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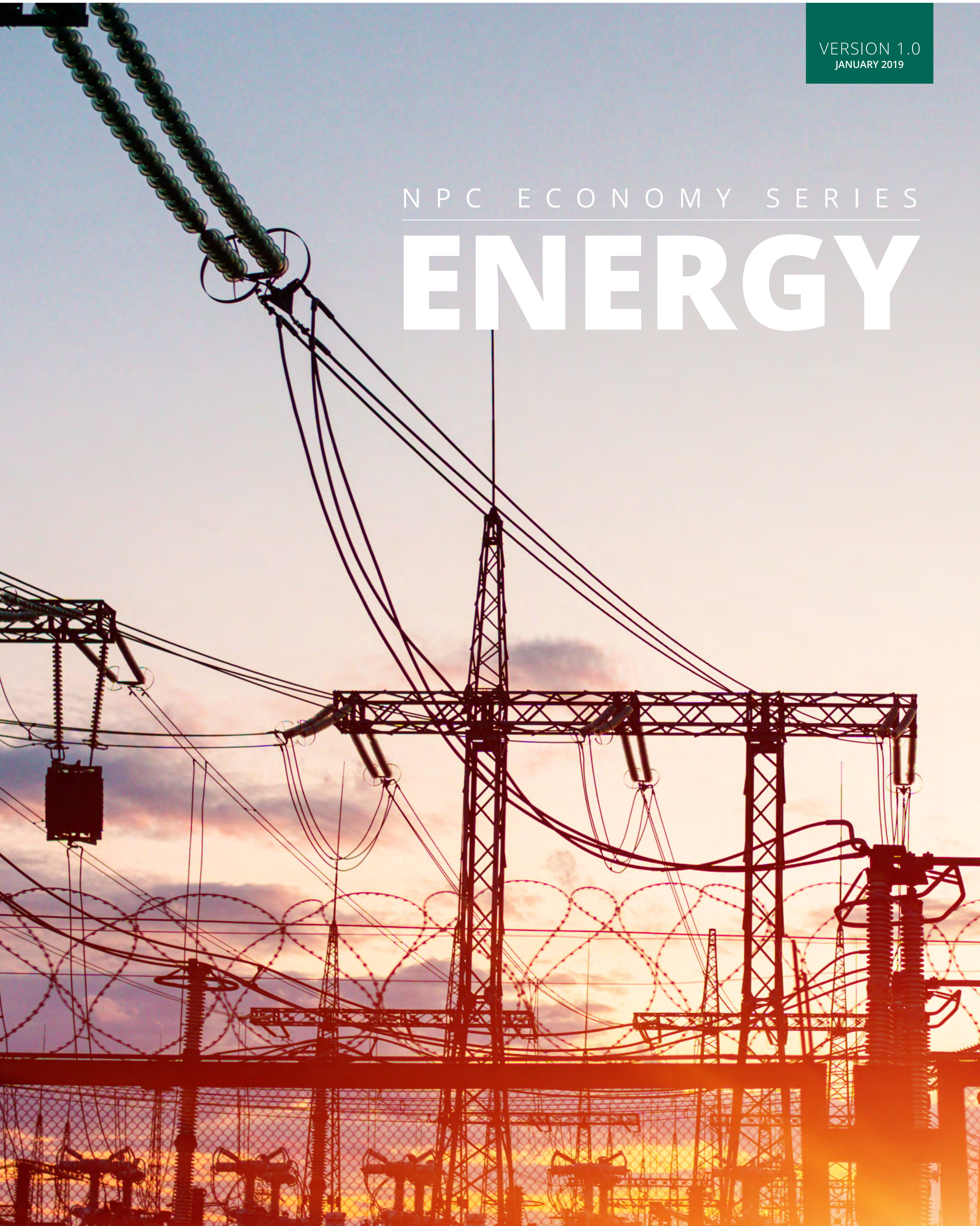

NPC ECONOMY SERIES

ENERGY

Foreword

This paper was first released in February 2018 by the National Planning Commission (NPC) of South Africa following consultations with selected stakeholders. This updated version has taken into account comments from various rounds of public consultation that followed and has been revised accordingly.

The NPC is an independent body appointed by the President of South Africa and consisting of experts in diverse fields. 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 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 overall strategic objectives of the NDP are 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.

The National Planning Commission would like to acknowledge the inputs provided during public consultations from various stakeholders.

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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 fuel supply shortages in 2005 and electricity shortages in 2007/08 and 2014/15. More recently, worrying alleged financial irregularities and governance concerns at a number of State Owned Enterprises (SOEs) have emerged amongst a range of other challenges.

Adding to this context, is the dynamic energy planning, regulatory and governance environment within which the sector operates. Both domestically and globally, disruptive technologies, shifting global megatrends and governance are challenging existing paradigms and long-term planning outcomes. Thus, the National Planning Commission deemed it necessary to update the position on energy in the context of the National Development Plan (NDP) 2030. 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 and the positions covered in this paper address these priorities specifically. It is by no means an exhaustive positioning but 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, this publication focusses on addressing existing challenges and pertinent issues within the South African energy sector whilst maintaining a long-term outlook on opportunities that may exist to achieve the NDP vision. As such, it does not contain an exhaustive list of potential goals but instead addresses key areas to be prioritised in order to make necessary impact. In pursuing this, it addresses and attempts to balance the goals envisioned in the NDP 2030 of reducing inequality, alleviating poverty and creating jobs.

Since the adoption of the NDP in 2012, two significant changes in the energy sector 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 with impacts on other energy carriers. Both of these have further 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 and institutional arrangements.

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 the costs of conventional sources have remained largely unchanged. Specifically, solar photovoltaic (PV) and wind have been procured as part of the Renewable Energy Independent Power Producer Procurement 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].

This context of rapid changes, being seen globally and domestically, 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 position on the future of the South African energy sector to 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 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 guided by the NDP and a strategic energy planning framework led 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 have been recently published by the Department of Energy (DoE) with plans for updated versions of these to be submitted to Cabinet 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 minimal wholesale (or retail) competition in the supply of electricity. Electricity supply adequacy has been a concern for a number of years with boom-bust cycles being realised in the supply-demand balance. This is manifested in either over-supply where parts of the existing 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, liquid fuels and RES more recently).

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 (over and above those justifiably needed to move towards cost-reflectivity). This has resulted in a reliance on funding injections from the shareholder placing further strain on public finances. As noted, recent allegations of financial irregularities and governance issues along with a failure in leadership at the highest levels need to be sufficiently addressed and assurance provided that this would not occur again.

[1] The value these generators provide should be considered in the context that both are 'dispatched' by the weather and not controllable in the traditional sense. This is not deemed problematic and is dealt with in further detail in this document. Conventional generators are typically considered dispatchable in the sense that a system operator can dispatch capacity as needed e.g. coal, nuclear, liquid fuel/ natural gas fired and hydro (to some extent).

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 CO2 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% of this (with smaller contributions from transportation and direct end-use). This is primarily as a result of the use of significant domestic coal resources for coal-fired power generation and production of synthetic liquid fuels.

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 but fast-growing embedded generation market in South Africa.

Nuclear new build programme

South Africa has successfully operated nuclear power generation at Koeberg as a CO2 free supply option since the 1980s and is expected to continue to do so until the planned decommissioning of this plant.

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, published 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. The Draft IRP 2018 does not include nuclear in most scenarios and does not include nuclear in any scenarios prior to 2030.

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, i.e. the 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)

Generally, it could be argued that large energy infrastructure (mega-projects) investments in a developing economy like South Africa are sometimes unavoidable. Examples of these in the energy sector are some of the Strategic Integrated Projects (SIPs) identified by the Presidential Infrastructure Coordinating Commission (PICC).

A more recent example of this was the new-build generation capacity developed by Eskom in the form of the Medupi and Kusile power stations. While these were deemed necessary and economical at the time of decision, these mega-projects have experienced significant cost and time over-runs. These have burdened the state-owned electricity utility financially and affected customers directly with the resultant electricity tariff increases.

Other major energy infrastructure projects being planned include a large new refinery investment, a nuclear new-build programme and new heavy-haul rail infrastructure for coal transportation from the Waterberg region.

The existing coal generation fleet in South Africa is also aging and has experienced a number of reliability challenges 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. Life extension as well as early retirement of this fleet has been considered and is currently under discussion.

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. A new-build gas-to-power programme is being considered but has not yet been implemented and may be broadened for a number of end-use sectors.

It is understood that, amongst other processes related to shale gas, the Strategic Environmental Assessment for Shale Gas Development has been completed to inform future policymaking. Regulatory frameworks and permitting decisions for exploratory drilling for shale gas have been granted and should commence in the near future.

Natural gas 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.

Liquid fuel investments and strategic liquid fuel stocks

As a result of minimal domestic oil resources, South Africa has a considerable dependence on the import on oil and refined liquid fuels. The majority of imports come from Angola, Saudi Arabia and Nigeria and is used predominantly in 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. The new refinery investment is expected to produce approximately 250 000-300 000 bbl/day which is significant as it would provide ≈40% of additional refinery capacity for the country.

Upgrading the existing refining capacity in South Africa has also been considered for some time but is yet to be implemented (Cleaner Fuels II regulations and standards).

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 suggests that the strategic petroleum stock requirement should be 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.

Affordable energy 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 is 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.

The provision of free basic electricity (FBE) and free basic alternative energy (FBAE) is an important existing policy that allows for productive use of energy in poor households.

Energy planning and governance framework

1. Updated strategic national energy plans and, more importantly, an updated IRP to inform the most appropriate future procurement decisions is critical to avoid an 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 broadly and comprehensively participatory to promote this 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 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 (or entities) 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 and during the process in order to gain trust and confidence of all stakeholders. However, the executive authority and mandate related to these strategic plans should not in any way be shifted from the responsible governmental custodian (currently the DoE).

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. In particular, there should be a focus on the direct supplier, indirect and induced job creation potential (and potential job losses), GHG emissions, water usage and other identified externalities not already accounted for. These dimensions should then be included in planning process outcomes to inform energy policy discussion and adjustments.

6. The current centralised planning and largely prescriptive approach to energy planning may need revision more generally in the long-term. This would entail a switch of focus to using the existing integrated energy planning framework as a conceptual vision that provides direction whilst enabling, market-based policy and legislation incentivises the necessary investment and behaviour. This could include all relevant dimensions deemed as priorities and managed as part of a long-term just transition (described later).

7. In general, there should be active and ongoing incentivisation and funding provided for innovative research, development and demonstration from the private and public sector in the appropriate, disruptive energy technologies and systems to enable identified comparative and competitive advantages.

Electricity sector vision

8. The vision for the South African electricity sector needs to be fully investigated and understood 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.

9. The NDP 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.

10. Long-term electricity regulatory reform will require legislative changes, which should take a phased approach and be considered in close consultation with relevant stakeholders most importantly, Eskom. However, this should not be used as a reason to avoid reform or allow slow regulatory reform but as impetus to define and promulgate necessary legislation to enable the envisioned reform. 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.

11. In principle, the necessary enabling market design for all options being considered for electricity market reform should include the explicit need for energy capacity and ancillary services as fundamental products needed for the provision of electricity services.

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

13. Selected generation assets of Eskom should be unbundled into a separate state-owned entity (set of state-owned entities) or sold to private investors competing with IPPs in the medium-term with the explicit provision of ensuring that the 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.

14. 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).

15. Distribution and electricity sales to small customers should remain regulated and with Eskom and municipalities in the interim while larger customers become competitive in the medium- to long-term. Sufficient capacitation of municipalities via service level agreements with Eskom, larger municipalities or the private sector with available capacity should be pursued where feasible. The funding and business models applied in the distribution industry including municipalities will need to change whether embedded generation grows further or not and the necessary planning should be prioritised to ensure ongoing electricity service delivery.

The future of coal and carbon pricing

16. 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, significant negative externalities, 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 transition in the medium- to long-term.

17. Existing infrastructure upgrading 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, synthetic liquid fuel production and/or existing local industrial use should be pursued on a case-by-case basis.

18. A carbon-pricing mechanism with appropriately designed allowances or carbon budgeting will send the required signals for substitution of carbon-intensive fuels to enable a transition to a low-carbon economy. A carbon tax is currently under discussion and seems to be the preferred mechanism. A phased and predictable approach over time should also ensure minimal shock to the incumbent industry, economic growth and energy prices. The strategic energy plans that indicate an electrical energy mix that enables a transition to meet South Africa's GHG emissions commitments could be further accelerated by the use of a carbon tax as one of many possible policy instruments.

Modular, robust and sustainable energy infrastructure investment

19. 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 could be further enabled by electrical demand-dependant sustained rolling Bid Windows (BWs) of the highly successful REIPPPP (adjusted based on learning from previous BWs). This would enable further local participation across the value chain or an appropriately structured distributed program linked to the learnings of the REIPPPP could be pursued at a national, provincial or local government level.

20. Embedded generation technologies should be deployed where appropriate in the context of the opportunities in distributed energy systems. However, it needs to take into account the requirement of significant investment in distribution network infrastructure (refurbishment, upgrade and maintenance), fair and equitable tariff designs, enabling legislation and appropriate institutional arrangements.

21. **There is significant opportunity in the following dimensions in this regard:**
    - 21.1. Small business development and micro-enterprise job creation;
    - 21.2. Improved national energy security, sustainability and affordability;
    - 21.3. Alleviation of energy supply-demand imbalances; and
    - 21.4. Localised business and revenue potential for owners and communities in rural areas in particular.

22. Innovative tariff approaches and broader energy support including resources and tools for local government should be supported on an ongoing basis and be incentivised.

23. 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 localised goods and services.

Nuclear new build programme

24. A 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.

25. 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 to obtain support from all stakeholders.

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

27. 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 energy infrastructure (mega-projects)

28. Planning for the continuous maintenance of energy infrastructure, in particular the Eskom coal generation fleet and transmission/distribution networks, should be prioritised and pursued to ensure reliable medium to long-term electricity supply and to manage risks.

29. 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 Medupi and Kusile, in future, South Africa should instead opt for smaller, modular, flexible, easily manageable and scalable projects depending on strategic needs.

30. Other notable mega-projects include a proposed new refinery investment as well as a possible nuclear new-build programme (as discussed). These need to be carefully considered as a significant risk of asset stranding exists where more economically viable alternatives exist. Where unavoidable, mega-projects should be pursued with careful attention being paid to improved planning, governance and management.

Role of natural gas

31. 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. The role of natural gas should be clearly articulated as part of the strategic national energy planning framework.

32. Gas-fired power generation could provide a flexible power generation source in the electricity sector to complement demand and supply side variability as the existing coal fleet decommissions over time.

33. Natural gas could also be used in a range of other end-use sectors including direct end-use for industrial process and space heating, for example.

34. Infrastructure for liquefied natural gas (LNG) imports at strategic port locations should be prioritised in the short- to medium-term with the associated improved policy and regulatory certainty.

35. 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 particularly water usage are alleviated (coal bed methane (CBM), underground coal gasification (UCG) and shale gas).

Liquid fuel investments and strategic liquid fuel stocks

36. The upgrading of existing South African liquid fuel refineries to improved fuel standards should be incentivised and the decision about new refinery capacity needs to be finalised. The investment in new refinery capacity needs to be offset against international competition, domestic and regional demand for liquid fuels, alternative energy carriers, the availability and expansion of existing refinery capacity and the financial sustainability of the state-owned oil and gas company.

37. The importing of liquid fuels in the short- to medium term would likely prove more cost-effective than investing in a new large refinery, which may not be required in the medium- to long-term. Possible investment in regional refining capacity may also prove a better option. Increased liquid fuel imports would then require the requisite port infrastructure investment in handling and storage instead of new refinery capacity investment.

38. 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.

39. 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 further assist in offsetting the requirement for liquid fuel imports. This could also be converted into a significant opportunity for clean transportation fuel for export markets thereby providing a competitive advantage.

