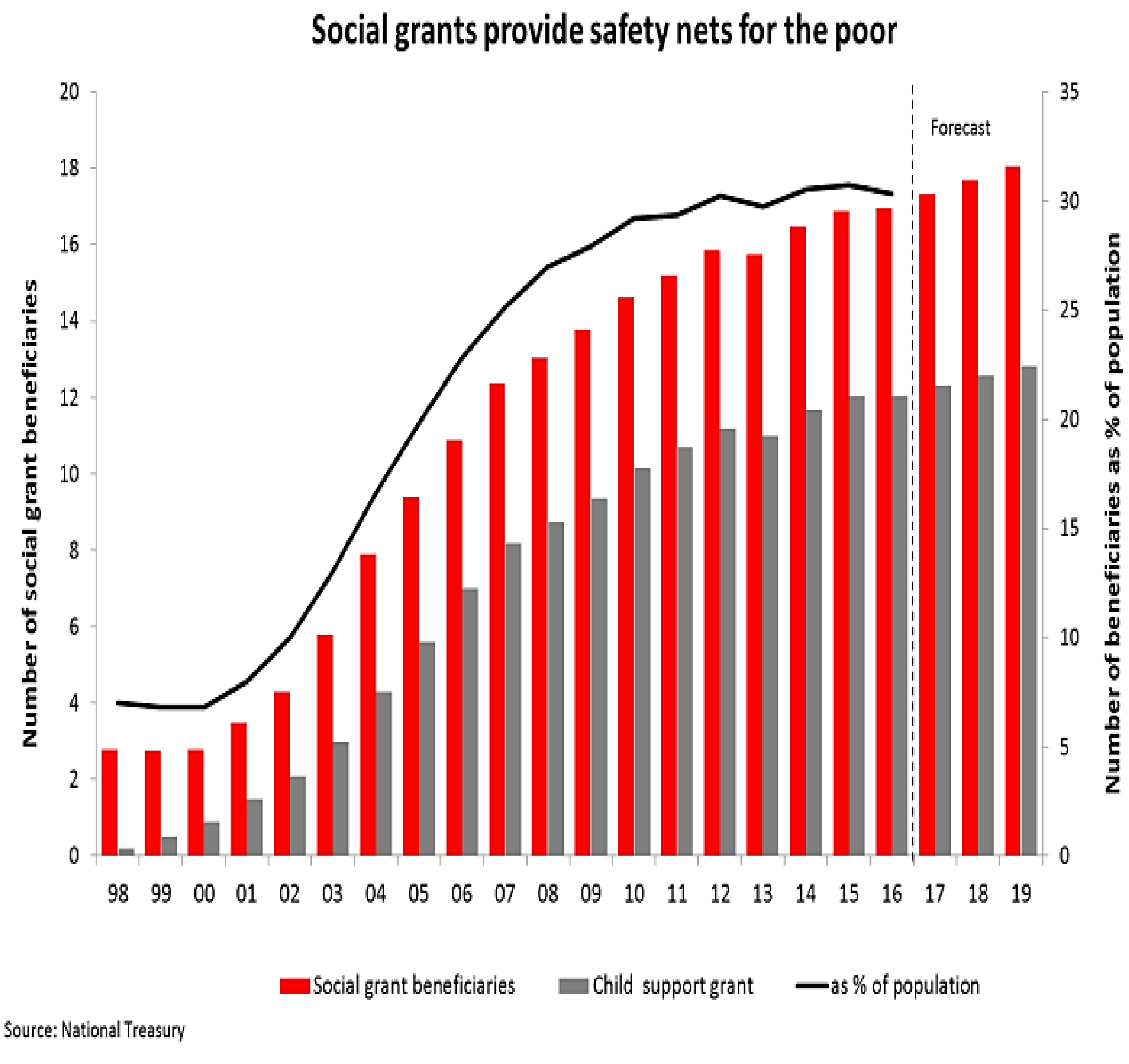


**Figure 61: Social grants in South Africa**

It should be noted that the changes in the South African economy brought about by the recent economic downturn, the impact of Covid and now the Ukraine war have dramatically altered economic statistics and their trends. The figures for social grants have deteriorated. It may take years to obtain any improvement.

The unemployment rate of young adults is estimated to be approximately 40% or more and increasing. Only through higher economic growth, focused on the goods-producing sectors, will there be sufficiently high sustainable growth to absorb the workforce's growth and potentially decrease these dangerously elevated levels of current unemployment and excessively high social grants in proportion to the size of the working population.

The country already has over 17.6 million people on social grants and only about 7 million taxpayers (Stats SA, 2016; StatsSA, 2019 ). Increasing unemployment will place even more people on social grants. The country also needs to reduce its population growth rate. Raising living standards and education through a higher sustainable growth rate is the best way of achieving this. The fact is that industrialisation and larger projects spawn smaller upstream suppliers and downstream industries.

More significant industrial businesses, essentially megaprojects, play a vital and influential role in economic development. Not only do such more substantial industries and companies supply essential products for export and the local market, but through their multipliers, they create other industries, including other businesses that are often smaller and more labour intensive. South Africa also has very low labour productivity. South Africa is in the bottom quartile in global labour productivity statistics, despite having one of the highest expenditures on education as a percentage of Gross Domestic Product (GDP). What is wrong is a potential social ethic driven by our labour laws, where workers are excessively protected, and wages are not in line with productivity. Union activity protects workers. Minimum wages effectively block more efficient workers amongst the unemployed from becoming employed and a host of other effects. These and other laws are creating a drive towards more capital-intensive equipment. These trends are a global problem. Unemployment amongst the youth or young adults runs at excessive levels in South Africa of more than 35%. The policies implemented to protect labour often contribute to the high unemployment rate. A Carbon Tax will significantly contribute to this state of affairs.

### 5.9.9 THE DAMAGE TO ECONOMIC POTENTIAL

In short, Carbon Tax and specific labour laws, although having good intent, result in lower investment, slower economic growth and increased investment in more energy-efficient equipment (J. Jeffrey, 2015). Perversely, these foster higher levels of investment in more capital-intensive equipment to increase output. At the same time, reduced productivity will also foster more Investment in capital-intensive, labour-saving equipment, which is naturally more energy-intensive. Those who believe energy intensivity or electricity intensity will continue to decline are sadly unaware of economic reality or the country's economic and financial needs and necessities (Lane, 2018).

With correct policies and adequate and secure electricity growth, South Africa could have a potential sustainable GDP growth rate of approximately 4.1% per annum. Because of several policy issues, insufficient security of supply and non-competitive prices of electricity, the Carbon Tax and the switch to more costly renewables and other investment adverse policies, South Africa's sustainable GDP is unlikely to exceed 2.5% per annum. Low growth will result if the current IRP 2016 base case, its unconstrained alternative, or the IRP 2019 is implemented ( Jeffrey, 2019).

The detrimental impact on the country's goods-producing industries, particularly mining, mining beneficiation, manufacturing, and Agri-processing sectors, is colossal. By 2035, this would result in GDP being approximately R1.4 trillion less than what should be achieved, while employment levels could be some 5.0 million lower than the required levels. A Carbon Tax will play a substantial role in this poor economic performance, which will have detrimental impacts on living standards, unemployment and the social and political structure of South Africa. More particularly, it would make South Africa's crucial goods-producing sector less competitive and cause further structural problems for the Balance of Payments current account. In recent years with slow economic growth, the deficit has decreased markedly. In the global competitiveness report by 2014, out of 144 countries, South Africa has fallen to 113th in terms of its labour market efficiency.

**Table 32: Global competitive index**

## Global Competitiveness Index

| Global Competitiveness Index | Rank 2014/2015 | Score (1-7) |
|---|---|---|
| GCI 2014-2015 (out of 144) | **56** | **4.4** |
| GCI 2013-2014 (out of 148) | **53** | **4.4** |
| GDI 2006-2007 (out of 125) | **45** | **4.4** |
| **Sample Size** | **144** | |
| **Basic Requirements (40.0%)** | **89** | **4.3** |
| Institutions | 36 | 4.5 |
| Infrastructure | 60 | 4.3 |
| Macroeconomic environment | 89 | 4.5 |
| Health & primary education | 132 | 4.0 |
| **Efficiency enhancers (50.0%)** | **43** | **4.4** |
| Higher education & training | 86 | 4.0 |
| Goods market efficiency | 32 | 4.7 |
| Labour market efficiency | 113 | 3.8 |
| Financial market development | 7 | 5.4 |
| Technological readiness | 66 | 3.9 |
| Market size | 25 | 4.9 |
| **Innovation & sophistication factors (10.0%)** | **37** | **4.1** |
| Business sophistication | 31 | 4.5 |
| Innovation | 43 | 3.6 |

Source: The Global Competitiveness Report

Sources: World Economic Forum

It fell to 89th in terms of its macroeconomic environment. It has recently improved its position, and in 2020 it is now ranked 60th out of 141 countries. This is not nearly good enough. The Carbon Tax will only exacerbate these trends. Most importantly, it will likely result in a further deterioration in South Africa's sovereign rating with grave consequences to South Africa's cost of capital, raising capital and attracting foreign investment.

### 5.9.10 THE POTENTIAL TOTAL ECONOMIC IMPACT

The total potential economic impact of introducing the Carbon Tax, the greater use of renewables and their impact through higher input costs flowing through the economy on investment is set out in this table.

**Table 33: Potential impact of slow growth from 2014 to 2035**

| Potential cost of Incorrect policies 2014 to 2035 | |
|---|---|
| **POTENTIAL PROSPERITY FOREGONE** | |
| **LOSS OF GDP** | **R Million** |
| **GDP Agriculture** | -7622 |
| **GDP Mining** | -128302 |
| **GDP Industry** | -329783 |
| **GDP Services** | -974929 |
| **GDP TOTAL** | **-1440636** |
| **ASSOCIATED EMPLOYMENT** | -7459913 |
| **DEPENDENTS** | 20877757 |
| **POPULATION** | **60728000** |

Sources: Economic Modelling Solutions EconomicRisk

It must be made clear that the implications for investment include the effects of the current weak confidence caused by various policies affecting the business investment in the environment in South Africa. It is impossible to say the Carbon Tax directly impacts direct business investment in the economy. The effect of the coronavirus on economic growth rates is substantial. The Chapter on Previous research and literature sets the analysis and comments. All statements and forecasts are based on information available before the outbreak of the coronavirus

- This results in a reduction in the annual growth rate of approximately 1.3% per annum. This would lead to a decrease in GDP of R1 billion by 2035 and five million fewer jobs being created. The number of dependents affected adversely could be 18 million.

