national planning commission

Department of Planning, Monitoring and Evaluation
REPUBLIC OF SOUTH AFRICA

2030 NDP

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ENERGY

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Foreword

This paper was first released in February 2018 by the National Planning Commission (NPC) of South Africa.

The NPC is an independent body appointed by the President of South Africa and consisting of experts in diverse field. Commissioners serve for a five-year term on a part-time basis. The responsibility of the first Commission was to develop a long term Vision and Plan for South Africa. This was finalised and adopted by Parliament and the Cabinet in 2012 and is called the National Development Plan: Vision 2030 (NDP).

The NDP is a long-term, comprehensive, integrated developmental plan that is backed up by strategic medium and short-term plans. The strategic objectives of the NDP is to eradicate poverty, reduce inequality and address unemployment.

In September 2015 the President announced the appointment of the second NPC. This second NPC was appointed to, amongst others, promote, advance and monitor the implementation of the National Development Plan by government and across all sectors of South African society. The Commission conducts regular engagements with key stakeholders and wider society on all matters pertaining to the long-term development of the country. This Paper forms part of the ongoing work of the NPC in its task to consult and advise on the implementation of the NDP.

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Executive Summary

Context and background

Many successes have been realised in the South African energy industry but many critical issues persist or have emerged in recent times. One of these successes is access to electricity for more than 85% of South African households. However, the country has experienced considerable energy sector challenges including those in electricity in 2007/08 and 2014/15 via extended periods of load-shedding. More recently, worrying alleged financial irregularities and governance concerns at a number of State Owned Enterprises (SOEs) have surfaced (including at Eskom - responsible for the supply of 95% of electricity in South Africa).

Adding to this, is the dynamic energy planning, regulatory and governance environment within which the sector operates. Both domestically and globally disruptive technologies, global megatrends and governance concerns are challenging existing paradigms and long-term planning outcomes. Thus, an updated discussion on energy in the context of the National Development Plan (NDP) 2030 has been deemed necessary by the National Planning Commission (NPC). The aim of this publication is to assist in achieving the transformative goals envisioned in the NDP 2030 while remaining cognisant of the aforementioned dynamic environment within which the global and domestic energy sector operates.

The NDP 2030 proposes clear objectives for the energy sector (shown below) and the discussion covered in this paper addresses these priorities specifically. It is by no means an exhaustive list but is instead an intentional prioritisation of key areas in the energy sector.

South Africa will have an energy sector that promotes:

- *Economic growth and development through adequate investment in energy infrastructure. The sector should provide reliable and efficient energy service at competitive rates, while supporting economic growth through job creation.*
- *Social Equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households*
- *Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.*

[National Development Plan 2030]

In this context, the fundamental objective of this publication is to focus on addressing challenges and pertinent issues within the energy sector while maintaining a long-term outlook on opportunities that may exist. In pursuing this, it addresses the goals envisioned in the NDP 2030 of reducing inequality, alleviating poverty and job creation.

Since the adoption of the NDP in 2012, there have been a number of changes in the energy sector - two of which deserve special mention. Firstly, South Africa committed to its Nationally Determined Contribution (NDC) as part of the Paris Agreement at the 21st Conference of the Parties (COP21) in 2015. Secondly, there have been unprecedented changes in the relative costs of power generation technologies in the electricity sector. Both of these have implications for existing as well as future investments in the energy sector (not just the electricity sector) in the context of a carbon-constrained economy as well as likely changes in primary energy carriers.

A comparison of technology costs between when the NDP was adopted in 2012 and the current period provides an interesting and notable illustration of how quickly the energy sector is changing. The costs of renewable energy sources (RES) have reduced globally as well as domestically while conventional sources have remained largely unchanged. Specifically, solar photovoltaic (PV) and wind have been procured as part of the Renewable Energy Independent Power Producer Programme (REIPPPP) resulting in 80% cost reductions for solar PV and 60% cost reductions for wind in just four years. This has made these technologies, in particular, the cheapest new-build technologies available in South Africa[1].

It is this context of rapid changes in the energy sector being seen globally and domestically that present opportunities, risks and transition costs for all countries – including South Africa. With an increased knowledge base and understanding of the significant domestic resources available in South Africa combined with associated cost reductions in recent years, the NPC is obliged to provide an updated discussion on the future of the South African energy sector to

[1] Of course, the value that these generators provide to the energy sector needs to be carefully considered as both are *'dispatched'* by the weather and not necessarily controllable in the traditional sense (like conventional power generators are e.g. coal, nuclear, liquid fuel/natural gas fired generators).

achieve the objectives outlined in the NDP. As briefly mentioned, the objective of this publication is to focus on addressing challenges and pertinent issues within the South African energy sector while maintaining a long-term outlook for opportunities that may exist.

Status quo

Energy planning and governance framework

South Africa implements a central energy planning paradigm with the strategic energy planning framework being defined by an overarching Integrated Energy Plan (IEP) that informs resulting plans, roadmaps and policy. Of these, the Integrated Resource Plan (IRP) is critical as it directly informs policy direction and resulting investments in the electricity sector. There has not yet been a promulgated version of the IEP while the most recent promulgated version of the IRP is currently more than 5 years old. Drafts of the IEP and IRP were published by the Department of Energy (DoE) in late November 2016 with plans for updated versions of these to be submitted to Cabinet within the 2017/18 financial year and promulgated soon thereafter.

Electricity sector regulatory framework

The South African electricity sector is a single-buyer model with Independent Power Producers (IPPs) being contracted by a vertically-integrated, state-owned utility complemented by municipal distributors. There is no wholesale (or retail) competition in the supply of electricity. Electricity supply adequacy has been a concern for a number of years in South Africa with boom-bust cycles in the supply-demand balance. This is manifested in either over-supply where parts of the existing Eskom coal fleet are put on cold stand-by in anticipation of increased demand or increased levels of electricity exports to the Southern African region are pursued on an ad-hoc basis. Under-supply situations have also occurred and are much more economically harmful as was felt during 2007/08 and 2014/15 load-shedding periods. The existing electricity mix is based predominantly on coal-fired generation (supplemented by minority shares of hydro, nuclear and liquid fuels) while in recent times renewable energy IPPs have been introduced (mostly solar PV and wind).

Operational inefficiency, financial irregularities and long-term sustainability of the existing Eskom business model including increased primary energy costs as well as time and cost over-runs on large capital projects have resulted in continued tariff increases and reliance on funding injections from the shareholder placing further strain on public finances. As noted, there have been recent public allegations of concerning financial irregularities and governance issues along with a failure in leadership at the highest levels which need to be sufficiently addressed and assurance provided that this would not occur again.

Coal and carbon pricing

Existing domestic policy including the National Climate Change Response White paper (2011), recent commitments to domestic greenhouse gas (GHG) mitigation as part of the recent ratification of the Paris Agreement as well as similar global movements and imperatives for GHG emission mitigation and adaptation are well understood and accepted in South Africa. The Paris Agreement is a near-global understanding of the requirement for GHG emission reductions into the future and the appropriate pricing of the externalities of GHGs into energy markets globally (more specifically CO_2 emissions).

The existing coal-dominated energy-mix in South Africa results in the majority of South Africa's GHG emissions arising from energy supply/use (~80%) with the electricity sector alone making up 45%. This is primarily as a result of the use of significant currently cheap domestic coal resources for coal-fired power generation. The second major contributor to energy related GHG emissions in South Africa is the use of coal-to-liquids (CTL) technology for liquid fuel production in the transportation sector.

Developments in modular, robust and sustainable energy investments

Considerable cost reductions realised as part of the REIPPPP have made solar PV and wind the cheapest new-build options in South Africa today. There exists a significant domestic wind and solar resource in South Africa, which is widely dispersed resulting in very few locations which do not have economically viable solar and/or wind resources. There is currently a very small-embedded generation market in South Africa.

Nuclear new build programme

The promulgated IRP 2010-2030 included 9.6 GW of nuclear power generation capacity, which has been confirmed as existing policy on numerous occasions. The Draft IRP 2016 that is in the public domain for consultation following a significant time-lapse since the promulgation of the IRP 2010-2030 in 2011 has a Base Case that requires nuclear power by 2037 (earliest) while a Carbon Budget scenario requires it by 2026.

Following the release of the Draft IRP 2016 and the appointment of Eskom as the owner and operator of a possible nuclear fleet in South Africa – Eskom received a number of responses to a Request for Information (RfI) in early 2017 for the procurement of a nuclear fleet as early as 2025.

The actions taken between 2013 and 2016 in relation to nuclear procurement (S(34) Ministerial Determinations as well as three Inter-Governmental Agreements (IGAs) with the United States of America, the Republic of Korea and the Russian Federation) were legally challenged. The Western Cape High Court passed down judgement in this regard in early 2017 stating that these actions were deemed irrational, unlawful and unconstitutional and should be set aside.

South Africa's research efforts into Small Modular Reactors (SMRs) have recently been revived via research efforts focussed on an Advanced High Temperature Reactor (AHTR) for commercialisation in the 2030s based on previous research as part of the Pebble Bed Modular Reactor (PBMR).

The investment levels required for a nuclear programme at scale in South Africa will be unprecedented which requires a particular focus on this technology. As outlined in the NDP 2030, evaluation criteria specific to nuclear as a technology should include *inter alia* financing options, institutional arrangements, safety, environmental costs and benefits, localisation and employment opportunities, uranium enrichment and fuel fabrication. Other aspects would include regulator capacity (unique risks), global trends and modularity with the associated flexibility robustness of investment decisions.

Existing and new-build infrastructure (mega-projects)

The existing coal generation fleet in South Africa is aging and has experienced a number of reliability issues in the recent past. The recent stabilisation of this fleet should be commended but needs to be put into the context of reduced demand. The life extension of this fleet has been considered and is under discussion.

It is known that the new-build generation capacity projects at Medupi and Kusile have experienced significant cost and time over-runs. These have burdened Eskom financially and eventually burden end-users directly in the resulting electricity tariff. The completion of these should be prioritised where economically feasible to ensure the long-term electricity supply-demand balance is maintained while domestic institutions should use lessons learnt in the pursuit of mega-projects and strictly apply them if and when considering any possible future mega-projects. If avoidable, South Africa should not pursue mega-projects in future and instead opt for smaller, modular and more flexible projects where economies of scale are still reasonable, manageable and scalable depending on strategic needs in the future.

Role of natural gas

Natural gas currently plays a relatively small role in the South African energy mix as a result of relatively small domestic resource availability. It is predominantly imported via piped gas from Mozambique with some level of domestic offshore gas production. Gas-to-power is being considered in the near future but has not yet been implemented and may be broadened for use in a number of end-use sectors.

It is understood that amongst other processes related to shale gas that the Strategic Environmental Assessment for Shale Gas Development is underway and should be completed soon to inform future policymaking. Regulatory frameworks and permitting decisions for exploratory drilling have been granted recently for shale gas and should commence in the 2017/18 financial year.

Natural gas whether imported via regional pipelines or liquefied natural gas (LNG) terminals at strategic port locations should be prioritised as it could play an important role in a transition to a low-carbon economy. It is versatile, releases fewer emissions than coal when burnt, has minimal localised air pollution impact relative to coal and can be a game-changer for use in a range of end-use sectors (not only power generation). Gas-fired power generation will provide a flexible power generation source in the electricity sector to complement variability as the existing coal fleet decommissions over time.

Liquid fuel investments and strategic liquid fuel stocks

As a result of minimal domestic resources, South Africa has a near-complete import dependence on oil and liquid fuels for the transportation sector. It is understood that stakeholder consultation on the supply-demand balance for liquid fuels in South Africa is ongoing and that a decision on the new refinery was expected in 2017.

With regard to oil and liquid fuel strategic stocks, the Energy Policy White Paper of 1998 recommends South Africa holds 90 days of consumption while the Draft Strategic Stocks Petroleum Policy and Draft Strategic Stocks Implementation Plan circulated in 2013 for comment recommends 60 days. The global standard employed by International Energy Agency (IEA) member countries is a strategic petroleum stock requirement of at least 90 days of the previous year's imports. The Draft Strategic Stocks Implementation Plan circulated in 2013 for comment suggests that the state should hold crude oil strategic stocks while the private sector holds refined liquid fuel strategic stocks.

Electricity access

Post-apartheid South African electrification was funded by the electricity industry during the period of 1994-2001. From 2001 onwards, the state-funded Integrated National Electrification Programme (INEP) took over as a subsidy-driven program to fund electrification.

There has been significant progress made in electricity access, which should be commended as on-grid electricity access of more than 85%. The NDP 2030 goal is for universal electrification by 2030 with 90% on-grid connections and the remaining access being provided by off-grid connections or energy alternatives.

Key Proposals

Energy planning and governance framework

1. Updated strategic national energy plans and more importantly an updated IRP to inform the most appropriate procurement decisions for the future is critical to avoid insufficient and inefficient energy and electricity service. In future, the periodic and consistent updating, publishing and promulgation of these key strategic national energy plans as part of the strategic energy planning framework should be prioritised with a particular focus on transparency, quality and completeness. The process of updating and publishing strategic energy plans should be as participatory as possible to promote transparency, quality and comprehensiveness, and to gain trust from all stakeholders.

2. The finalisation of these strategic national energy plans should be based on a consistent process that applies the principles of least-cost augmented quantitatively with the relevant dimensions identified up-front as part of the consistent and transparent process.

3. If sufficient capacity does not exist within the DoE, the development and collation of all input assumptions, technical modelling and necessary related investigations for future revisions of strategic energy plans could be undertaken by an entity capable of providing the necessary services with no vested financial interest in the future energy mix. This entity will likely require separate governance structures to ensure complete transparency before the process is initiated in order to gain trust and confidence of all stakeholders.

4. A rigorous peer review process (defined ex-ante) should be run concurrently with the publication of all input data, technical modelling and scenario outcomes.

5. The socio-economic implications of each technology choice as part of the integrated energy-planning framework should be assessed following the least-cost planning outcomes. More particularly, a focus on the direct supplier, indirect and induced job creation potential, GHG emissions, water usage and other identified externalities not already accounted for. These dimensions should then be included in planning process outcomes to inform policy discussion and adjustments.

Electricity sector end-state

6. The vision and end-state for the South African electricity sector needs to be finalised in order to create long-term certainty that will reduce electricity prices (relative to the status quo), further promote investment in various parts of the electricity supply chain, drive sustainable economic growth, meet the needs of the poor, and move towards a low-carbon economy.

7. The NDP 2030 is explicit on the requirement for the system operations, planning, power procurement, purchasing and contracting functions within Eskom to be separated into an independent institution entirely.

8. Electricity regulatory reform will require legislative change, which should take a phased approach and be considered in close consultation with relevant stakeholders (most importantly - Eskom). A fundamental principle in this regard is one in which efficiency in the supply and use of the necessary service should be a top priority.

9. In undergoing any restructuring process – it is critical to ensure that the regulator is sufficiently funded and capacitated to assess, monitor and appropriately manage any possible electricity regulatory reform process independently.

10. The generation assets of Eskom should be unbundled into a separate state-owned entity (or set of state-owned entities) or sold to a number of private investors competing with IPPs in the medium-term with the up-front provision of ensuring necessary developmental mandates are fulfilled. In addition, easy to implement new alternative models for production and ownership of electricity generation should be explored in the medium-term.

11. In transmission, the natural monopoly wires related businesses should remain an entity in itself in the long-term with a medium-term goal of splitting the procurement, operations and planning component into a separate entity (likely state-owned).

12. Distribution and electricity sales to small customers should remain regulated and with Eskom/municipalities in the interim while larger customers become competitive in the medium- to long-term.

The future of coal and carbon pricing

13. A transition away from coal use locally in key sectors in the medium- to long-term is necessary for a number of reasons including *inter alia* single and finite resource risks as well as environmental sustainability. In this regard, there is an urgent need for co-ordinated stakeholder action driven by government to facilitate a transparent decision-making process on the future of coal in South Africa as part of a just energy transition in the medium- to long-term.

14. Existing infrastructure and proposed new infrastructure investment in coal-mines and transport links to ensure security of coal supply for the remaining life of existing coal power stations and/or existing local industrial use should be pursued on a case-by-case basis.

15. A carbon pricing mechanism with appropriately designed allowances will send the required signals for substitution of carbon-intensive fuels to enable a transition to a low-carbon economy. A phased and predictable approach over time should also ensure minimal shock to the incumbent industry, economic growth and energy prices. The carbon tax needs to be complemented by strategic energy plans that mandate an electricity generation mix that meets South Africa's GHG emissions commitments.

Modular, robust and sustainable energy investment

16. The significant opportunity, associated economic growth potential, foreign direct investment and localisation potential of utility-scale and embedded solar PV and wind deployment in South Africa (in particular) could be further enabled by sustained rolling Bid Windows (BWs) of the highly successful REIPPPP.

17. Embedded generation technologies present an opportunity for distributed energy systems development in the South African electricity sector but there is significant investment required in distribution network infrastructure (refurbishment, upgrade and maintenance), fair and equitable tariff designs, enabling legislation and appropriate institutional arrangements.

18. There is significant opportunity in the following dimensions in this regard:

    18.1. Small business development and micro-enterprise job creation;

18.2. Improved national energy security, sustainability and affordability;

18.3. Alleviation of energy supply-demand imbalances; and

18.4. Localised business and revenue potential for owners and communities in rural areas in particular.

19. Innovative tariff approaches and broader energy support including resources and tools for local government being considered should be supported on an ongoing basis and incentivised as much as possible.

20. Consistent and sustained policy and regulatory frameworks are necessary to incentivise embedded generation deployment by municipalities and various end-users in the industrial, commercial and residential sectors to promote localisable goods and services.

Nuclear new build programme

21. The prospective nuclear programme investment needs to be transparently considered based on cost (with particular focus on the real risk of time and cost over-runs) as well as affordability (for end-users and the national fiscus) when compared to alternatives in the context of long-term electricity system costs.

22. As should be the case for all power generation technologies, all of the above should be published in the interest of openness and transparency while removing any speculation surrounding possible corruption and obtaining buy-in from all stakeholders.

23. The ongoing concerns surrounding the safety of high-level and low-level nuclear waste management and storage need to be addressed sufficiently for all affected stakeholders.

24. The opportunity for SMRs to be included as an option in the integrated energy-planning framework should be considered with appropriate realistic costs and learning curves expected.

Existing and new-build infrastructure (mega-projects: generation capacity focus)

25. Continued planned and preventative maintenance of energy infrastructure (in particular the Eskom coal generation fleet and transmission/distribution networks)

should be pursued and not de-prioritised in any manner to ensure medium to long-term reliable electricity supply.

26. The completion of the Eskom new-build programme (Medupi, Kusile and Ingula) should be prioritised where economically viable to ensure that the long-term electricity supply-demand balance is maintained. Based on the lessons from Kusile and Medupi, in future, South Africa should instead opt for smaller, modular, flexible, easily manageable and scalable projects depending on strategic needs.

Role of natural gas

27. Natural gas is often considered as a transition fuel to a low-carbon economy and could be a game changer in South Africa's energy mix for use in a range of end-use sectors (not just for power generation).

28. Infrastructure for liquefied natural gas (LNG) imports at strategic port locations should be prioritised in the short- to medium-term.

29. Additional regional pipeline natural gas imports should be considered for use in the short- to medium-term with unconventional domestic natural gas resources as long-term options only if environmental concerns are alleviated (coal bed methane (CBM) and shale gas).

Liquid fuel investments and strategic liquid fuel stocks

30. The upgrading of existing South African liquid fuel refineries to improved fuel standards should be incentivised while the decision for new refinery capacity needs to be finalised. The investment in new refinery capacity needs to be offset against demand for liquid fuels, alternatives, availability and expansion of existing refinery capacity, international market trends and the financial sustainability of the state-owned oil and gas company.

31. Importation of liquid fuels in the short- to medium term would likely prove more cost-effective than investing in a new large refinery, which may only be required in the medium- to long term. Increased liquid fuel imports would then require the requisite port infrastructure investment in handling and storage instead of new refinery capacity investment.

32. In the short- to medium-term, incentivising the switch to electric mobility for relevant portions of the transportation sector in urban environments (motor cars, minibuses, light duty vehicles) would create a considerable reduction in the requirement for imported liquid fuels and positively impact energy security, the South African trade balance as well as assist more sustainable energy use.

33. In the medium to long-term, in addition to electric mobility, the creation of alternative fuels for transportation (hydrogen, natural gas and/or synthetic liquid fuels) based on electricity would assist further in offsetting the requirement for liquid fuel imports. This could be converted into a significant opportunity for clean transportation fuel export markets (providing a competitive advantage).