40. 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 a lower level of strategic fuel stocks be considered in the interim at the most appropriate locations until the fiscal environment changes notably.

Affordable energy access

41. As universal energy access is a key goal of the NDP (predominantly driven by electrification), on-grid electrification should shift focus 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. This could include hybrid energy options using alternative energy carriers and standalone systems.

42. Continued provision of free basic electricity (FBE) and free basic alternative energy (FBAE) is encouraged but with an associated improvement in communications about payment for energy services beyond FBE and FBAE. Long-term broader structural improvements in the economy that enable the creation of jobs and ensure poverty alleviation should improve the ability to pay for energy services and reduce the need for FBE and FBAE.

43. Appropriate governance structures and procurement processes should be in place with the most appropriate oversight institution(s) based 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.

Notes

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 still literature being developed or that may not have reached the public domain that could add value to the discussion, proposals and recommendations in this paper. Information about these would be welcomed to enrich ongoing discussion where appropriate.

As this was initially published for discussion purposes, it was expected to elicit wide-ranging views and opinions which have led to substantial debate on the contents. These debates and discussions are appreciated and have been 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 particular aspects have generated considerable debate within the NPC itself. We list some of these below for reference.

Challenges for focused consideration

1. There is agreement on the principle that regulatory reform in the South African electricity sector is required but what the electricity sector vision 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 CO2) into a sustainable development agenda for South Africa is accepted. However, the manner in which this can be achieved and the timing thereof is not settled. This will be part of an ongoing process where the NPC is engaging stakeholders on a just transition.
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. A prospective nuclear programme investment and the role of nuclear capacity when compared to alternatives in the long-term must be resolved.
5. There is an unresolved challenge of whether the existing life of the Eskom coal generation should be extended, and whether the coal power stations under construction should be completed or any new-build coal power stations be pursued. This forms part of the broader discussion on a just transition for South Africa.

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
UCG	Underground Coal Gasification

Type	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 (CO2) as part of their operations. It is the amount that must be paid for the right to emit a volume of CO2 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 Convention 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 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), 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 1OC, 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.

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 the dominant renewable energy technologies of solar PV and wind respectively (using information from auction results for RES technologies globally in recent years) [8]. The IEA summaries of these trends [9] amongst a number of others [10] 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 that includes the South African context [11] also summarises these global trends quite well. In a number of regions including South America, Europe and more recently Sub-Saharan Africa (including South Africa), similar trends have been realised recently as part of successful energy auction programs [12], [13]. 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 application of the competitive auction process.

1.2.6. A range of reputable institutions including IEA, Bloomberg New Energy Finance (BNEF), the National Renewable Energy Laboratory (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 [14]. The IEA conservatively expects cost reductions of 40-70% for solar PV and 10-25% for onshore wind by 2040 [15]. BNEF expects a 66% reduction for solar PV and 47% for onshore wind respectively by 2040 [16]. NREL expects solar PV and onshore wind to reduce by 57-70% and 29-48% by 2040 respectively [17].

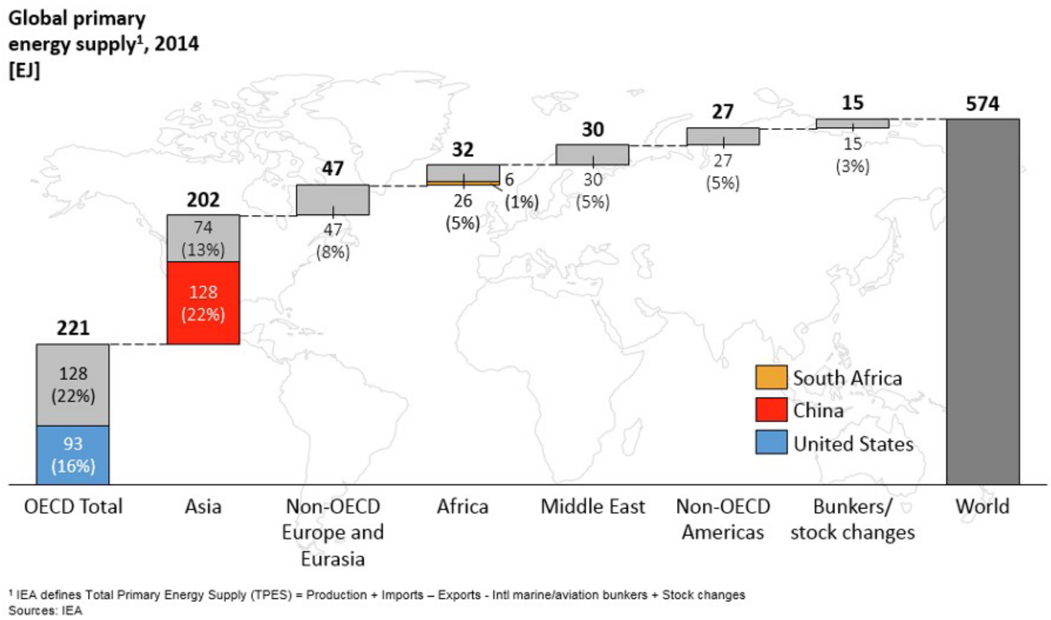


Figure 1. Global total primary energy supply (2014) by region highlighting the significant role of the United States and China along with the energy role Africa and South Africa play globally.

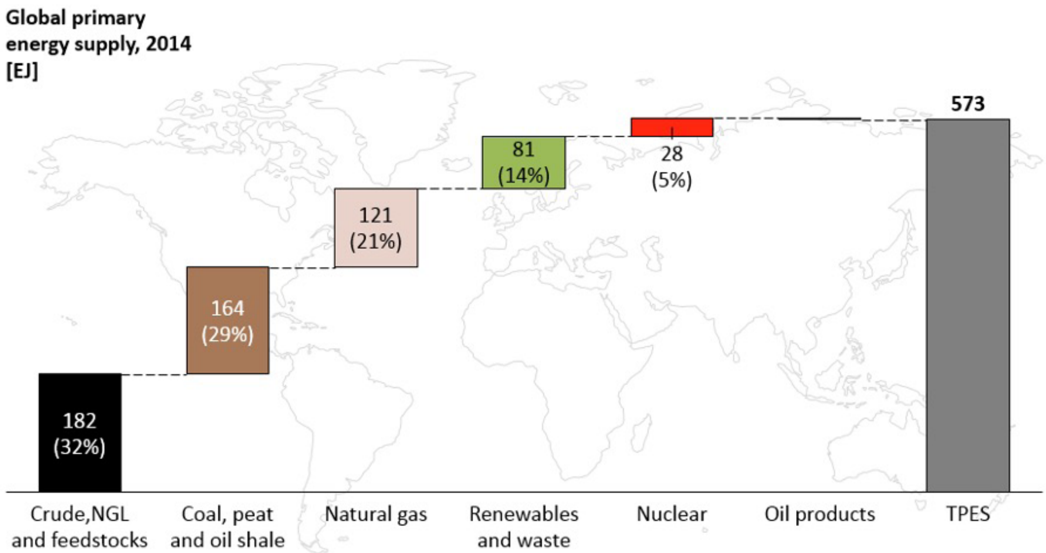


Figure 2. Global Total primary energy supply (2014) by primary energy supplier showing existing dominance of coal, oil and gas supplying ~80% of TPES.

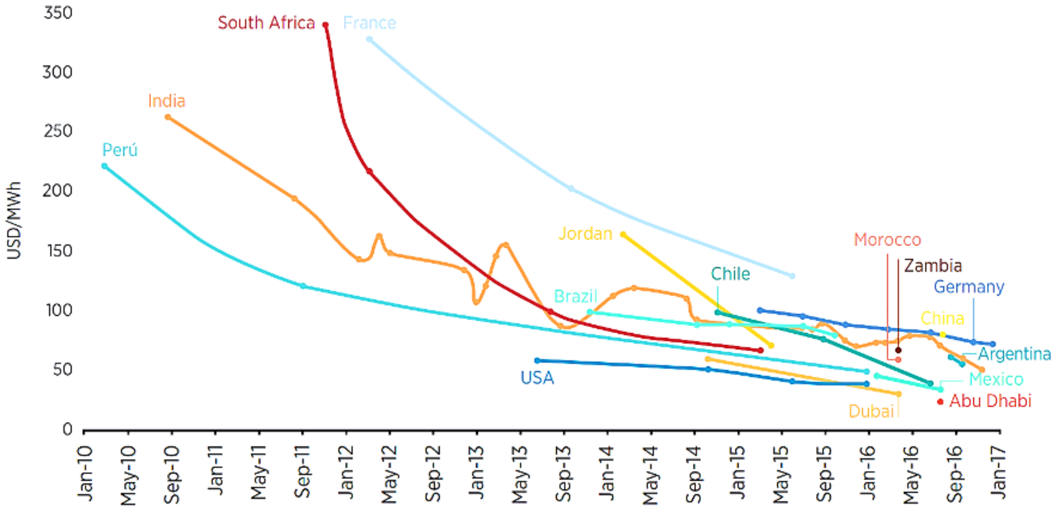


Figure 3. Average auction prices for solar PV for a range of countries for 2010-2016 (Source: IRENA).

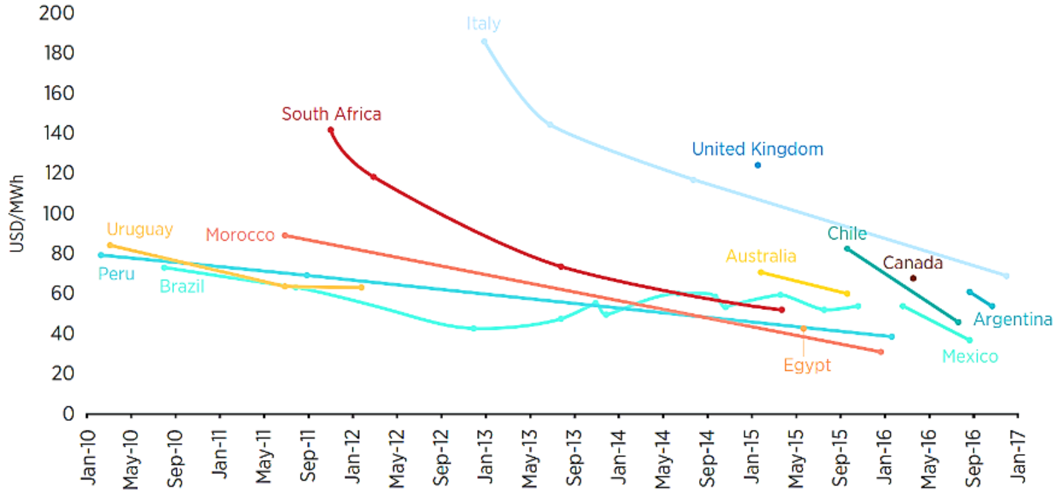


Figure 4. Average auction prices for onshore wind for a range of countries for 2010-2016.

1.3.7. Summaries of the South African primary energy supply and final end-use are shown in Figure 5 and Figure 6 respectively with a breakdown by primary energy carrier provided in Figure 7 (for 2014). South Africa is a relatively energy-secure country with most domestic energy needs being met by domestic coal. The majority of our energy imports is made up of a significant amount of oil and liquid fuels. 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% made up of 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%). Final end-use is spread across traditional biomass (primarily in the residential sector), liquid fuels (predominantly in the transportation sector), coal (primarily in the industrial sector), electricity (across almost all sectors) with a small role for natural gas.

1.3.8. 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 a considerable portion 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 32 PJ in 2017 (0.4%) while contributing 1.0% in 2014 up to 3.8% in 2017 to electricity production [18]–[20]. This is shown in Figure 7 as well but is 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 [21]. A key outcome of the REIPPPP (even at this early stage) is the removal of cost uncertainty as well as a 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 [22]. Actual tariffs realised as part of the REIPPPP thus far, are summarised in Figure 8 where an ≈80% reduction in solar PV and ≈60% reduction wind had been realised between 2011-2015 [23].

1.3.4. The NDP 2030 envisages that the South African economy will continue to grow and it is recognised that as a developing country, its economic growth is still strongly correlated with primary energy demand (albeit not as strongly as it has been historically) [24]–[26]. The geospatial context of this energy demand development needs to be well understood in order to achieve the NDP goals and objectives considering the legacy of spatial segregation and the historical exclusion of a significant proportion of the population from the economy.

1.3.5. In term of policy, South Africa adopts a central energy planning paradigm with the strategic energy planning framework being defined more generally by the National Development Plan (NDP) [27], an overarching Integrated Energy Plan (IEP) and resulting plans, roadmaps and policies. 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 for a future South African energy sector based on electricity as a primary energy carrier mainly as a result of relatively cheap and abundant domestic resources:

1.3.7.1. Global trends 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) [28]–[30]. 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 a number of countries globally [28], [31], [32].

1.3.7.2. Considering these global megatrends, there are clear implications for South African energy planning where appropriate and compatible 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 9 and Figure 10). This could be harnessed to drive a future sustainable economy with 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.

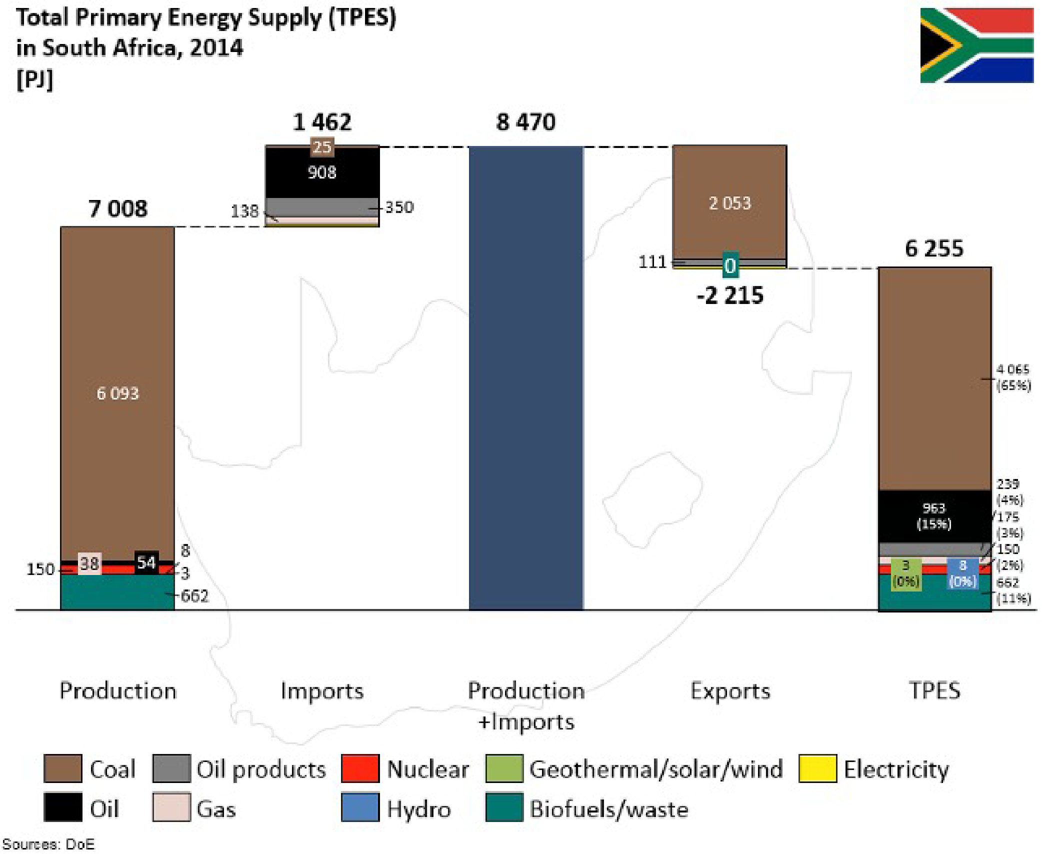


Figure 5. Figure 5 Primary energy supply in South Africa (2014) showing significant reliance on coal as a primary energy supplier and single resource import risk (oil and liquid fuels).