- The combined effects are potentially highly damaging to the economy. They could easily result in the economic growth rate being reduced from a potential growth rate of more than 4.0% per annum to a rate close to the former growth forecast rate of less than 1.0% this year, next year of 1.8% and in the next few years possibly a maximum of 2.5%.
- It is problematic to analyse the difference between the impacts of uncompetitive price increases and investment and business-unfriendly political and economic policies.
- South Africa's economic growth rate is stuck in the low region of emerging countries' economic growth range at less than 2.5% per annum. In contrast, other countries classified as emerging economies, including India, China and the ASEAN countries, have economic growth rates and planned growth rates greater than 5%.
- Many countries are not endowed with the natural energy and other resources that South Africa has in abundance. Something is radically wrong with its political, social and economic policies and energy and electricity generation policies.
- Many current policies affect labour; BEE, affirmative action, and minimum wage rates drive labour-saving investments. They drive a greener economy artificially through a Carbon Tax and other disincentives for businesses forcing higher prices into the system. They will not create a more labour-intensive economy. They will do precisely the opposite. They discourage South Africa as a business destination and reduce investment growth in substantial developments and smaller, more labour-intensive businesses.
- Significantly, slower growth could reduce the cumulative regular taxes collected by 2035 by approximately R600 billion. It will require a costly bureaucracy to run this complex, cumbersome and highly inefficient tax. The lower taxes collected through normal channels would have to offset the estimated Carbon Tax collected.
- With the correct policies and adequate secure electricity growth, South Africa should have a potential sustainable GDP growth rate of approximately 3.8% per annum. Because of several policy issues, insufficient security of supply and non-competitive prices of electricity, the Carbon Tax and the switch to more costly renewables and other investment adverse policies, South Africa's sustainable GDP is unlikely to exceed 2.5% per annum.
- These issues will have a detrimental impact on the country's goods-producing industries, particularly industrial development, mining, mining beneficiation, manufacturing, agriculture, and Agri-processing sectors. By 2035, this would result in a GDP of between R1.0 trillion and R1.4 trillion, less than what should be achieved. Employment levels could be approximately 5.0 to 7.0 million lower than the levels possible.
- A Carbon Tax will play a substantial role in this poor economic performance, which will have detrimental impacts on standards of living, unemployment and the social and political structure of South Africa. More particularly, it would make South Africa's crucial goods-producing sector less competitive and cause further structural problems for the current account of the balance of payment.

- While there is a complex web of offsets in the Carbon Tax bill, excluding some industries or sectors, these will be reduced over time. More than that, the link between sectors becomes blurred because all sectors are strongly linked. Cost increases in one sector find their way into other sectors, and numerous unintended consequences exist.

Notwithstanding any exceptions and offsets, the potential damage to the economy consequent from introducing a Carbon Tax is so substantial and overwhelming that the strongest possible recommendation is made that the introduction of the Carbon Tax is cancelled and uncertainty avoided. Unless this is done, investment uncertainty will remain. Two reports summarise the author's previous written opinions on South Africa's economic and development problems. This thesis references most of these elsewhere (Jeffrey, 2017c. Jeffrey, 2018b).

## 5.10 CONCLUSION

This section broke down the cost of different electricity-generating technologies based on historical figures made available from several sources. In particular, it analyses more carefully the impact of each electricity-generating technology on employment and economic growth. The statistics were based on information made available by several sources on costs, jobs created by each technology, and their economic impact on South Africa's economy. This section has provided further detail and background to the section dealing with the values of the leading alternative electricity generating technologies in SA.

Further detail is available in the various sections, but in summary, the analysis shows that:

- The energy return over energy invested for MW output and the REIPPP costs defined as R were as follows:
    - Rn showed that nuclear was 14% less efficient than coal, and Rr showed renewables being 39% less efficient than coal
- Based on costs
    - Rn showed nuclear being 23% less efficient than coal, and Rr showed renewables being 70% less efficient than coal
- Based on increasing the fleet size to compensate for different load factors
    - Rn showed nuclear being 13% less efficient than coal, and Rr showed renewables being 47% less efficient than coal

All methodologies confirm that nuclear as being more expensive than coal. Importantly, renewables are shown to be significantly more costly a

# 6 DISCUSSION OF RESULTS, ENERGY SOVEREIGNTY AND THESIS CONCLUSION

## 6.1 OVERVIEW OF ENERGY, POVERTY, UNEMPLOYMENT AND GROWTH

This chapter reviews some critical issues that are covered in this thesis. These issues include the renewable challenges, the potential problems posed by nuclear power, Independent Power Producers and environmental concerns. Finally, the section suggests a way forward for the South African economy regarding its power generation policy. The chapter discusses the following key issues identified and reflected in the article "Solving Energy Poverty, Unemployment, and Growth Challenges in South Africa" ( Jeffrey, 2017b).

## 6.2 THE TOTAL ECONOMIC IMPACT OF THE RENEWABLE POLICY

Often recommendations, particularly by overseas observers and advisors, show very little understanding of the realities that face developing countries, such as South Africa. Nor do foreign observers and advisors understand the energy realities required for sustainable economic growth and rising standards of living in such economies. The commentaries received are dominated by vested financial and ideological interests. The economic realities of emerging industrialising economies require electricity supply security at the most cost-effective commercial and economical prices. These steps are necessary to raise their economic growth rates and improve living standards in a modern competitive global economy.

In summary, South Africa is facing a national crisis. The government must raise the funds required to avert the potential long-term economic stagnation of the country. ESKOM must be adequately and effectively structured and funded shortly so that the state can restructure the industry, introduce IPPs, encourage co-generation and foster genuine electricity efficiency. It would be incorrect and a fatal economic error if the capital build programme is delayed and partially funded out of current tariff increases, making domestic industry uncompetitive globally.

Electricity-generating capacity increases are the single most prominent employment-generating decisions policymakers can make. This thesis utilised econometric techniques to develop the necessary models to analyse the potential benefits of alternative industrial strategies, and the damage potential shortages of electricity capacity and excessive pricing can cause to the national economy. However, analysis of some simple economic trends supports the need to act. The research acknowledges that a successful strategy will bring handsome rewards for job growth and financial payback for any investment.

Three significant impacts linked to the Carbon Tax have substantial adverse effects on the economy. The introduction of the tax could

- Negatively impact mining GDP growth by approximately 0.3% per annum. By 2035 its cumulative GDP reduction could be about 3.5% o. The GDP would be about R11 bn less than it could have been. Around 40000 fewer jobs could be available. Recent growth in the sector has been limited, and it can be anticipated that the industry will decline without other measures. Apart from these direct effects, there are potential negative impacts on the industry and associated coal exports ( Jeffrey, 2017d).

- Manufacturing GDP growth will be slowed by approximately 0.3%. By 2035, the manufacturing sector could reduce its potential cumulative GDP contribution by around 2.5%. Its GDP would be about R20 billion less than it could have been. A total of 150 000 fewer jobs would be generated.
- The impact on agriculture could also be considerable. As stated previously, agriculture must cope with the vagaries of the weather. Protecting a country's food resources and farming community is imperative.

**Table 34: Total potential reduction of GDP and employment**

**Cumulative reduction in potential growth & employment**

**Impact of Carbon Tax**
**GDP Growth: -4.4% -R200 billion**
**Employment: -1.1 million jobs**
**Impact of Renewables**
**GDP growth: -4.4% R200 billion**
**Employment: -1.1 millions**
**Impact on Fixed Investment**
**GDP growth: -10.0% -R500 billion**
**Employment: -2.5 million**
**Impact on the coal mining industry**
**GDP growth: -2.5% -100 bn**
**Employment: 300000**
**Total impact on GDP and employment**
**GDP growth: –R1000 billion**
**Employment: -5.0 million**

Source: ESKOM SARB Economic Modelling Solutions EconomicRisk

There are four negative economic impacts that result from the Carbon Tax and the associated renewable programmes by 2035.

- The first is the direct negative impact on the economy of about R200 billion.
- The second is the direct impact of the renewables programme due to increased prices and instability in the grid of about R200 million.
- The third is the negative impact on domestic and foreign direct investment of approximately R500 billion.

- Finally, there is the direct impact of a decline in the coal mining and mining industries and a reduction in its exports of R100 billion (Jeffrey, 2017d). It is estimated that there could be a reduction of 37% in the size of the industry. This reduction would reduce GDP by 1.8% and the decline in direct and indirect employment of more than 175000 people.

Conservatively, this is a reduction in one trillion Rands GDP from the size the economy could have grown to by 2035. It would reduce the economic growth rate potentially by 0.8% per annum. If policies are in place for an economic growth rate of 4.1% (including energy policies), the combined impact will reduce the GDP growth rate to less than 2.5% per annum. Significantly it could reduce employment by more than 5 million jobs.

### 6.3 RENEWABLE CHALLENGES

The first key issue concerns the debate regarding renewables. Many experts attest to the significant fallacies and weaknesses of the primary renewables, wind and solar. Renewables are highly variable, often supplying power when not needed and not providing power when needed (PeacockB, 2016). Thus, these are expensive forms of energy production ( Jeffrey, 2016c). The supply must be purchased at set prices as in the purchase agreements. Germany's experience (under its *Energiewende* program) wherein the country sells unwanted electricity at a loss to other countries and purchases the necessary supply at a premium is well known (Sopher, 2015; Sopher, 2016a). In effect, these prices are financial subsidies for wind and solar.

Germany is fortunate to have other major electricity-generating countries nearby. It can tap into electricity provided by nuclear power plants in France, coal-generated electricity in Poland, or hydroelectricity from Scandinavia or Switzerland. South Africa does not have those options. Moreover, due to these financial subsidies, Germany has the most expensive industrial and household electricity in Europe, aside from Denmark (Terbrugge and Collins, 2017; Rentier et al., 2019). Consequently, Germany placed a cap on the supply of renewables and, for a period, was in the process of removing all financial subsidies to renewable companies (Horgan J, 2016). *Energiewende* has established that wind energy and concentrated solar power are not technologies suitable for mass baseload electricity supply (Andrews, 2016). This theme has been repeated in other countries, such as Australia, where their wind energy drive echoes what has happened in Germany (Sloan Judith, 2016; Jeffrey, 2017b).

The drive for “green energy” is slowing growth and enforcing poverty in emerging economies. In developed economies, it is causing unemployment, reducing living standards, and increasing energy poverty. The political backlash in Britain, the U.S., and Germany confirms this. In these nations, environmentalists argue that the cost is merited. They lobby financial institutions and governments. The institutions have changed their policies with disinvestment from coal in response to lobbying. There are also more secure profits because of guaranteed prices and subsidies from governments (Bryce, 2015; Guardian, 2015).

Further obstacles are taxes to fund renewable energy programs and other environmental programs. These green taxes are regressive, with people on lower disposable incomes paying more than people on higher incomes. Consequently, renewables are, in effect, a tax on the poor (Stephen, 2018).

In South Africa, concern exists over plans to introduce massive windfarms totalling 60 GW under the theory that geographically separated windfarms will ensure a more continuous supply of electricity (Plan, 2019). The unconstrained plan put forward in 2016 by the Council for Scientific and Industrial Research (CSIR) envisages more than 100 GW of wind.

A wind profile study conducted across the country appears to confirm that this is the case (Bofinger et al., 2016; Fraunhofer, 2016). Based on these findings, they claim that somewhere in the country, the wind is blowing, and the sun is shining (CSIR; SANEDI, 2016).

However, South Australia has had significant problems with its wind energy power strategy (ESKOM, 2016). This is not the experience in Europe and the UK, where the average load factor from all onshore windfarms remains 30% or less. Electricity generation still needs a backup for baseload power when the supply fails. As set out by the CSIR, a full-delivery plan for 16 GW of baseload electricity requires 60 GW of energy capacity, consisting of onshore facilities. They are far too expensive and supposedly require 32 GW of wind, 12 GW of solar PV, and 16 GW of gas for consistent, secure electricity delivery. This full-delivery plan for 16 GW baseload power would require more than 6000 square Km of unsightly windfarms generally built on high ground to ensure maximum efficiency (Plan, 2019). More than 12,000 Km of roads will be needed to service all the units, and the countryside landscape will be crisscrossed by at least 10,000 Km of additional transmission lines. The local habitat would also be damaged with extensive evidence from other windfarms of mortality to insects, birds, and bats. Wind farm developers must take adequate preventative provisions and actions to avoid habitat, ecological, and environmental problems in the planning stages.