34. The costs of ensuring global standards of strategic fuel stocks need to be commensurate with the risk of insufficient crude oil and liquid fuels. Considering fiscal constraints, it is recommended that a detailed cost-benefit analysis be undertaken but that in the interim a lower level of strategic fuel stocks be considered at the most strategic locations until the fiscal environment changes notably.

Electricity access

35. With universal electricity access a key goal of the NDP 2030, on-grid electrification programmes should continue but with future increased focus on off-grid solutions including sustainable micro-grids and focussed attention on ongoing maintenance of infrastructure, appropriate governance structures and procurement processes. These should be developed with the vision to interconnect with the main South African grid in future if demand grows sufficiently or micro-grids spread sufficiently geographically.

Notes/Caveats

Considering the nature of the topic, this publication relies on the associated necessary terminology. We have attempted to explain or rephrase some of these terms so that the paper is as accessible as possible. However, in some cases it is unavoidable and in the interest of accuracy, we accept that some of the retained terminology and expressions may make this paper challenging. We have added a list of abbreviations and a glossary of terms to assist in this regard.

This paper has been developed using publicly available data and literature. While the paper cast the net as wide as possible, it is accepted that there is literature being developed or has not reached the public domain that could add value to the discussion, proposals and recommendations in this paper. These would be welcomed to enrich the discussion where appropriate.

As this is published for discussion purposes, it is expected to elicit wide-ranging views and opinions and may lead to substantial debate on the contents. These debates and discussions will be appreciated and engaged with on the basis of rationality and supported by relevant data, literature and associated supportive arguments.

Therefore, in this context, it should be noted that aspects of this publication have generated considerable debate within the NPC itself and we list some of these challenging topics below for reference.

Challenges for focussed consideration

1. There is agreement on the principle that regulatory reform in the South African electricity sector is required but what the electricity sector end-state should be is unresolved.
2. With regard to the future of carbon and coal-pricing, the principle of including the externalities of coal and GHG emissions (specifically CO_2) into a sustainable development agenda for South Africa is accepted. However, the manner in which this can be achieved and the timing thereof has not been settled. This will be part of an ongoing process where the NPC will be engaging stakeholders on a long-term just energy transition for South Africa.

3. While the available literature and supportive body of legitimate evidence supports the integration of high levels of variable RES, there is not full consensus on the matter yet.
4. Similarly, the prospective nuclear programme investment and role of nuclear capacity when compared to alternatives in the context of total electricity system costs in the long-term must be resolved.
5. There is an unresolved challenge of whether existing Eskom coal generation should be life-extended, under construction coal power stations should be completed or any new-build coal power stations should be pursued. This forms part of the broader discussion on a just energy transition for South Africa.

Abbreviations

AHTR	Advanced High Temperature Reactor
BP	British Petroleum
BNEF	Bloomberg New Energy Finance
CBM	Coal Bed Methane
CTL	coal-to-liquids
COP	Conference of the Parties
DFI	Development Finance Institution
DMR	Department of Mineral Resources
DoE	Department of Energy
DPE	Department of Public Enterprises
GHG	Greenhouse gas
GUMP	Gas Utilisation master Plan
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEP	Integrated Energy Plan
INEP	Integrated National Electrification Programme
IPP	Independent Power Producers

IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
LFMP	Liquid Fuels Master Plan
LNG	Liquefied Natural Gas
MPRDA	Mineral and Petroleum Resources Development Act
MTSF	Medium-Term Strategic Framework
NDC	Nationally Determined Contribution
NDP	National Development Plan
NERSA	National Energy Regulator of South Africa
NPC	National Planning Commission
NREL	National Renewable Energy Laboratory
PBMR	Pebble Bed Modular Reactor
PPA	Power Purchase Agreements
PV	Photovoltaic
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RES	Renewable Energy Sources
RfI	Request for Information

RfP	Request for Proposals
SMR	Small Modular Reactor
SOEs	State-Owned Enterprises
SSEG	Small-Scale Embedded Generation

Glossary of Terms

Term	Description
Base Case	In an energy planning context, a Base Case defines the resulting outcomes from a scenario using a particular set of input assumptions. These are typically based on a continuation of the status-quo policy which can then be used for comparison to a range of other scenarios.
Carbon Budget	A carbon budget can be defined as a tolerable quantity of greenhouse gas (GHG) emissions that can be emitted in total over a specified time. The budget needs to be in line with what is scientifically required to keep global warming and thus climate change "tolerable." Carbon budgeting should not be confused with the use of targets, thresholds or caps to set emissions reduction goals.
Carbon Pricing	An approach for including the externalities associated with the use of carbon with the aim of reducing GHG emissions. Carbon pricing charges those who emit carbon dioxide (CO_2) as part of their operations. It is the amount that must be paid for the right to emit a volume of CO_2 into the atmosphere. Carbon pricing usually takes the form either of a carbon tax or a requirement to purchase permits to emit, generally known as cap-and-trade, but also called "allowances".
COP 21	The Conference of Parties (COP) was established on 1994 to review the implementation of the UN Framework on Climate Change (UNFCCC) that was adopted at the Rio Earth Summit in 1992. The framework sets out actions aimed at stabilising atmospheric concentrations of greenhouse gases (GHGs) to avoid "dangerous anthropogenic interference with the climate

Term	Description
	system." The COP has taken place annually and now has a near-universal membership of 195 parties. In 2015 COP21, also known as the 2015 Paris Climate Conference, for the first time in over 20 years of UN negotiations, aimed to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C.
Fugitive Emissions	Emissions due to leaks and other unintended releases of gasses.
Greenhouse gas (GHG)	A greenhouse gas (GHG) is a gas that both absorbs and emits radiation in the infrared range, commonly called thermal radiation or heat. The primary GHGs in Earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, and ozone. When present in the atmosphere, these gases trap radiation in the form of heat, causing a warming process called the greenhouse effect. Some concentration of GHGs in the atmosphere is normal and in fact necessary for life on Earth as we know it. However, with the dawn of the human industrial age, came vast additions of GHGs into the atmosphere, mostly from the combustion of fossil fuels (liquid fuels, coal, oil etc.). These emissions, or infusions of thermally active gases into the atmosphere came at a much higher rate than anything previously seen on Earth. It has been estimated that if GHG emissions continue at the present rate, Earth's surface temperature could exceed historical values as early as 2047, with potentially harmful effects on ecosystems, biodiversity and the livelihoods of people worldwide.
Integrated National Electrification Programme (INEP)	INEP is the Department of Energy's programme responsible for achieving universal access to electricity in the country by 2025. INEP is responsible for planning, project management and funding the bulk infrastructure (e.g. MV lines and substations),

Term	Description
	grid and non-grid new connections for households that cannot afford to pay on their own to receive access to electricity.
Joule	J (Joule) is a unit of energy (defined relative to the mechanical equivalent of heat, the calorie, which is the amount of energy transfer needed to raise the temperature of 1 g of water by 1^{O}C, 1 cal ≡ 4.186 J). - 1 EJ = 1000 PJ = 1 000 TJ = 1 000 000 GJ = 1 000 000 000 kJ. - It takes ≈340 kJ of energy to boil 1 litre of water from room temperature. It takes ≈200 000 kJ to drive a small petrol vehicle 100 km (at 100km/h).
Low-carbon economy	A low-carbon economy is an economy based on low carbon energy sources that therefore minimise greenhouse gas (GHG) emissions into the biosphere, but specifically refers to the greenhouse gas carbon dioxide (CO_2).
Nationally Determined Contribution (NDC)	Nationally determined contributions are at the heart of the Paris Agreement and the achievement of the associated long-term goals. Nationally Determined Contributions (NDCs) embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.
Peak-Plateau-Decline	This refers to the South African defined trajectory where annual GHG emission levels would rise for a pre-defined period following which they would level-off (for a pre-defined period) before then declining thereafter.

Term	Description
Renewable energy	Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, biomass and geothermal heat.

1 Context

1.1 General

1.1.1 The first National Planning Commission (NPC) appointed in 2010 for a five-year term was tasked with the primary responsibility of drafting a Vision Statement for the country and developing a National Development Plan (NDP). The NDP 2030 was adopted by Cabinet in September 2012 [1].

1.1.2 The Medium-Term Strategic Framework (MTSF) 2014-2019 [2] with resulting Programme of Action [3] and more recently the Nine-Point Plan [4] are government's implementation frameworks for the NDP.

1.1.3 The second NPC appointed in 2015 has, as part of its mandate, the responsibility of overseeing the implementation of the NDP and advising government in this regard. To give effect to this the NPC is focussing on, amongst others, indicators to measure and monitor progress with the implementation of the NDP 2030. These will be contextualised by work undertaken in workstreams of the NPC.

1.1.4 This publication is conceptualised as part of a series of publications on significant issues aimed at guiding progress to achieving the goals of the NDP. These papers aim to take stock of the implementation of the NDP, identify constraints and propose how these can be overcome by suggesting pointed interventions. We will provide focused recommendations on how to stimulate momentum in the economy and sustain a more constructive pathway to achieving the objectives of the NDP.

1.1.5 This publication has been informed by the NDP as well as being updated taking into account the fast-paced and disruptive changes that have occurred within the energy sector since adoption in 2012. It focuses on suggested energy-related actions that should be prioritised to achieve key objectives and priorities in the NDP as they relate to the energy sector.

1.2 Global and regional energy status quo with an outlook to 2030 and beyond

1.2.1 The global and regional energy context is crucial to understand the approach and discussion in this paper (graphically illustrated in Figure 1 to Figure 4).

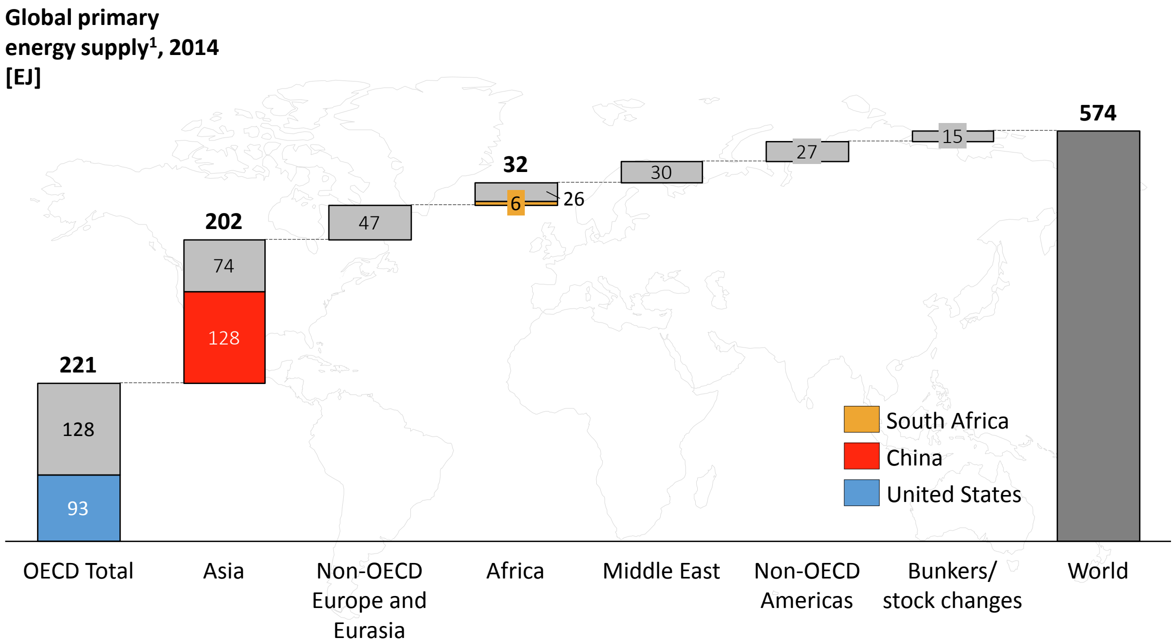
1.2.2 Figure 1 shows the global total primary energy supply by region for 2014, and indicates that global total primary energy supply was ≈574 EJ. The total primary energy supply for the USA was 93 EJ while for China this was 128 EJ indicating that these two countries currently produce just under 40% of the world's total primary energy supply. To understand this in perspective, Africa produces ≈ 32 EJ (4.6%) and South Africa ≈6.2 EJ (1.1%).

1.2.3 Figure 2 is an indication of the sources of energy supply showing how global primary energy supply is currently dominated by oil, gas and coal (≈80%) and complemented by nuclear, renewable energy sources (RES) and waste.

1.2.4 There are clear global and regional long-term trends that have emerged from recent periodic reviews that are used to inform energy planning globally (a summary has been attached as Appendix A). These trends illustrate how ongoing energy transitions around the world have been accelerated in recent years as a result of significant cost reductions in RES technologies and expected future cost reductions (combined with other supporting technologies in the energy supply chain). In addition, it has been shown that for the last decade the International Energy Agency (IEA) has continually downplayed and wholly under-estimated the potential contribution of wind and solar PV globally [5]–[7]. Conventional electricity generation technologies have largely reached technological maturity and thus costs for these technologies are not expected to change significantly in future. As a result, a number of jurisdictions globally have revised policies and plans in their energy sectors.

1.2.5 Figure 3 and Figure 4 illustrate the significant technology cost reductions for solar PV and wind respectively using information from auction results for RES technologies globally in the past 5 years [8]. The IEA summaries of these trends [9] show that the global average index of solar PV (utility-scale) has reduced by 65% and wind (onshore) by 30% between 2010-2015. Other more recent literature also summarises these global trends quite well while providing the South African context [10]. These trends have made solar PV and wind in particular cost-competitive with new-build conventional thermal generation technologies in a number of countries globally. As will be further outlined in section 1.3, these technologies are already cheaper than new-build conventional technologies in South Africa as a combined result of domestic resources, fundamental technology cost reductions and the competitive auction process applied.

1.2.6 A range of reputable institutions including IEA, Bloomberg new Energy Finance (BNEF), the National Renewable Energy Agency (NREL) and the International Renewable Energy Agency (IRENA), amongst others expect the costs of these technologies to continue to decline in future (albeit at a slower pace than has been seen in recent years). IRENA expects a decrease of 60-68% for solar PV and up to a further 26% decrease for onshore wind by 2025 [11]. The IEA conservatively expects cost reductions of 40-70% for solar PV and 10-25% for onshore wind by 2040 [12]. BNEF expects a 66% reduction for solar PV and 47% for onshore wind respectively by 2040 [13]. NREL expects solar PV and onshore wind to reduce by 57-70% and 29-48% by 2040 respectively [14].



[1] IEA defines Total Primary Energy Supply (TPES) = Production + Imports – Exports - Intl marine/aviation bunkers + Stock changes
Sources: IEA

Figure 1 Global total primary energy supply (2014) by region highlighting the significant role the United States and China play along with the energy role Africa and South Africa play globally.

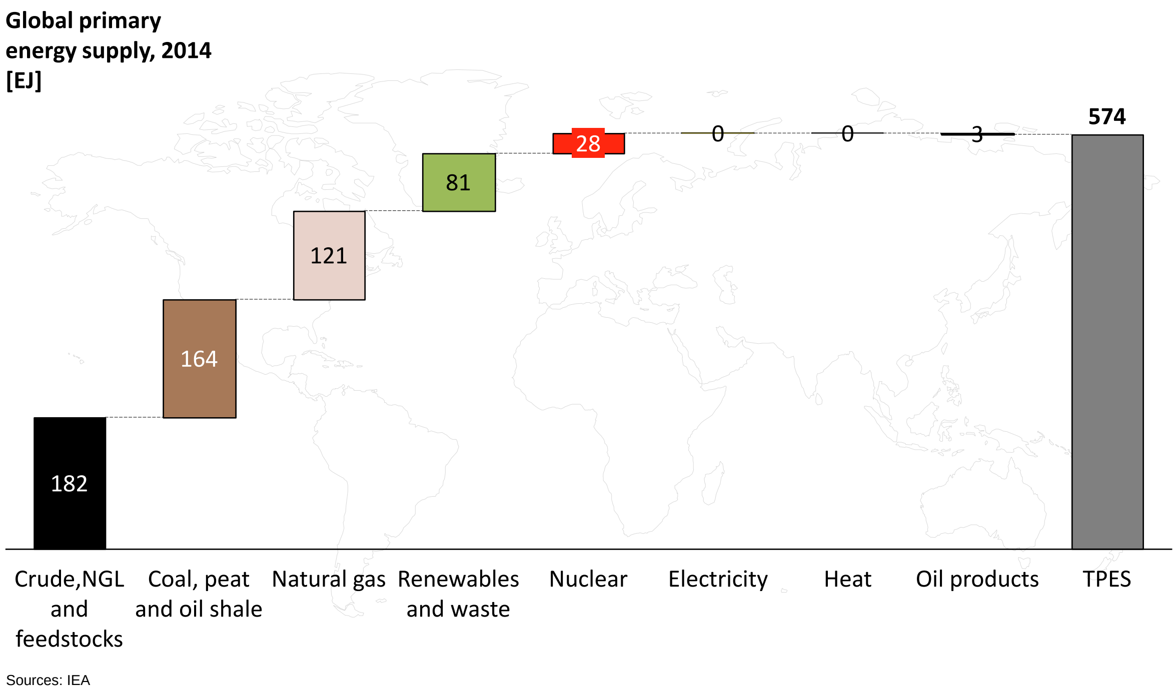


Figure 2 Global Total primary energy supply (2014) by primary energy supplier showing existing dominance of coal, oil and gas supplying ~80% of TPES.

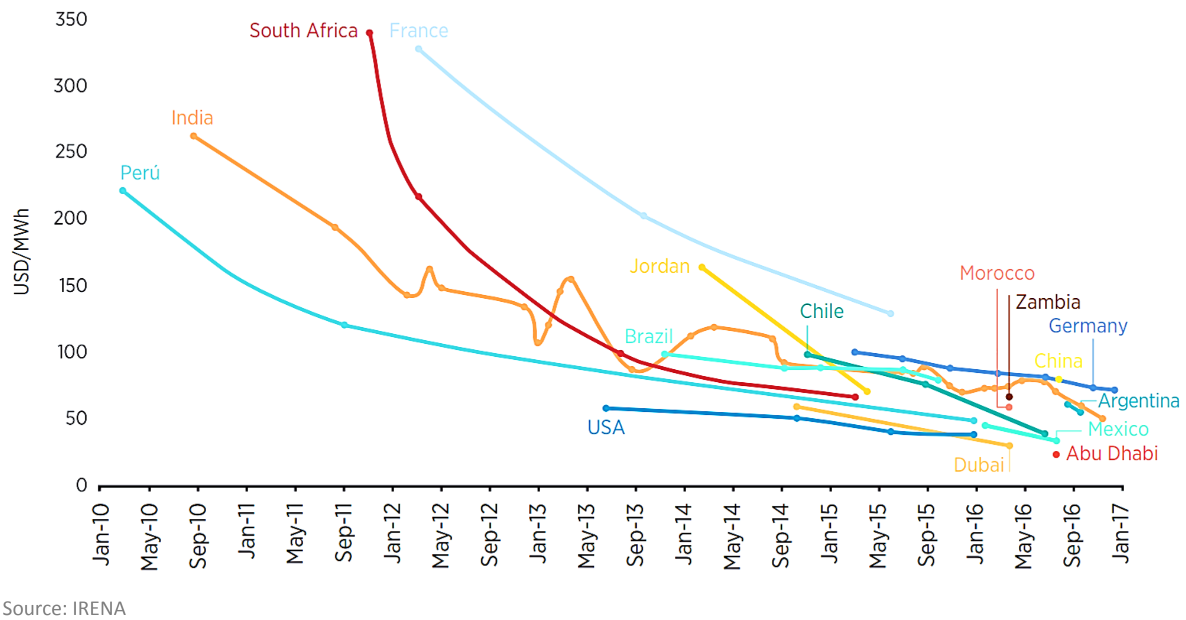
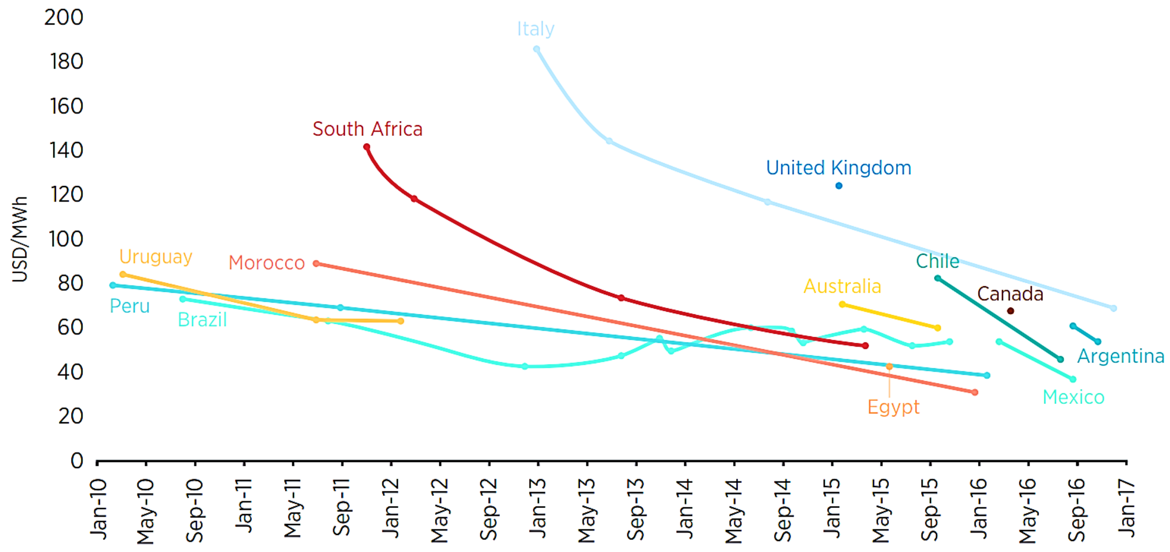


Figure 3 Average auction prices for solar PV for a range of countries for 2010-2016 (Source: IRENA).