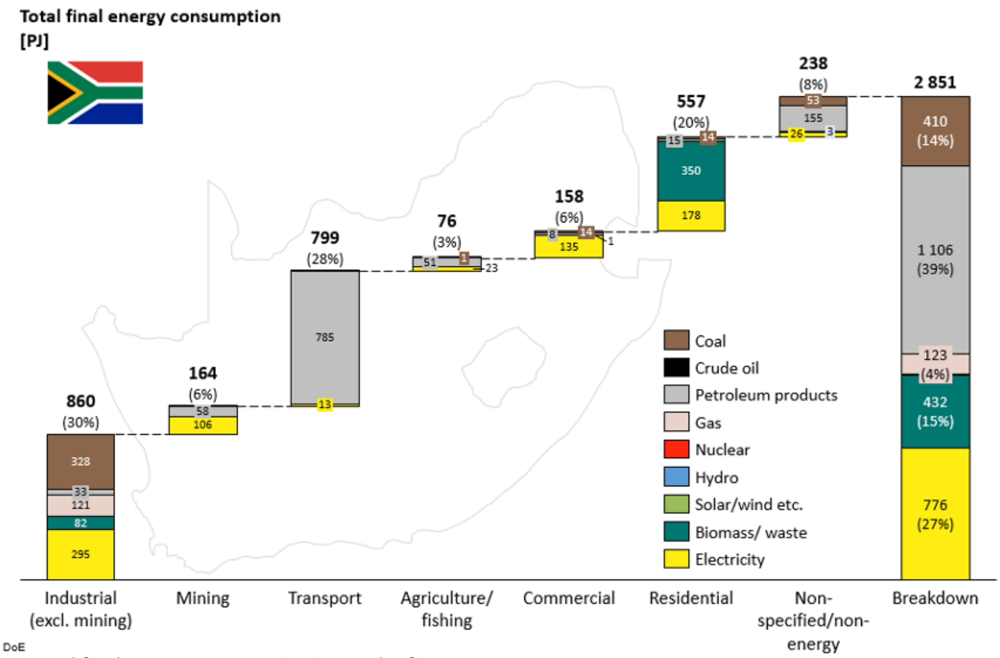
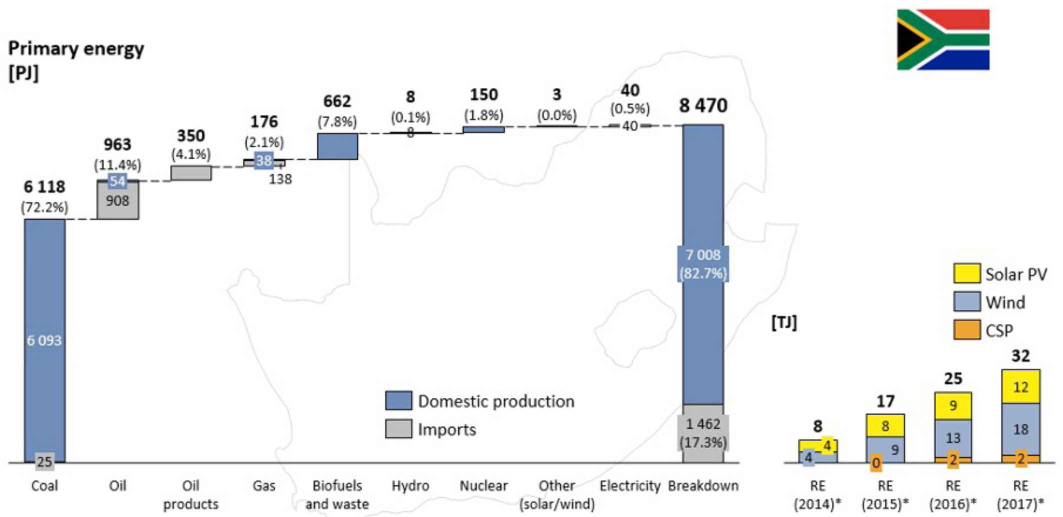
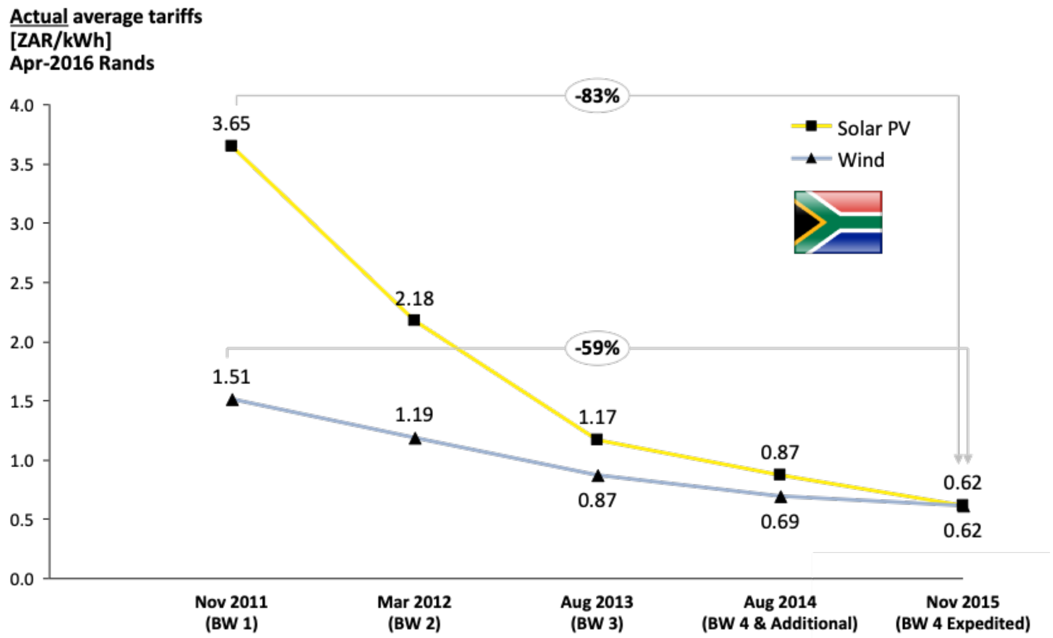


Figure 6 Total final energy consumption in South Africa (2014).



* Not to scale (included for representative purposes only)
Sources: DoE; CSIR

Figure 7 Primary energy supply in South Africa (2014) showing relative energy security but near full reliance on oil and liquid fuels 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 8 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.

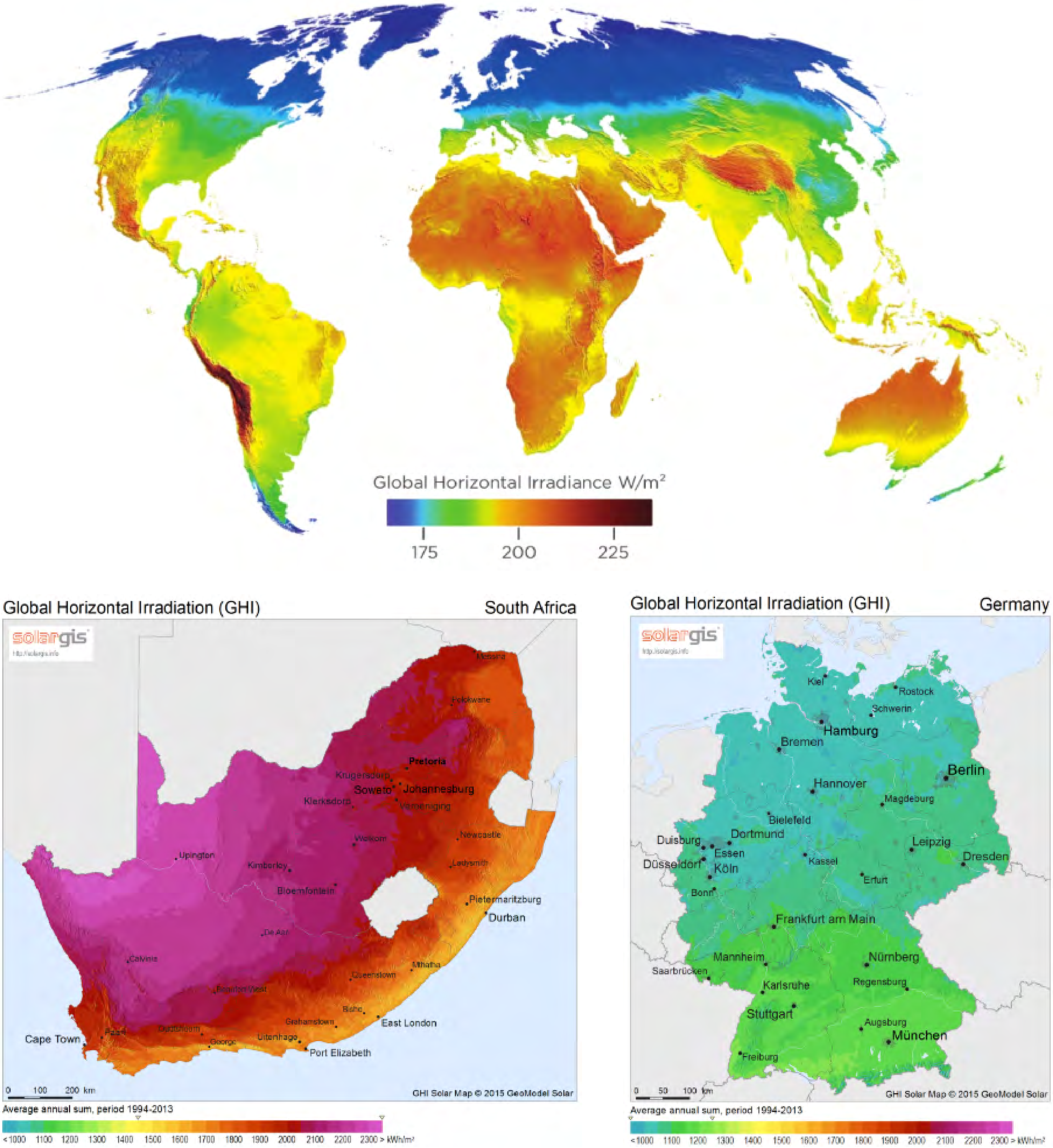


Figure 9. *Relative comparison of (top) South Africa's solar resource to global solar irradiance and (bottom) relative comparison of South African average annual GHI to an early adopter of solar PV (Germany).*

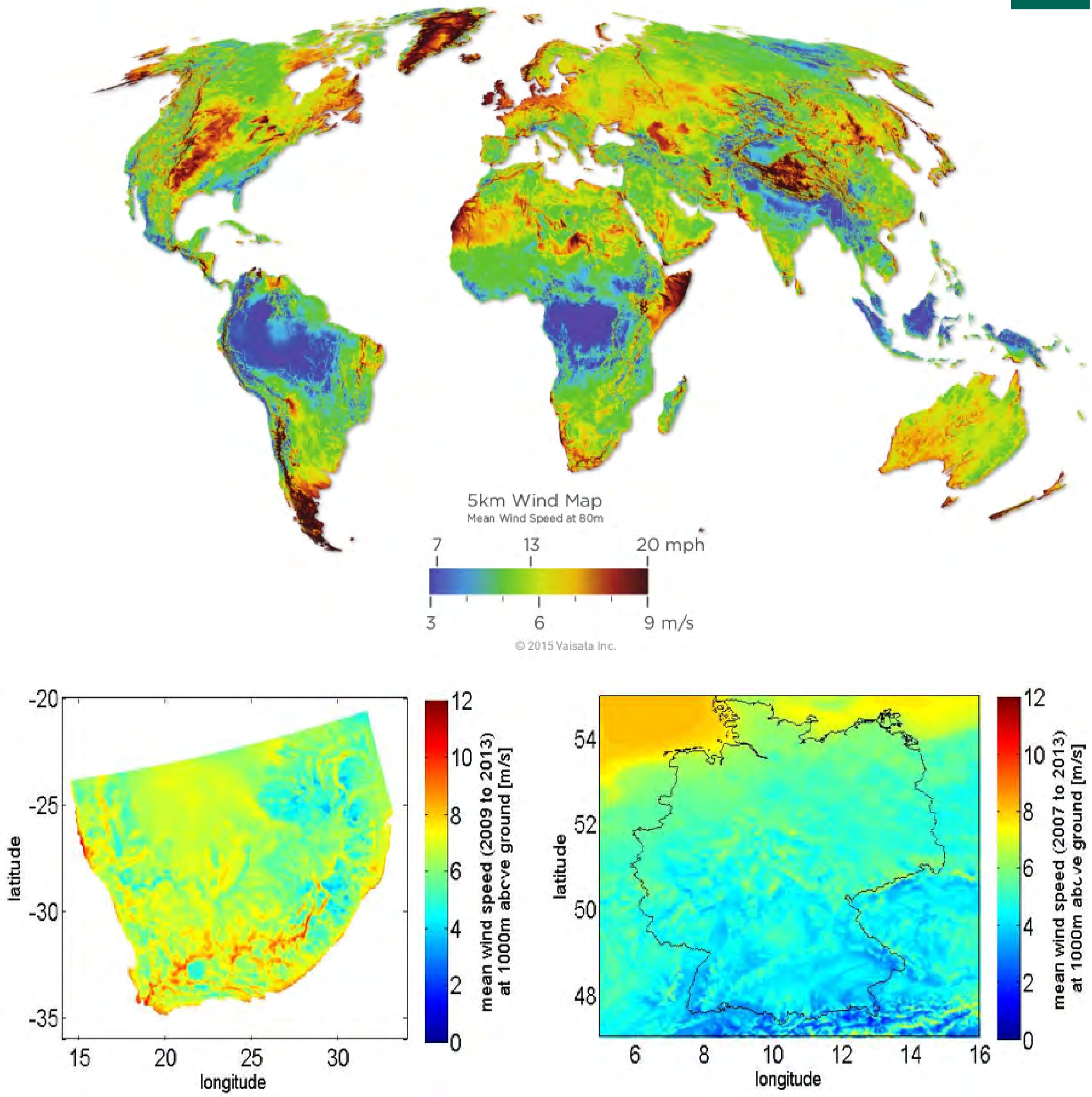


Figure 10. Relative comparison of (top) South Africa's wind resource to global wind (mean wind speed at 80 m above ground) and (bottom) relative comparison of South African mean wind speed between 2009-2013 at 100 m above ground to an early adopter of wind (Germany). General

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 [27] persist. In addition, a dynamic energy planning, regulatory and governance environment 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 the global and domestic energy sector.

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.

2.1.5. These objectives will implicitly require trade-offs to be well understood and decisions on long-term energy policy made as a result.

2.1.6. This publication focusses on addressing existing challenges and pertinent issues within the South African energy sector whilst maintaining a long-term outlook on opportunities that may exist. As such, it 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.

2.1.7. 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.

2.1.8. This publication is intentionally succinct and made accessible to ensure as wide an audience as possible, 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. Position

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 7 years old [33].

Drafts of the IEP and IRP were published for comment by the Department of Energy (DoE) in late November 2016 [34], [35] and more recently in August 2018 [36]. Following this, stakeholder comments were incorporated and further consultation undertaken. Policy adjustment is expected to be initiated based on this and the IRP promulgated.

Discussion and Proposals

3.1.1. Currently, energy sector infrastructure investments are not informed by a complete and up-to-date IEP or supporting strategic plans. 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 [33]). 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. The current centralised planning and largely prescriptive approach to energy planning in South Africa may also need revision more generally. This should entail a switch of focus to using the existing integrated energy planning framework to be more of a visionary recommended direction whilst enabling, market-based policy and legislation incentivises the necessary investment and behaviour. This could include all relevant dimensions deemed as priorities and managed as part of a just transition (described later).