Of course, this comes down to the following critical issues and debates. Are renewables, primarily wind and solar, efficient and sustainable? Can they ensure the "*security of electricity supply"* at a competitive economic price that can enable the government to achieve its goal of "*enabling economic growth and prosperity*"? The Chinese and the facts of real life strongly suggest not.

There is a perpetual debate in the literature surrounding Levelised Costs of Electricity (LCOE). Wind and solar have the lowest LCOE at approximately 62c/kWh compared to coal's LCOE of R1.05/kWh and nuclear at R1.30/kWh. However, these figures do not consider that these renewables deliver electricity less than 35% of the time, are unpredictable and highly variable and are subject to the vagaries of the weather. Their generating lives are very different, twenty years or less compared to nuclear 60 years or more. The fact is that one cannot easily compare dispatchable electricity (coal, nuclear and gas) with non-dispatchable electricity (wind and solar). The literature is replete with papers on the subject, but three are highly relevant to this debate. They are reports by May entitled Energy and Power Plants and Renewable Energy, what is the cost? (Andrew May, 2017; Andy May, 2017)

### 6.4 NUCLEAR POWER

The second major issue concerns nuclear power. In South Africa, it is believed by many experts that baseload electricity should be provided by coal (presumably including other fossil fuels, primarily gas) and nuclear. The question remains, how much nuclear? Nuclear power stations can take seven years or longer to build, and the upfront costs make a large-build fast-track program unaffordable for a country such as South Africa. For example, Britain approved the Hinckley Point nuclear power station project (Macalister, 2016; IAEA, 2018). The total cost for the 3200-MW power station could be $US30 billion. In comparison, the new 4800-MW Medupi coal-fired power station in South Africa cost an estimated $US14 billion and the initial, now installed, renewables 2310-MW program cost approximately $US12 billion (Yelland, 2016).

Renewables in South Africa only have an average load factor or deliver the power of about 31% depending on the mix (Wind at approximately 35% and solar at 26%), nuclear with load factors of 92% while “clean-coal”-fired plants such as Medupi have load factors of about 82%. Renewable capital costs have dropped substantially since 2011 and are far below the original costs. The delivered costs for wind-generated electricity at the gate are said to be approximately 62 cents/kWh. A first assessment indicates that wind is cheaper than coal and nuclear competitors. This price does not consider the cost of surplus energy unable to be stored from non-dispatchable power sources such as wind.
Furthermore, based on this guaranteed delivered price and a load factor of less than 35%, this price effectively becomes a subsidised price as it is paid for whether the electricity is required or not. There are also increased costs due to the low load factor, higher transmission costs and greater distances. Wind power's actual cost as a delivered baseload-dispatchable power source is significantly more expensive than coal-generated electricity (Jeffrey, 2016a).

These higher delivered electricity prices will have a significant detrimental impact on the economy. Increased electricity costs slow economic growth and devastate the goods-producing industries, particularly the critical mining, manufacturing, agricultural, and Agri-processing industries. These industries are essential to South Africa’s export performance and employment growth, particularly in the relatively unskilled workforce. Estimates indicate that 16 million new workers will enter the workforce by 2035. With low baseload electricity growth of only 2.5% per annum, due to the planned considerable reliance on renewables unsuitable for baseload power, GDP growth is unlikely to increase at more than approximately 2.8% per annum. At this growth rate, fewer than 6 million jobs will be created by 2035, resulting in unemployment growing by at least 7 to 10 million job seekers.

### 6.5 CHALLENGES FOR INDEPENDENT POWER PRODUCERS

The third major issue concerns the role of independent power producers (IPPs). ESKOM stated it would no longer sign new agreements with IPPs but has since signed. The concern is with the guaranteed prices and offtakes of renewables and should not be with the IPPs themselves. As is the case overseas in Germany, for example, paying uneconomic guaranteed prices without assurance that electricity will be delivered when required. From a business perspective, this is correct. However, IPPs are essential for the future of energy provision and the economic development of the economy. However, they must deliver secure dispatchable suitable power at a reasonable financial, commercial and economic cost.

In South Africa, ESKOM is already a giant monopoly, controlling the entire market's generation, transmission, and distribution, which needs to be re-examined in a mixed market-oriented economy. ESKOM generates, distributes, and controls close to 40,000 MW through the grid. By 2050 or shortly thereafter, South African electricity demand is expected to increase to over 70,000 MW. A sizable proportion of this electricity growth should be provided by IPPs to ensure a more competitive power market.

ESKOM should focus on baseload generation and build new HELE “clean-coal” and nuclear power stations, and refurbish the more economical its ageing fleet of coal-fired power stations (Endfield and others, 2019). These will need to be supported by gas operations. Any new structure must allow the IPPs to flourish and bring genuine competition free of subsidies. This competition and cost structure must include all generating, grid, and distribution subsidies and costs. If subsidies are required, for example, to encourage distribution and poverty alleviation, these must be government-funded, not utility-funded. Some difficult political decisions would need to be made transparently.

### 6.6 ENERGY SOVEREIGNTY

The fourth major issue in every energy decision background is climate change, the commitment to COP 21 and energy sovereignty. The outcome of COP 21 was the Paris Agreement (Paris Agreement, 2019). What was important was not only what was agreed upon but, more importantly, what was not agreed.

Governments negotiated a set of sound, long-term global objectives. The Paris Agreement reflects a "hybrid" approach, blending bottom-up flexibility to achieve broad participation with top-down rules to promote accountability and ambition (Strek et al., 2016). Notably, the agreement asked for no firm commitments by any country (Mathai and Narayan, 2017). Many provisions establish common goals while allowing flexibility to accommodate different national capacities and circumstances. An objective or goal without binding obligations was that various countries could not reach national political agreement internally (e.g., the U.S.). Emerging countries could not make commitments as they have other priorities, such as high poverty levels or abundant fossil fuel reserves. In summary, regarding the signed Paris Accord, governments are expected to do what is in their countries' best economic, commercial, and financial interests. This agreement wording needs to be exploited by all emerging economies with high poverty and unemployment levels, particularly where they have been endowed with extensive, relatively cheap fossil fuel resources, such as South Africa.

This Thesis has frequently stressed that South Africa would be severely damaged by moving away from coal-fired power stations to the available renewables, namely solar and wind. It would also be affected by the loss of its energy sovereignty. Instead of being a net energy exporting country through its significant coal exports, it would become a net energy importing country because of the need for substantial gas imports. The impact would be that South Africa's balance of payments would get worse, i.e., higher deficits. The only reason there are occasional surpluses now is that there is no growth and no fixed domestic or foreign investments.

Of great importance is the global political and economic issues. This Thesis has often stressed the importance of maintaining energy sovereignty. From an energy supply point of view, South Africa is isolated from neighbouring countries. In Europe, neighbouring countries often have surplus energy that can be used in emergencies. However, in the case of energy, it affects a country's entire economy. This is precisely the situation that has occurred in Europe. By moving to unreliable renewables, mainly wind but also gas (except for Norway, Sweden and Switzerland, which draw power from Hydroelectricity power plants and France, which has maintained their nuclear dependence), they become dependent on gas. In effect, prices have increased, losing their energy and economic and political sovereignty to Russia. This is something that many experts have warned about for many years. Whilst there remains a belief in Green energy, there is now a strong belief that coal-fired power stations should be reopened and new ones built. These points have been discussed in Chapter 2.6.3. There are many reports on this subject, and a summary by Dr Jordaan is given below. He has twice been awarded South Africa's economist of the year. This article was published in one of South

Africa's leading journals named “Modern Mining” and titled “Coal benefits from Global Market Challenges.”

“**T**he Russian invasion of Ukraine on 24 February caused further market panic and has led to significant disruptions in the production and trade of commodities – especially in those commodities where Russia and Ukraine are significant exporters – as sanctions against Russian exports started piling up. A commodity that benefitted significantly from the increase in demand, supply disruptions and market panic is coal, ironically during a time of increasing global pressure and commitment to reducing its use. Coal remains the largest source of electricity generation and the largest single source of CO2 emissions. Oil and natural gas prices in Europe, which increased almost 600% year-on-year in March, have forced countries like Germany to reactivate coal plants, putting further pressure on coal demand.”

“Policies to secure energy independence, especially in China and India, could increase local coal production in major markets and reduce export opportunities. This could contribute to pressure on prices. Furthermore, there could be new Covid 19 variants that cause additional disruptions. The impact of the Chinese zero-Covid policy that resulted in new lockdowns in major economic hubs could impact the demand and supply of commodities and products. Commitments to climate change policies and the adoption of renewable energy are predicted to reduce coal demand in the longer term. The move to renewables could be accelerated if fossil fuel prices remain high for longer. However, coal is expected to remain the primary source of electricity for some time to come.”
The logic and recommendations of Dr L Schernikau and Dr Jordaan align with the discussion and recommendations in this Thesis. It can be said that the thesis is in line with acknowledged experts in the field.

## 6.7 THE WAY FORWARD

South Africa is facing slow growth and a lack of both domestic and foreign investment, primarily in the goods-producing industries, mining, manufacturing and Agri-processing. From a policy perspective, public policies need to change radically to make South Africa, containing a treasure chest of coal and minerals, attractive to such investment again. Planning for low-baseload electricity growth is a self-fulfilling prophecy. Industrialised countries must recognise that the needs and requirements of emerging and developing economies are independent of their own, with different priorities. Emerging markets need secure-baseload electricity power at the lowest possible cost to give them a comparative economic advantage, whether the natural resource used is oil, hydro, thermal or a fossil fuel such as coal or gas. The developed world needs to recognise that fossil fuels in the form of gas and coal will continue to play a substantial role as a significant energy source for certain emerging economies at this technological development stage. During his Presidency, President Obama acknowledged that emerging economies such as India, China, and the ASEAN countries would be building coal-fired power stations out of necessity but advised they should use "clean-coal" technology (Harris 2016; Martin, 2016).

South Africa must break away from the vested ideological and financial interests driving the large renewable expansion schemes. They are not the panacea for the country's future energy problems and growth (Jeffrey, 2016a). Nuclear and coal are the only sources of energy that can secure a baseload electricity supply at internationally competitive prices. Since nuclear power is capital-intensive upfront, South Africa cannot afford a significant fast-track programme. It is unlikely that more than 3200 MW of nuclear can be installed by 2030 (Macalister, 2016; IAEA, 2018). After that, a regular build programme should be followed each decade. The way ahead for South Africa lies in an initially limited nuclear build, a major new HELE "clean-coal" build, and a significant refurbishment of older coal-fired power plants with "clean-coal" power generation supported by a more modest expansion of CCGT gas plants. Other initiatives that should be implemented include installing solarPV on new domestic houses and all business buildings with tax incentives to install solar PV on new and existing structures. The pricing of purchases from such facilities and sales of backup power must be reviewed to ensure that the utility, in this case, ESKOM, is not subsidising these sources of energy.

This chapter reviewed several critical issues that are covered in this thesis. These issues include the renewable challenges, the potential problems posed by nuclear power, Independent Power Producers and environmental concerns. Finally, the section suggests a way forward for the South African economy regarding its power generation policy.

## 6.8 CONCLUSIONS, LIMITATIONS AND FUTURE WORK

### 6.8.1 THE CHOICE SOUTH AFRICA FACES FOR GROWTH OR STAGNATION

The choice between growth and stagnation depends on the selected energy mix and policy choices. They will determine the economic path of South Africa for the next decade (Jeffrey, 2017b). An important statement by the Minister of Public Enterprises some time ago gave cause for some hope. The Minister said, "South Africa is not about to turn its back on coal". However, the debate rages on, and the question remains about how quickly South Africa will move towards renewables (Jeffrey, 2017b).