Source: IRENA

Figure 4 Average auction prices for onshore wind for a range of countries for 2010-2016.

1.3 Domestic energy status quo with an outlook to 2030 and beyond

1.3.1 A summary of the South African energy balance is shown in Figure 5 with a breakdown by primary energy carrier provided in Figure 6 (for 2014). South Africa is a relatively energy-secure country with most domestic energy needs being met by domestic coal while imported oil and liquid fuels make up the majority of our energy imports. Domestic primary energy production is mainly coal-based (> 85%) and has historically been the driving force behind the South African economy. Most of the remainder is sourced from biomass/waste, nuclear and hydro sources (≈15%). Of South Africa's primary energy imports, oil and liquid fuels dominate (≈85%) with the remaining ≈ 15% coming from natural gas, electricity and coal. It is important to note that almost all of South Africa's oil and liquid fuel demand is met by imports (≈ 99%).

1.3.2 As a result of the above, although South Africa is relatively energy-secure, the existing overall energy mix points to two main risks:

1.3.2.1 Primary energy diversity: South Africa has a substantial reliance on coal as a primary energy source i.e. a single resource risk. This is not necessarily a problem if there are sufficient sustainable resources to meet growing energy requirements. However, in a future carbon constrained economy with a growing energy requirement, this will result in an unsustainable energy mix. This will need to be incorporated into future energy planning for South Africa and just energy transition will be necessary.

1.3.2.2 Primary energy imports: With almost all of South Africa's oil and liquid fuel demand being met by imports, a significant energy security risk exists along with considerable impacts on the fiscus. Whether this is sustainable in the long-term is an important consideration in planning South Africa's energy future.

1.3.3 In recent years, the procurement of RES in the electricity sector in South Africa (predominantly solar PV and wind) as part of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) has resulted in a growing domestic primary energy contribution of ≈8 PJ in 2014 (0.1%) to 25 PJ in 2016 (0.3%) while contributing 1.0% in 2014 and 2.9% in 2016 to electricity production [15], [16]. This is shown in Figure 6 as well but not to scale. This share of RES (dominated by solar PV and wind) is still a relatively small contribution considering South Africa's significant domestic wind and solar resources as demonstrated in [17]. A key outcome of the REIPPPP (even at this early stage) is the removal of cost uncertainty as well as significant reduction in absolute cost levels (for wind and solar PV in particular) as developers gain confidence in the transparent process and fully understand the rules of engagement [18]. Actual tariffs realised as part of the REIPPPP thus far are summarised in Figure 7 where an ≈80% reduction in solar PV and ≈60% reduction wind had been realised between 2011-2015 [19].

1.3.4 As envisioned in the NDP 2030, the South African economy will continue to grow. As is well known, this will require new primary energy in a developing country like South Africa where economic growth is still strongly correlated with primary energy demand (albeit not as strongly as it has been historically) [20]–[22]. The geospatial context of this energy demand development needs to be well understood in order to achieve NDP goals and objectives considering the legacy effects of spatial segregation and historical exclusion from the economy of a significant proportion of the population.

1.3.5 In term of policy, South Africa adopts a central energy planning paradigm with the strategic energy planning framework being defined by an overarching Integrated Energy Plan (IEP) and resulting plans, roadmaps and policy being informed by this. Some more pertinent examples of these are:

1.3.5.1 Integrated Resource Plan (IRP);

1.3.5.2 Gas Utilisation Master Plan (GUMP) / Gas Infrastructure Master Plan (GIMP);

1.3.5.3 Liquid Fuels Master Plan (LFMP);

1.3.5.4 Coal Roadmap; and

1.3.5.5 Renewable energy Roadmap;

1.3.6 From the guidance provided by these plans and roadmaps, a range of more detailed plans and strategies are developed by relevant stakeholders at national, provincial and local levels and implemented accordingly (this includes industry associations, business and organised labour).

1.3.7 With the global and domestic energy context provided, there exists significant economic opportunities that await a future South African energy sector based on electricity as a primary energy carrier primarily as a result of relatively cheap and abundant domestic resources:

1.3.7.1 Global megatrends are beginning to emerge where end-users are switching primary energy sources as a result of considerable technology cost reductions in the electricity sector (driven by significant investments in solar PV and wind technologies globally amongst other emerging technologies along the energy supply chain) [23]–[25]. Electricity is becoming a more dominant primary energy carrier with increased levels of sector-coupling between energy end-use sectors (electricity, heating/cooling, mobility) already occurring and being planned for in the long-term in a number of countries globally [23], [26], [27].

1.3.7.2 Considering these global megatrends, there are clear implications for South African energy planning where inappropriate and incompatible existing and future energy infrastructure investments could be made.

1.3.7.3 South Africa has a considerable comparative and resulting competitive advantage in this regard considering the world-class domestic solar and wind resource available (as summarised graphically in Figure 8 and Figure 9). This could be harnessed to drive a future sustainable economy with an embedded support for local research, development and innovation (in various domains). Supportive technologies and services across the energy supply chain should be incentivised to enable this future energy economy while at the same time supporting economic growth in various other economic sectors.

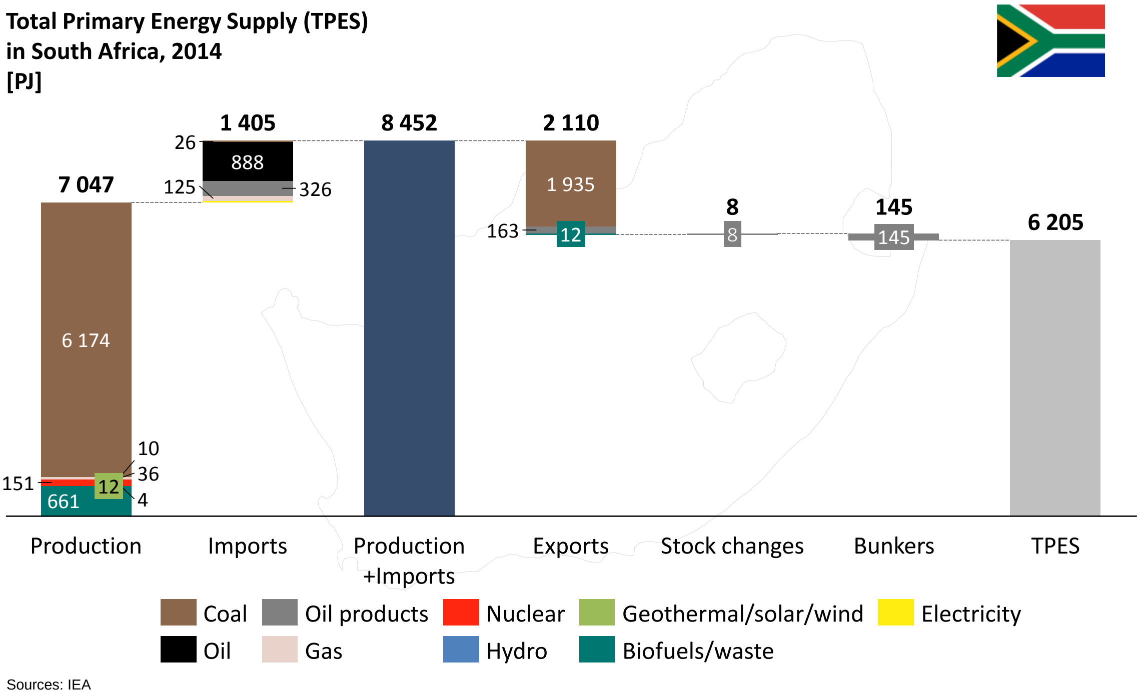


Figure 5 Primary energy supply in South Africa (2014) showing significant reliance on coal as a primary energy supplier and single resource import risk (oil and liquid fuels).

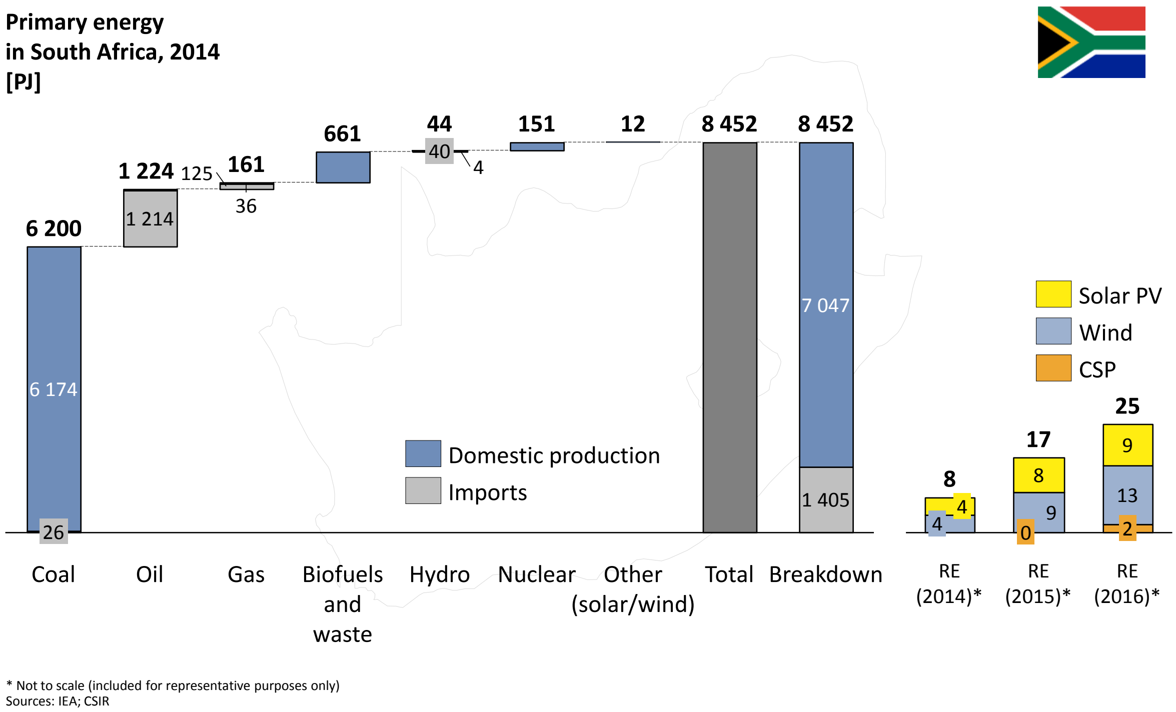
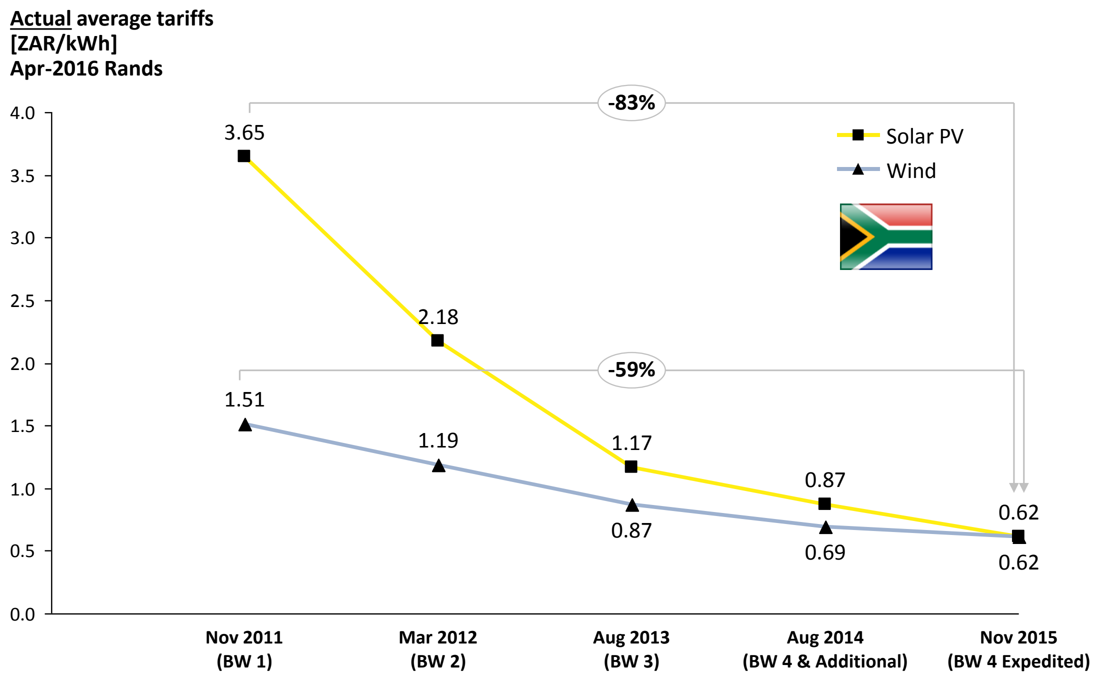
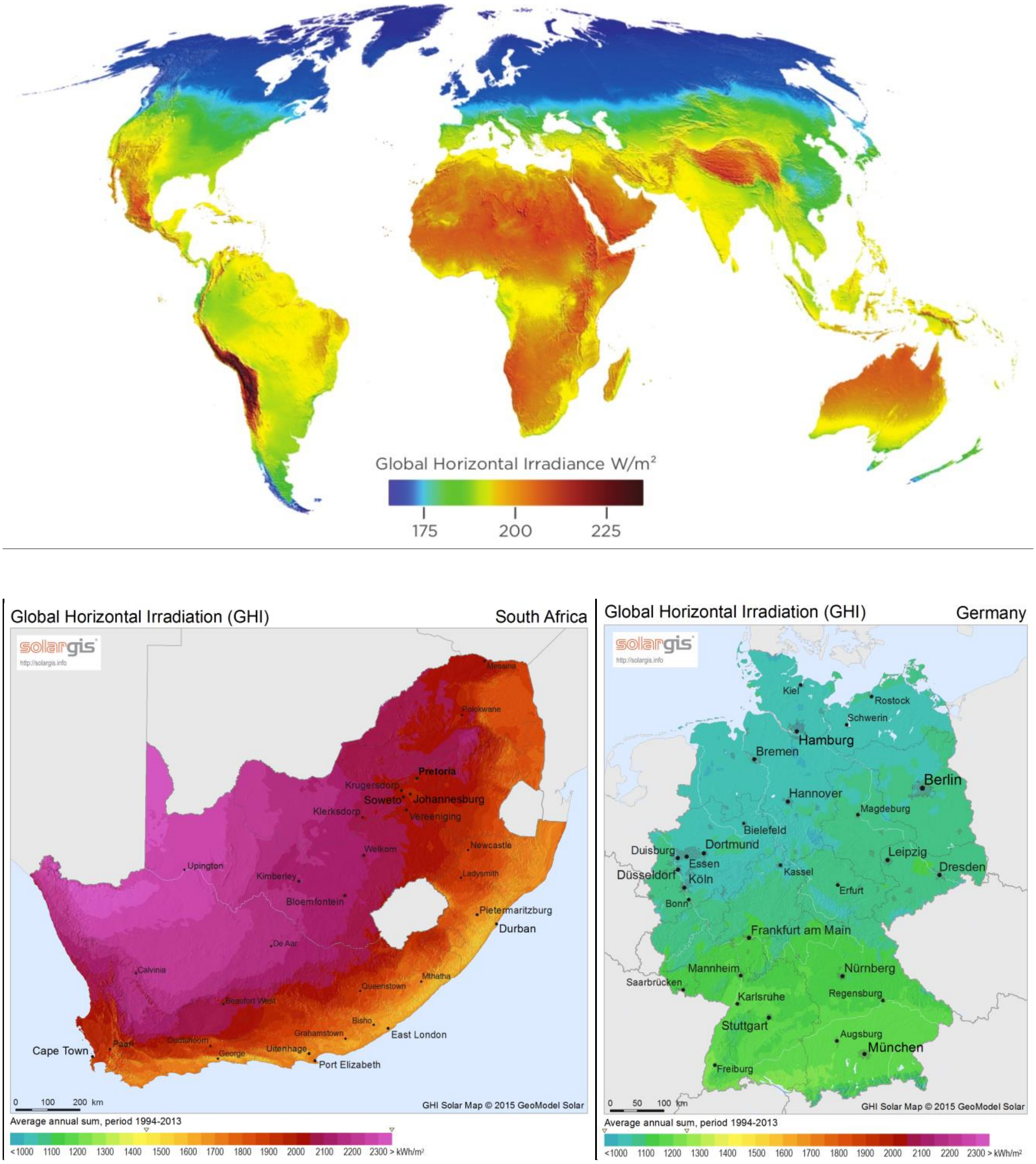


Figure 6 Primary energy supply in South Africa (2014) showing relative energy security but near full reliance on oil imports.