3.1.4. 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. An example of the increased active role envisioned for local government can be found in [37].

3.1.5. 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, SOx/NOx 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.

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

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

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

3.1.7. If sufficient capacity does not exist within the mandated custodian (DoE), the development and collation of input assumptions, technical modelling and necessary related investigations for future revisions of strategic energy plans could be undertaken by an independent entity capable of providing the necessary services and 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 the trust and confidence of all stakeholders. However, the Executive authority and mandate of the custodian of these strategic plans should not be shifted from the responsible custodian.

3.1.8. The process of updating and publishing strategic energy plans should be broadly and comprehensively participatory 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.

3.1.9. 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.

3.1.10. 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.

3.1.11. 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 (The Draft IRP 2018 starts to consider this via collector station cost estimates for integrating all technologies [36]). Although integrated generation/transmission expansion planning is possible with available tools, the problem becomes intractable 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 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 sufficiently to change the least-cost generation expansion planning outcomes (and overall strategic direction and policy).

3.1.12. 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.

3.1.13. 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 (and potential job losses) domestically including possible export potential (localised, localisable and global). This dimension can then be included in the planning process outcomes to inform policy discussion and adjustments.

3.1.14. More generally – there should be an active and ongoing incentivisation and funding provided for innovative research, development and demonstration from the private and public sector in the appropriate disruptive energy technologies and systems to enable identified comparative and competitive advantages.

3.2. Electricity sector vision Discussion and Proposals

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 with boom-bust cycles in the supply-demand balance. This is manifested in either over-supply where parts of the existing coal generation 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 (over and above those needed to move towards cost-reflectivity) and continued reliance on funding injections places a strain on public finances.

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

The existing 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 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 example that reached Parliament in 2011 in the form of a draft bill [38]. In its presentation to Parliament in May 2017, the Department of Energy [39], 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. The NPC understands that this has not yet occurred.

3.2.1. The vision for the South African electricity sector needs to be fully investigated and understood in order to create long-term certainty that will reduce electricity prices (relative to the status quo which is reaching a tipping point [40], [41]), 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 (likely state-owned). The current environment within which the South African electricity sector operates, associated existing business models and sustainability thereof 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. With Eskom being a dominant player in the electricity sector, the Eskom status-quo (operational and financial sustainability) needs to be considered carefully whilst short- to medium-term operations are 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. 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.

3.2.4. Wide-ranging research provides a valuable contribution to the updated options available for electricity sector reform globally and in South Africa. [37], [42]–[48]. A synthesis of the research can be briefly summarised as follows:

3.2.4.1. Supply-demand balance and associated boom-bust cycles;

3.2.4.2. The need to provide affordable electricity to the poor;

3.2.4.3. 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;

3.2.4.4. Failure to recognise and act on technological disruption;

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

3.2.4.6. Second order aspects like resulting rising electricity costs to the consumer and environmental sustainability of the electrical energy mix.

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

3.2.5. A key reform driver discussed above which deserves additional explanation concerns the fair treatment of planning, grid connection and operation of other industry players (IPPs) relative to Eskom-owned generation into the future. This has been magnified by the recent refusal 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 [49], [50]). 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 the transmission planning, grid connection and operations functions [44], [51], [60]–[62], [52]–[59].

3.2.6. The desired outcomes of the electricity sector could be characterised as:

3.2.6.1. Environmental and social sustainability of electricity supply and end-use;

3.2.6.2. Sufficient and reliable electricity supply;

3.2.6.3. Financial sustainability of electricity sector entities;

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

3.2.7. 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. It is critical that any regulatory reform 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. This should not be used as a reason for non-existent or slow regulatory reform but as an impetus to define and promulgate the necessary legislation to enable the envisioned reform.

3.2.8. Eight (8) industry reform alternatives are presented in research in [42] that was commissioned for government. It includes the status quo and is evaluated based on:

3.2.8.1. Impact on efficiency;

3.2.8.2. Conducive environment for private funding;

3.2.8.3. Reliance on government funding;

3.2.8.4. Ease and cost of implementation;

3.2.8.5. Impact on electricity prices

3.2.9. Although an updated detailed impact assessment regarding the options available for the vision 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:

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

3.2.9.2. Generation (competitive): Selected Eskom generation assets are unbundled into a separate state-owned entity (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. No individual institution should dominate the generation sector and thus a suggested maximum market share per institution should be defined ex-ante. 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 and storage (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.

3.2.9.3. Transmission (regulated): The natural monopoly transmission wires related business along with selected procurement, operations and planning functions for security of supply should become an independent separate entity enabling non-discriminatory open-access to all appropriately licensed suppliers and end-users (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 removal of any conflict of interest (as currently exists in the status-quo).

3.2.9.4. Distribution (regulated): Distribution (the wires) and electricity sales to small customers should remain regulated and with Eskom/municipalities in the interim. Larger customers could 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 poor customers will be protected from considerable tariff increases. Sufficient capacitation of municipalities via service level agreements with Eskom, larger municipalities with available capacity or the private sector should be pursued where feasible. The funding and business models applied in the distribution industry including municipalities will need to change whether embedded generation grows or not and the necessary planning should be prioritised to ensure ongoing electricity service delivery.

3.2.10. In principle, in all options considered for electricity market reform, the necessary enabling market design should include the explicit need for energy capacity and ancillary services.

3.2.11. The estimated cost of the maintenance backlog by municipal distributors is 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) as well as allowing for municipalities to cut off electricity supply as a powerful tool to ensure revenue security whilst also enabling improved payment by municipalities to Eskom.

3.2.12. 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. 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.

3.2.13. 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.

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

3.2.15. 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.

3.2.16. 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 CO2 emissions in South Africa are as a result of coal-fired electricity generation. Other components of CO2 emissions includes the synthesis of liquid fuels via coal-to-liquids (CTL) technology, transportation and final end-use.

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 CO2 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 CO2 emissions) [63].

The Carbon Tax Bill, released initially for comment in November 2015 [64], has recently been published for consideration in Parliament by National Treasury [65] as a mitigation option in a broader GHG Emission Reduction Strategy for South Africa to incorporate the externality costs of CO2 into the South African economy. This second draft of the Carbon Tax Bill was published for public comment at the end of 2017 is currently undergoing consultation [65].

3.3.1. Following the publication of the South African Coal Road Map in 2013 [66], there was an urgent need for co-ordinated stakeholder action driven by government to facilitate a transparent decision-making process for a just transition in South Africa. This has been echoed in [67] where coal was highlighted as a valuable export earner but has seen reduced levels of integrated development across the supply chain (coal mines, transport infrastructure and ports) as well as responsible institutions and stakeholders.

3.3.2. 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 the 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, significant negative externalities as well as environmental sustainability and resiliency. A range of work in this regard has been undertaken ([32], [68]–[74]) and there is a process being undertaken by the NPC to inform a just transition for South Africa where coal will constitute a central focus. This aims to provide a broader discussion over and above the existing and draft policy (e.g. Coal for Energy Policy Position Paper, Draft IEP 2016, Draft IRP 2016, Draft IRP 2018) 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 its impact on government, SOEs, businesses, organised labour and civil society [74], [75].

3.3.3. Existing infrastructure upgrading 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 direct end-use (industrial/ domestic) should be pursued on a case-by-case basis. This should be considered in the broader context of the previously mentioned just transition and sustainable energy end-use. In this regard, the risk of stranded infrastructure investment in the South African coal industry is significant and has been noted globally as well as domestically whether South Africa pursues a limited carbon emissions trajectory or not [32], [68], [71], [76]–[78]. Lowering the use of fossil fuels in the energy mix will be further driven by these international commitments and an appropriate national policy direction [79]–[82] combined with new technologies and energy efficiency.

3.3.4. A carbon pricing mechanism (a carbon tax is currently under discussion and seems to be the preferred mechanism) or carbon budgeting with appropriately designed allowances will send the relevant signals for substitution of carbon-intensive fuels and alternative chemicals manufacturing (where feasible) to enable a transition to a low-carbon economy. A phased and predictable approach over time should also ensure minimal shock to the industry, encourage economic growth and regulate 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 local and national environmental and health benefits (amongst others) [83].

3.3.5. 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 CO2 emissions. Thus, the carbon tax is an important mitigation measure in this regard and is supported by the NPC.

3.3.6. With the policy guidance provided by strategic energy plans that indicate an electrical energy mix that transitions to meet South Africa's GHG emissions commitments (defined by Peak-Plateau-Decline trajectory or alternatively adopted trajectory), the carbon tax could be seen as an additional policy instrument (one of many) to accelerate this transition.

3.4. Modular, robust and sustainable energy infrastructure 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), [81], [84] and Figure 5, 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. Other major components as it relates to the energy sector include the production and refining of synthetic liquid fuels followed by direct end-use.

Global movements and imperatives for GHG emission mitigation and adaptation are well understood and accepted [63], [85]. South Africa has also committed to domestic GHG mitigation measures as part of the recent ratification of the Paris Agreement [82].

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 [18]. 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 [21]. 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) [29], [44]. 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 but fast-growing embedded generation market in South Africa. Nersa has released a draft of Small-Scale Embedded Generation (SSEG) Regulatory Rules [86] 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 and resiliency 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, regional and domestic technology cost trends not only for wind and solar PV but also for stationary storage technologies [8], [9], [12], [29], [87]–[89]. This could be enabled by electrical demand dependant sustained rolling Bid Windows (BWs) for renewable energy as an extension of the highly successful REIPPPP (adjusted based on learning from previous BWs). This would enable further local participation across the value chain or an appropriately structured distributed program linked to the learnings of the REIPPPP could be pursued at a national, provincial or local government level. 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 (which could be further improved), manufacturing and ownership as procurement programmes are fine-tuned to progressively require more local content.

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 more relevant and a priority (with the associated costs) when renewable energy penetration levels of 20-30% and beyond are reached (by annual energy share) [88]. However, this may occur slightly earlier in South Africa due to the existing relatively inflexible existing generation fleet and should be thoroughly investigated. Beyond this, these concerns have largely declined and are being solved locally with recent research, standards development and application [90]–[93] as well as extensive research for many years globally [94], [95], [104]–[106], [96]–[103]. Operational solutions are also being applied and experience is being gained around the world. See references [107], [108], [117]–[123], [109]–[116] (amongst others).

3.4.4. The global shift away from the centralised utility model to distributed energy systems [44] 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 3.2.9.4, 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:

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

3.8.3.2. Improved national energy security, sustainability and affordability.

3.8.3.3. 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).

3.8.3.4. 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 customers that can afford the upfront capital investment in self-supply (whether partially or completely) 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 [124]. This should be supported and incentivised on an ongoing basis.

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.

Status-quo

For many years since the 1980s), South Africa has successfully operated nuclear power generation (at Koeberg) and is expected to continue to do so until the planned decommissioning of this plant.

The promulgated IRP 2010-2030 included 9.6 GW of nuclear power generation capacity [33]. Following this, the Minister of Energy made a Ministerial Determination that confirmed it in December 2016 [125].

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 [126], [127]. This has not taken place.

As noted, the IRP is currently being updated and the Draft IRP 2016 as well as Draft IRP 2018 were put in the public domain for consultation [34], [36] following a significant time-lapse since the promulgation of the IRP 2010-2030 in 2011 [33]. In the Draft IRP 2016, a Base Case requires nuclear power by earliest 2037 while a Carbon Budget scenario requires it by 2026. The Draft IRP 2018 does not include nuclear in most scenarios and does not include nuclear in any scenarios prior to 2030 [36].

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) [128], [129] 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 [130].

South Africa's research efforts into Small Modular Reactors (SMRs) have been recently revived via Advanced High Temperature Reactor (AHTR) research efforts for commercialisation in the 2030s based on the previous work as part of the Pebble Bed Modular Reactor (PBMR) [131].

3.5.1. Large-scale nuclear for power generation provides carbon-free electricity over a relatively long technical lifetime (typically 60-80 years). It is also technically capable of operating flexibly to some extent (if required) [132]–[134]. However, it is appreciated that this is typically not a technical limitation but rather linked to the economics of the technology. That is, the capital-intensive nature of the technology means it is more economical to operate it as a base-supplier and not as a flexible resource (as is the case at Koeberg power station and most existing nuclear power stations globally).

3.5.2. The investment levels required for the envisaged size of the South African nuclear programme will be unprecedented requiring a particular focus on this technology. However, it is appreciated that the programme would be phased in over a number of years and is not a once-off investment. 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 including that of beneficiation, localisation and employment opportunities. Other aspects would include regulator capacity (unique risks), global trends and modularity with the associated lack of flexibility and robustness of investment decisions.

3.5.3. 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.

3.5.4. Information publicly available in a number of jurisdictions globally [90], [91], [143]–[148], [135]–[142], should inform future possible nuclear energy provision which would need to be 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 engagement processes and future IRP processes (see section 3.1).

3.5.5. Significant experience in operating nuclear facilities has been gained globally and domestically (Koeberg, Pelindaba and associated facilities) for many decades as South Africa has played a significant role in the use of nuclear technologies across nuclear energy and nuclear medicine (amongst others). However, as a result of the impact of historical accidents at nuclear facilities, perceived public concerns surrounding the safety of operating nuclear facilities locally and globally have been highlighted. Although South Africa has also safely handled, managed and stored radioactive waste for almost three decades (predominantly from Koeberg), the ongoing perceived concern surrounding the safety of high-level and low-level nuclear waste management and storage needs to be addressed sufficiently for all affected stakeholders.

3.5.6. Considering the significant economies of scale that result from building large-scale nuclear reactors (>1000 MW per unit), small modular reactors (SMRs) have typically been considered prohibitively expensive [145], [147]. However, the opportunity for SMRs to be included as an option in the integrated energy planning framework should be considered with appropriate realistic costs, technical characteristics and learning curves expected. This is in the context of recently revived research efforts focussed on an AHTR for commercialisation in the 2030s [131] as well as historical research and development efforts in the U.S.A., China, Russia, South Korea and Argentina [149]. This should be considered by fully appreciating existing commercially available nuclear power generation technologies [150] as well as alternative technologies and the economics thereof.

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

Status-quo

Generally, it could be argued that large energy infrastructure ("mega-projects") in a developing economy like South Africa are sometimes unavoidable. Examples of these are some of the Strategic Integrated Projects (SIPs) as part of the Presidential Infrastructure Coordinating Commission (PICC) [151].

A more recent example of this was the new-build generation capacity developed by Eskom in the form of the Medupi and Kusile power stations (these were deemed largely necessary at the time of decision). It is also known that these mega-projects have experienced significant cost and time over-runs [152]. These have burdened the state-owned electrical utility financially affecting customers directly with the resulting electricity tariff increases.

The existing coal generation fleet in South Africa is also aging and has experienced a number of reliability challenges 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. Life extension as well as early retirement of this fleet has been considered and is under discussion.

Other major energy infrastructure projects planned to be implemented include a large new refinery investment, the proposed nuclear new-build programme and new heavy-haul rail infrastructure for coal transportation from the Waterberg region.

3.6.1. Whether in developed or developing economies, it has been shown from empirical experience that although mega-projects are typically preferred due to the economies of scale they exhibit, the majority implemented globally inevitably experience time and cost overruns [153]–[155]. Mega-build energy infrastructure is no exception and has demonstrated similar characteristics historically [156], [157].

3.6.2. A key example of the implementation challenges experienced in energy sector mega-projects in recent times in South Africa have come from the pursuit of the Medupi and Kusile power stations. The number of lessons that have been learnt here should be strictly applied when considering possible future mega-projects. As mentioned, sometimes mega-projects are unavoidable and it could be argued that Medupi and Kusile were examples of this at the time of the decision. However, if avoidable, in future South Africa should instead opt for smaller, modular, flexible, easily manageable and scalable projects depending on strategic needs. This does not mean that South Africa should never pursue mega-projects as there are a number of sectors where they would prove to be the most cost-effective and least-risk options (with the associated improved planning, governance and management). The range of skills developed and sustained as part of a continued infrastructure roll-out should not be under-estimated but this does not depend directly on mega-projects and can still be ensured via the aforementioned smaller, modular project development preference (where feasible).