It is essential to look at some of this controversy as it has emerged in the media recently. The first aspect has been the criticism of ESKOM and its executives for refusing to sign Power Purchase Agreements (PPAs) with 37 Independent Power Producer Agreements selected under the government's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). However, this criticism is unjustified and unfair. They were merely carrying out the terms of their mandate. The ESKOM mandate:

> "Our mandate, which is aligned to the Strategic Intent Statement issued by Department of Public Enterprises (DPE) in August 2015, is to provide electricity in an efficient and sustainable manner; this includes the generation, transmission, distribution and sale thereof. ESKOM is a critical and strategic contributor to the Government's goal of ensuring the security of electricity supply to the country and enabling economic growth and prosperity." To execute the mandate, "Our strategy aims to deliver an electricity price path that supports economic growth and improves our financial and business sustainability."

### 6.8.2 IMPACT ON THE COAL INDUSTRY

Finally, the renewable lobby will find it difficult to argue with the fact that South Africa will pay an extraordinarily high economic price if South Africa's coal industry declines. Any decline in the coal and associated industries will profoundly negatively impact the economy. It is estimated that if ESKOM demand declined by 37% because of the closing coal plants, the coal sector would shrink by 17%. This will reduce South Africa's GDP by over 0.9% (R27.8 billion) and reduce employment by more than 60,000 people affecting almost 250000 dependents. Also, coal export sales could likely be reduced by more than R10 billion per annum. In practice, the overall economic impact will be far more significant than these figures imply, and probably more than 300000 people will lose their jobs. The IRP 2016 base case and unconstrained scenario will likely be the final nail in the mining industry's coffin (Fossil Fuel Foundation, 2016). South Africa is facing economic stagnation with significant economic, political and social implications.

Unfortunately, the decision mix has many vested domestic and foreign financial and ideological interests. Financial institutions have entire departments geared towards pushing the renewable energy agenda. This is not surprising. After all, they are interested in the precious prize of investing their own and clients' money in long-term high-return index-linked government-guaranteed investments. The fact is that they are joining forces with foreign vested commercial and financial interests that have only one aim: to increase their overseas renewable technology sales in a new market. Meanwhile, their domestic market is at best losing steam, if not declining, because of the technology's failure. Followers should look closely at the failure of *Energiewende* in Germany and wind in South Australia (Sopher, 2016; Sopher, 2015; Sopher, 2016a; Sopher, 2016b).

### 6.8.3 THESIS CONCLUSION

The Thesis has confirmed the hypothesis. The research has found substantial evidence available from acknowledged global experts and logic that Anthropogenic Global Warming caused by fossil fuels was not an existential threat to humanity. Furthermore, the thesis confirmed that in many countries rich in fossil fuels, such as South Africa, using solar and wind would be highly expensive and lead to slow economic growth, higher levels of poverty, and slower social development. It would significantly set the country back in its primary objectives, reducing inequality, unemployment and poverty. The only successful way forward is by achieving high levels of economic growth and ensuring that policies spread these benefits across the population, so that poor people benefit from the higher economic growth. In South Africa, the country needs base load electricity for its mining, industry, Agri-industry and other goods-producing industry. The energy must come from fossil fuels, mainly coal and nuclear, with a minor backup from gas, primarily for domestic purposes. Solar and wind can only be used for minor or specialised purposes.

### 6.8.4 FUTURE WORK

This thesis sets out the fundamental issues faced by South Africa and recommends the solutions to resolve them. The country must address three primary issues: inequality, unemployment, and poverty. These problems can be remedied only by raising the economic growth rate. A higher growth rate depends on correct public policies coupled with an adequate and growing supply of affordable electricity. South Africa must develop its industrial base and supply secure power at the lowest possible cost.

The country's future energy potential lies in those efficient, proven nuclear and coal technologies that give South Africa a competitive edge and comparative advantage, reinforced by significant solar for domestic and general business use. These, in turn, must be supported by a substantial gas expansion but only if South Africa can find it in sufficient commercial quantities. The way forward involves building new modern coal plants and refurbishing old power stations where it is economically possible to do so, not to close them. The IRP 2016 plan, supported by many vested financial and ideological interests and their enthusiastic but often ill-informed idealistic public followers, is about to overinvest in a technology that has proven to be one of the worlds' least economically efficient and ineffective technologies. It is not surprising that sailing ships and clippers, although beautiful, finally became obsolete and died out in the second half of the 1800s. ESKOM officials were doing their job of looking after the interests of the country and the public. Renewables, particularly wind, increase energy poverty and effectively becomes a tax on the poor (Stephen, 2018).

The research in this thesis is unique in that it investigates the in-depth impact of coal, solar and wind on costs, risk, economic growth and unemployment whilst emphasizing their impact on climate change. However, it has several limitations as it has not investigated sustainability and the costs from various externalities and existential environmental matters resulting from mining, construction, land use and disposal of waste replacement and related costs. In other words, investigation of the entire production process and the environmental and other externalities have been excluded. Future research and work in South Africa and wherever energy is vital to meet the goal of increasing economic growth and development of its citizens must include detailed investigation based on scientific facts of at least the above and following:

- The direction of climate change based on scientific facts about the short-, medium- and long-term natural cycles.
- Natural climate change and the impact on climate and weather of energy generation.
- The impact of electricity generation based on different energy sources after taking into account the backup systems required and any proven technical improvement to mitigate their impact their damage to the environment, climate and weather.
- The energy sources available in the country, in this case, South Africa and the region where the electricity generation will be delivered.
- The significant requirements in terms of electricity usage to meet its economic growth and the benefits of the country or region. These primary needs must be carefully examined and analysed.
- The actual economic cost of dispatchable electric generation, supply and delivery. This analysis must include the generation supply and delivery of the electricity generated plus the full backup cost, full economic cost, and long-term economic impact.
- There are likely to be changed costs of the various technologies, and new technologies are likely to be developed. These would all need to be investigated and factored into an in-depth study of the vital subject of energy source, supply and delivery.
- Externalities have not been included in this study as they are extensive, unpredictable and often, actual probabilities and costs for each energy source are unknown. These need to be included.

## APPENDIX 1: SUMMARY OF THESIS

This thesis aimed to analyse and recommend the energy source mix requirements for emerging and developing economies rich in fossil fuels. The analysis used South Africa as an example.

The thesis hypothesised that emerging and developing economies rich in fossil fuels, such as South Africa, should fully use the natural resources that give them a comparative economic and competitive advantage. The thesis evaluated the significant elements and factors that are required to make such a decision. Provided all queries were answered, the hypothesis was that the primary energy resources used were its coal and coal reserves in South Africa's case. Furthermore, the country also has substantial quantities of uranium. Because of these uranium reserves, nuclear power generation should also be a significant energy source if it can be financially and economically cost-competitive. Finally, the country has existing skills and resources in these technologies, reinforcing these technologies' use. The thesis emphasised the requirement for reliable, secure power at the lowest financial and economic cost. At this economic and technological development stage, all other energy sources are for backup purposes or to fulfil specialist regional or business needs.

The thesis looked at specific vital components and their subsets influencing the future combination of electricity-generating energy resources. All critical components and their investigated subsets reinforced the thesis's hypothesis. The reinforcing findings included the following.

### ENVIRONMENTAL FACTORS AND CARBON DIOXIDE EMISSIONS

Chapter 3 showed there is sufficient expert evidence to support the view that Anthropogenic Global Warming (AGW) is not the critical issue made out by the IPCC and that carbon dioxide is not the damaging gas that it is made out to be (Climate Depot, 2010; Kauppinen and Malmi, 2019). This evidence is sufficient to support the hypothesis of this thesis that emerging economies with a comparative advantage in fossil fuels, such as South Africa, should explore all the options for alternative electricity generation and should not exclude coal and fossil fuels because of potentially damaging environmental impacts. The chapter shows that the potential costs of moving away from coal far exceed the potential benefits that South Africa may gain by using renewables. Such adverse effects are not proven and are uncertain. By being aware of potential negative consequences, the authorities can mitigate any possible harmful effects by utilising technical advances that have been made in these electricity generating fields.

The critical references regarding the issues raised in this chapter are set out in the bibliography. Importantly, the references link to lists of eminent scientists and knowledgeable people. They firmly believe that Anthropogenic Global Warming (AGW) is not the critical issue made out by the IPCC and that carbon dioxide is not the damaging gas it is made out to be. Instead, it is an odourless, colourless, non-toxic trace gas essential for life on this planet. The works of these eminent scientists and their reasoning and conclusions are crucial. Their argument forms part of the critical reading of those involved in the debate regarding environmental change and the discussion concerning "clean-coal" energy and the use of renewables.

**THE IMPORTANCE OF COAL AND GAS TO SOUTH AFRICA**

Chapter 3 also examined the coal and possible gas resources of the country. It highlighted the importance of coal in South Africa's economic development and its relevance to mining and industry and the industrial heartland of South Africa in Gauteng. An examination of the importance of South Africa's mineral resources and commodities in the balance of payments is reviewed. It established that any reduction and ultimate destruction of coal mining and coal use for electricity generation could have a significant adverse effect on the economy. The negative impact would be felt by the coal industry, industries dependent on it, and the entire mining industry, with severe detrimental economic implications. It scrutinised the potential for developing a gas industry and the role it could play in creating a new industry in South Africa. Importantly it highlights the need to find local deposits for gas to make any substantial contribution to South Africa's energy requirements and economy

A rough estimated forecast was prepared to assess the upstream and downstream economic impact of developing a natural gas industry in South Africa. Based on a single project at a single location, an estimated gas turnover of R15 billion per annum, upstream and downstream turnover could total as much as R50 billion per annum. Of this production value, the total value added to the economy is estimated at R26 billion per annum. Average upstream and potential downstream employment created could peak at an estimated 70,000, that level being achieved during the mature phase of the project's production life. The potential economic impact of such a vast gas resource find as the Karoo shale gas, supported by other local finds should they exist, is very significant for the South African economy.

Its impact is substantial if sufficient domestic gas and all five regional projects are fully developed. Its value add could exceed R100 billion and create over 200,000 jobs. A national gas project would help restore confidence in South Africa and could significantly enhance its geopolitical and economic standing as a hub for energy and resource development in Southern Africa.

The total impact on individual technologies is set out in the table below.

**Table 35: Risk-related True Economic LCOE by Technology**

The table below indicates the Total potential impact of new electricity generation.

## Risk related True economic LCOE by Technology

| Potential Dispatchable Cost | Nuclear | New Coal | Wind | SolarPV |
|---|---|---|---|---|
| Apparent LCOE R/kWh | R1.30 | R 1.05 | R 0.62 | R 0.62 |
| Average capacity Load factor | 90% | 82% | 35% | 26% |
| Life in years | 60 yrs | 30 yrs | 20 yrs | 20 yrs |
| True Risk related LCOE based COUE at IRP rates R77.30/kWh | R1.33 | R1.10 | R2.02 | R2.83 |
| Total capital cost per delivered real kwh | R0.17 | R0.19 | R0.31 | R0.31 |

Economic Risk Consultant

**Table 36: Total potential reduction of GDP and employment**

**Cumulative reduction in potential growth & employment**

**Impact of Carbon Tax**
**GDP Growth: -4.4% -R200 billion**
**Employment: -1.1 million jobs**
**Impact of Renewables**
**GDP growth: -4.4% R200 billion**
**Employment: -1.1 millions**
**Impact on Fixed Investment**
**GDP growth: -10.0% -R500 billion**
**Employment: -2.5 million**
**Impact on the coal mining industry**
**GDP growth: -2.5% -100 bn**
**Employment: 300000**
**Total impact on GDP and employment**
**GDP growth: –R1000 billion**
**Employment: -5.0 million**

Source: ESKOM SARB Economic Modelling Solutions EconomicRisk

**Table 37: Economic impact of potential electricity generation**

| Electricity | 4,000 MW | 8,600 MW |
|---|---|---|
| **GDP** | R300 bn | 645 bn |
| **Employment** | 800,000 | 1,720,000 |
| **Dependents** | 3,200,000 | 6,880,000 |

Source: EconomicRisk, Estimates based on SARB, StatsSA

The figures above estimate the potential beneficial economic impacts of approximately 4,000 MW of electricity and 8,600 MW generated by several power stations. The data are rough estimates but give a reasonable idea of the potential impact of electricity generation on South Africa's economy and future growth.