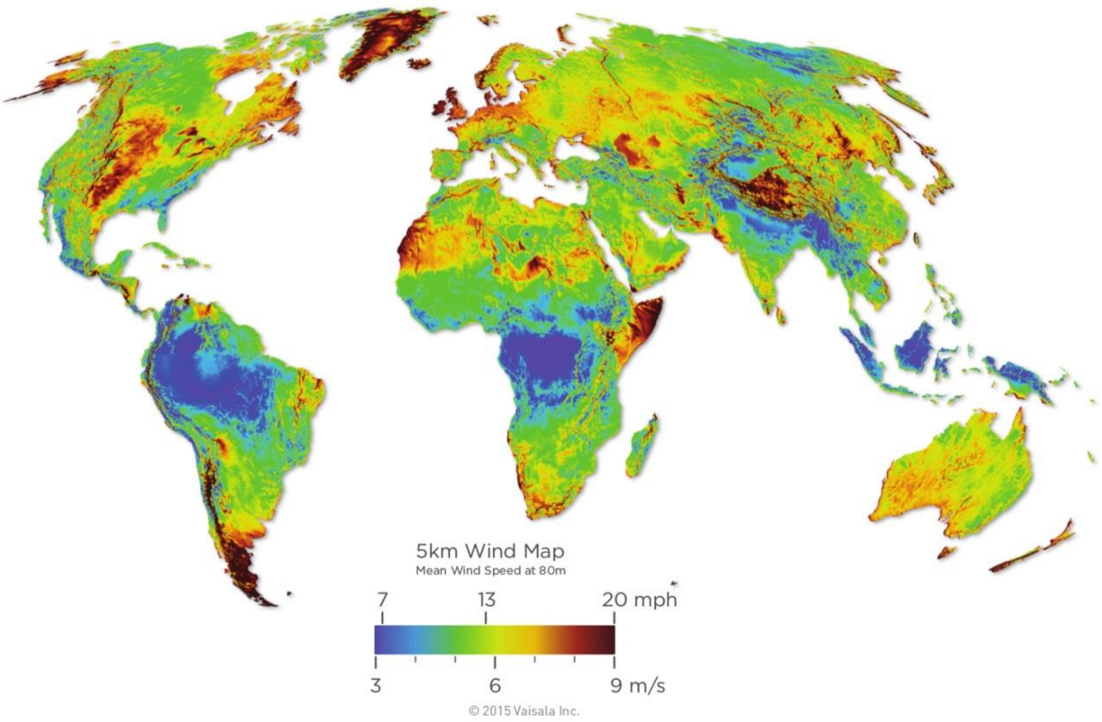
Sources: http://www.energy.gov.za/files/renewable-energy-status-report/Market-Overview-and-Current-Levels-of-Renewable-Energy-Deployment-NERSA.pdf; http://www.saippa.org.za/Portals/24/Documents/2016/Coal%20IPP%20factsheet.pdf; http://www.ee.co.za/wp-content/uploads/2016/10/New_Power_Generators_RSA-CSIR-14Oct2016.pdf; StatsSA on CPI; CSIR analysis

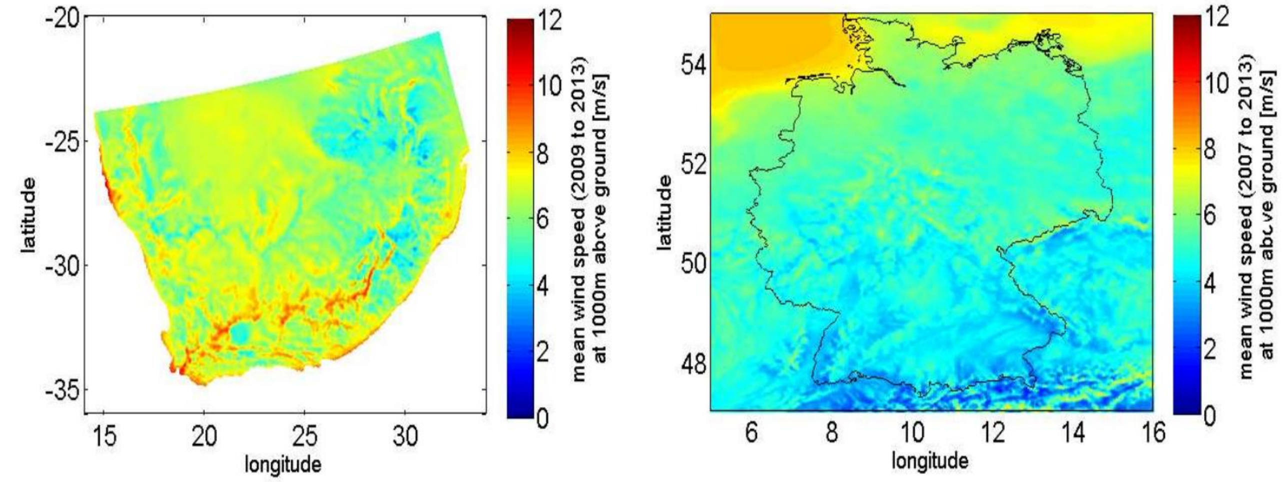
Figure 7 South African REIPPPP actual tariffs per Bid Window (BW) for solar PV and wind showing significant technology cost reduction in relatively short period of time.



Source: solargis, CSIR, Vaisala

Figure 8 Relative comparison of (top) South Africa's solar resource to global solar irradiance and (bottom) relative comparison of South African average annual GHI to an early adopter of solar PV (Germany).





Source: Vaisala, CSIR

Figure 9 Relative comparison of (top) South Africa's wind resource to global wind (mean wind speed at 80 m above ground) and (bottom) relative comparison of South African mean wind speed between 2009-2013 at 100 m above ground to an early adopter of wind (Germany).

2 Objectives

2.1.1 While there have been many successes in the South African energy industry, many critical issues as identified in the NDP 2030 [28] persist. In addition, there is the dynamic energy planning, regulatory and governance environment that has been changing rapidly in recent years. Disruptive technologies, governance concerns combined with global megatrends outlined previously are challenging existing paradigms and long-term planning outcomes.

2.1.2 A discussion of revised priorities for the future of the South African energy industry is, thus, necessary in the context of the NDP 2030 while remaining cognisant of the opportunities, risks and transition costs within which the global and domestic energy sector operates.

2.1.3 The approach in this publication is to take an independent view and in that respect, it may not explicitly align with existing government policy and where divergence may occur with the NDP 2030, it is overtly stated.

2.1.4 The NDP 2030 is clear on the objectives of the energy sector:

> *South Africa will have an energy sector that promotes:*
>
> - *Economic growth and development through adequate investment in energy infrastructure. The sector should provide reliable and efficient energy service at competitive rates, while supporting economic growth through job creation.*
> - *Social Equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households*
> - *Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.*
>
> *[National Development Plan 2030]*

2.1.5 An objective of this publication is to focus on addressing challenges and pertinent issues within the South African energy sector while maintaining a long-term outlook in terms of opportunities that may exist. As such, this publication does not contain an exhaustive list of potential goals but instead addresses key areas in the energy sector to be prioritised in order to make the necessary impact.

2.1.6 These areas are discussed in the context of feasible implementation in the short- to medium-term (2015-20) while maintaining a long-term perspective with respect to implications for 2030 and beyond, where relevant.

2.1.7 This publication is intentionally succinct and made accessible to ensure that a wide as possible an audience whether within government, business, organised labour and/or civil society. It is aimed at providing the strategic advice needed to reach the goals and objectives in the NDP. A comprehensive list of references is provided for those requiring additional information and insight.

3 Discussion

3.1 Energy planning and governance framework

Status-quo

South Africa implements a central energy planning paradigm with the strategic energy planning framework being defined by an overarching Integrated Energy Plan (IEP) that inform resulting plans, roadmaps and policy. Some more pertinent examples of these are:

- Integrated Resource Plan (IRP);
- Gas Utilisation Master Plan (GUMP) / Gas Infrastructure Master Plan (GIMP);
- Liquid Fuels Master Plan (LFMP);
- Coal Roadmap;
- Renewable Energy Roadmap

The most important strategic plan remains the IEP as the over-arching strategic plan to inform other plans in each energy sub-sector. This is followed by the IRP for electricity which is critical as it directly informs significant policy direction and the resulting investments in the electricity sector. Versions of the GUMP/GIMP and LFMP have not been published yet but will likely be informed by the latest versions of the IEP and IRP. There has not yet been a promulgated version of the IEP and the most recent promulgated version of the IRP is currently more than 5 years old [29].

Drafts of the IEP and IRP were published by the Department of Energy (DoE) in late November 2016 with public consultation until the end of March 2017 [30], [31]. Following this, stakeholder comments were planned be incorporated and further consultation undertaken following which policy adjustment would be initiated and promulgated.

According to the DoE's presentation to the Portfolio Committee on Energy on their Strategic Plan, Annual Performance Plan and Budget Vote in May 2017 [32], updated versions of the IRP, IEP and GUMP would be submitted to Cabinet within the 2017/18 financial year (latest February 2018).

Discussion and Proposals

3.1.1 Currently, with specific reference to the electricity sector and the dynamic environment within which it operates, it could be argued that South Africa is procuring generation capacity based on outdated information (the promulgated IRP 2010-2030 [29]). An updated IRP to inform the most appropriate procurement decisions for the future is critical to avoid insufficient and inefficient electricity service.

3.1.2 The periodic and consistent updating, publishing and promulgation of key strategic national energy plans as part of the strategic energy planning framework should be prioritised with a particular focus on transparency, quality and completeness.

3.1.3 These updated plans should incorporate inputs and comments gathered from transparent and comprehensive engagement processes so that it is able to inform the detailed plans and strategies developed by various national/provincial/local departments, State-Owned Enterprises (SOEs), industry stakeholders, organised labour and civil society.

3.1.4 The finalisation of these strategic plans should be based on a consistent process that applies the principles of least-cost which are augmented quantitatively with the relevant factors identified up-front as part of the process. Examples of these factors include the total system costs, job creation, energy adequacy, environmental impacts (water usage, CO_2 emissions, particulate matter, SO_x/NO_x emissions etc. Any deviations from this should then be transparently quantified in scenarios in order to ensure an informed policy discussion and decision-making framework.

3.1.5 In the context of the most efficient allocation of available resources, the IEP and IRP should reflect:

3.1.5.1 More accurate demand forecasts based on updated historical end-use data considering declining electricity intensity and innovative approaches to energy efficiency and demand side management; and

3.1.5.2 Continually updated supply technology costs with particular attention paid to innovative and disruptive supply technologies that are already cost competitive with conventional supply resources and on significant learning curves. Incentivising research and development in promising technologies and services in various parts of the supply chain which should be prioritised where feasible.

3.1.6 If sufficient capacity does not exist within the DoE, the development and collation of all input assumptions, technical modelling and necessary related investigations for future revisions of strategic energy plans could be undertaken by an entity capable of providing the necessary services and with no vested financial interest in the future energy mix[2]. This entity will likely require separate governance structures to ensure complete transparency before the process is initiated in order to gain trust and confidence of all stakeholders.

3.1.7 The process of updating and publishing strategic energy plans should be as participatory as possible to promote transparency, quality and comprehensiveness, and to gain trust from all stakeholders. This will ensure a more informed policy-making process as well as clear policy direction for all stakeholders. To enable this, data, models, approaches and outcomes should be publicly available.

3.1.8 In addition, regardless of which entity undertakes the process, a rigorous peer review process (defined ex-ante) should be run concurrently with the publication of all input data, technical modelling and scenario outcomes.

3.1.9 Once energy plans are updated and promulgated, a strong commitment to implementation is necessary from all stakeholders. Most importantly, however, this is crucial for all key decision-makers and enablers at all levels including government, business and organised labour.

3.1.10 The spatial dimension of the integrated energy planning framework and more specifically IRP (network related costs) has not been included in these processes as yet. Although integrated generation/transmission expansion planning is possible with available tools, the problem becomes considerably large (mathematically) quite quickly and thus it may be of more value to either include a simplified representation of networks or assess network cost implications of scenarios ex-post. Total system costs (including network costs) can then be compared on a like-for-like basis across

[2] Currently, this is not the case. Eskom currently performs this technical work as a service provider to the DoE [57].

all scenarios developed. What is important to consider in this regard is whether network cost implications of scenario outcomes will shift overall total system costs enough to change the least-cost generation expansion planning outcomes (and overall strategic direction and policy that results).

3.1.11 The DoE is commended for the inclusion of externality costs in the IEP and IRP thus far as a starting point to internalise externality costs of various primary energy suppliers and technology options. Externality costs should continue to form part of energy planning in South Africa and updated accordingly based on the latest available research.

3.1.12 The socio-economic implications of each technology choice as part of the integrated energy planning framework should be assessed ex-post following the least-cost planning outcomes, more particularly, with a focus on the direct supplier, indirect and induced job creation potential (localised, localisable and global). This dimension can then be included in the planning process outcomes to inform policy discussion and adjustments.

3.2 Electricity sector end state

Status-quo:

The South African electricity sector is a single-buyer model with Independent Power Producers (IPPs) being contracted by a vertically integrated, state-owned utility complemented by municipal distributors. There is no wholesale (or retail) competition in the supply of electricity. Self-supply of electricity is allowed in selected cases while draft regulations on small-scale embedded generation are currently under discussion.

Electricity supply adequacy has been a concern for a number of years in South Africa with boom-bust cycles in the supply-demand balance. This is manifested in either over-supply where parts of the existing Eskom coal fleet are put on cold stand-by in anticipation of increased demand or increased levels of electricity exports to the Southern African region are pursued on an ad-hoc basis. Under-supply situations have also occurred and are much more economically harmful as was felt during 2008 and 2014 load-shedding periods.

Operational inefficiency and long-term financial sustainability of Eskom including cost and time over-runs on large capital projects, that have resulted in sustained tariff increases and continued reliance on funding injections places a strain on public finances.

In recent times, there have been public allegations of concerning financial irregularities and governance issues at Eskom along with a failure in leadership at the highest levels.

The existing electricity mix is based predominantly on coal-fired generation (supplemented by minority shares of hydro, nuclear and liquid fuels) while in recent times RES IPPs have been introduced (mostly solar PV and wind). An impasse occurred between 2015-2017 where duly procured RES IPPs as part of existing government policy (REIPPPP) did not reach financial close as a result of Eskom not signing Power Purchase Agreements (PPAs).

Electricity industry reform in South Africa has been proposed on numerous occasions in the past including one that reached Parliament in 2011 [33] in the form of a draft bill. In its presentation to Parliament in May 2017, the Department of Energy [32], indicated that a Cabinet memo on the end-state of the South African electricity sector will be submitted by the third quarter of the 2017/18 financial year.

Discussion and Proposals

3.2.1 The vision and end-state for the South African electricity sector needs to be finalised in order to create long-term certainty that will reduce electricity prices (relative to the status quo), further promote investment in various parts of the electricity supply chain, drive sustainable economic growth, meet the needs of the poor, and move towards a low-carbon economy.

3.2.2 The NDP 2030 is explicit on the requirement for the system operations, planning, power procurement, purchasing and contracting functions within Eskom to be separated into a an independent institution entirely. The current environment within which the South African electricity sector operates provides for an increased incentive for this to be undertaken and prioritised in a phased approach in the short-to medium-term while considering the long-term implications thereof.

3.2.3 Wide-ranging research provides a valuable contribution to the updated options available for electricity sector reform in South Africa. [34] - [35]–[37]. A synthesis of the research can be briefly summarised as follows:

3.2.3.1 Supply inadequacy and associated boom-bust cycles;

3.2.3.2 The need to provide affordable electricity to the poor;

3.2.3.3 Operational inefficiency and long-term financial sustainability of Eskom including cost and time over-runs on large capital projects, debt obligations, resulting sustained tariff increases and continued reliance on funding injections placing strain on public finances;

3.2.3.4 Failure to recognise and act on technological disruption;

3.2.3.5 Allegations of governance and financial irregularities within Eskom (responsible for all components of the electricity supply chain);

3.2.3.6 Second order aspects like resulting rising electricity costs to the consumer and environmental sustainability of the South African electricity mix.

3.2.3.7 A recognised conflict of interest (whether perceived or real) in the fair treatment of IPPs for planning, grid connection and operation relative to self-owned generation assets is of concern. Generation is bought from IPPs by Eskom, which also owns generation assets itself and may own additional generation assets in future.

3.2.4 A key reform driver which deserves additional explanation concerns the fair treatment of planning, grid connection and operation of IPPs relative to Eskom-owned generation into the future. This has been magnified by the refusal of Eskom to sign Power Purchase Agreements (PPAs) on the basis of cost between 2015-2017 as part of the DoE REIPPPP thereby contradicting government policy as well as announcements from the Executive [38], [39]. This demonstration of monopolistic behaviour has been of global concern and a primary driver for electricity industry restructuring since the late 1980s which has predominantly split the generation function from transmission planning, grid connection and operations functions [35], [40]–[51].

3.2.5 The desired outcomes of the electricity sector are:

3.2.5.1 Environmental and social sustainability of electricity supply and end-use;

3.2.5.2 Sufficient and reliable electricity supply;

3.2.5.3 Financial sustainability of electricity sector entities;

3.2.5.4 Efficient, reasonable and cost-reflective electricity prices with no cross-sectoral subsidisation (transparent subsidisation within the sector may be required to enable affordable access for the poor).

3.2.6 As a result, there seems to be an inherent requirement for electricity regulatory reform in South Africa as the status quo will not deliver the required outcomes. This will require legislative change, which should take a phased approach and consider the long-term implications thereof. It is critical that any regulatory reform considered should be considered in close consultation with Eskom. A fundamental principle in this regard is one in which efficiency in the supply and use of the necessary service needs to be a top priority.

3.2.7 Eight (8) industry reform alternatives are presented in the research (including the status quo) and evaluated based on:

3.2.7.1 Impact on efficiency;

3.2.7.2 Conducive environment for private funding;

3.2.7.3 Reliance on government funding;

3.2.7.4 Ease and cost of implementation;

3.2.7.5 Impact on electricity prices

3.2.8 Although an updated detailed impact assessment regarding the options available for the end-state of South Africa's electricity sector will be necessary, at a high level, the NPC presents the following discussion points on electricity sector regulatory reform:

3.2.8.1 *Regulator:* Ensure that the regulator is sufficiently funded and capacitated to assess, monitor and appropriately manage any possible electricity regulatory reform process independently.

3.2.8.2 *Generation (competitive):* The generation assets of Eskom are unbundled into a separate state-owned entity (or set of state-owned entities) or sold to a number of private investors competing with IPPs in the medium-term with the up-front provision of ensuring necessary developmental mandates are fulfilled. In addition, easy to implement new alternative models for production and ownership of electricity generation should be explored in the short- to medium-term. This should include embedded generation (discussed below) as well as the ability for generation providers to sell to willing off-takers to remove constraints on the provision of reliable and sustainable electricity (whether municipalities or aggregated domestic, commercial and/or industrial customers) facilitated by a Transmission System Operator (TSO) outlined below.

3.2.8.3 *Transmission (regulated):* The natural monopoly wires related businesses should be a company in itself in the long-term with a medium-term goal of splitting the procurement, operations and planning component into a separate entity (likely state-owned). This entity should have its own separate governance structures from the previously mentioned competitive generation business(es) to ensure appropriate separation of interests and the removal of any conflict of interest that currently exists as the status-quo.

3.2.8.4 *Distribution (regulated):* Distribution (the wires) and electricity sales to small customers should remain regulated and with Eskom/municipalities in the interim while larger customers become competitive in the medium- to long-term (as briefly discussed above). It is important to note that as a result of this component of the supply chain remaining highly regulated that the poor will be protected from considerable tariff increases.

3.2.9 The estimated cost of the maintenance backlog by municipal distributors is currently in excess of R70-billion and has reached the point where it may be unmanageable (a crisis). In order to promote investment in the distribution network infrastructure, it may require the explicit ring-fencing of electricity revenue (or at least the strict monitoring of the Municipal Standard Chart of Accounts to be implemented in 2017) as well as allowing for municipalities to cut off electricity supply as a powerful tool to ensure revenue security.

3.2.10 Improved long-term planning capacity within municipalities is required to rectify this crisis, so that funds are spent appropriately. With 80% of municipal electricity distributed by the 12 large metropolitans and towns, contributing ~75% to South Africa's GDP, there is a critical need to ensure technical excellence within these municipalities at the very least either via Service Level Agreements with Eskom or professional service providers to help municipalities. There should be a stipulation that this assistance must be accompanied by skills transfer programs. Further capacity development could be enabled by the DoE. The development of accurate asset registers and maintenance plans will be critical in this process for sustainability in future.

3.2.11 As an interim measure, fiscal transfers to deal with the existing maintenance backlog may be necessary. It is crucial that it not be provided on a sustained basis as this provides perverse incentives and drives incorrect behaviour. Financing of the necessary maintenance, and investment in refurbishment and expansion of distribution networks could be sourced from domestic and international Development Finance Institutions (DFIs) while remaining cognisant of the effects on end-user tariffs.

3.2.12 Future maintenance requirements will need to be more closely monitored and incentivised by NERSA with municipal tariff increases dependent on proven efficient maintenance and expansion expenditure.

3.2.13 Smaller municipalities should be encouraged to work with large municipalities and/or Eskom (Distribution) to give effect to these recommendations. These arrangements should be managed by Service Level Agreements.

3.2.14 Embedded generation and resulting energy self-supply has become economical in a number of end-use sectors and should be incentivised as much as possible while remaining cognisant of the impacts on incumbent utility providers (see 3.4 for more details).

3.3 The future of coal and carbon pricing

Status-quo:

As has been previously demonstrated (Figure 5), a significant portion of energy-related CO_2 emissions in South Africa are as a result of coal-fired electricity generation. The secondary component of this is the coal-to-liquids (CTL) technology that converts coal to liquid fuels for use in the transportation sector.

It is understood that a Coal for Energy Policy Position Paper has been developed by the Department of Mineral Resources (DMR) and is undergoing consultation.

South Africa has ratified the Paris Agreement to endorse our Nationally Determined Contribution (NDC) which will require considerable reductions in energy-related CO_2 emissions in South Africa. The Paris Agreement is a near-global understanding of the requirement for GHG emission reductions into the future and the appropriate pricing of the externalities of GHGs into energy markets globally (more specifically CO_2 emissions) [52].

The Carbon Tax Bill was released for comment in November 2016 [53] and is being considered has recently been publicised for consideration in Parliament by National Treasury [54] as a mitigation option in a broader GHG Emission Reduction Strategy for South Africa to incorporate the externality costs of CO_2 into the South African economy.