3.6.3. 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 [77], [158]. The Eskom coal fleet will likely continue to play a major role in this regard in the medium- to long-term until decommissioned.

3.6.4. Other notable mega-projects include a proposed new refinery investment as well the nuclear new-build programme (the nuclear new-build programme is discussed in detail in section 3.5). On a new refinery, at the scale intended, there exists a risk of asset stranding regardless of whether it is private or state-owned as alternative energy carriers for the transportation sector could be more economical (resulting in insufficient demand) e.g. electricity, hydrogen. Although transportation sector liquid fuel demand would dominate this reduced demand, this displacement does not necessarily affect the use of liquid fuels or petroleum products in other end-use sectors. This is discussed further in section in section 3.8.

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 the 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 has been completed and will inform future policy making in this regard [159]. Regulatory frameworks and permitting decisions for exploratory drilling have been granted recently for shale gas (not finalised) and should commence in the near future [160].

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 exhibits lower relative CO2 emissions when burnt than coal. As a result, it can be considered a transition fuel to a low-carbon economy. It also exhibits minimal localised air pollution (relative to coal). Fugitive emissions of natural gas should be limited appropriately if leakage rates are to be effectively enforced and aligned with best practice.

3.7.2. As a result, natural gas can be a key contributor to South Africa's future 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. Its role should be clearly articulated as part of the strategic national energy planning framework (section 3.1). 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 particularly water usage are alleviated (coal bed methane (CBM), underground coal gasification (UCG), shale gas).

3.7.3. In order to encourage exploratory drilling domestically, policy certainty is required. More specifically, 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. 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 [34], [90], 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). This includes flexible power generation capacity that 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. The timing and sizing of an initial gas-to-power programme should be informed by the necessary detailed investigations and offset against other competitive technologies whose costs are changing extremely quickly e.g. stationary storage, demand side-response.

3.7.7. 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 [161], [162] (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 oil resources, South Africa has a considerable import dependence on oil and refined liquid fuels, with the majority of imports coming from Angola, Saudi Arabia and Nigeria. These are predominantly used in 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 a new refinery was expected in 2017 but the NPC understands that no decision has been made as yet. Based on the targets in the DoE presentation to the Portfolio Committee in May 2017 [39], a Cabinet memo on the decision for a new refinery was expected to be submitted by the third quarter of 2017/18 but this does not yet seem to have been tabled. The new refinery investment is understood to be of the order of 250 000-300 000 bbl/day. This is significant as it would add ≈40% of additional refinery capacity.

Upgrading existing refining capacity in South Africa has also been considered for some time now but is yet to be implemented (Cleaner Fuels II regulations and standards).

With regard to oil and liquid fuel strategic stocks, the Energy Policy White Paper of 1998 [163] 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 [164] 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 [164] suggests that the state should hold crude oil strategic stocks while the private sector holds refined liquid fuel strategic stocks.

Discussion and Proposals

Liquid fuel investments:

3.8.1. The upgrading of existing South African liquid fuel refineries to improved fuel standards (Cleaner Fuels II regulations and standards) should be incentivised.

3.8.2. The investment in new refinery capacity needs to be finalised. This decision should be carefully considered and offset against global and regional competition, domestic and regional demand for liquid fuels, alternative energy carriers (predominantly electricity and hydrogen), availability and expansion of existing refinery capacity and the financial sustainability of the state-owned oil and gas company. This has been recently highlighted in [165] where modest deployment of vehicles using alternative energy carriers offset the need for a new refinery investment alone. 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 not necessarily be required in the medium- to long-term (possible investment in regional refining capacity may also prove a better option). Increased liquid fuel imports would then require the requisite port infrastructure investment in handling and storage instead of new refinery capacity investment.

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

3.8.3.1. 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;

3.8.3.2. 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 on electricity would assist in further offsetting the requirement for liquid fuel imports in South Africa. This could also be converted into a significant opportunity for the export of clean transportation fuel to other markets providing a competitive advantage for South Africa.

3.8.4. 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:

3.8.5. These should always be maintained to the highest possible standard that is economically optimal in order to minimise the 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.

3.8.6. 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. Affordable energy access

Status-quo

Energy access predominantly driven by significant electrification (post-apartheid) was funded by the electricity industry between 1994-2001. From 2001 onwards, the state-funded Integrated National Electrification Programme (INEP) took over as a subsidy-driven program to fund electrification. This was primarily driven on the basis of increased domestic electricity access being an enabler for reduced inequality and poverty alleviation.

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 or alternative energy options. Alternative energy options are also being identified where electricity may not be the most appropriate energy access option including the use of liquefied petroleum gas (LPG) as end-users move away from traditional biomass and coal.

The provision of free basic electricity (FBE) and free basic alternative energy (FBAE) is an important existing policy that allows for productive use of energy in poor households.

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 [166]. There are plans for 235 000 on-grid and 15 000 off-grid/island-grid connections in 2017/18 [39].

Discussion and Proposals

3.9.1. With universal energy access a key goal of the NDP (predominantly driven by electrification), 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 and hybrid energy options (including alternative energy carriers) could be developed with the vision to interconnect with the main national grid in future if demand grows sufficiently or micro-grids geographically spread sufficiently. There are a number of examples of this globally [167] and these have recently been demonstrated in South Africa [168], [169] while there is ongoing research at various institutions to determine optimal approaches to financing, design and implementation.

3.9.2. Continued provision of free basic electricity (FBE) and free basic alternative energy (FBAE) is encouraged but with an associated improvement in communications as it relates to payment for energy services beyond FBE and FBAE. Long-term broader structural improvements in the economy enabling the creation of jobs and associated poverty alleviation should further improve the ability pay for energy services and reduce the need for FBE and FBAE in the long-term.

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

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Summaries of global energy trends from BP as well as IEA are provided for reference. These are shown graphically in Figure 11 to Figure 24. Other reference works not analysed at this stage include StatOil Energy Perspectives (now known as Equinor) [170], [171] and the U.S. Energy Information Administration (EIA) Annual Energy Outlook (AEO) [172]

BP Energy Outlook [173]: 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 11 to Figure 14. 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 15, 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) [174]: 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 CO2). The energy consumption, percentage share and growth in primary energy suppliers globally and for Africa are summarised in Figure 16 to Figure 25 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 22, 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.

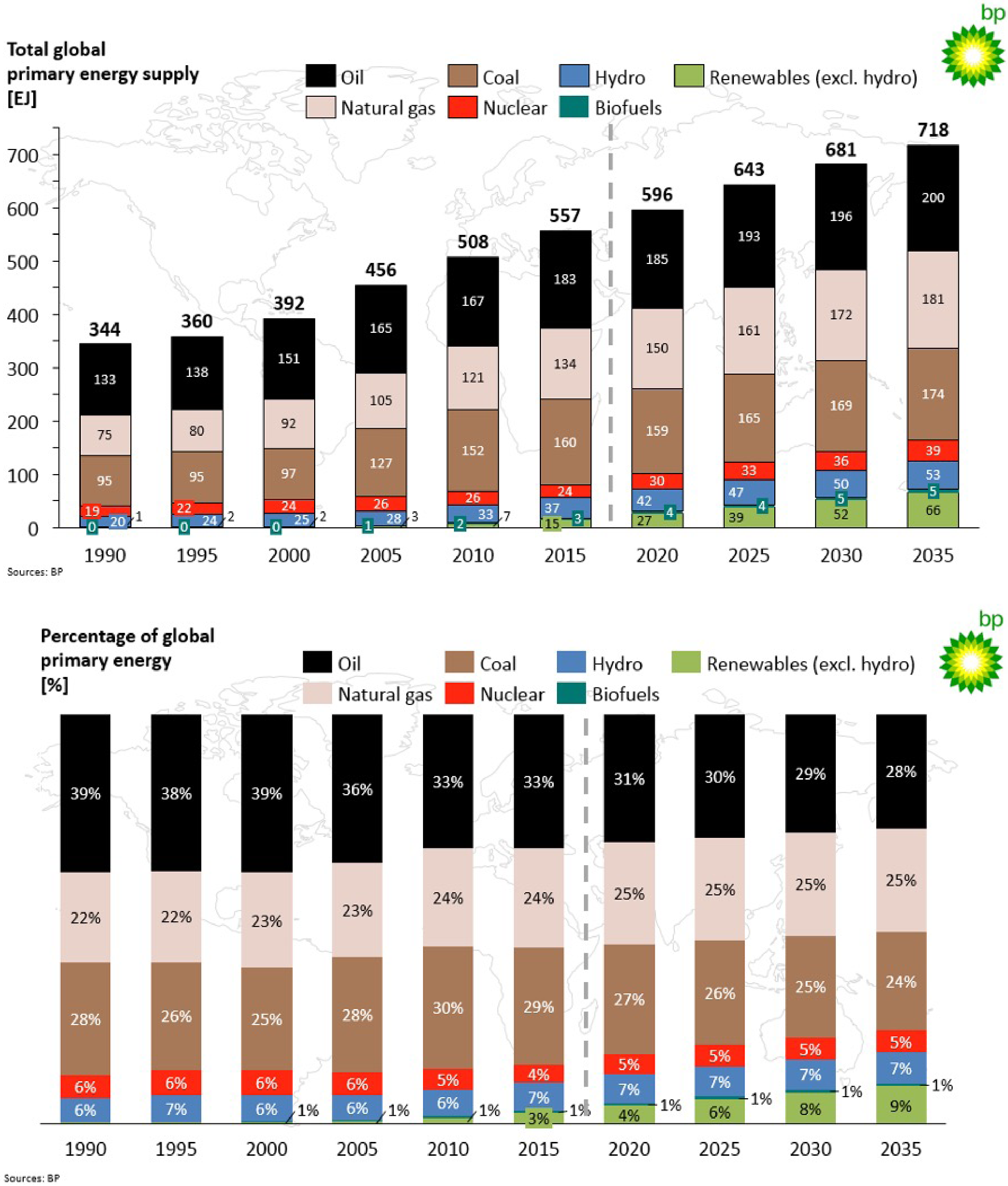
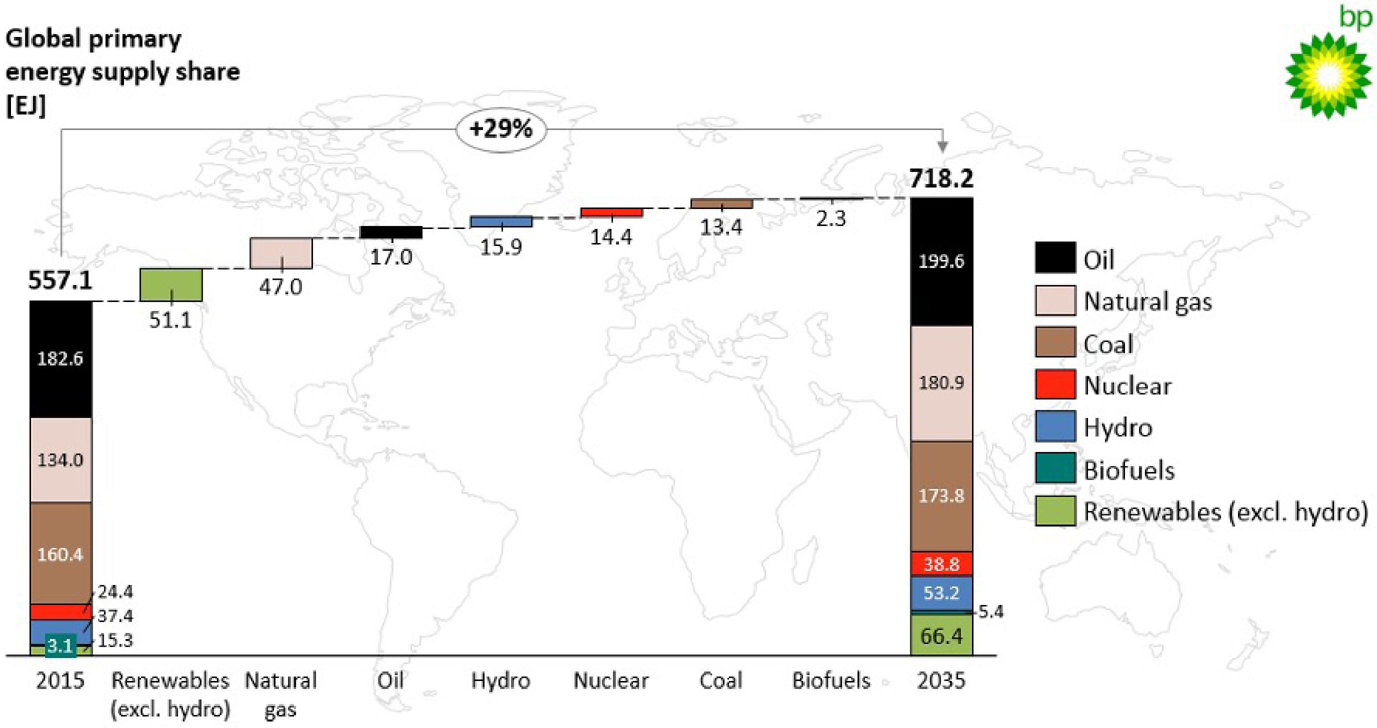
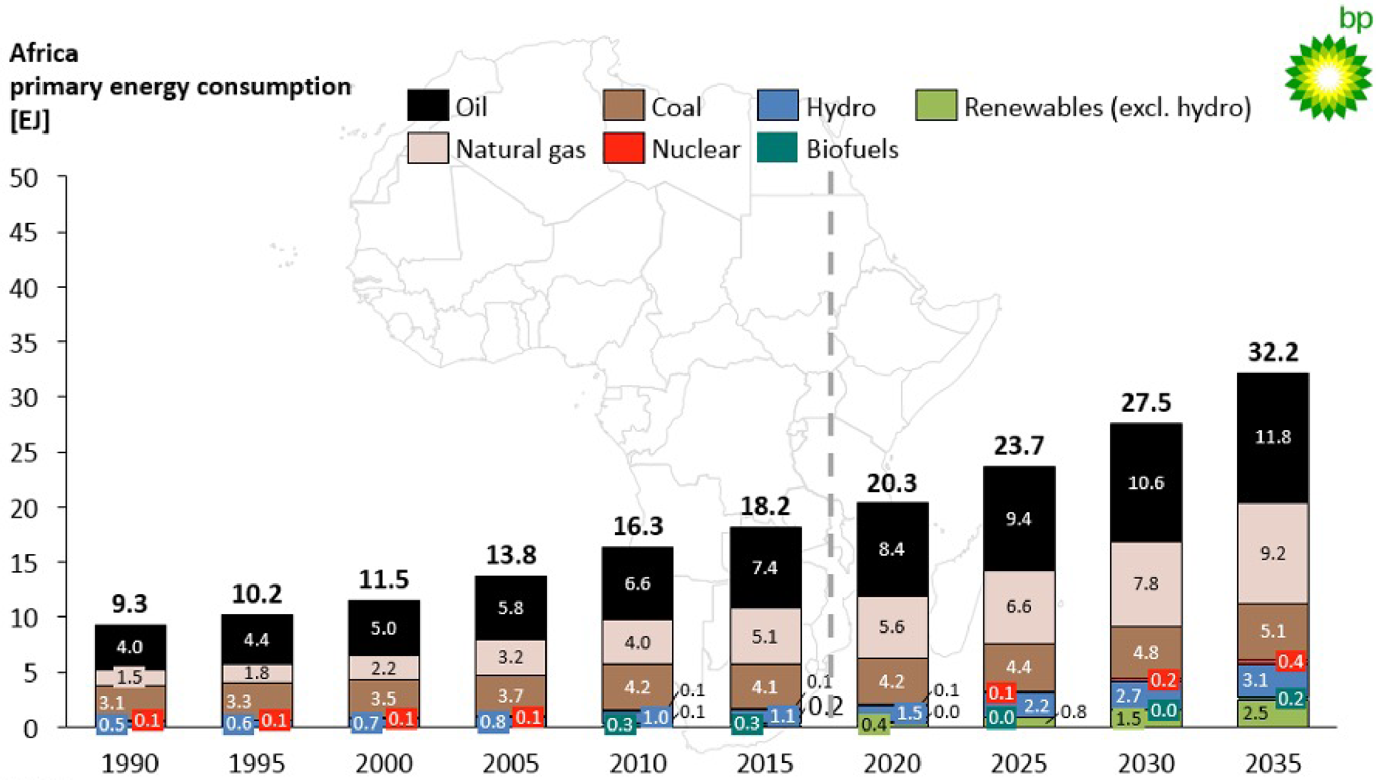