It should be noted that the above economic impacts can only be delivered by dispatchable electricity generating sources such as gas, nuclear and "clean-coal" (Minchener, 2016). The economic benefits above cannot be provided by non-dispatchable electricity-generating solar and wind sources. Wind and solar deliver electricity less than 30% of the time, and not only that, the supply is variable, unpredictable and interruptible. In other words, there is a high risk of non-supply of electricity which is unsuitable for business and industrial development. In fact, divide the above benefits by three if one selects a renewable build programme. In summary, it suggests substantial economic advantages in researching and installing gas and other dispatchable electricity generating sources before considering any investment in variable, unpredictable interruptible renewables such as solar and wind. Solar has a potentially important role in domestic use and office development.

## ELECTRICITY GROWTH NEEDS FOR SOUTH AFRICA

Chapter 4 reviewed the country's economic growth needs and forecasted the GDP growth potential required to achieve South Africa's primary objectives of reducing poverty, inequality and unemployment. It examined the structural and sectoral industrial and economic growth requirements for South Africa to meet its critical primary goals. These require growth in the economy's more electricity-intensive industrial, manufacturing and mining sectors. It reviewed and forecasted the likely electricity-generating demand for alternative sectoral growth strategies in the debate regarding environmental change and the discussion concerning "clean-coal" energy and the use of renewables.

At this stage, the selected long-term sustainable growth rate of 3.8% was considered the country's maximum long-term sustainable economic growth.

These GDP growth numbers are considerably less than the original ASGISA economic growth targets of 6.5% and far short of the NDP target of 5.5% per annum (National Planning Commission, 2011). An alternative objective would be to increase this target growth rate to closer to 5% per annum. In this document, the lower rate of 3.8% per annum was used, as it has important implications for the electricity generating capacity build programme even at this level. Currently, given the state of the economy, it won't be easy to achieve. Higher growth at these levels would release the South African economy's growth potential, given its resource richness. At these higher growth levels, the country becomes a magnet for domestic investment and real foreign direct investment (Jeffrey, 2016c). These higher growth figures could become a realistic, achievable and sustainable long-term objective if there were the political-economic and social determination and will to achieve them. The required energy growth, in this case, electricity growth, needed to make the 3.8% rate of economic growth is a growth of approximately 3.0% per annum in electricity growth, given the selected sectoral growth targets and assumptions utilised in the model above.

The growth in electricity generation of 3.0% per annum and the resulting higher generation capacity creates the potential for higher GDP growth, higher employment, lower unemployment and a higher standard of living. This growth target assumes that policies are implemented to encourage higher growth in industry and mining-related activities. Employment growth would be roughly 3.4% per annum. It can be anticipated that there will be consistent growth in exports at 3.8% per annum. Imports would rise in the same proportion. If there is a weaker Rand, combined with more bias towards mining and manufacturing, it can be anticipated that there would be higher exports, lower imports and more unskilled persons being employed. Similarly, the electricity growth required would increase above 3.0% per annum to support this growth.

The electricity capacity growth should be planned to sustain these economic growth levels, provided an adequate and complete reserve margin is maintained. There must be time to increase the electricity generating capacity growth programme to cater for periods of higher sustained growth. Similarly, this would make it possible to slow the build programme with lengthy periods of slower growth. Inherently, planning for fully developing South African raw material and human resources richness is necessary. Any growth that is less than that would not be doing justice to the people of South Africa. Significantly, ongoing electricity shortages would reduce investment and ensure that the economy does not achieve the economic growth rates it can produce.

In summary, small electricity generating capacity increases would ensure lower economic growth. Slow growth would become a self-fulfilling prophecy. It would justify the inadequate planning and capacity decisions made previously. The resulting outcomes are detrimental to South Africa as it would reduce employment growth, increase unemployment levels, and result in a lower standard of living.

**COMPARISON OF THE COSTS OF GENERATING ELECTRICITY**

Chapter 4 also evaluated the real cost of generating electricity for each technology to determine the least-cost energy mixture. It examined the strengths and weaknesses of the methodology currently favoured by renewable lobby groups and energy planners in South Africa and elsewhere. The least-cost mix is determined by utilising the Levelised Cost of Energy. It concluded that electricity delivered was not equal and distinguished between dispatchable and non-dispatchable power and, in particular, the quality and price or cost at the gate of the supplier and the cost of energy supplied to the user. The impact of the load factor and the life of the technology are discussed. The chapter discussed the role of risk and uncertainty and how the cost of unserved energy (COUE) must be included in the cost of each technology as it was integral to the technology cost structure and builds a model based on the introduction of these concepts to the electricity generating costs of these technologies. On this basis, the chapter showed clearly that the cost of renewables, defined here as wind and solar, were significantly more expensive than HELE "clean-coal" and nuclear. The potential economic damage of wind and solar is excessively high. This is due to the risk and uncertainty caused by their inherent variability, intermittency and unpredictability. These are unacceptably high for emerging developing industrialising economies. The model developed and utilised can be utilised in different countries and various economic situations down to the state or regional level in a country. The chapter concludes that by any measure, the cost of wind and solar as a power source for an industrialising economy such as South Africa is significantly higher than that of nuclear and solar. In South Africa, coal-generated electricity is cheaper than nuclear power.

Emerging economies need to focus on those technologies which are efficient and effective. In South Africa, mining, manufacturing, and industry need electricity supply security at competitive financial and economic prices. This country's only two electricity-generation energy sources that can achieve these objectives would appear to be High-Efficiency Low-Emissions (HELE), otherwise called "clean coal", and nuclear.

The country must raise its economic growth rate by ensuring it has a sustainable, secure electricity supply at the lowest financial and economic cost. This must be accompanied by supporting conditions fostering domestic and foreign investment in its economy (Jeffrey, 2016c). The arguments above show clearly that renewables in the form of solar and wind, in particular, almost certainly have substantial additional costs that are not fully accounted for in the current prices. This also means that the so-called least-cost optimum mix is wrong. As a result, this methodology is severely flawed as currently defined and used.

Furthermore, increased penetration of technologies such as solar and wind, variable, unreliable, intermittent, and unpredictable, will automatically lead to the optimum mix cost. Finally, the risk and uncertainty posed by solar and wind lead to rapidly increasing economic costs measured by the COUE. These are not currently allowed for or measured accurately in current models associated with the least-cost energy mix. The impact and economic COUE set out by the IRP in 2019 is approximately R87.85/kWh. The 2016 IRP sets these costs at R75/kWh. The technique and methodology recommended using statistical methods based on variable estimates utilising each technology's variance and mean to calculate the COUE and the risks associated with each energy source.

The above arguments and estimates lend force to the case that solar and wind, in particular, are unaffordable in the current economic situation in the country. The estimates strongly suggest that the least-cost methodology is severely flawed. In the future, the renewable technologies of wind, in particular, should play a marginal role in any future technology mix for the country despite the views of the CSIR (Centre for Environmental Rights (CER), 2017). Solar could have a more substantial part in office development and the residential market with a more limited role in the industrial market.

The final blow for South Africa is that increased wind penetration will lead to a rapidly rising import bill for gas imports and its coal mining industry's demise, if not a severe decline in the entire mining industry (Jeffrey, 2017d). These catastrophes could ensure that South Africa's future moves towards rising unemployment, increasing poverty, and increasing social and political instability. South Africa needs to focus its energy plans on HELE or “clean coal”, nuclear, domestic solar and limited gas, apart from using other sustainable energy sources such as biomass, Hydro and pump storage.

**THE REALITY OF ADDITIONAL COSTS OF WIND AND SOLAR**

Chapter 5 examined the additional cost that wind and solar add or impose on a system in greater detail. It is claimed that wind and solar are far the cheapest electricity source, and these sources should dominate the future electricity supply. There is substantial debate regarding this subject. There are many complex issues that are involved. These include environmental issues and many other externalities. This section focuses on known costs and subsidies and excludes these other issues. That is not to say these other issues are unimportant or that no additional costs are involved. All energy sources and associated technologies are subject to similar problems and additional charges to varying degrees. Those imposed by wind and solar are often hidden and subsidised by others. They are significant but are left out of costing information. They are not taken into account in the LCOE as formerly calculated, which only measures the costs at the gate of the supplier, not those at the demand user's door. They also exclude those costs imposed on the economy and the user because of their unreliability, variability, interruptibility and unpredictability.

Emerging economies need to focus on those technologies which are efficient and effective. In South Africa, mining, manufacturing and industry need the security of electricity supply at competitive prices. The only two electricity generation sources of energy that can achieve these objectives in this country would appear to be High-Efficiency, Low-Emissions (HELE) coal, otherwise called “clean coal”, and nuclear.

The government must raise its economic growth rate by ensuring it has a sustainable, secure electricity supply at the lowest financial and economic cost. This must be accompanied by the necessary supporting condition fostering domestic and foreign investment into its economy (Jeffrey, 2016c). The arguments above show clearly that solar and wind in the form of solar and wind in particular almost certainly have substantial additional costs that are not fully accounted for in the current costs. This also means that the so-called least-cost optimum mix is wrong. As a result, this methodology is severely flawed as currently defined and used.

Furthermore, increased penetration of technologies such as solar and wind, variable, unreliable, intermittent, and unpredictable, will automatically lead to the optimum mix cost. Finally, the risk and uncertainty posed by solar and wind lead to rapidly increasing financial and economic costs as measured by the COUE. These are not currently allowed for or measured accurately in current models associated with the least-cost energy mix. The impact and economic COUE set out by the IRP in 2019 is approximately R87.85/kWh. The 2016 IRP utilises a figure for COUE of R75/kWh. The technique and methodology recommended using statistical calculations based on variable estimates utilising each technology's variance and mean to estimate the COUE.

**JOB CREATION AND GROWTH CAPABILITIES OF TECHNOLOGIES**

Chapter 5 also evaluated each electricity-generating technology's job creation and economic growth capabilities. There has been widespread discussion on this subject, with a particular focus by energy planners on wind and solar. Wind lobbyists on the number of jobs and additional growth each technology creates in its own right in terms of its own construction and operation of the technology itself. This section has shown that this is severely flawed and results in a total misrepresentation of each technology’s economic contribution. The chapter has set the correct evaluation path for examining job creation and electricity generation technology (Jeffrey, 2017).

It is clear from the above that wind and solar are hopelessly unreliable, inefficient and expensive as reliable energy sources. Furthermore, they are not suitable for developing the economy of an emerging economy such as South Africa. This holds for any emerging economy with uranium or fossil fuel resources, with objectives and aspirations of developing their goods-producing industries, particularly those of industry, manufacturing, mining and agricultural production and processing.