Discussion and Proposals

3.3.1 Following the publication of the South African Coal Road Map in 2013 [55], there was an urgent need for co-ordinated stakeholder action driven by government to facilitate a transparent decision-making process for a just energy transition in South Africa. This is in the context of ensuring long-term sustainability of energy-use with a particular focus on coal considering the significant role it currently plays. In this regard, although coal will continue to play a major role in South Africa's energy mix (specifically in electricity sector), a transition away from coal use locally in key sectors in the medium- to long-term is necessary for a number of reasons including *inter alia* single and finite resource risks as well as environmental sustainability. A range of work in this regard has been undertaken (amongst others [27], [56]–[60]) and there is a process being undertaken by the NPC to inform a just energy transition for South Africa. This would aim to fulfil a broader discussion over and above the existing and draft policy (e.g. Coal for Energy Policy Position Paper) to consider the impact of the global energy transition underway in the context of coal and the role it has in South Africa's energy future. It is clear that there is need for a phased approach in order to appropriately manage this transition and minimise the impact on government, SOEs, businesses, jobs and organised labour.

3.3.2 Existing infrastructure and proposed new infrastructure investment in coal mines and transport links to ensure security of coal supply for the remaining life of existing coal power stations and/or existing local industrial use should be pursued on a case-by-case basis. This should be considered in the broader context of the previously mentioned just energy transition and sustainable energy end-use for South Africa. In this regard, the risk of stranded infrastructure investment in the South African coal industry is significant and has been noted domestically and globally as well as if South Africa pursues a Peak-Plateau-Decline emissions trajectory or carbon budget approach to emissions [27], [56], [59], [61], [62]. Lowering the use of fossil fuels in the energy mix will be driven by these international commitments and an appropriate national policy direction [63]–[66] combined with disruptive technologies and energy efficiency policies.

3.3.3 A carbon pricing mechanism (a carbon tax in South Africa) with appropriately designed allowances will send the relevant signals for substitution of carbon-intensive fuels to enable a transition to a low-carbon economy. A phased and predictable approach over time should also ensure minimal shock to the incumbent industry, economic growth and energy prices (with particular focus on minimising the impact on the poor). In this regard, it is important to note benefits associated with a Carbon Tax including localised and national level environmental and health benefits (amongst others) [67].

3.3.4 The enactment and implementation of the Carbon Tax Bill with an appropriate carbon budget linked to this by 2020 is important as a starting point to incorporate the externality costs of coal use and resulting CO_2 emissions. Thus, the carbon tax is an important mitigation measure in this regard and is supported by the NPC.

3.3.5 In addition to this, the carbon tax needs to be complemented by strategic energy plans that mandate an electricity generation mix that meets South Africa's GHG emissions commitments (at least defined by the Peak-Plateau-Decline trajectory or alternatively adopted trajectory e.g. carbon budget).

3.4 Modular, robust and sustainable energy investment

Status-quo:

As is highlighted in the National Climate Change Response White paper (2011), the Greenhouse Gas Inventory for South Africa 2000 – 2010 (2014), [65], [68] and Figure 5 above, the majority of South Africa's GHG emissions arise from energy supply/use (~80%) while 45% is from electricity as a result of the significant use of cheap domestic coal resources.

Global movements and imperatives for GHG emission mitigation and adaptation are well understood and accepted [52]. South Africa has also made commitments to domestic GHG mitigation measures as part of the recent ratification of the Paris Agreement [66].

The considerable cost reductions realised as part of the REIPPPP have made solar PV and wind the cheapest new build options in South Africa today [15]. Of course, it needs to be appreciated that this is on a pure unitised cost basis (R/kWh) and does not necessarily mean that they provide the same value as other transmittable power generators.

There exists a significant domestic wind and solar resource in South Africa which is widely dispersed and there are very few locations which do not have economically viable solar and/or wind resources [17]. This provides for a localised potential deployment of modern energy sources that are sustainable in the long-term.

Developed nations as well as developing nations are now deploying RE on scale (particularly solar PV and wind) [24], [35]. For some perspective (on wind), 56 GW of wind capacity was added in 2016 (1.6x South Africa's peak demand) ending 2016 with 486 GW of installed wind capacity globally (14x South Africa's peak demand). China added ≈40% (23 GW) of the wind installed in 2016 and makes up ≈35% (169 GW) of total global installed wind capacity.

There is currently a very small-embedded generation market in South Africa. Nersa has released a draft of Small-Scale Embedded Generation (SSEG) Regulatory Rules [69] with the aim of exploring tariff options to promote SSEG (between 100 kW and 1 MW) that are attractive to investors and sustainable for distributors. Projects between 1 MW and 5 MW are covered under the DoE small-scale IPP programme whilst projects >5 MW fall under the DoE-run REIPPPP. Although the proposed draft SSEG Regulatory Rules have not come into effect yet, Nersa has approved municipal SSEG tariffs in the interim on a case-by-case basis. Some municipalities have already moved ahead in developing their own guidelines and regulations as a result of the significant demand for embedded generation, which will be updated accordingly once Nersa and DoE have finalised SSEG regulatory rules. These regulatory rules were targeted to be promulgated by Q2 2017/18.

Discussion and Proposals

3.4.1 There is an acceptance that all stakeholders who want improve the sustainability of South Africa's economy do so within the context of climate change while ensuring energy accessibility, affordability and adequacy.

3.4.2 In this context, there is a significant opportunity (along with associated economic growth potential, foreign direct investment and localisation) via utility scale and/or embedded generation investment considering recent global and domestic technology cost trends not only for wind and solar PV but also for stationary storage technologies [8], [9], [24], [70]–[72]. This could be enabled by sustained rolling Bid Windows (BWs) for renewable energy as an extension of the highly successful REIPPPP. This can be done either as a continuation of the REIPPPP, an adjusted REIPPPP program to enable further local participation across the value chain or an appropriately structured distributed RE program linked to the learnings of the REIPPPP. This will assist in ensuring the recently established industry maintains momentum and continues with already significantly reduced prices, relatively high-levels of localised job creation and community investment, manufacturing and ownership as procurement programmes are fine-tuned to require more local content over time to drive industrialisation.

3.4.3 Understandable technical concerns surrounding the integration of variable renewable energy sources like wind and solar typically focus on the predictability of the resource and associated cost implications for balancing and integration (complementary fleet flexibility, system stability and other network services). It has been shown that typically these concerns only start to become relevant and a priority when renewable energy penetration levels of 20-30% and beyond are reached (by annual energy share) [71]. Beyond this, these concerns have largely declined and are being solved locally with recent research, standards development and application [73]–[76] as well as extensive research for many years globally [77]–[88]. Operational solutions are also being applied and experience is being gained around the world. See references [89]–[104] (amongst others).

3.4.4 The global shift away from the centralised utility model to distributed energy systems [35] presents an opportunity for embedded generation in the South African electricity sector but there is significant investment required in distribution network infrastructure (refurbishment, upgrade and maintenance), fair and equitable tariff designs and appropriate institutional arrangements. As mentioned in section 3.2.8.4, there is an acknowledged lack of distribution network infrastructure maintenance and upgrading in South Africa which has resulted in a significant backlog. This will need to be addressed to enable any considerable level of embedded generation uptake.

3.4.5 On the demand side, it is likely that self-adoption without any form of incentivisation will happen naturally at an individual and firm level as the costs of embedded generation continue to decrease (particularly rooftop solar PV) while electricity tariffs continue to increase simultaneously. In this regard, there is significant opportunity in the following dimensions:

3.4.5.1 For small business development and job creation potential in the development, financing, ownership, installation and maintenance of embedded generation.

3.4.5.2 Improved national energy security, sustainability and affordability.

3.4.5.3 Alleviation of the energy supply-demand imbalance as the profile of solar PV technology aligns well with periods of high demand in South Africa (albeit not at evening peak demand times).

3.4.5.4 Embedded generation in rural areas specifically is a significant opportunity for localised business and revenue potential for owners and communities to invest in themselves and create sustained livelihoods in the long-term (see [116] for examples of this).

3.4.6 Grid defection by users that can afford the upfront capital investment in self-supply has the potential to leave behind customers who cannot. This creates the undesirable effect where utilities (Eskom and municipalities) need to recover similar fixed costs from a smaller volume of energy sales thereby requiring higher tariffs for remaining customers. Innovative tariff approaches and broader energy support including resources and tools for local government are already being considered in South Africa to avoid this effect and ensure the sustainability of electrical utilities and energy provision [105]. This should be supported on an ongoing basis going forward and incentivised as much as possible.

3.4.7 As mentioned, a driving force and central pillar behind the embedded generation market will be rooftop solar PV adoption by various end-users in the industrial, commercial and residential sectors. If consistent and sustained policy and regulatory frameworks are defined to incentivise this, there is a high likelihood of imported goods and services becoming localised if combined with research and development to develop best in-class technologies and services with resulting manufacturing, training and capacity development. The REIPPPP has already resulted in a high level of localisation but more can likely be achieved and the abovementioned sustained and consistent policy and regulatory frameworks should enable this to become a reality.

3.5 Nuclear new build programme

Status-quo:

The promulgated IRP 2010-2030 included 9.6 GW of nuclear power generation capacity [29]. Following this, the Minister of Energy made a Ministerial Determination that confirmed it in December 2016 [106].

A DoE briefing to the Parliamentary Portfolio Committee on Energy at the end of 2016 proposed a panel discussion specifically on the nuclear new-build programme with industry experts in early 2017 followed by public hearings with all interested stakeholders in 2017 [107], [108]. This has not taken place yet.

As noted, the IRP is currently being updated and the Draft IRP 2016 is in the public domain for consultation [30] following a significant time-lapse since the promulgation of the IRP 2010-2030 in 2011 [29]. In the Draft IRP 2016, a Base Case requires nuclear power by earliest 2037 while a Carbon Budget scenario requires it by 2026.

Following the release of the Draft IRP 2016 and the appointment of Eskom as the owner and operator of a possible nuclear fleet in South Africa – Eskom received a number of responses to a Request for Information (RfI) [109], [110] in early 2017 for the procurement of a nuclear fleet as early as 2025.

The actions taken by the state between 2013 and 2016 in relation to nuclear procurement (S(34) Ministerial Determinations as well as three Inter-Governmental Agreements (IGAs) with the United States of America, the Republic of Korea and the Russian Federation) were legally challenged. The Western Cape High Court passed down judgement in this regard in early 2017 stating that the section 34(1) determinations, three IGAs as well as the RfI already published by Eskom and proposed RfP thereafter have been determined to be irrational, unlawful and unconstitutional and should be set aside [111].

South Africa's research efforts into Small Modular Reactors (SMRs) have been recently revived via research efforts focussed on an Advanced High Temperature Reactor (AHTR) for commercialisation in the 2030s based on the previous work as part of the Pebble Bed Modular Reactor (PBMR) [112].

Discussion and Proposals

3.5.1 The investment levels required for a nuclear programme in South Africa will be unprecedented requiring a particular focus on this technology. As with any power generation technology, the prospective nuclear programme investment needs to be transparently considered based on cost (with particular focus on time and cost over-runs) as well as affordability (for end-users and the national fiscus) when compared to alternatives in the context of long-term total electricity system costs. As outlined in the NDP 2030, evaluation criteria specific to nuclear as a technology should include *inter alia* financing options, institutional arrangements, safety, environmental costs and benefits, localisation and employment opportunities, uranium enrichment and fuel fabrication. Other aspects would include regulator capacity (unique risks), global trends and modularity with the associated flexibility robustness of investment decisions.

3.5.2 As should be the case for all power generation technologies, all of the above should be published in the interest of openness and transparency while removing the speculation surrounding possible corruption and obtaining buy-in from all stakeholders.

3.5.3 Information publicly available in a number of jurisdictions globally [73], [74], [113]–[124], should inform future possible nuclear energy provision which would need to considered in the context of the entire suite of alternatives. A comprehensive set of views on this should form part of the broader integrated energy planning framework and more specifically as part of the latest IRP 2016 and future IRP processes (see section 3.1).

3.5.4 Significant experience in operating nuclear facilities has been gained globally and domestically (Koeberg, Pelindaba) for many decades. However, as a result of the significant impact of historical events at nuclear facilities including the more well known Chernobyl and Three-Mile Island as well as more recent events at Fukushima, public concerns surrounding the safety of operating nuclear facilities locally and globally have been highlighted. The ongoing concern surrounding the safety of high-level and low-level nuclear waste management and storage needs to be addressed sufficiently for all affected stakeholders.

3.5.5 Considering the significant economies of scale that result from building large nuclear reactors (>1000 MW per unit), small modular reactors (SMRs) have typically been considered prohibitively expensive. However, the opportunity for SMRs to be included as an option in the integrated energy planning framework should be considered with appropriate realistic costs and learning curves expected considering the recent revived research efforts focussed on an AHTR for commercialisation in the 2030s [112] as well as historical research and development efforts in the U.S.A., China, Russia, South Korea and Argentina [125]. This should be considered in the context of existing commercially available nuclear power generation technologies [126] as well as alternative technologies and the economics thereof.

3.6 Existing and new-build energy infrastructure (mega-projects)

Status-quo:

With particular focus on the existing coal generation fleet in South Africa, it is aging and has experienced a number of reliability issues in the recent past. The recent stabilisation of this fleet should be commended but needs to be put into the context of reduced demand for electricity. The life extension of this fleet has been considered and is under discussion.

It is known that the new-build generation capacity projects at Medupi and Kusile have experienced significant cost and time over-runs [127]. These burden the state-owned electrical utility financially and eventually end-users directly in the resulting electricity tariff.

Discussion and Proposals

3.6.1 The Eskom status-quo (operations and financial sustainability) needs to be considered carefully (see section 3.2) whilst in the short-term to medium-term needs to be made more efficient. It is critically important to ensure that the aging coal fleet is able to deal with the stress test of increased demand if and when it is realised and this risk should not be under-estimated i.e. sustained coal fleet performance is critical. Continued planned and preventative maintenance should be pursued and not de-prioritised in any manner in the interim to ensure the medium- to long-term reliable electricity supply for South Africa.

3.6.2 The completion of the Eskom new-build programme (Medupi, Kusile and Ingula) should be prioritised where economically viable to ensure that the long-term electricity supply-demand balance is maintained. The Eskom coal fleet will likely continue to play a major role in this regard in the medium- to long-term until decommissioned.

3.6.3 A number of lessons have been learnt in the pursuit of the Medupi and Kusile mega-projects and should be kept in mind and strictly applied when considering any possible future mega-projects. It is appreciated that sometimes mega-projects are unavoidable and it could be argued that Medupi and Kusile were examples of this.

However, if avoidable in future, South Africa should instead opt for smaller, modular, flexible, easily manageable and scalable projects depending on strategic needs. This is particularly pertinent in the electricity sector where one can manage the supply-demand balance with much more control via smaller, modular investment as opposed to mega-projects as has been the case for Medupi and Kusile specifically.

3.7 Role of natural gas

Status-quo:

As shown previously (Figure 5), natural gas currently plays a relatively small role in the South African energy mix as a result of relatively small domestic resource availability. It is predominantly imported via piped gas from Mozambique with some level of domestic offshore gas production.

Gas-to-power is being considered in the near future but has not yet been implemented and may be broadened for use in a number of end-use sectors.

The Strategic Environmental Assessment for Shale Gas Development is underway and should be completed in the near future to inform future policy making in this regard [128]. Regulatory frameworks and permitting decisions for exploratory drilling have been granted recently for shale gas and will commence in the current financial year (2017/18) [129].

Discussion and Proposals

3.7.1 Natural gas is versatile as it can be used in a number of ways depending on price levels (electrical power, compressed gas for transportation, conversion-to-liquid transportation fuels, fertilisers, industrial heat, space heating as well as residential cooking and hot water). It emits fewer emissions when burnt than coal and has minimal localised air pollution impact (relative to the coal). As a result, it can be considered a transition fuel to a low-carbon economy. Fugitive emissions of natural gas need to be limited appropriately if leakage rates are effectively enforced and aligned with best practice.

3.7.2 As a result, natural gas can be a game changer in South Africa's energy mix for use in a range of end-use sectors (not just for power generation). It is a very flexible technical and financial option that can be incorporated into the energy mix. Regional pipeline natural gas imports should be considered for use in the short- to medium-term (where capacity is available) with unconventional domestic natural gas resources as long-term options only if environmental concerns are alleviated (coal bed methane (CBM) and shale gas).

3.7.3 In order to encourage exploratory drilling, certainty is required regarding the Mineral and Petroleum Resources Development Act (MPRDA) Amendment Bill related to the state free carry, additional state participation and B-BBEE equity.

3.7.4 Thus, infrastructure for liquefied natural gas (LNG) imports at strategic port locations should be prioritised in the short- to medium-term. The inherent foreign exchange risk associated with imported LNG or pipeline gas from the region is appreciated but would need to be put into context considering expected volumes, the benefits of global integration with an international growing energy market for natural gas, and the benefits of economic use domestically.

3.7.5 As shown in the Draft IRP 2016 and complementary research [30], [73], all scenarios will require modular gas-fired power generation that is both technically and financially flexible as part of the energy mix (albeit in differing volumes). Flexible power generation capacity complements variability in the power system and more specifically is able to deal with the flexibility requirements of high penetration RE (solar PV and wind) as the existing predominantly coal generation fleet decommissions over time. It is possible that SOEs and private entities could play a role in domestic gas infrastructure and should be afforded the opportunity to compete where appropriate.

3.7.6 In the context of the REIPPPP PPA impasse between 2015-2017, it is important for South Africa to encourage investor confidence for a prospective gas programme to avoid similar issues in future and to develop an IPP industry that drives generation sector competition [130], [131] (see section 3.2 on the electricity sector vision for more detail).

3.8 Liquid fuel investments and strategic liquid fuel stocks

Status-quo:

As a result of minimal domestic resources, South Africa has a near-complete import dependence on oil and liquid fuels for the transportation sector. It is understood that stakeholder consultation on the supply-demand balance for liquid fuels in South Africa is ongoing and that a decision on the new refinery was expected in 2017. Based on the targets in the DoE's presentation to Parliament in May 2017 [32], a Cabinet memo on the decision for a new refinery was expected to be submitted by the third quarter of 2017/18.

With regard to oil and liquid fuel strategic stocks, the Energy Policy White Paper of 1998 [132] recommends South Africa holds 90 days of consumption while the Draft Strategic Stocks Petroleum Policy and Draft Strategic Stocks Implementation Plan circulated in 2013 for comment [133] recommends 60 days. The global standard employed by International Energy Agency (IEA) member countries is a strategic petroleum stock requirement of at least 90 days of the previous year's imports. South Africa's strategic fuel stocks have not been called on for an extended period of decades.

The Draft Strategic Stocks Implementation Plan circulated in 2013 for comment [133] suggests that the state should hold crude oil strategic stocks while the private sector holds refined liquid fuel strategic stocks.

Discussion and Proposals

<u>Liquid fuel investments:</u>

3.8.1 The upgrading of existing South African liquid fuel refineries to improved fuel standards should be incentivised while the decision for new refinery capacity needs to be finalised. The investment in new refinery capacity needs to be offset against demand for liquid fuels, alternatives, availability and expansion of existing refinery capacity, international market trends and the financial sustainability of the state-owned oil and gas company. Importation of liquid fuels in the short- to medium term would likely prove more cost-effective than investing in a new large refinery, which may only be required in the medium- to long term. Increased liquid fuel imports would then require the requisite port infrastructure investment in handling and storage instead of new refinery capacity investment.

3.8.2 On the basis of a relatively cheap set of domestic resources (solar and wind-based electricity), there is a significant opportunity for South Africa in the short- to medium-term as well as in the long-term to pursue a strategically competitive advantage in the transportation sector:

3.8.2.1 In the short- to medium-term, incentivising the switch to electric mobility for relevant portions of the transportation sector in urban environments (motor cars, minibuses, light duty vehicles) would create a considerable reduction in the requirement for imported liquid fuels and positively impact energy security, the South African trade balance as well as assist in the move towards more sustainable energy use;

3.8.2.2 In the medium- to long-term, in addition to electric mobility, the creation of alternative fuels for transportation (hydrogen, natural gas and synthetic liquid fuels) based purely on electricity would assist further in offsetting the requirement for liquid fuel imports in South Africa. This could be converted into a significant opportunity for clean transportation fuel export markets (a competitive advantage for South Africa).

3.8.3 There should be focussed attention and resources applied to support the necessary research and development that would create the innovative and possibly disruptive technologies at scale that would enable the aforementioned strategic direction.

Strategic fuel stocks:

3.8.4 These should always be maintained to the highest possible standard that is economically optimal in order to minimise energy security risk. It is also important to differentiate between the risk of insufficient imported crude oil (for domestic refining) and that of refined liquid fuels. In addition, the differentiation between which entities should hold crude oil and refined liquid fuels (the state and/or private sector and the split thereof) should be clarified.