Figure 11. Total global primary energy supply and share to 2035 (BP Energy Outlook, Base Case)

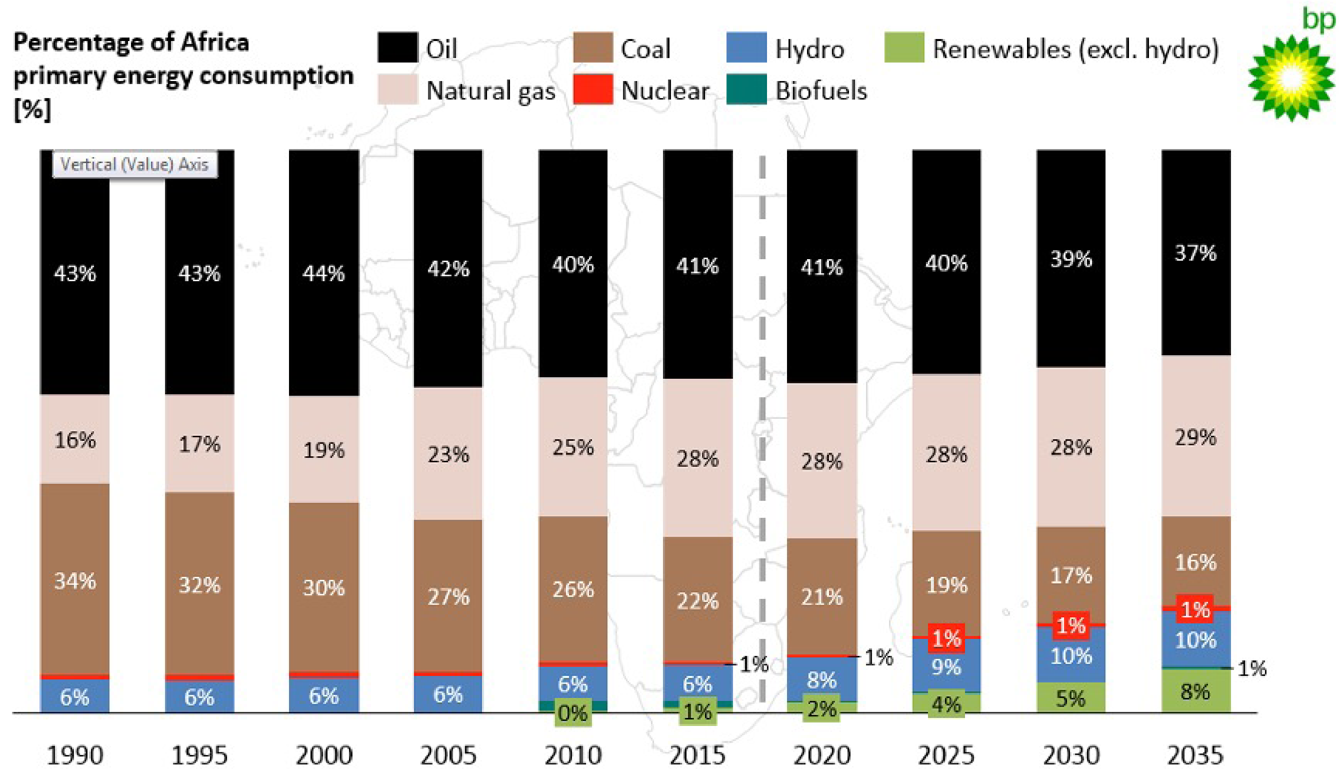


Sources: BP

Figure 12. Breakdown of change in primary energy carriers to 2035 (BP Energy Outlook, Base Case)



Sources: BP



Sources: BP

Figure 13. Total Africa primary energy consumption and share to 2035 (BP Energy Outlook, Base Case)

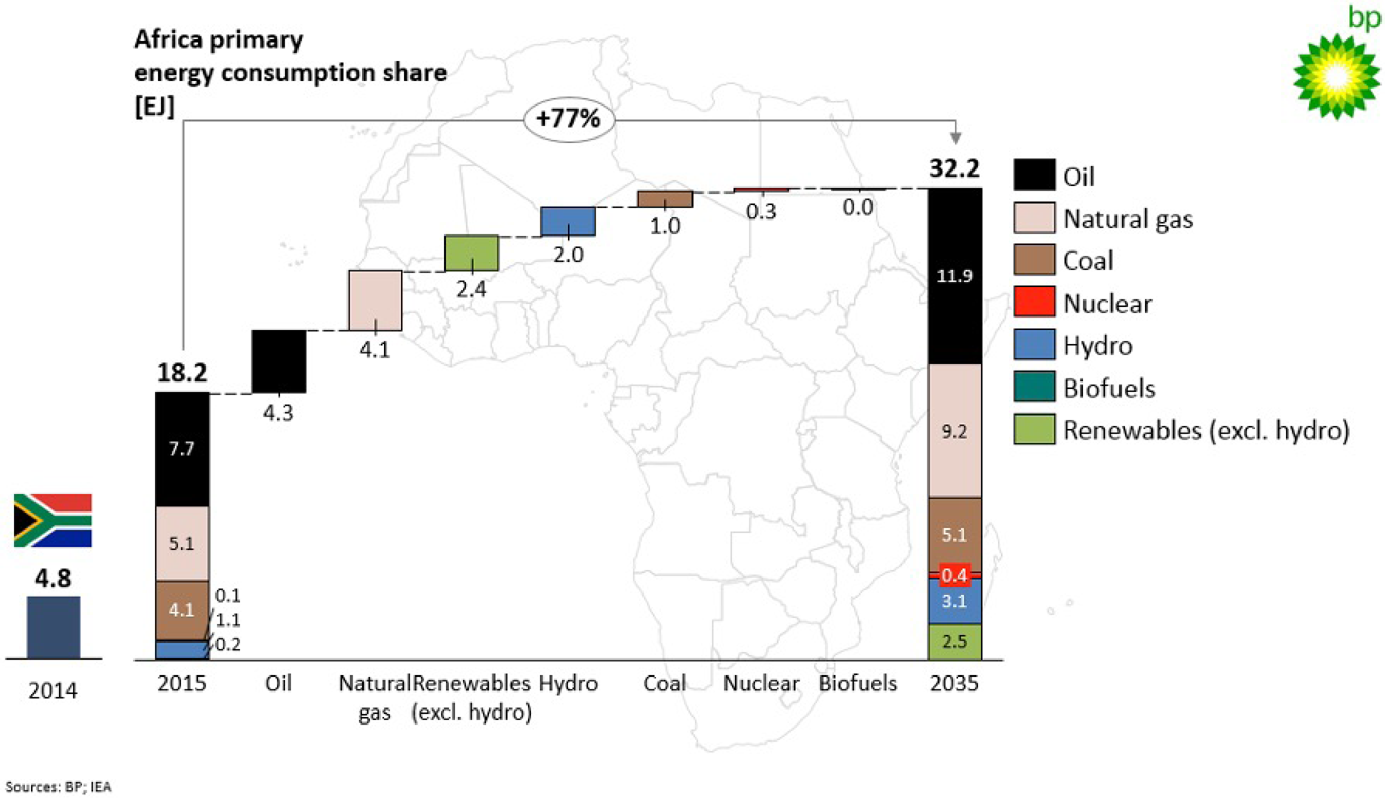


Figure 14. Breakdown of change in primary energy consumption in Africa to 2035 (BP Energy Outlook, Base Case)

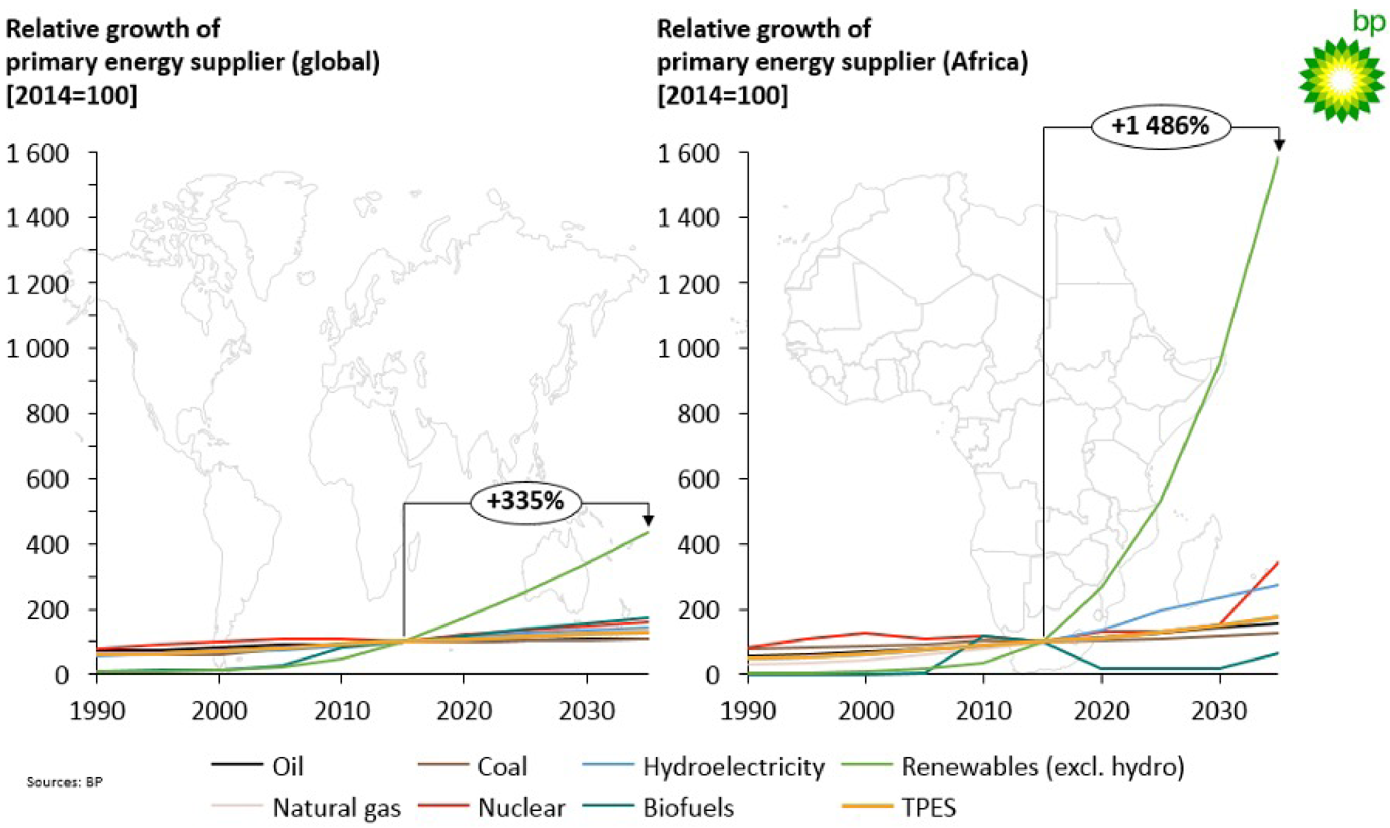
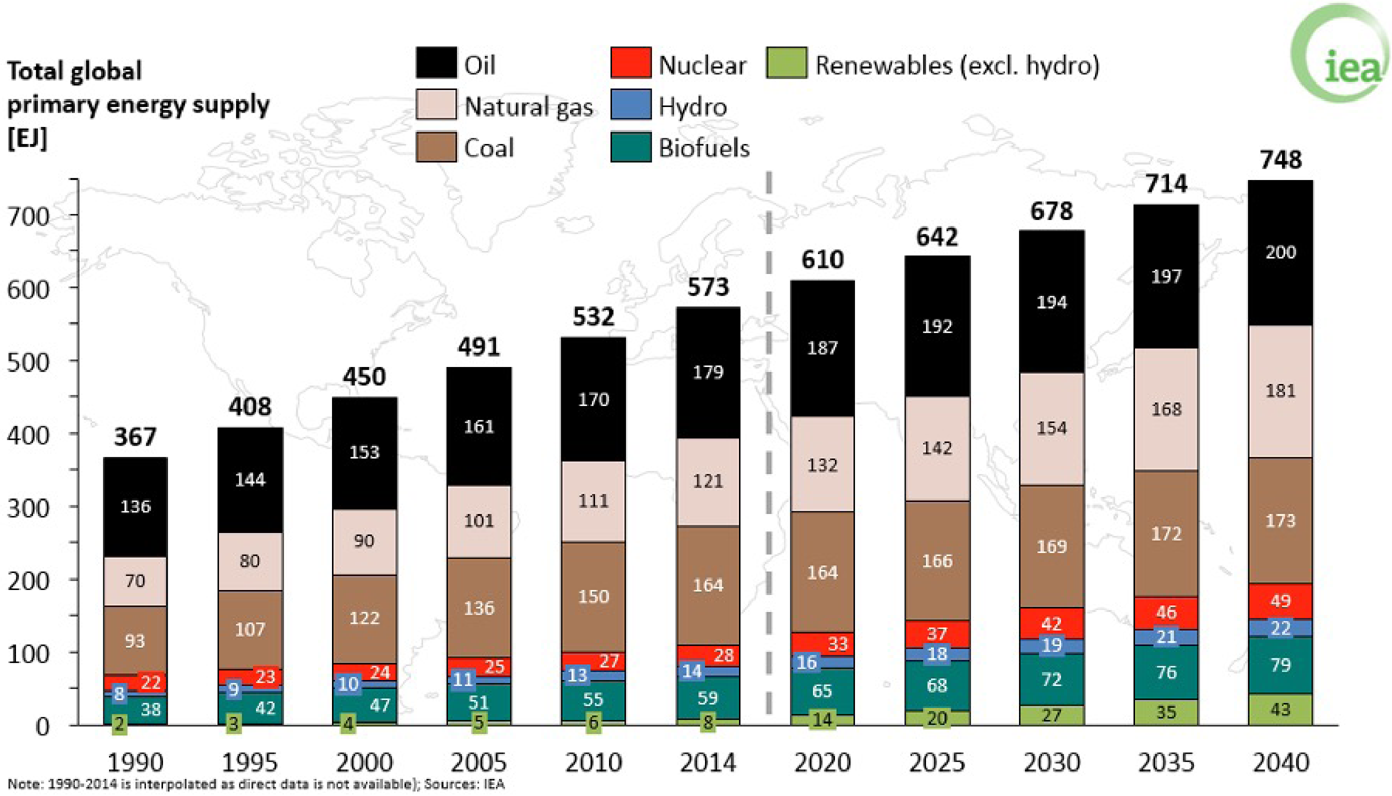


Figure 15. Relative growth expected in primary energy suppliers globally and in Africa to 2035 (BP Energy Outlook, Base Case)