**SOUTH AFRICA CAN AVOID ECONOMIC ENERGY DAMAGE**

Chapter 5 also broke down the cost of different electricity-generating technologies based on historical figures made available from several sources. In particular, it analyses more carefully the impact of each electricity-generating technology on employment and economic growth. The statistics used were based on information made available by several sources on costs, jobs created by each technology and their economic impact. This section has provided further detail and background to deal with the costs of the leading alternative electricity generating technologies in SA.

Further detail is available in the various parts of the chapter, but in summary, the analysis shows that:

- The energy return over energy invested for MW output and the REIPPP costs defined as R were as follows:
  - Rn showed that nuclear was 14% less efficient than coal, and Rr showed renewables being 39% less efficient than coal
- Based on costs
  - Rn showed nuclear being 23% less efficient than coal, and Rr showed renewables being 70% less efficient than coal
- Based on increasing the fleet size to compensate for different load factors
  - Rn showed nuclear being 13% less efficient than coal, and Rr showed renewables being 47% less efficient than coal

All methodologies confirm that nuclear as being more expensive than coal. Renewables are shown to be significantly more costly and less efficient than either coal or nuclear.

**OVERVIEW OF ENERGY, POVERTY, UNEMPLOYMENT AND GROWTH**

Chapter 6 also reviewed several critical issues that are covered in this thesis. These issues include the renewable challenges, the potential problems proposed by nuclear power, Independent Power Producers and environmental concerns. Finally, the section suggests a way forward for the South African economy regarding its power generation policy.

The chapter discusses the following key issues identified and reflected in the article entitled "Solving Energy Poverty, Unemployment, and Growth Challenges in South Africa" by Jeffrey (Jeffrey, 2017b).

The South African economy cannot afford to restructure its economy and industry toward renewable energy, nor can it afford the other structural changes this implies, including any form of a Carbon Tax, either now or in the future. Such a move will only increase uncertainty and reduce long-term domestic and foreign investment. Carbon Tax and ill-thought-out renewable policies are poised to take South Africa in the wrong economic direction, resulting in slow economic growth and increased unemployment. This will have significant detrimental economic, political, and social consequences affecting the country for a generation (Lucas et al., 2017).

Renewables are favoured by notable environmentalists and the Green movement that has dominated world energy thinking over the past two decades, led by the IPCC's work on the environment.

There are substantial question marks regarding renewable policies abroad, particularly Germany's *Energiewende* and South Australia. Electricity prices in Germany are amongst the highest in Europe because of the move to renewables. As a result, specific critical electricity-intensive industries are considering moving to the United States. There is rising energy poverty in many countries, states and provinces where renewables, particularly wind, have grown substantially. Renewables must have almost 100% backup power. They, particularly solar, have a role in certain instances but are unsuitable for baseload power. Coal and nuclear in South Africa are the only sources of significant baseload power. Nuclear certainly has a role at the coast, but it is more expensive, and it has high upfront capital costs. Due to this, South Africa cannot afford a rapid roll-out of nuclear power plants except to focus on development at the coast. South Africa must diversify its energy sources but cannot do so nearly as rapidly as currently envisaged or planned. In the short term, South Africa does need renewables but should look at solar PV and a support role by gas. Inland coal should remain dominant for many years.

The cost and burden of such plans fall primarily on the poor regarding high unemployment, regressive taxation, and increasing poverty. South Africa already has these problems and needs to follow other emerging nations and possibly the United States that are increasingly using coal and gas to pursue higher growth. Energy, electricity, and employment growth are the keys to South Africa's future economic, social, and political prosperity, sustainability, and stability. It is time to put South Africa first (Bohlmann, 2019).

Unfortunately: Standard deviation IRP documents, which were released, based on recent forecasts, show that there will be insufficient electricity generating capacity from 2030 onwards.

Because renewables only provide power approximately 30% to 35% of the time due to their variability and unpredictability, they will require additional backup power of roughly 18,000 MW.

The price of electricity will increase by a minimum of 20% in real terms because of the significant move towards more expensive and variable unpredictable renewables, which will slow economic growth. This excludes the effect of a Carbon Tax should that be introduced.

**CONCLUDING COMMENTS**

Finally, Chapter 6 sets out the fundamental issues faced by South Africa and recommended solutions to resolve them. The country must address three primary issues: inequality, unemployment, and poverty. These problems can be remedied only by raising the economic growth rate. A higher growth rate depends on correct public policies coupled with an adequate and growing supply of secure affordable electricity. South Africa must develop its industrial base; therefore, it is essential to supply reliable, stable power at the lowest possible financial and economic cost.

The country's future energy potential lies in those efficient, proven technologies of nuclear and coal that give South Africa a competitive edge and comparative advantage, reinforced by significant solar for domestic and general business use. These, in turn, must be supported by a substantial gas expansion but only if South Africa can find it in sufficient commercial quantities. The way forward involves building modern, clean coal plants and refurbishing old power stations if economically possible. The IRP 2016 plan and IRP 2019 plan, supported by many vested financial and ideological interests and their enthusiastic but often ill-informed idealistic public followers, are about to overinvest in a technology proven to be one of the worlds' least economically efficient and least effective technologies. It is not surprising that sailing ships and clippers, although beautiful, finally became obsolete and died out in the second half of the 1800s. ESKOM officials were doing their job of looking after the interests of the country and the public. Renewables, particularly wind, by increasing costs, increase energy poverty and effectively become a tax on the poor (Stephen, 2018). In those countries that have moved significantly towards renewables, primarily wind, an old joke is returning to haunt them "what did humans use before they had candles… -electricity".

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## APPENDIX 3: MODELS

### Scenario Model

SCENARIO MODEL -
Growth 2050 Min Req

### Comparison of costs

Comparison of Costs
per Technology F2 12

Dr Jordaan of Economic Modelling Solutions did most of the modelling and calculations. In 2016, Dr Jordaan was named Economist of the Year for his long-term views and forecasts as the most accurate forecaster in South Africa. He was awarded the acclaim 'Economist of the year" again in August 2019 and 2020. In addition, the writer of this thesis has written many opinion pieces over the past ten years. Where relevant, these have also been referenced.

## APPENDIX 4: CARBON TAX AND ITS IMPACT

### INTRODUCTION

This section examines the impact of the Carbon Tax on The South African economy. This tax and its date of introduction have been changed several times. It is now scheduled to be implemented in a phased approach, with the first phase extending from June 2019 to December 2021, escalating at 2% above the consumer price index annually. A significant report was prepared by the writer and Dr J Jordaan and was submitted by Econometrix to the Davis Tax Committee in 2015. Once the tax is fully implemented, many of that report's findings stand today (Jeffrey and Jordaan, 2017; Jeffrey and Jordaan, 2015a; Jeffrey and Jordaan, 2015b). They are, therefore, included in this section of the thesis. As a result, this work done by the writer is frequently referenced and cited in this thesis. Importantly, it also covers the combined impact of the tax and renewables on South Africa's economy and their effect on domestic and foreign investment and, ultimately, on its economic growth. Consideration cannot be confined to only the economic impact of renewables (Jeffrey R, 2016). It must be combined with any carbon tax's effects (Jeffrey R, 2015). The two are inseparably linked due to the climate change mitigation requirements proposed by the IPCC and the Paris Agreement.

Carbon Tax and the excessive use of renewables at this stage will reduce sustainable economic growth in South Africa with detrimental consequences to employment and potentially to the country's economic, social and political stability (Jeffrey, 2015; Jeffrey and Jordaan, 2015b). Taxation is necessary. However, unnecessary and inefficient taxation can have negative economic and social consequences (Lucas et al., 2017). Slow economic growth arises when the size of the government is massive. As a result, taxation is unnecessarily high. However necessary the tax is viewed by those introducing them (Jeffrey, 2015a; Jeffrey, 2015;) A few facts concerning the trends and the taxes that are being considered:

- Taxing a relatively efficient power source and effectively subsidising a costlier, less efficient energy source will negatively impact economic and employment growth.
- Significantly, the US Senate passed amendments blocking the federal government from taxing carbon dioxide emissions and two measures that attributed climate change to human activity.
- The above was initially introduced under the Obama presidency. The movement away from such taxes will undoubtedly increase under the new administration. The Presidential election has considerably impacted the USA's Climate Change and Energy Policy. Biden and a Democratic Presidency's election have reversed the previous administration's policies and supported the IPCC, AGW movements, and renewable energy technologies.
- China and India have a clear focus on continuing their industrialisation programmes. While they have large renewable plans, they focus on effective electricity-generating programmes based on fossil fuel and primarily coal-fired HELE power stations.
- The focus on fossil fuels in India and China is anticipated to continue for the future period to 2035 and possibly beyond. ASEAN countries are equally focused on utilising their coal and gas resources.
- They have done this because they wish to maximise economic growth to alleviate poverty and raise employment levels. They recognise that achievement of that objective must be based on generating electricity from the cheapest possible source, namely coal and gas, which they have in abundance.
- Electricity generation must be regarded as the first step in a value-adding chain, extending to using it to add value to other products in the manufacturing, Agri-processing, mining and mining beneficiation processes.
- South Africa aims to maintain or increase its coal exports, allowing other countries to add value to their imported coal by generating electricity cheaply and increasing their value-added production processes. The reasoning for this policy is illogical. Other countries' products become cheaper, while South Africa’s manufactured products become more expensive because they are curbing more affordable coal power while significantly focussing on more costly renewable energy.
- The Carbon Tax amounts to a tax on efficient industries and uses these funds as a subsidy to develop renewables and a less efficient green economy. South Africa will reduce its comparative economic advantage in its export markets and import substitution and

replacement industries. Losing its comparative advantage will significantly impact its trade balance and slow its potential growth rate further and limit its sustainable growth rate (Jeffrey, 2015).

- For this reason, and because there is insufficient information about how the tax will be recycled into the economy, any recycled benefits have been excluded from this study.
- Electricity generation must be regarded as the first step in a value-adding chain, extending to adding value to coal and other products in the manufacturing, Agri-processing, mining and mining beneficiation processes.

**MODELLING**

Several modelling types exist that can be used to perform economic impact estimations. Each of these has strengths, weaknesses, limitations and assumptions. Externalities have also been excluded as these are both difficult to predict and cost. Therefore, different models will give different answers (Jeffrey and Jordaan 2015a). However, it is always essential to test the results against economic logic and a priori expectations.

- There would appear to be different models or assumptions leading to two different outcomes regarding introducing a Carbon Tax and the move and investment in renewables. The first set of models would indicate that a Carbon Tax and investment in the green economy, including renewables, will hardly impact economic growth and employment. The other model and its assumptions forecast significantly lower economic and job growth.
- The model used here has assumptions that forecast lower economic growth and employment. The model estimates that the economic reasoning in this summary supports the lower growth. Two models were used to estimate the impact of the Carbon Tax. The first is based on standard regression analysis using time-series data. The methodology includes partial equilibrium equations estimated for the price elasticity of demand and a Keynesian demand-side macro-model. The second method is based on an economic impact model constructed using a 2012 Social Accounting Matrix (SAM). The model has a Leontief structure.

The modelling exercise's objective was to quantify the impact of various approaches to escalating electricity prices and input costs at different rates and varying periods on specific sectors of the South African economy. The mining and manufacturing sectors of the economy were focal points, being significant employers.