3.8.5 The costs of ensuring global standards of strategic fuel stocks need to be commensurate with the associated risk of insufficient crude oil and liquid fuels. Considering existing fiscal constraints, it is recommended that a detailed cost-benefit analysis be undertaken but that in the interim a lower level of strategic fuel stocks be considered at the most strategic locations until the fiscal environment changes notably.

3.9 Electricity access

Status-quo:

Post-apartheid electrification was funded by the electricity industry 1994-2001. From 2001 onwards, the state-funded Integrated National Electrification Programme (INEP) took over as a subsidy-driven program to fund electrification.

There has been significant progress made in electricity access which should be commended (on-grid electricity access of more than 85%). The NDP goal is for universal electrification by 2030 with 90% on-grid connections and remaining access provided by off-grid connections.

For the 2016/17 financial year, the INEP revised budget was R 5.6-billion with plans for R 6.2-billion (2017/18), R 6.4-billion (2018/19) and R 7.8-billion (2019/20) for 723 000 on-grid and 60 000 off-grid connections [134]. There are plans for 235 000 on-grid and 15 000 off-grid/island-grid connections in 2017/18 [32].

Discussion and Proposals

3.9.1 With universal electricity access a key goal of the NDP, the focus of the INEP may need to shift from on-grid electrification to off-grid electrification and the development of sustainable micro-grid solutions as it becomes more expensive to extend electricity networks to deep rural areas. In this dimension, micro-grids could be developed with the vision to interconnect with the main grid in future if demand grows sufficiently or micro-grids geographically spread sufficiently. There are a number of examples of this globally and it has recently been demonstrated in South Africa [135] while there is ongoing research at various institutions to determine optimal approaches to financing, design and implementation.

3.9.2 Appropriate governance structures and procurement processes should be in place with the most appropriate institution(s) with oversight at a national level. It is critical to ensure that these solutions are then appropriately operated and maintained to ensure sustained quality of service as well as affordability for end-users.

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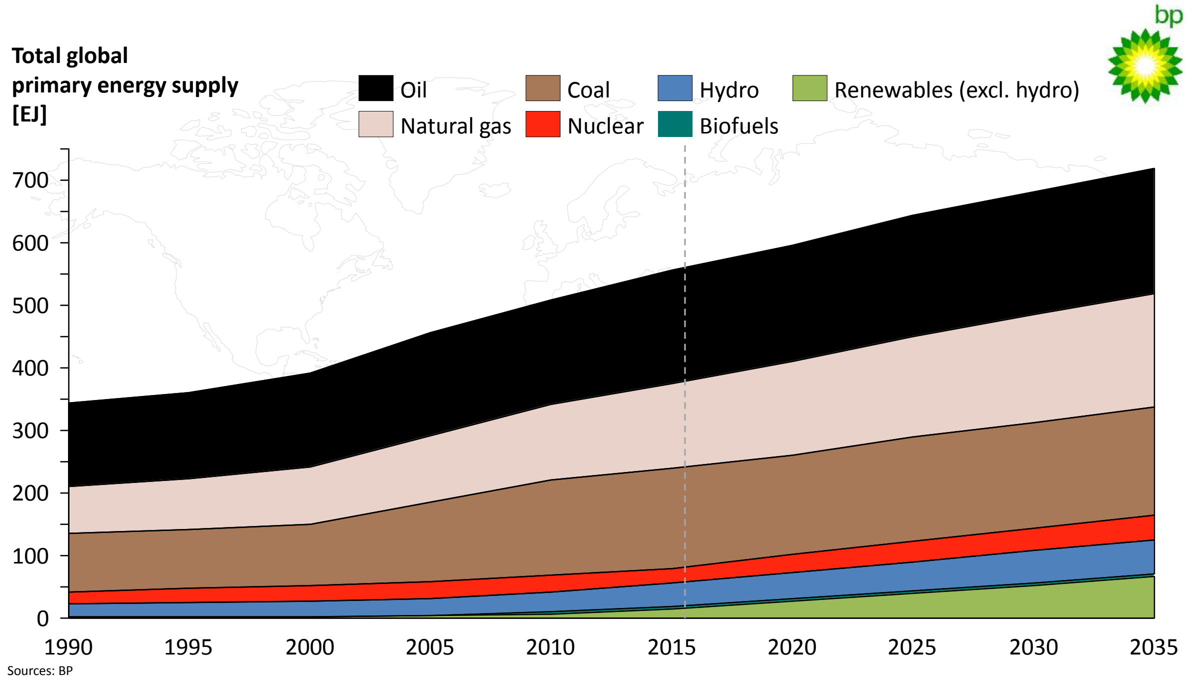
Appendix A Global energy trends

Summaries of global energy trends from BP as well as IEA are provided for reference. These are shown graphically in Figure 10 to Figure 23. Other reference works not analysed at this stage include StatOil Energy Perspectives [137] and the U.S. Energy Information Administration (EIA) Annual Energy Outlook (AEO) [138]

BP Energy Outlook [139]: The energy consumption, percentage share and growth of primary energy suppliers in the energy mix globally and for Africa from the Base Case of the BP Energy Outlook 2017 are summarised in Figure 10 to Figure 13. Globally, energy demand will keep growing (≈30% more by 2035, annual growth of 1.3%) while Africa will grow faster than this (by ≈80% by 2035, annual growth of 2.9%). Oil and coal remain critical parts of the energy mix by 2035 and continue to grow in absolute terms (relatively slowly globally, quicker in Africa) but have a smaller absolute share in the energy mix globally and in Africa by 2035. Natural gas grows by 2035 in absolute terms and plays a marginally larger absolute role in the energy mix globally and in Africa while nuclear plays a similar role in the energy mix globally and in Africa by 2035. As can be seen in Figure 14, driven by energy transitions globally, the significant growth market (albeit from a low base) is from RES where the market is expected to grow more than three times over globally by 2035 (from 3% to 9%) while in Africa growth in the order of fifteen times larger than 2014 levels is expected by 2035 (from 1% to 8%).

IEA World Energy Outlook (WEO) [140]**:** Two key scenarios from the IEA World Energy Outlook are included for reference (the 'New Policies' scenario which serves as the baseline and includes existing policy announcements by countries globally and the '450 scenario' which sets out an energy pathway consistent with limiting the concentration of GHGs in the atmosphere to 450 parts per million of CO_2). The energy consumption, percentage share and growth in primary energy suppliers globally and for Africa are summarised in Figure 15 to Figure 24 for both scenarios. In the New Policies scenario, global energy demand will keep growing (≈30% more by 2040, annual growth of 1.1%) while Africa will grow faster than this (≈70% by 2040, annual growth of 2.2%). Again, oil and coal remain critical parts of the energy mix by 2035 and continue to grow in absolute terms (relatively slowly globally, quicker in

Africa) but have a smaller share in the energy mix globally and in Africa by 2040. Natural gas grows by 2040 quite considerably in absolute terms and plays a much larger role in the energy mix globally and in Africa while nuclear plays a similar role in the energy mix globally and in Africa by 2040. As can be seen in Figure 21, for the New Policies scenario the growth in RES both globally and in Africa is significant as it grows five times over globally and 22x over in Africa by 2040. Demand globally and in Africa still grows to 2040 in the 450 scenario but considerably slower globally relative to the New Policies scenario (Africa's demand growth is still considerable even in the 450 scenario). There is a substantial decrease in coal and oil demand globally (in absolute terms and on a percentage share basis) for the 450 scenario while there is significant growth in RES (9x globally and 33x in Africa by 2040) and growth in gas, biofuels and nuclear. In Africa, the 450 scenario sees a growth in all primary energy suppliers except coal while considerable growth is seen in RES, biofuels and natural gas.



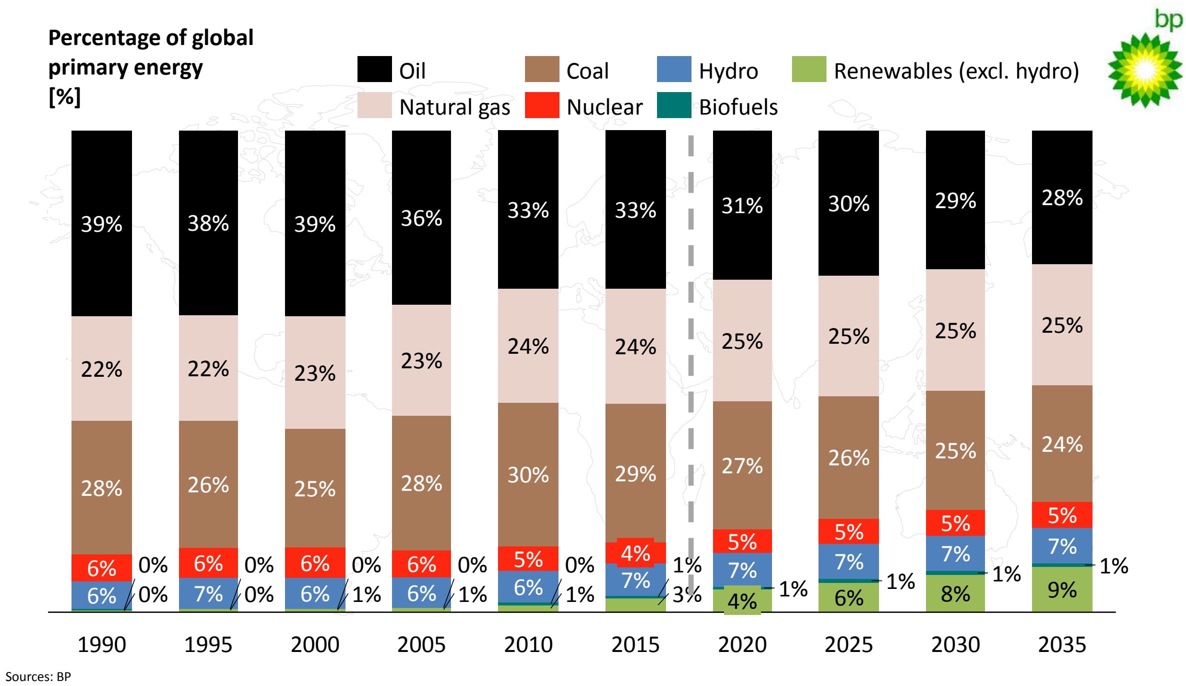


Figure 10 Total global primary energy supply and share to 2035 (BP Energy Outlook, Base Case)

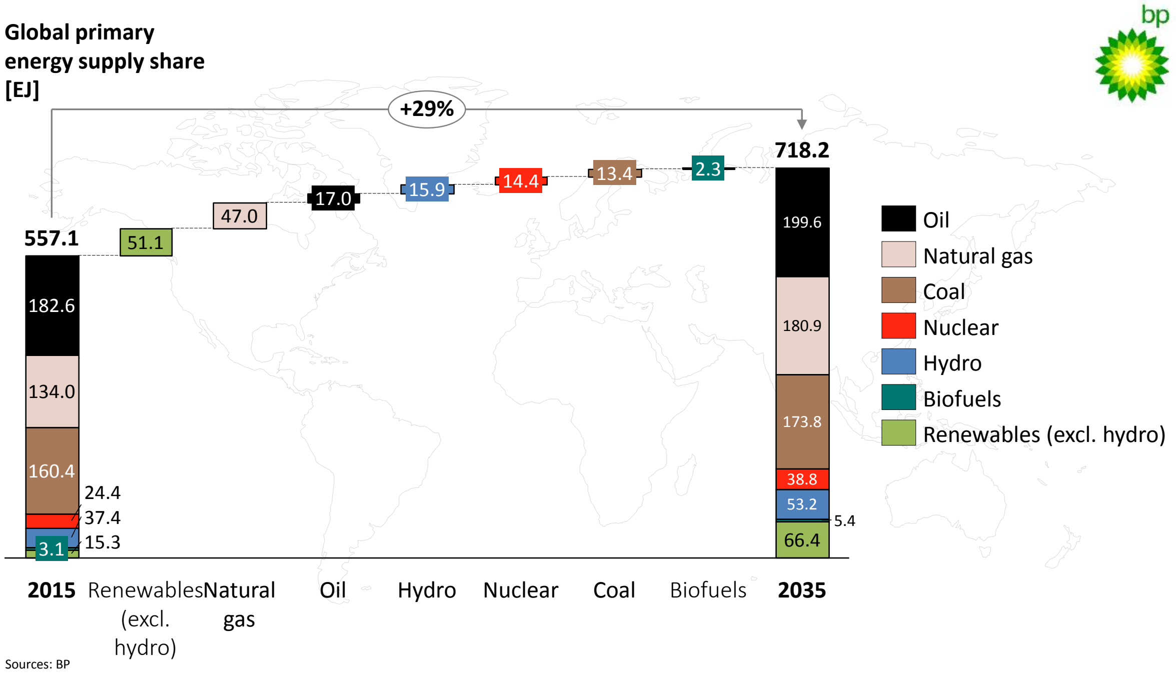
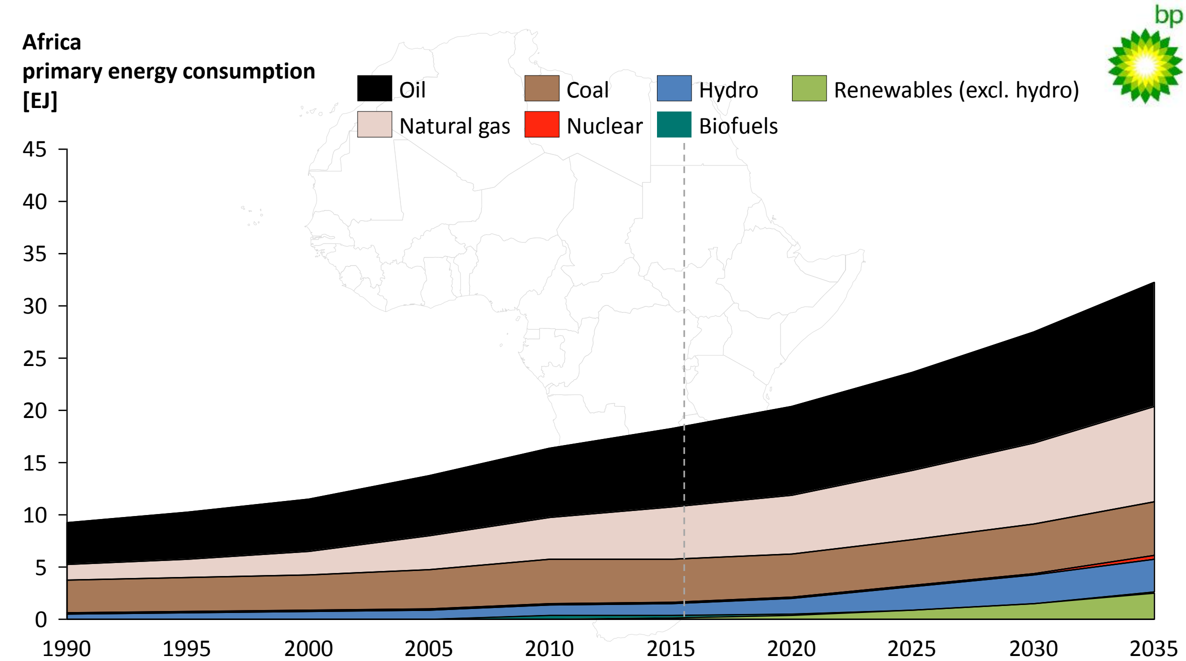
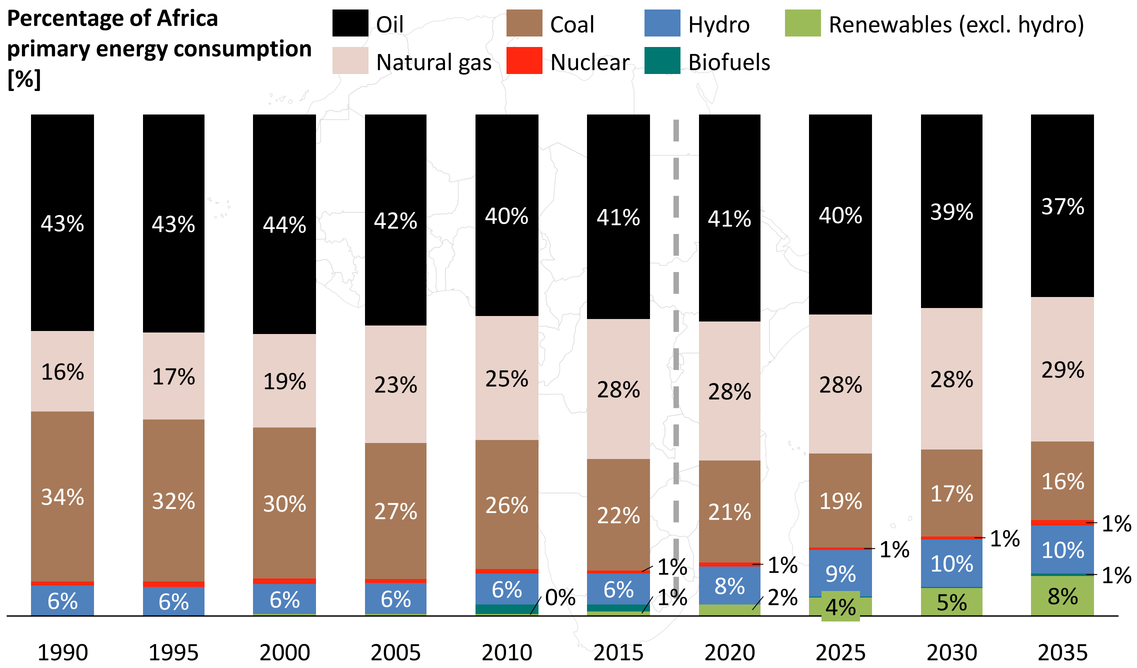


Figure 11 Breakdown of change in primary energy carriers to 2035 (BP Energy Outlook, Base Case)



Sources: BP



Sources: BP

Figure 12 Total Africa primary energy consumption and share to 2035 (BP Energy Outlook, Base Case)

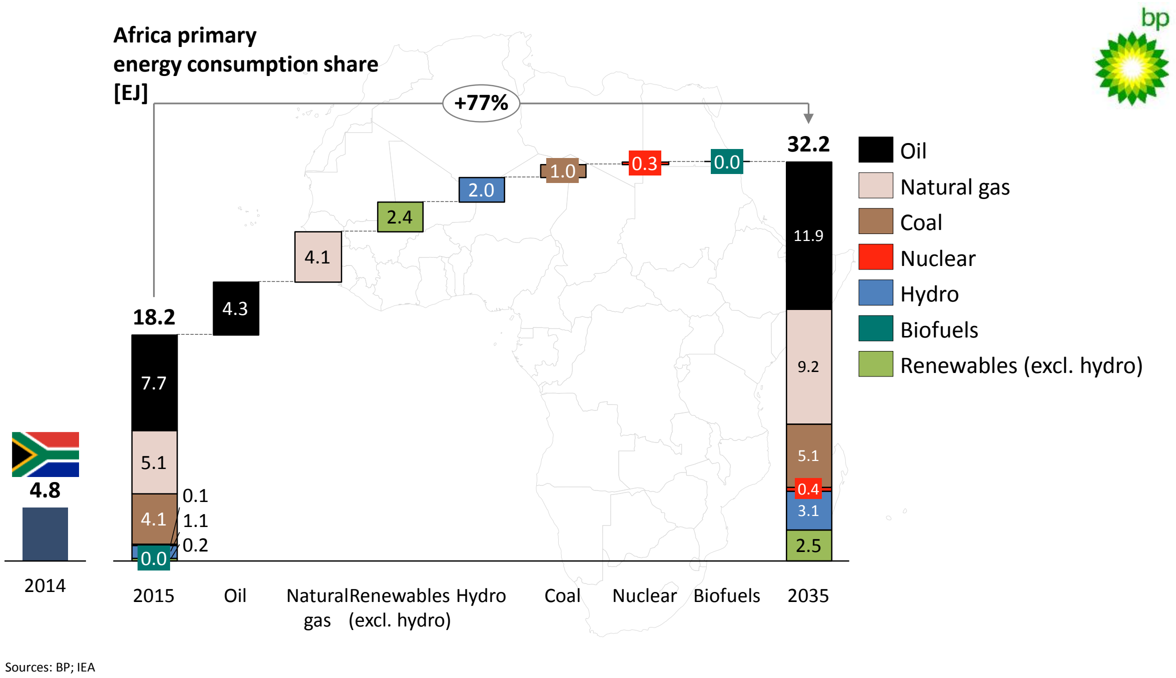


Figure 13 Breakdown of change in primary energy consumption in Africa to 2035 (BP Energy Outlook, Base Case)