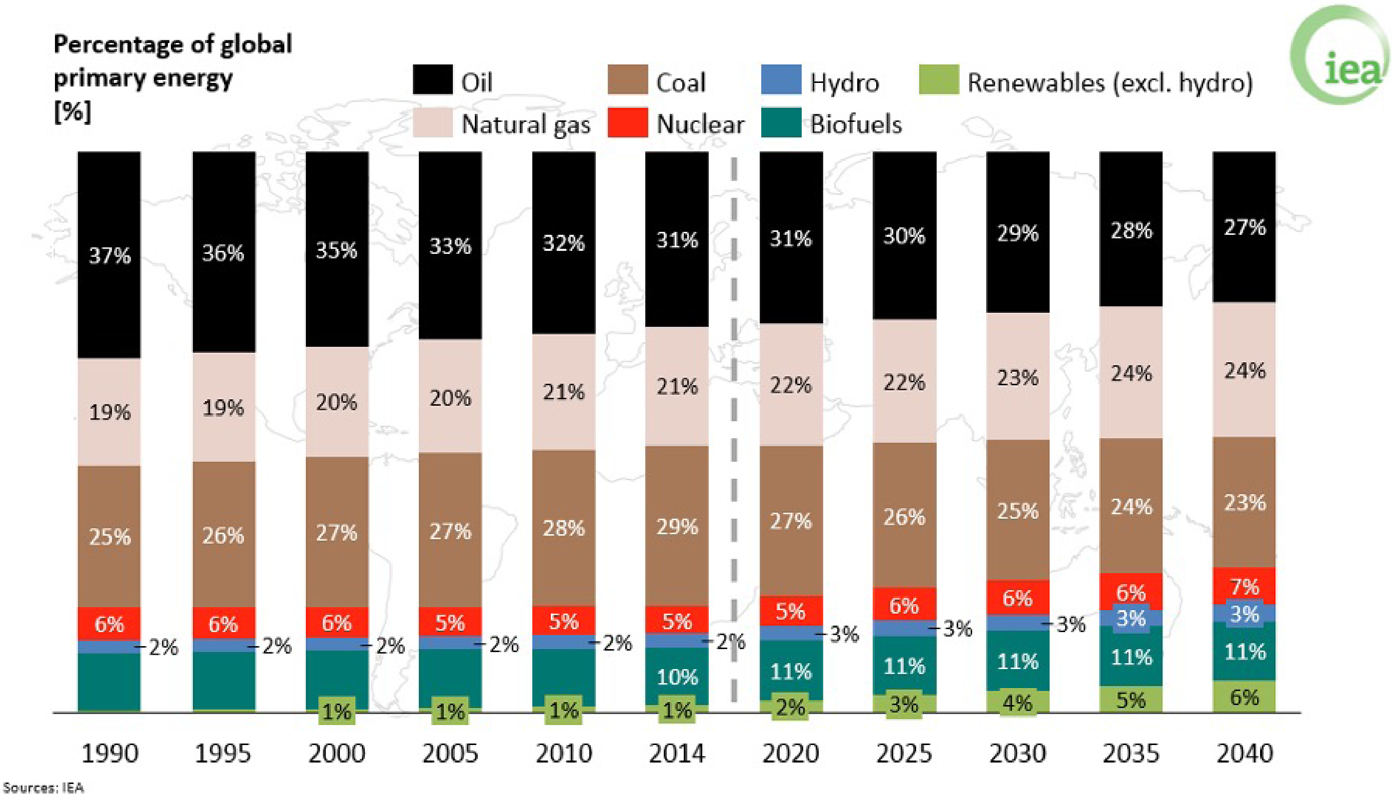
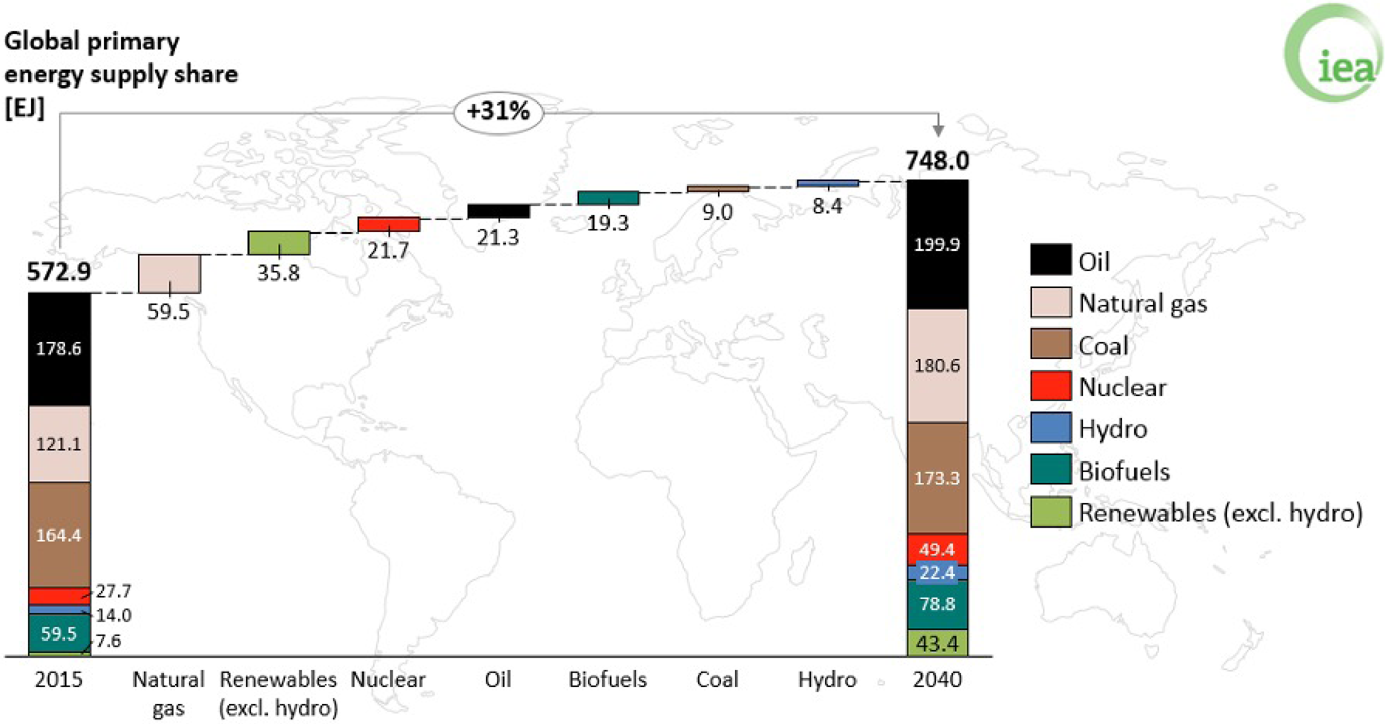
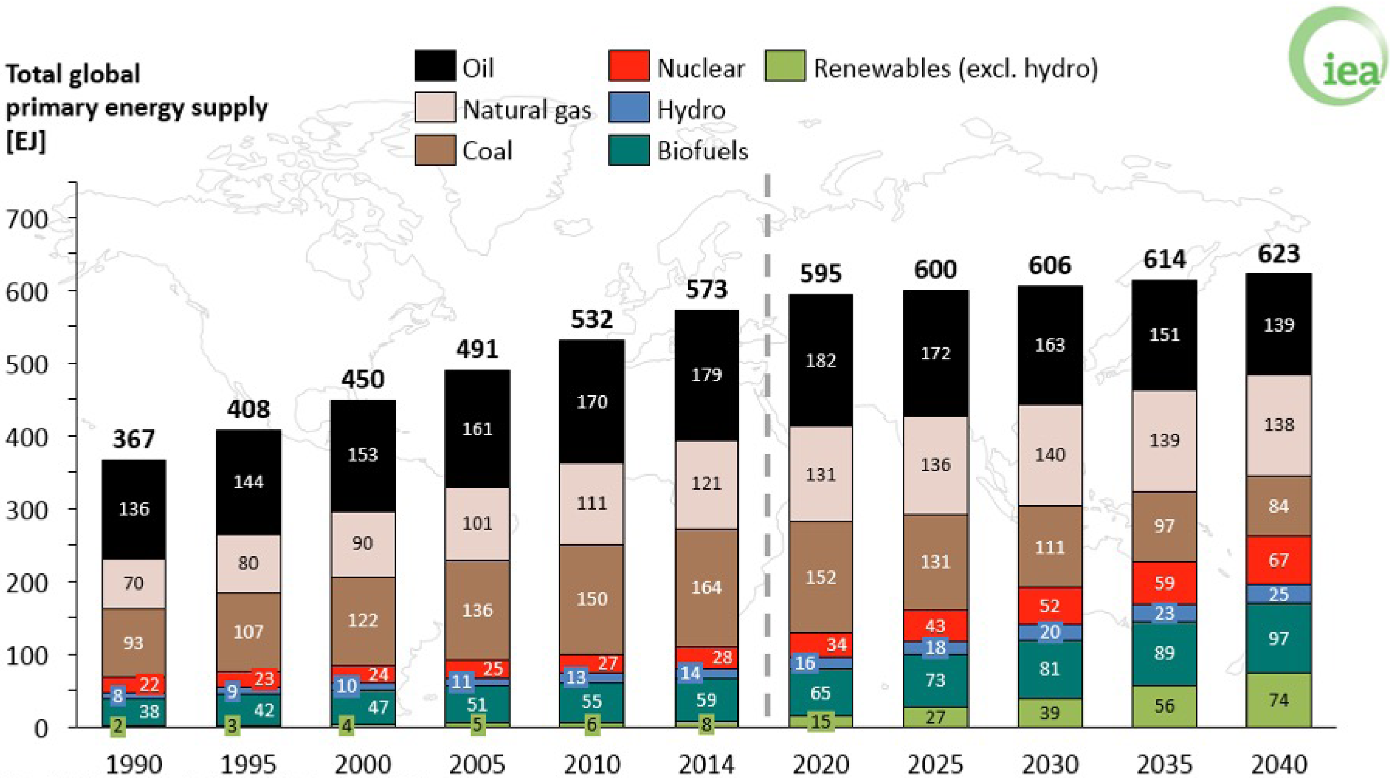


Figure 16. Total global primary energy consumption and share to 2040 (IEA Annual Energy Outlook, New Policies)

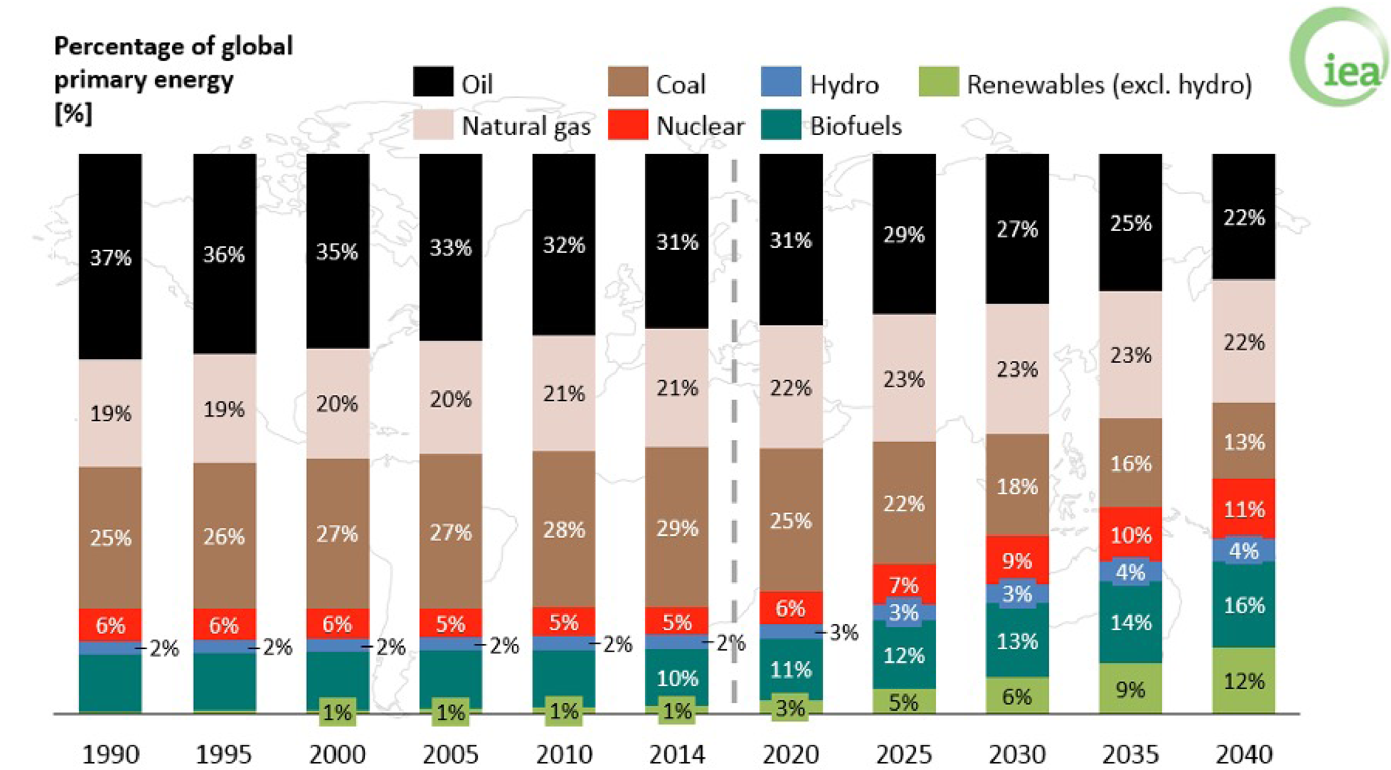


Sources: IEA

Figure 17. Breakdown of change in primary energy consumption globally to 2040 (IEA World Energy Outlook, New Policies)



Note: 1990-2014 is interpolated as direct data is not available); Sources: IEA



Sources: IEA

Figure 18. Total global primary energy consumption and share to 2040 (IEA Annual Energy Outlook, 450 scenario)