An infinite number of scenarios could have been run through different models. The impacts of various assumptions could have been made regarding the adjustment levels to the electricity tariff represented in the Producer Price Index (PPI) model for electricity and the urgency with which the required changes have been made. On the other side of the relative price, hosts of assumptions regarding the escalation rate of the GDP deflators for each mining, manufacturing and aggregated economic sector can also be tested. It was also essential to consider the various time periods to form the basis of the calculations. These figures were prepared three years ago. It is believed they have not changed materially. The objective is to consider the economy's ultimate capability instead of its limited capability following the economic downturn and the COVID Virus's effects. Importantly, it gives an idea of the substantial negative impact the Carbon Tax has on South Africa's economy. In the meantime, some of these industries have already been severely damaged by the global recession and the local downturn. A Carbon Tax and the move towards renewables will exacerbate their recovery and could worsen the figures.

**CONSUMPTION OF ELECTRICITY AND CARBON DIOXIDE EMISSIONS**

This section summarises the findings. Although the modelling process was undertaken for the Davis Tax Committee in 2014, the figures are relevant today, assuming later start dates (Davis Tax Committee, 2015; Jeffrey and Jordaan, 2015b). The table below shows the Scope 1 carbon emissions in South Africa per the 2013 CDP report. The cost of the 2013 carbon emissions, at R120 per ton, adds up to R67.2 billion or 1.9% of the 2013 GDP.

**Table 38: Top CO2 emitters in South Africa**

| SA Scope 1 emissions (2013) | CO2e (tons) | Percentage Share | Total value of emissions at R120/ton (Rm) |
|---|---|---|---|
| SA Scope 1 (Excluding JSE 100, ESKOM & Transnet) | 239 166 956 | 42.7% | R28 700 |
| ESKOM | 227 900 000 | 40.7% | R27 348 |
| Sasol | 59 880 000 | 10.7% | R7 186 |
| Arcelor Mittal South Africa Ltd | 11 318 077 | 2.0% | R1 358 |
| JSE 100 (excel top ten emitters) | 7 279 498 | 1.3% | R874 |
| Pretoria Portland Cement Co Ltd | 4 437 330 | 0.8% | R533 |
| BHP Billiton | 2 947 000 | 0.5% | R354 |
| Sappi | 2 620 570 | 0.5% | R315 |
| Anglo American | 1 954 091 | 0.3% | R235 |
| Gold Fields Ltd | 792 618 | 0.1% | R95 |
| Mondi Plc | 733 832 | 0.1% | R88 |
| Anglo American Platinum | 524 028 | 0.1% | R63 |
| AngloGold Ashanti | 96 000 | 0.0% | R12 |
| | **559 650 000** | | **R 67 158** |

Source of CO2, CDP 2013. Economic Modelling Solutions

The table below shows the top 18 electricity consumption sectors with an estimated R120/ton CO2 emission tax. The data includes the industry size, compensation of employees, Gross Value Added (GVA), expenditure on electricity, Gross Operating Surplus (GOS) (all in Rand million), estimated GWh consumed, estimated CO2 emissions impact (based on 2013 ESKOM CO2 per GWh) and estimated impact, in Rand millions, given the emissions, at R120 per ton. The GWh is calculated based on the average tariffs per sector reported in ESKOM Annual reports and calibrated to the economy's total emissions.

The GOS can be used as a proxy for the profit per industry or an indicator of such a sector's sustainability if this is compared over several years.

Research by Muhammed Bah et al. explores the causal relationship between electricity consumption, economic growth, financial development, and CO2 emissions in South Africa from 1971-2012 ( Bah and Azam, 2017).

### Table 39: Top electricity consumption sectors: Impact of the Carbon Tax

Top 18 electricity consumption sectors (as % of intermediate inputs) with an estimated impact of an R120/ton CO2e tax ( Jeffrey and Jordaan, 2015a. Jeffrey and Jordaan, 2015b).

| Industry | Industry size (Rm) | Compensation of employees (Rm) | GVA (Rm) | Expenditure on electricity (Rm) | Electricity as a % of intermediate consumption | GOS (Rm) | Estimated GWh | Estimated CO2e impact (million) given electricity consumption | Estimated Rm impact on electricity consumption at R120/Co2e |
|---|---|---|---|---|---|---|---|---|---|
| Mining of gold and uranium ore | 37 513 | 32 789 | 52 676 | 11 101.8 | 29.59% | 18 920 | 10 929 | 11.55 | 1 386.1 |
| Electricity, gas, steam and hot water supply | 59 286 | 25 174 | 92 398 | 8 738.2 | 14.74% | 67 059 | 10 544 | 11.14 | 1 337.4 |
| Nuclear fuel, basic chemicals | 88 603 | 11 062 | 16 488 | 8 868.4 | 10.01% | 6 164 | 7 885 | 8.33 | 1 000.1 |
| Mining of metal ores | 120 650 | 51 126 | 129 350 | 11 505.8 | 9.54% | 77 455 | 11 326 | 11.97 | 1 436.6 |
| Glass | 6 604 | 2 732 | 3 302 | 489.6 | 7.41% | 524 | 435 | 0.46 | 55.2 |
| Basic precious and non-ferrous metals | 36 883 | 4 597 | 10 715 | 2 723.0 | 7.38% | 6 040 | 2 421* | 2.56 | 307.1 |
| Basic iron and steel, casting of metals | 133 334 | 13 852 | 14 634 | 7 953.7 | 5.97% | 382 | 7 072 | 7.47 | 897.0 |
| Real estate activities | 139 287 | 13 555 | 184 224 | 7 734.9 | 5.55% | 148 900 | 9 088 | 9.61 | 1 152.7 |
| Other chemical products, synthetic fibres | 90 693 | 22 461 | 24 697 | 4 200.7 | 4.63% | 1 718 | 3 735 | 3.95 | 473.7 |
| Mining of coal and lignite | 45 650 | 18 862 | 63 998 | 1 942.8 | 4.26% | 44 414 | 1 913 | 2.02 | 242.6 |
| Other mining and quarrying | 37 425 | 15 504 | 38 339 | 1 570.3 | 4.20% | 22 489 | 1 546 | 1.63 | 196.1 |
| Forestry | 10 276 | 2 519 | 7 319 | 369.1 | 3.59% | 4 629 | 627 | 0.66 | 79.5 |
| Agriculture | 103 307 | 19 269 | 62 678 | 3 545.1 | 3.43% | 43 272 | 6 023 | 6.37 | 763.9 |
| Other business activities | 157 011 | 80 324 | 110 761 | 4 913.1 | 3.13% | 29 568 | 5 773 | 6.10 | 732.2 |
| Paper | 56 009 | 8 080 | 19 713 | 1 517.8 | 2.71% | 11 561 | 1 350 | 1.43 | 171.2 |
| Non-metallic minerals | 31 884 | 5 269 | 13 175 | 816.3 | 2.56% | 7 797 | 726 | 0.77 | 92.1 |
| Spinning, weaving and finishing of textiles | 23 313 | 3 769 | 4 959 | 575.9 | 2.47% | 1 107 | 512 | 0.54 | 64.9 |
| Fishing | 1 701 | 1 332 | 3 313 | 41.9 | 2.47% | 1 960 | 37 | 0.04 | 4.7 |

Source: Own calculations based on 2013 StatsSA Use table. Economic Modelling Solutions

*The emissions impact of the underlying precious and non-ferrous metal is potentially much higher, as indicated given the reduced electricity tariff arrangement. This table is estimated based on the average tariff estimations per sector from ESKOM annual reports.

Electricity expenditure by households is just over 3% of total consumption (R64 billion in 2013). This expenditure is not included in the table.

The table below shows the estimated impact per GOS, given the CO2 emission impact on electricity. Already the basic iron and steel casting of metals show a negative GOS. These figures exclude the Scope 1 emissions impact that will lead to further losses. If such losses occur over time, higher-cost producers in such industries will either close their businesses in

SA or move to countries with lower input costs. These factors may also deter further investment in such sectors in the future. The impact may also be much worse, compared to that indicated, in sectors like basic precious and non-ferrous metals, including the Hillside aluminium smelter that currently has a favourable tariff with ESKOM. In the case of these smelters, their contract for cheap electricity expires in 2025. The impact of much higher tariffs combined with carbon emissions may result in closing such smelters. Exports from these smelters will be lost, and products currently produced must be imported.

**Table 40: Impact of CO2 emission tax on electricity (R120/ton) on GOS (2013)**

| Industry | Adjusted GOS given tax on electricity emissions at R120/ton | Percentage impact |
|---|---|---|
| **Mining of gold and uranium ore** | 17 193 | -7.3% |
| **Electricity, gas, steam and hot water supply** | 65 721 | -2.0% |
| **Nuclear fuel, basic chemicals** | 5 164 | -16.2% |
| **Mining of metal ores** | 75 955 | -1.9% |
| **Glass** | 469 | -10.5% |
| **Basic precious and non-ferrous metals** | 5 379 | -5.1% |
| **Basic iron and steel, casting of metals** | -1 873 | -234.5% |
| **Real estate activities** | 147 748 | -0.8% |
| **Other chemical products, synthetic fibres** | 1 245 | -27.6% |
| **Mining of coal and lignite** | 44 172 | -0.5% |
| **Other mining and quarrying** | 22 293 | -0.9% |
| **Forestry** | 4 549 | -1.7% |
| **Agriculture** | 42 508 | -1.8% |
| **Other business activities** | 28 836 | -2.5% |
| **Paper** | 10 988 | -1.5% |
| **Non-metallic minerals** | 7 172 | -1.2% |
| **Spinning, weaving and finishing of textiles** | 1 042 | -5.9% |
| **Fishing** | 1 956 | -0.2% |

Sources: StatisticsSA Economic Modelling. Economic Modelling Solutions.

## THE ECONOMIC IMPACT ON GDP AND EMPLOYMENT

All figures are approximate and focus on the cost side of the potential impact. Not enough information is available on how such a tax will be recycled into the economy. As a result, this was left out of this study. This instance will undoubtedly result in a tax on the economy's efficient side and a subsidy of inefficient industries with substantial adverse effects on the economy. Tax support for investment in energy-saving technology may increase imports, resulting in a worsening trade balance. This would result in a depreciating currency, higher inflation, and a higher relative interest rate. Taxing current sustainable businesses will result in lower profits, taxes, employment, investment, and potential business failures that will shift the supply and demand curves and remove the domestic supply altogether. This issue will especially apply in the ferrous and non-ferrous smelters (and the combined impact of much higher electricity tariffs from ESKOM). Business failures in these sectors, combined with an existing demand in the domestic economy for such products (for example, steel or aluminium), will increase imports and worsen the trade balance. With business failures, exports from these sectors will also be reduced, negatively impacting the trade balance. It must also be noted that it is not a given that new 'green' manufacturing and electricity generation businesses will be sustainable without subsidies and incentives. This situation is the case in Germany which has now taken away subsidies and possibly put a cap on renewable energy because of its inefficiency, variability and interruptibility.

- The direct introduction of the Carbon Tax alone could slow GDP growth by between 0.3% and 0.43% per annum.

This decline would reduce between 4.4% and 6.2% in the GDP by 2035, or between approximately R213 billion and R300 billion. Between 1.1 million and 1.5 million fewer jobs could be available by 2035. The number of dependents detrimentally affected is therefore estimated at approximately 5.0 million. These numbers impact an economy, with a population estimated to reach 75 million by 2035. Significantly, the slower growth could reduce the cumulative taxes collected by 2035 by approximately R600 billion. Besides, it will require a costly bureaucracy to run this complex, cumbersome and highly inefficient tax ( Jeffrey, 2015b).