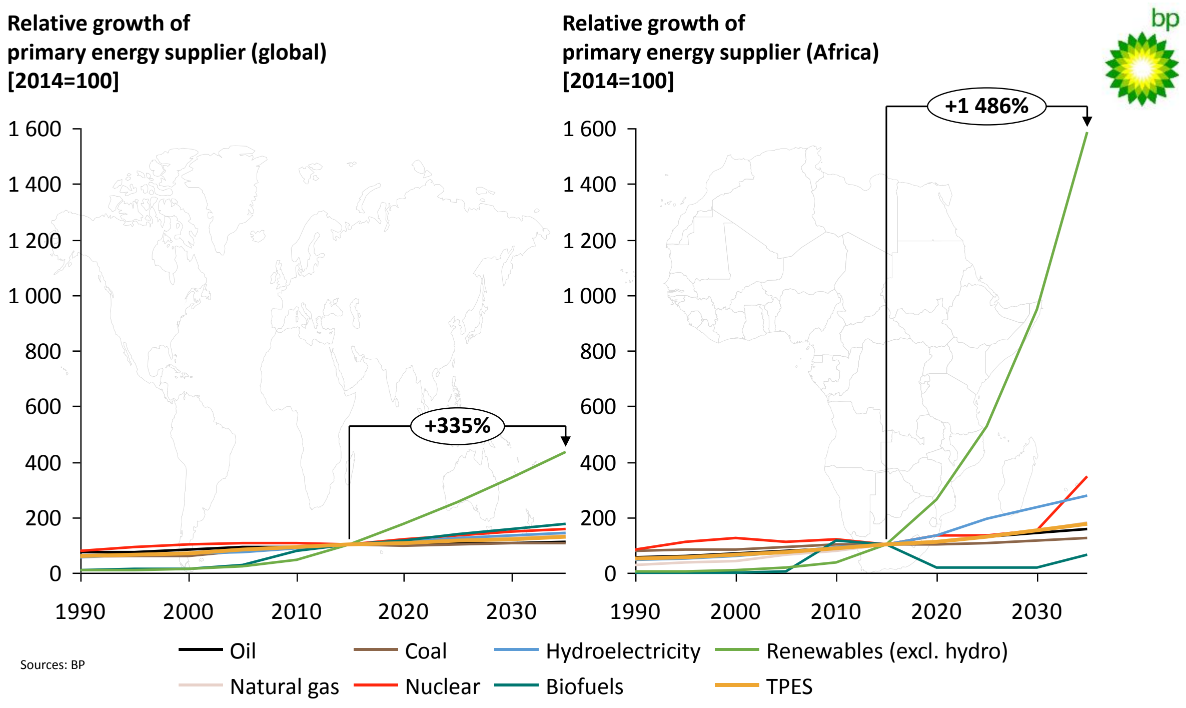
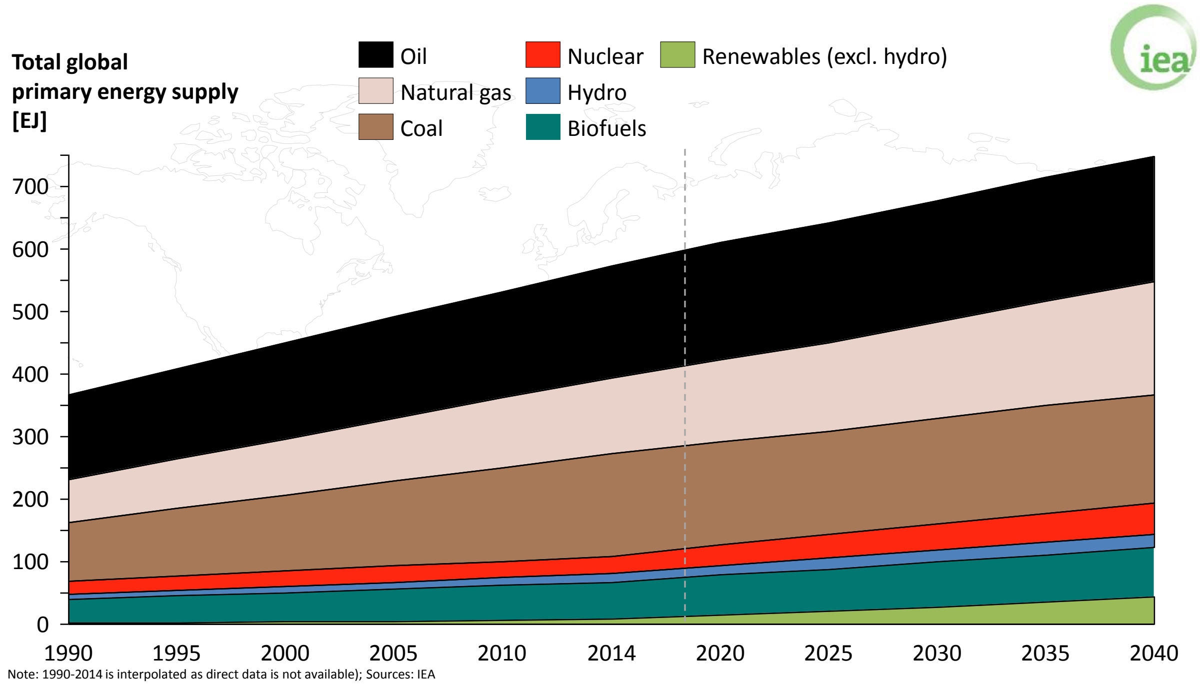


Figure 14 Relative growth expected in primary energy suppliers globally and in Africa to 2035 (BP Energy Outlook, Base Case)



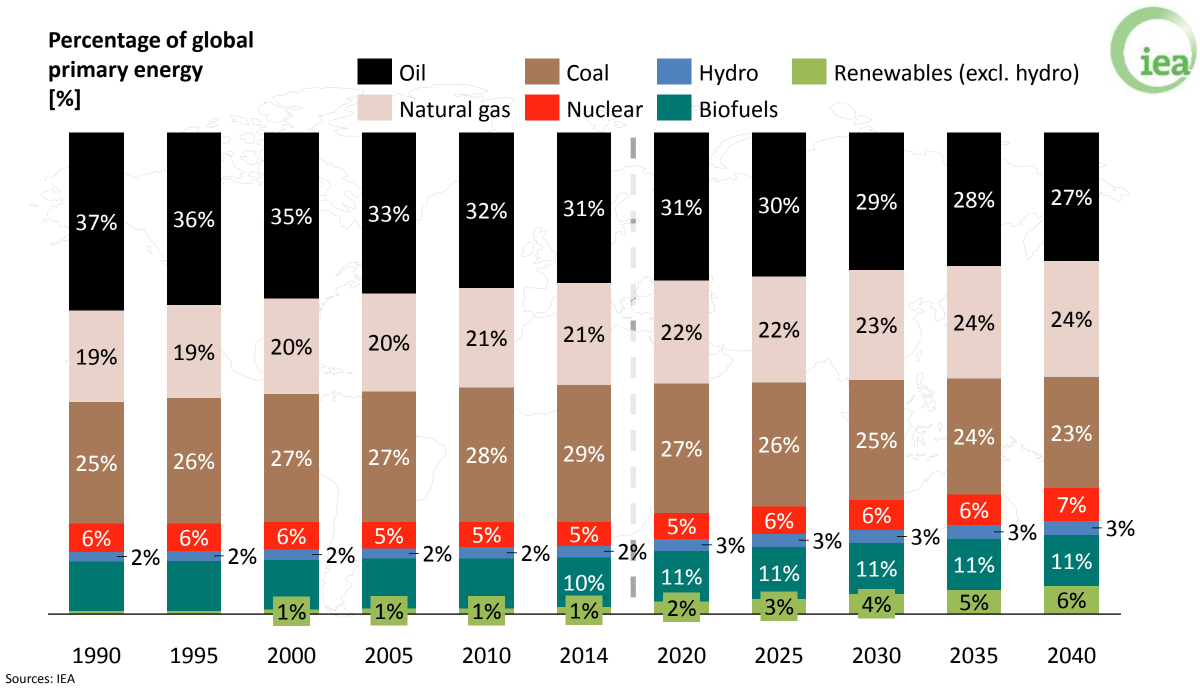


Figure 15 Total global primary energy consumption and share to 2040 (IEA Annual Energy Outlook, New Policies)

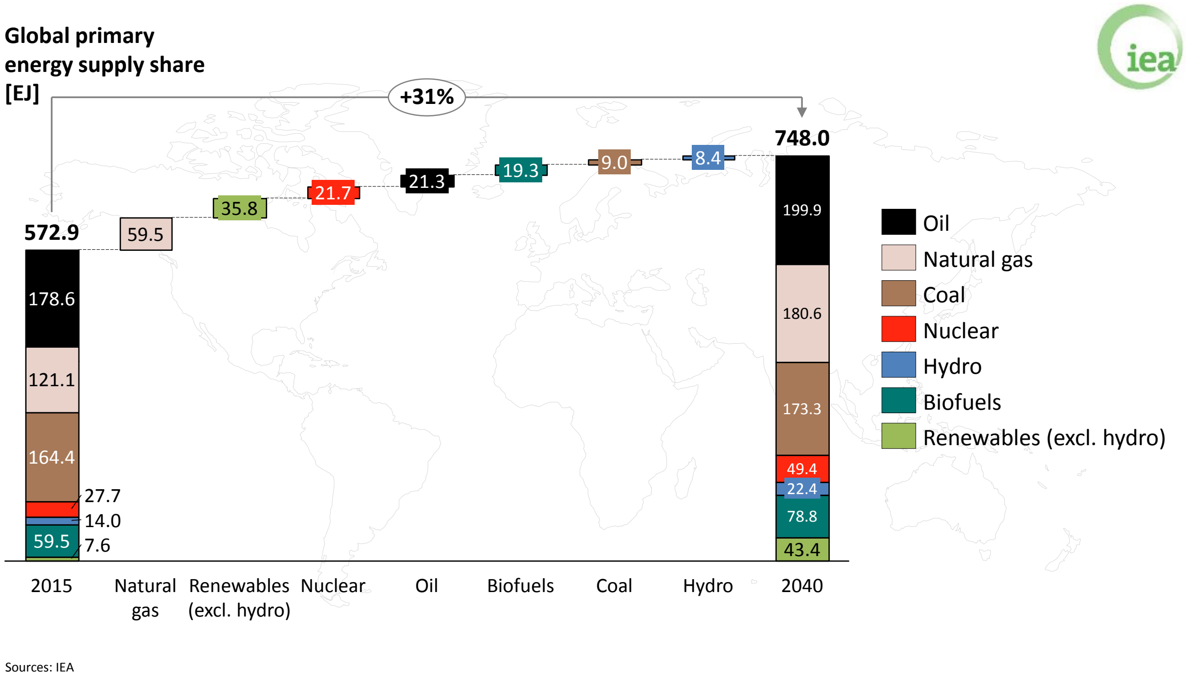
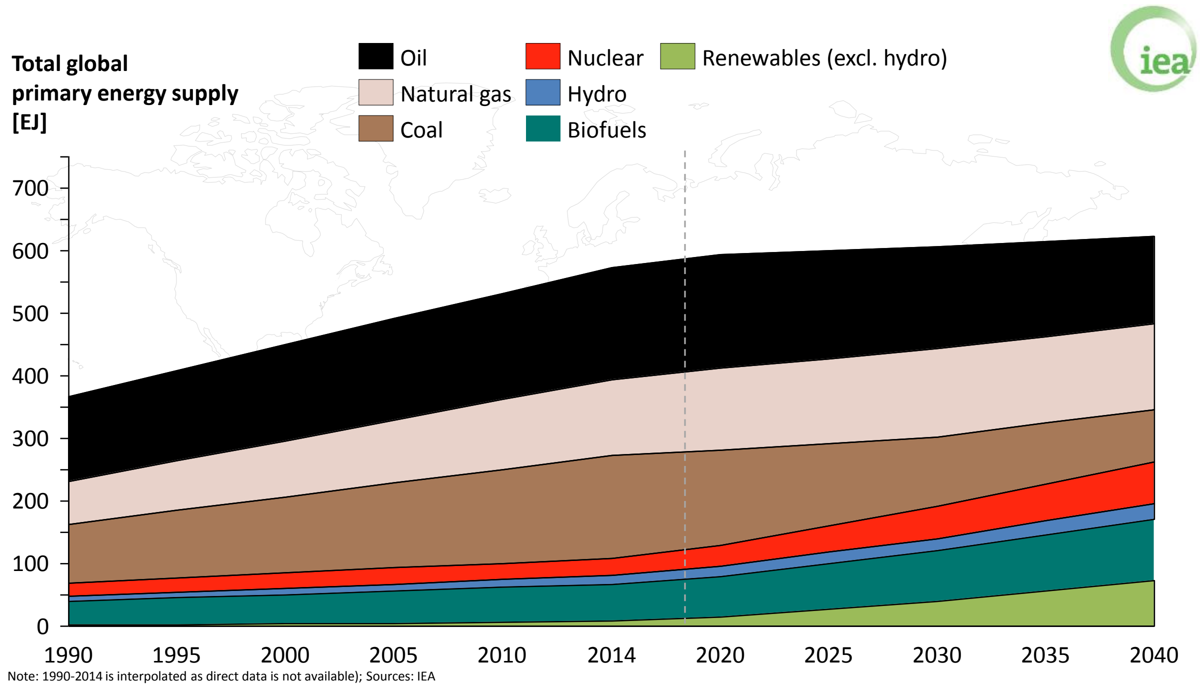


Figure 16 Breakdown of change in primary energy consumption globally to 2040 (IEA World Energy Outlook, New Policies)



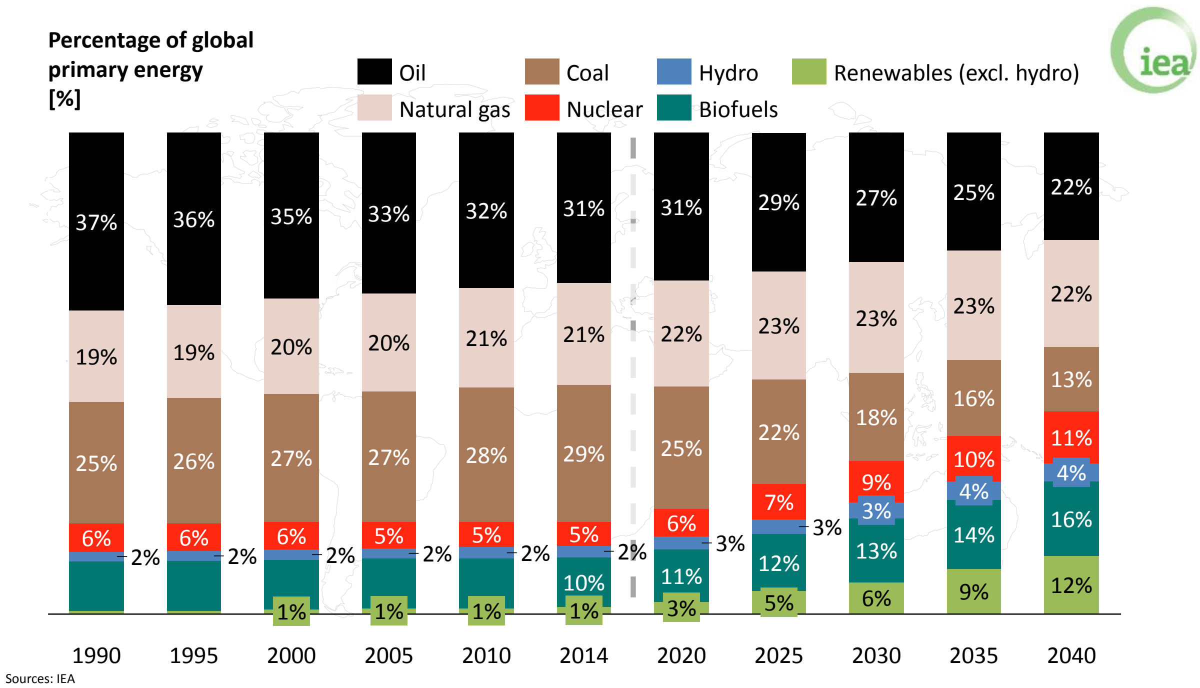


Figure 17 Total global primary energy consumption and share to 2040 (IEA Annual Energy Outlook, 450 scenario)

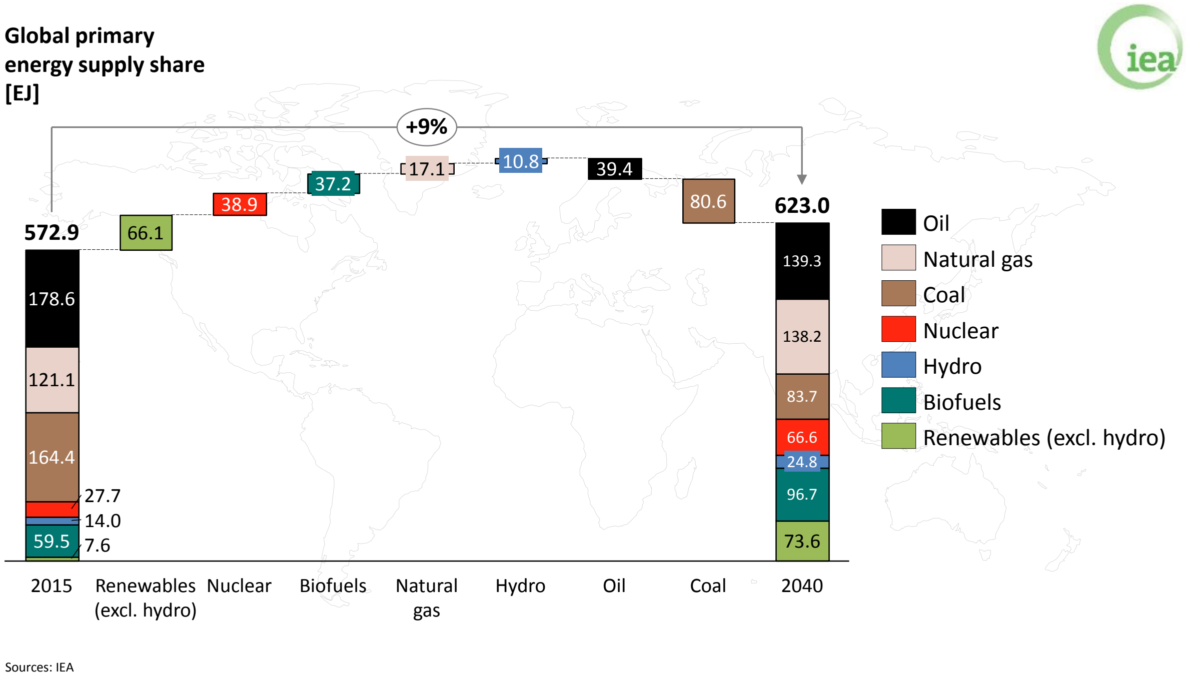
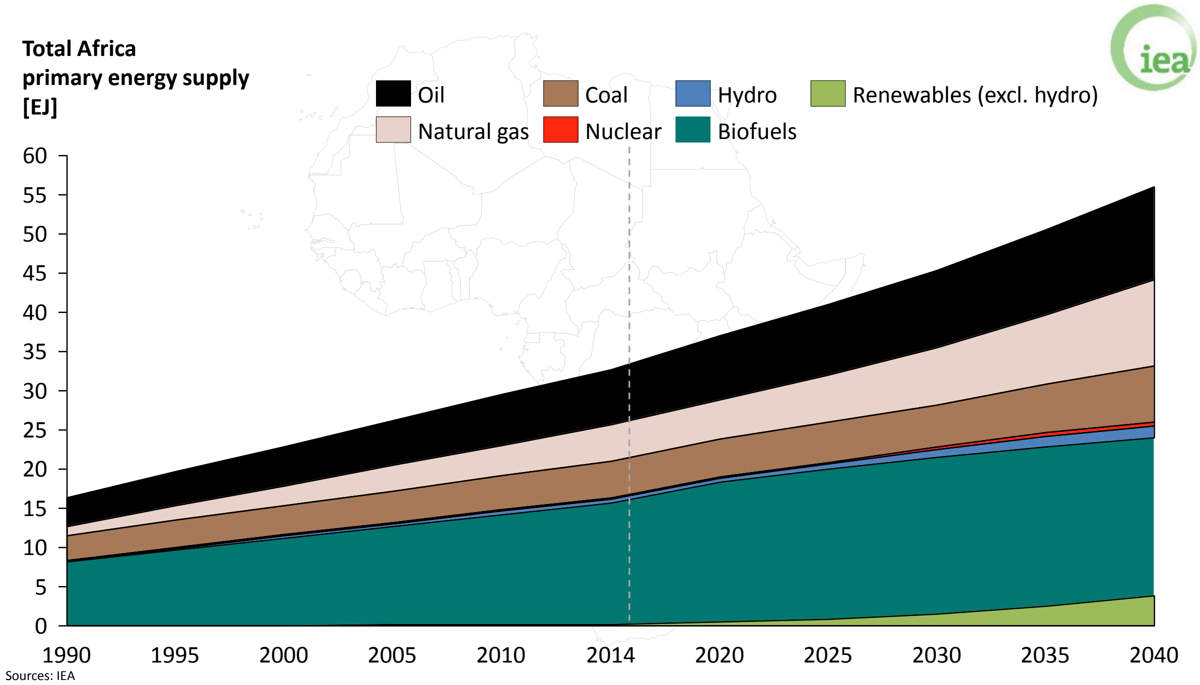


Figure 18 Breakdown of change in primary energy consumption globally to 2040 (IEA World Energy Outlook, 450 scenario)



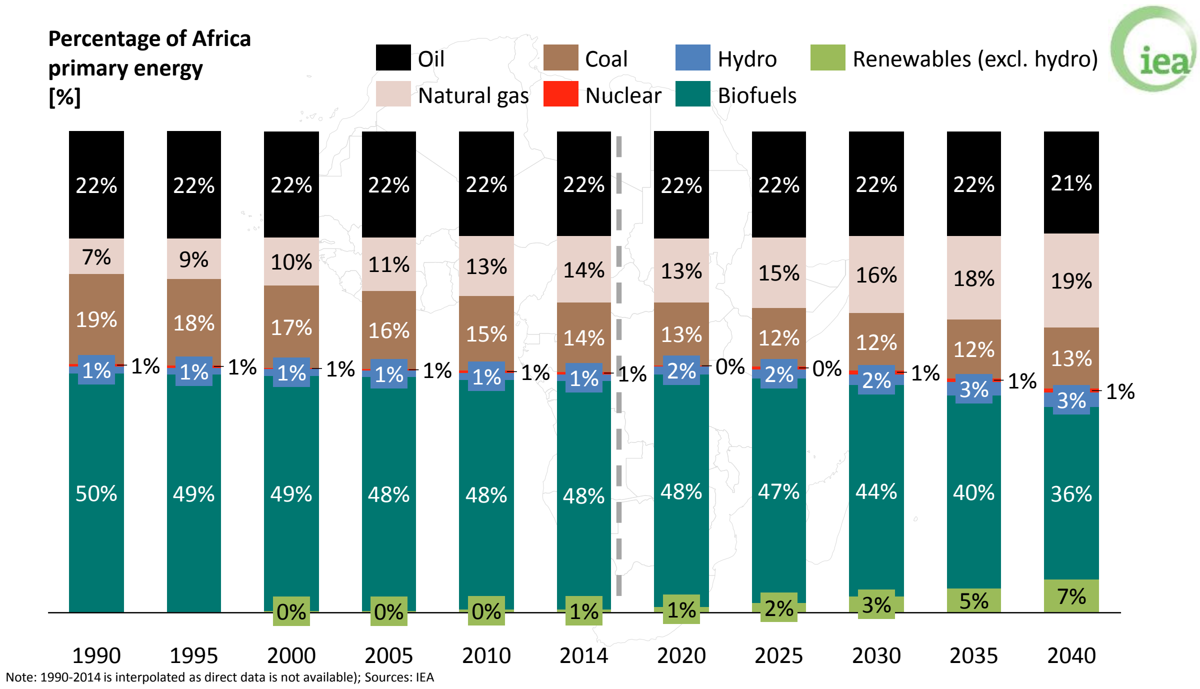
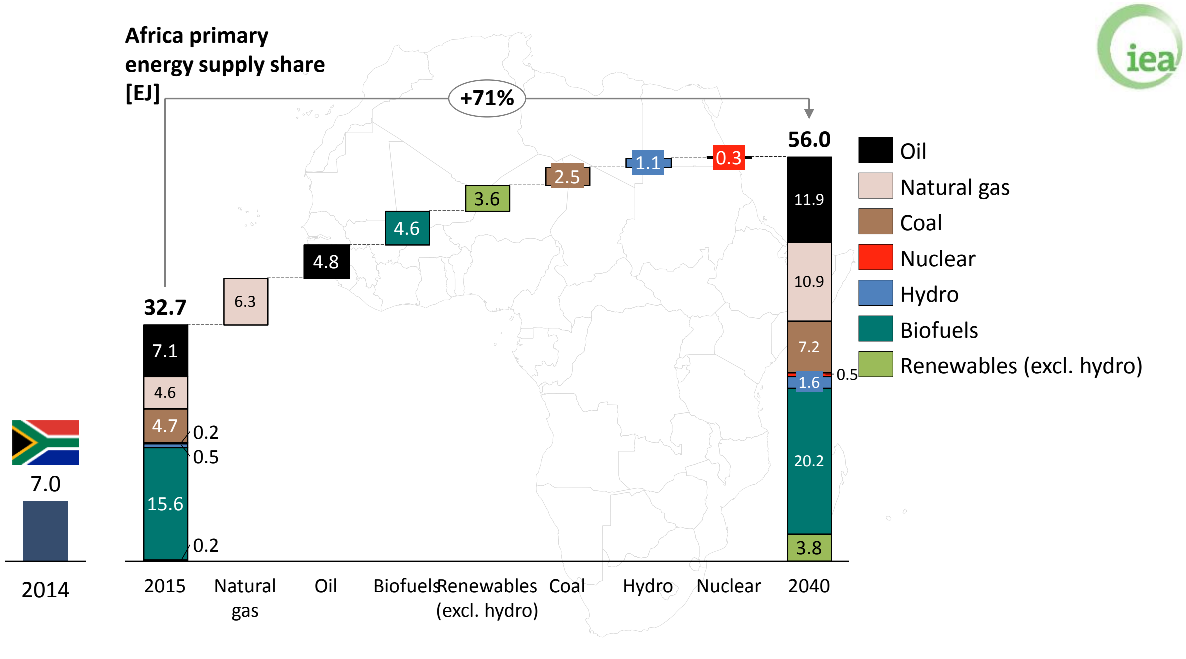
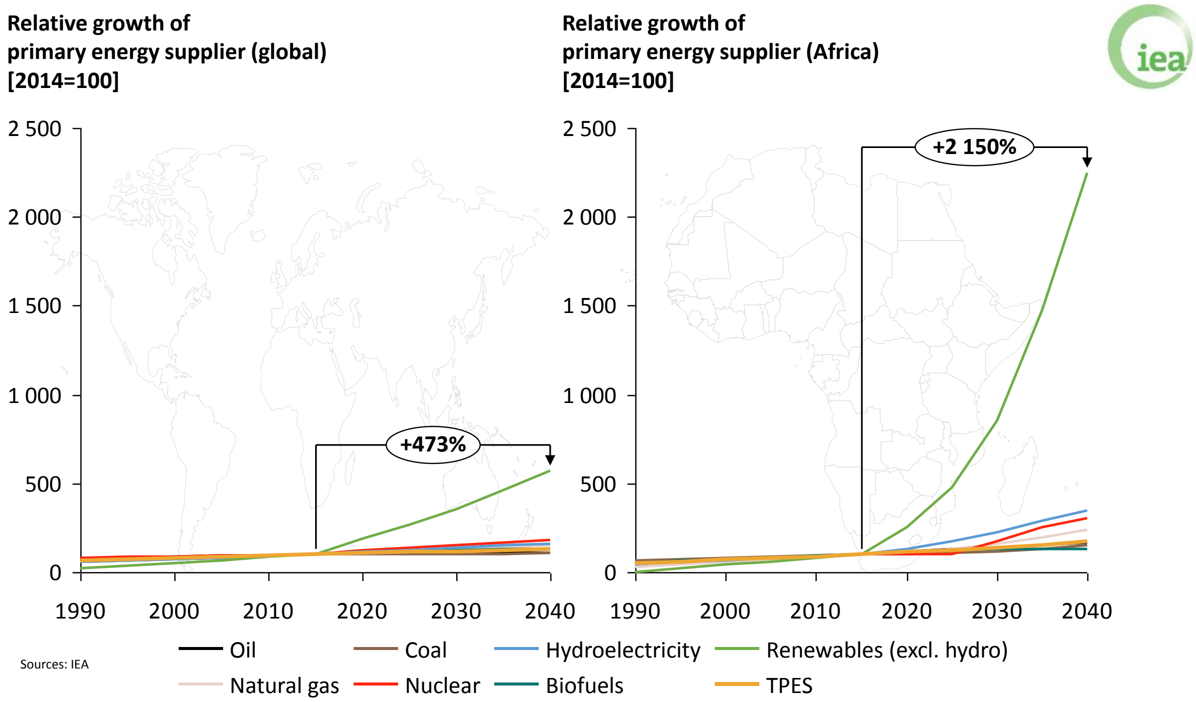


Figure 19 Total Africa primary energy consumption and share to 2040 (IEA Annual Energy Outlook, New Policies)



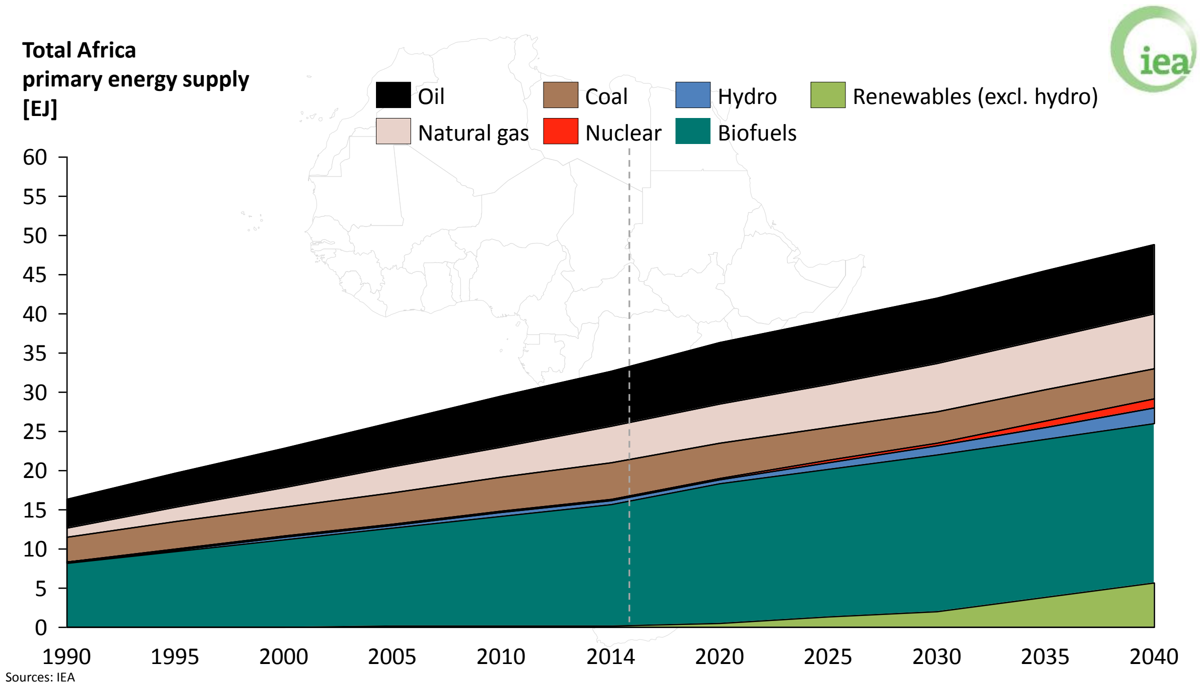
Sources: IEA

Figure 20 Breakdown of change in primary energy consumption in Africa to 2040 (IEA World Energy Outlook, New Policies)



Sources: IEA

Figure 21 Relative growth expected in primary energy suppliers globally and in Africa to 2035 (IEA World Energy Outlook, New Policies)



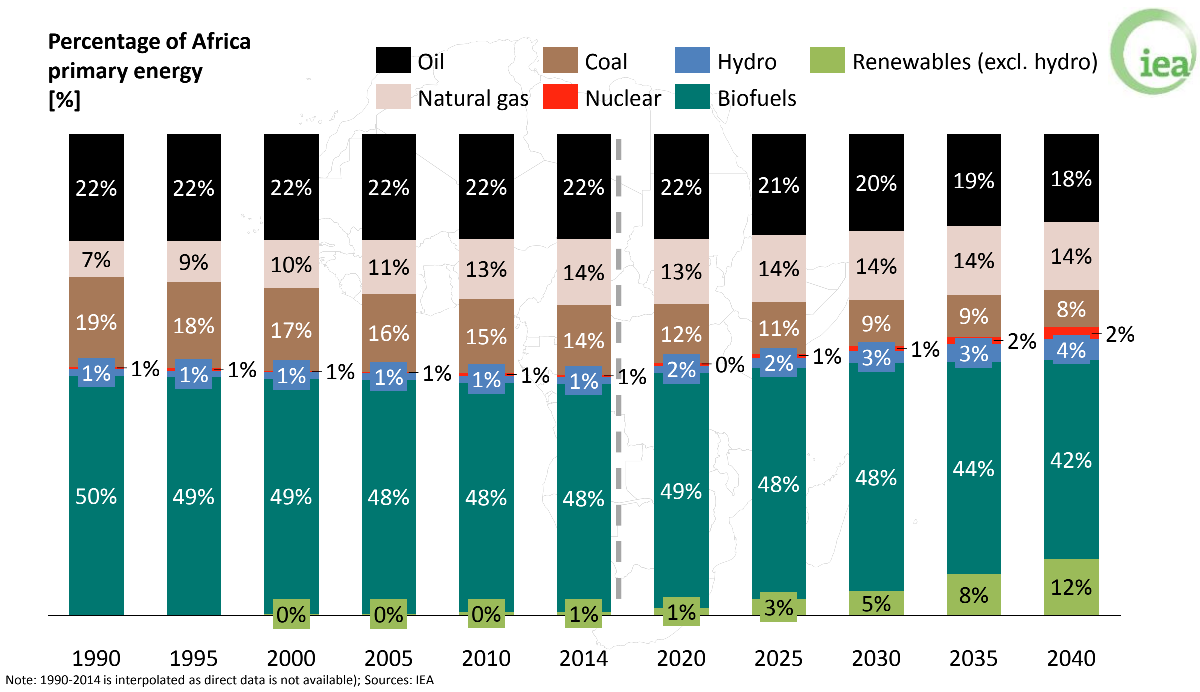
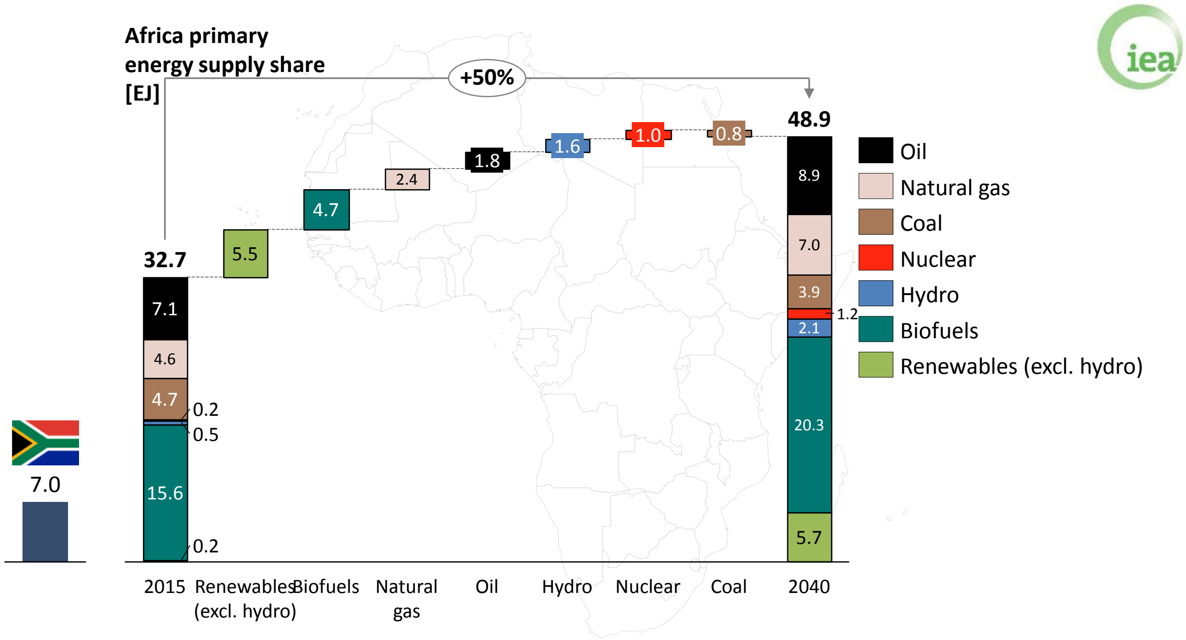
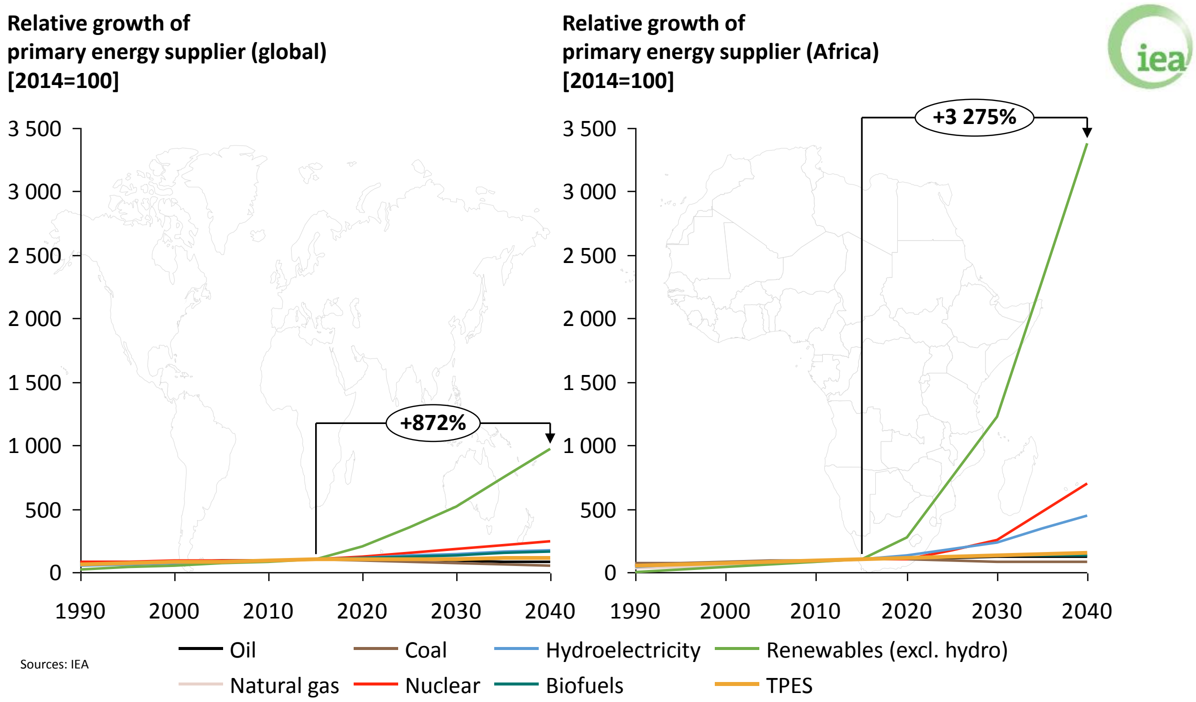


Figure 22 Total Africa primary energy consumption and share to 2040 (IEA Annual Energy Outlook, 450 scenario)



Sources: IEA

Figure 23 Breakdown of change in primary energy consumption in Africa to 2040 (IEA World Energy Outlook, 450 scenario)



Sources: IEA

Figure 24 Relative growth expected in primary energy suppliers globally and in Africa to 2035 (IEA World Energy Outlook, New Policies)