**Table 41: Sectoral employment trends: QES 2006 to 2012, 2013**

SECTORAL EMPLOYMENT TRENDS

GROWTH IN SERVICES DECLINE IN GOODS PRODUCING

**Employment trends, change from September of 2006 to 2012, 2013**

| Quarterly Employment Survey | Quarterly Employment Survey Formal Sector (Non-agricultural) 2006-2012 | Quarterly Employment Survey Formal Sector (Non-agricultural) 2006-2013 |
|---|---|---|
| **Total** | **333000** | **416000** |
| Mining | 44000 | 36000 |
| Manufacturing | -189000 | -203000 |
| Electricity, Gas & Water | 11000 | 10000 |
| Construction | -33000 | -32000 |
| Trade, Hotels & Non-Financial Services | 24000 | 45000 |
| Transport & Communications | 15000 | 6000 |
| Financial & Business Services | 74000 | 94000 |
| Community Services | 388000 | 461000 |
| Source : Statistics South Africa | | |

Economic Risk Consultant

Sources: StatisticsSA Econometrix

- The tax could impact mining GDP growth between 0.24% and 0.34% per annum. Therefore, the mining sector could have a cumulative GDP contribution by 2035 of between 3.5% and 5.0% less than would have been the case if the Carbon Tax had not been introduced. Over this period, the sector's GDP could be approximately R11 billion and R16 billion lower than if no carbon tax was added. About 35 000 and 50 000 fewer jobs could be available. Recent growth in the sector has been limited, and it can be anticipated that these trends could continue in the absence of other measures, and the sector could show little growth or a decline in growth (Publishing, 2019).

- The tax could slow manufacturing GDP growth by 0.1% and 0.36% per annum. By 2035, the manufacturing sector could have a cumulative GDP contribution of between 1.5% and 5.5% less than if the Carbon Tax had not been introduced. Over this period, the sector's GDP could be approximately R15 billion and R33 billion lower than if no carbon tax was added. These figures indicate that roughly between 120 000 and 225 000 fewer jobs would be available.
- The impact on agriculture could also be considerable. Agriculture must cope with the vagaries of the weather. There has been a diminution in the number of farmers over the past 25 years. Protecting a country’s food resources and farming community is imperative. Farming should be both safe and profitable. Input costs are critical components of the cost structure, and it is often forgotten that this vitally important industry depends on electricity. Examples of sub-sectors in the agricultural sector affected by price increases in power and absolute security of supply for whatever reason are:
    - **Poultry** production;
    - **Processing commodities Wheat**/flour, maize/animal feed;
    - **Food** storage: controls for apples and export fruit and dairy products;
    - **Vegetable** production and processing;
    - **Food security** is the most critical government requirement.

All the above raises costs & has **inflationary** consequences for citizens, and affects **export** competitiveness.

The impacts described above would be felt far beyond the economy's manufacturing, industrial, mining and agricultural sectors because their value chains are so enmeshed in the broader economy.

**IMPACT DUE TO REDUCTION IN FIXED INVESTMENT**

Not considered in the above figures is the likely drop in real foreign and domestic direct investment in the productive economy (Jeffrey R, 2016). It is estimated that a reduction of 1% in direct investment results in a reduction of between 0.04% and 0.17% in GDP. A reduction of approximately 10% in private sector investment would amount to about R50 billion per annum. This investment reduction could result in an annual reduction of between 0.4% and 1.7% per annum in GDP growth or between R12 billion and R50 billion per annum. This results in a reduction in the annual growth rate between 1% and 1.7% per annum. Many other countries are not endowed with the natural energy and other resources South Africa has in abundance. An annual reduction in private fixed investment of some R50 billion per annum because of the Carbon Tax, increased electricity prices, and other problems associated with the movement towards renewables could reduce annual GDP by a further 0.4% to 1.7% per annum. The combined effects are potentially highly damaging to the economy. They could easily result in the economic growth rate being reduced from a potential growth rate of more than 3.5% per annum to a potential rate of approximately 2.5% or less.

**PRICE AND THE ECONOMIC IMPACT**

A Carbon Tax will increase the costs of electricity and the products of many vital industries. These costs will be passed on through price increases to businesses and consumers (Jeffrey, 2015). Downstream businesses and industries faced with these increased costs will, in turn, pass them on to their consumers.

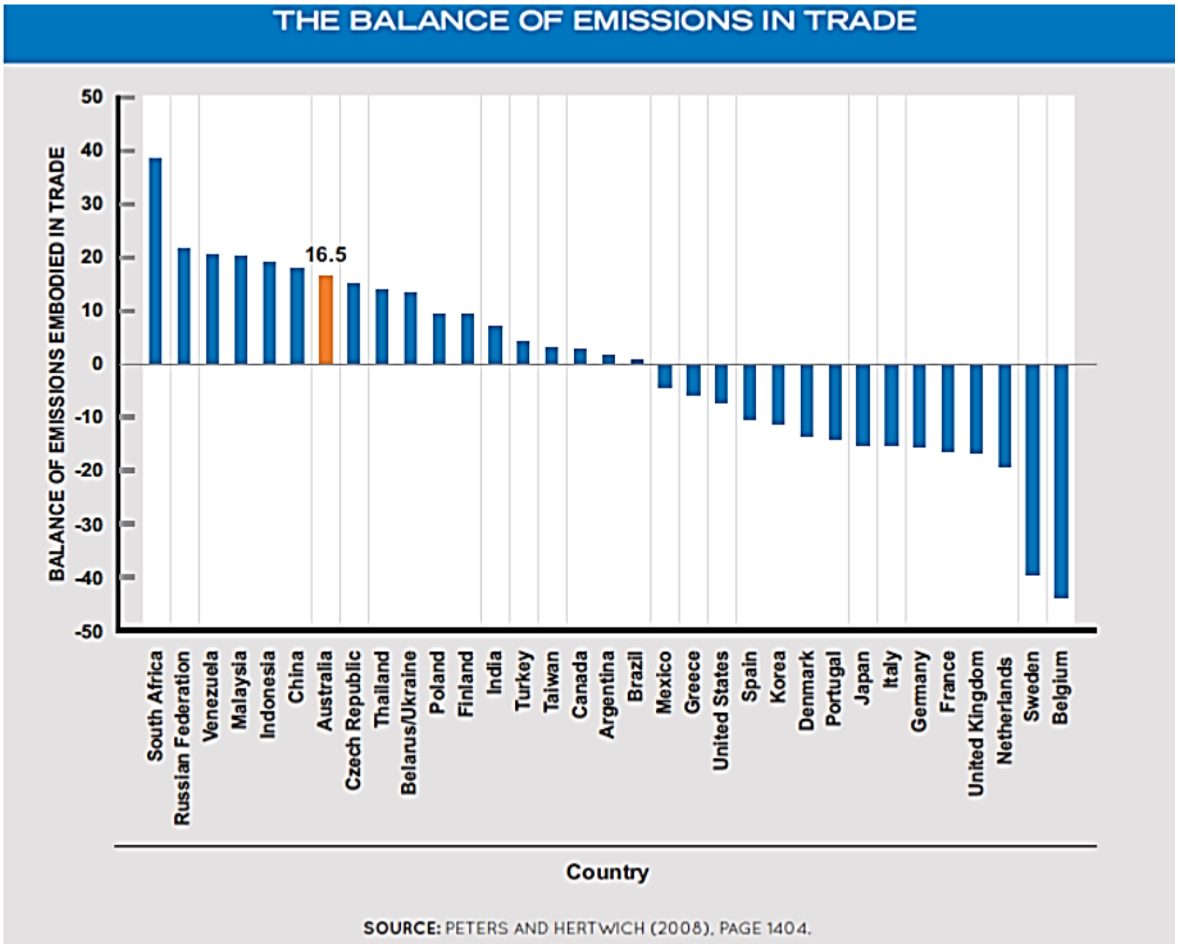


**Figure 62: Balance of emissions in trade**

Specific industries will be faced with a Carbon Tax in their own right, and in turn, their increased electricity costs and their Carbon Tax costs will also be passed on to their consumers and users. The ultimate impact will be felt through the price increases faced by consumers, and demand will decline as the price increases reduce consumers' disposable income. Export industries trading in the global competitive market will decline in demand and reduced prices with lower returns. The figure above shows that the more carbon-intensive the country's exports, the more significant the damage to its exports. This figure was prepared in Australia and formed part of the submission when Australia decided not to proceed with a Carbon Tax. As one of the most commodity and mining-orientated countries globally with power-based coal, South Africa is very carbon-intensive, as evident in the figure. Thus, the impact of the Carbon Tax will be significant. One can anticipate that the current balance of payments could come under pressure and slow sustainable economic growth even further.

In turn, imports would become more competitive, and import-sensitive industries would suffer. The complex impacts of unnecessary real price increases would further deteriorate the current balance of payments account, which will increase with higher growth from current levels associated with the slow growth in South Africa. Furthermore, there would be a decline in the return on investment of the affected businesses, and real investment would decline. It is already running below the required levels to sustain an acceptable economic growth rate. Each industry would need to be examined on its merits. Examples of the damage it could cause would be the motor vehicle industry and the coal industry extending into the mining industry and the beneficiation of mineral resources.

## IMPACT DUE TO RENEWABLES

The view that the Carbon Tax can be ring-fenced and its proceeds will be reinvested to develop the green economy must be treated with some circumspection. Besides that, and far more critical, if it is perceived that the proceeds should be used to develop renewable energy, this is not an economically sensible investment decision. It will result in a tax on the economy's efficiency and a subsidy towards less efficient energy and probably less efficient industries. Currently available technologies, renewables are significantly more expensive than efficient fossil fuel and nuclear technologies-based technologies.

In terms of this thesis's findings, it is estimated that the current IRP plans regarding the electricity-generating energy source would result in a real increase in electricity prices of approximately 20%. This increase would be a result of the switch to renewables.

Because of the introduction of more renewables, the figures set out above could also be doubled by 2035. There could be a cumulative loss of GDP of approximately 8.8% or over R400 billion Rand and over 2.0 million fewer people employed. There could be nearly 8 million dependents detrimentally affected by these decisions. These numbers are highly significant when considering a policy.

## CONCLUSION

This Appendix examines the impact of the Carbon Tax on the South African economy. The tax has been changed several times and is scheduled to be implemented in a phased approach. Once the tax is fully applied, many of the previous report's findings to the Davis Tax Committee in 2015 will remain. The thesis also covered the combined impact of the tax and renewables on South Africa's economy and their effect on domestic and foreign investment and, ultimately, its economic growth. Consideration cannot be confined to only the economic impact of renewables. It has to be combined with the effects of any Carbon Tax as the two are inseparably linked. This linkage is due to the requirements of climate change mitigation proposed by the IPCC and the Paris Agreement.

Notwithstanding any exceptions and offsets for the tax, the potential damage to the economy after introducing a Carbon Tax is substantial and overwhelming. Any possible recommendation made that the tax should be cancelled is negated. Such cancellation would avoid uncertainty. There is no doubt that the negative impact on long-term investment decisions will be substantial. A postponement still significantly negatively affects long-term investment, with ten to twenty-year and more investment time horizons in mining and manufacturing. Unsurprisingly, the Davis Tax Committee recommended an indefinite suspension of any such tax or similar tax (Davis Tax Committee, 2015). There is no need for South Africa to lead the pack and expose its economy and citizens to potentially severe damage and deprivation.

The above figures are conservative. The GDP reduction of R1 trillion Rand is less than the estimated GDP reduction of R1.4 trillion using a different methodology in a previous section. It points to the South African economy being 12% to 15% smaller than it should be by 2035. Such a result is disastrous, and the implications by the year 2050 are catastrophic.

## APPENDIX 5: FIGURES

## APPENDIX 6: TABLES