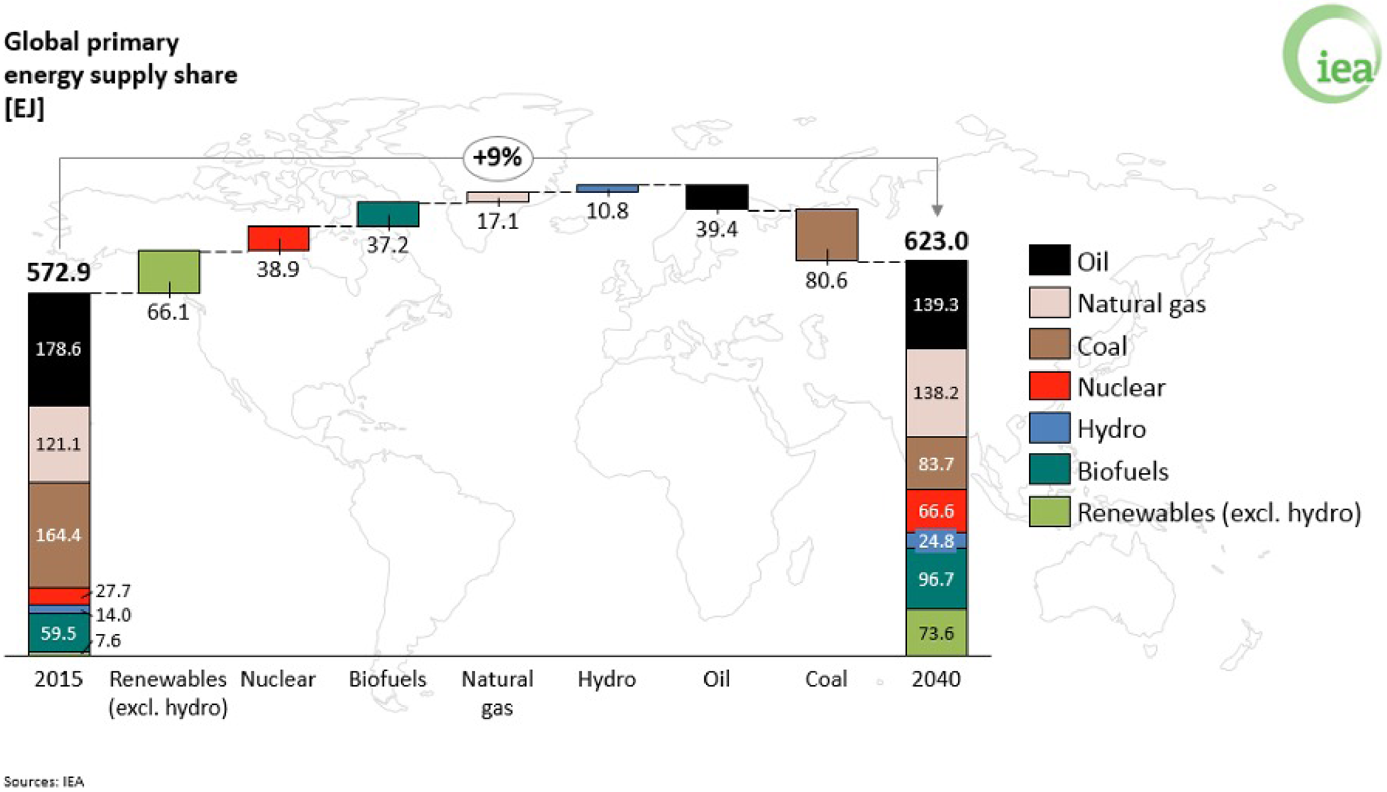
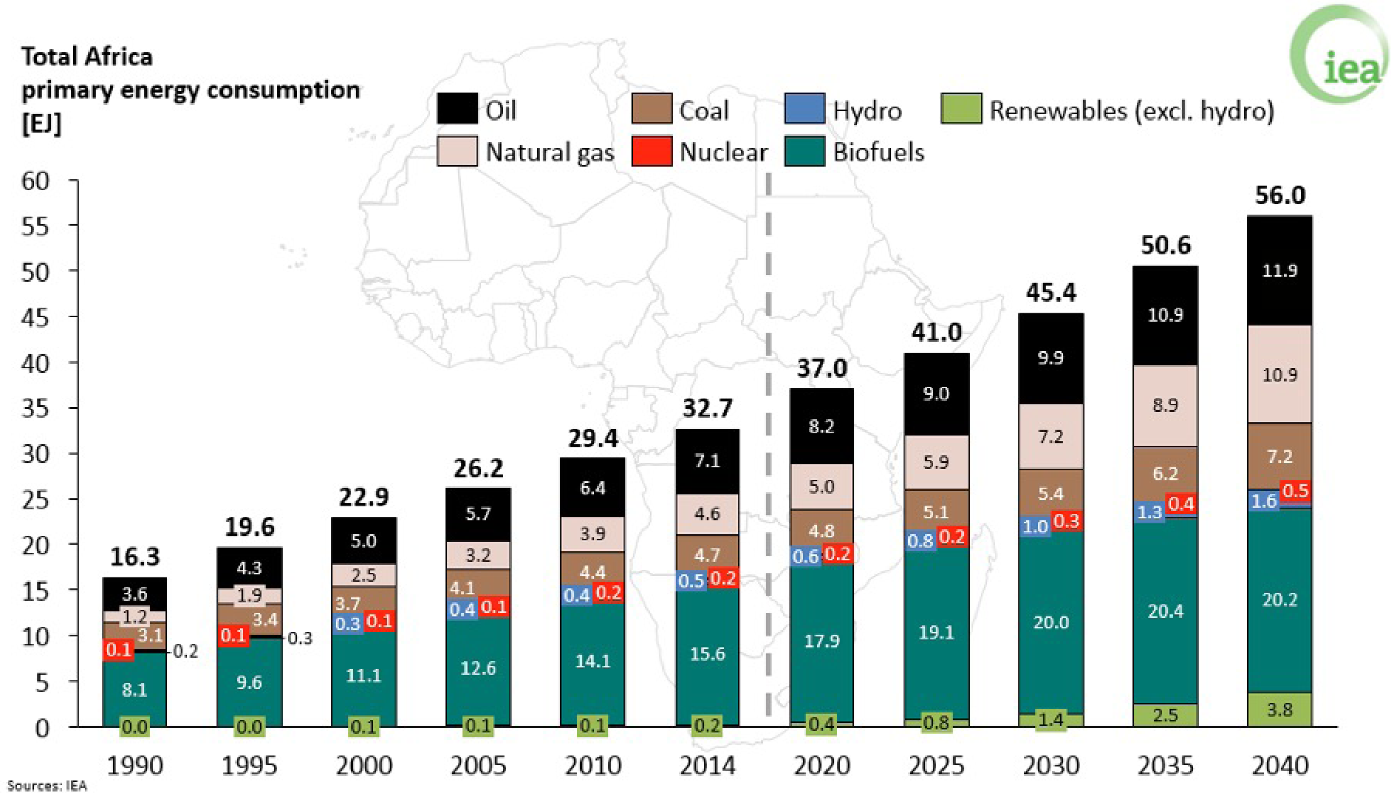


Figure 19. Breakdown of change in primary energy consumption globally to 2040 (IEA World Energy Outlook, 450 scenario)



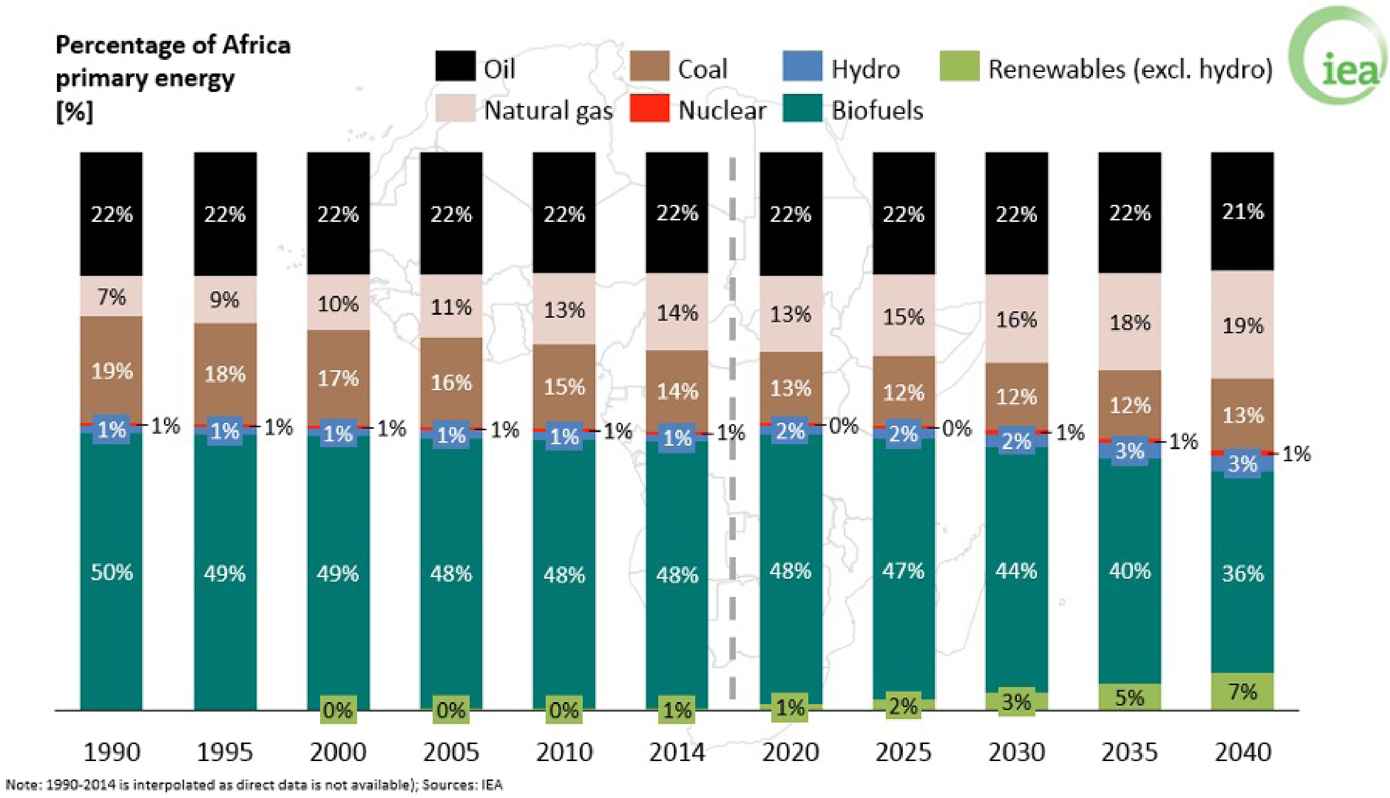
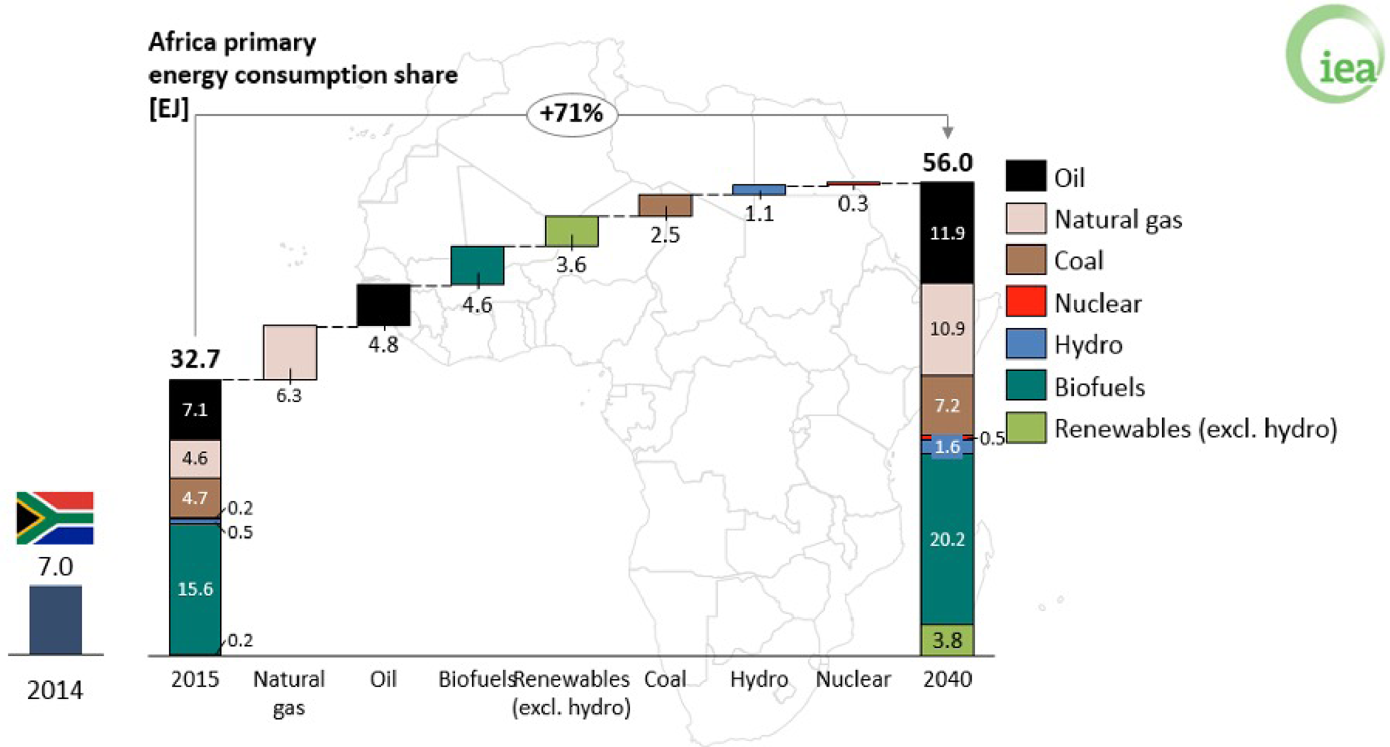
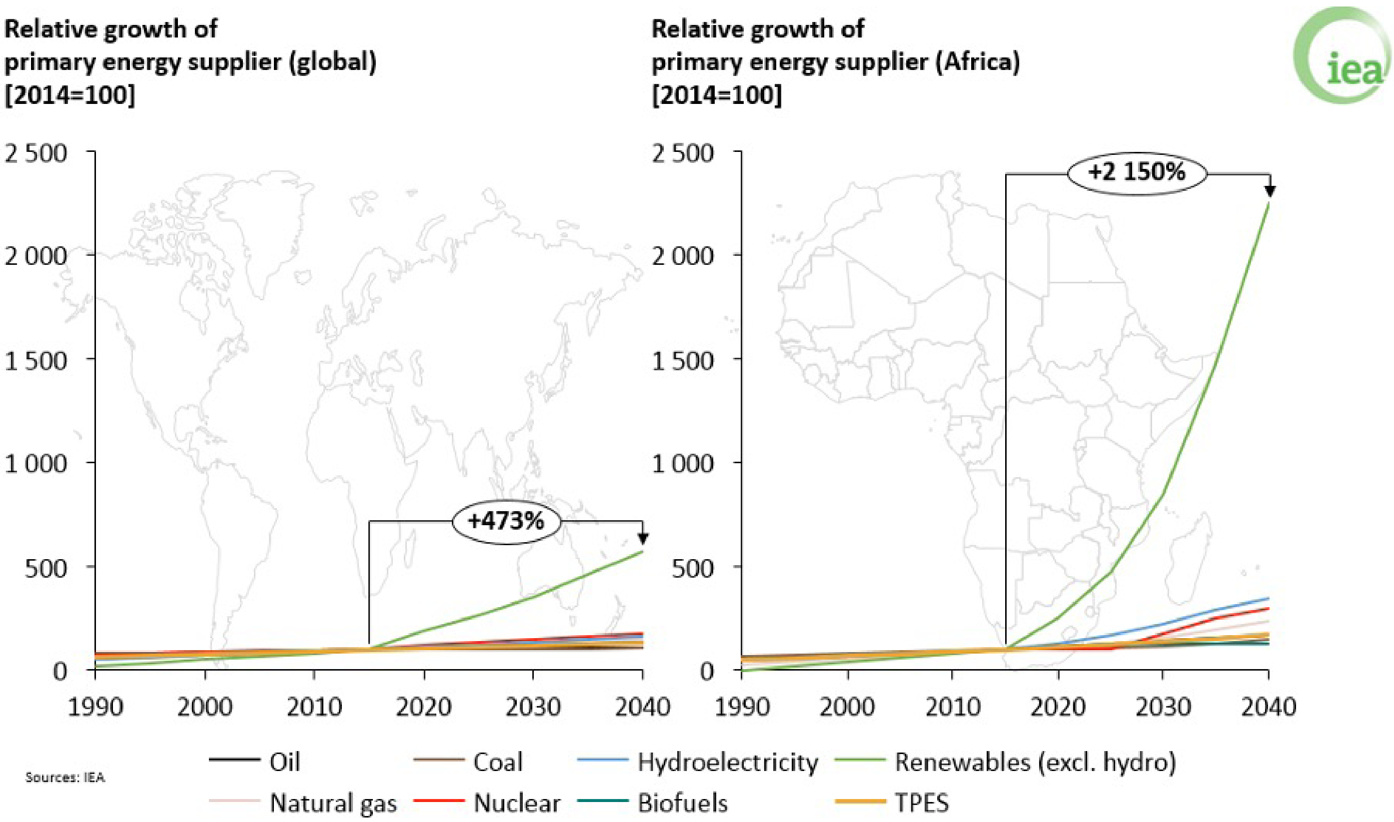


Figure 20. Total Africa primary energy consumption and share to 2040 (IEA Annual Energy Outlook, New Policies)



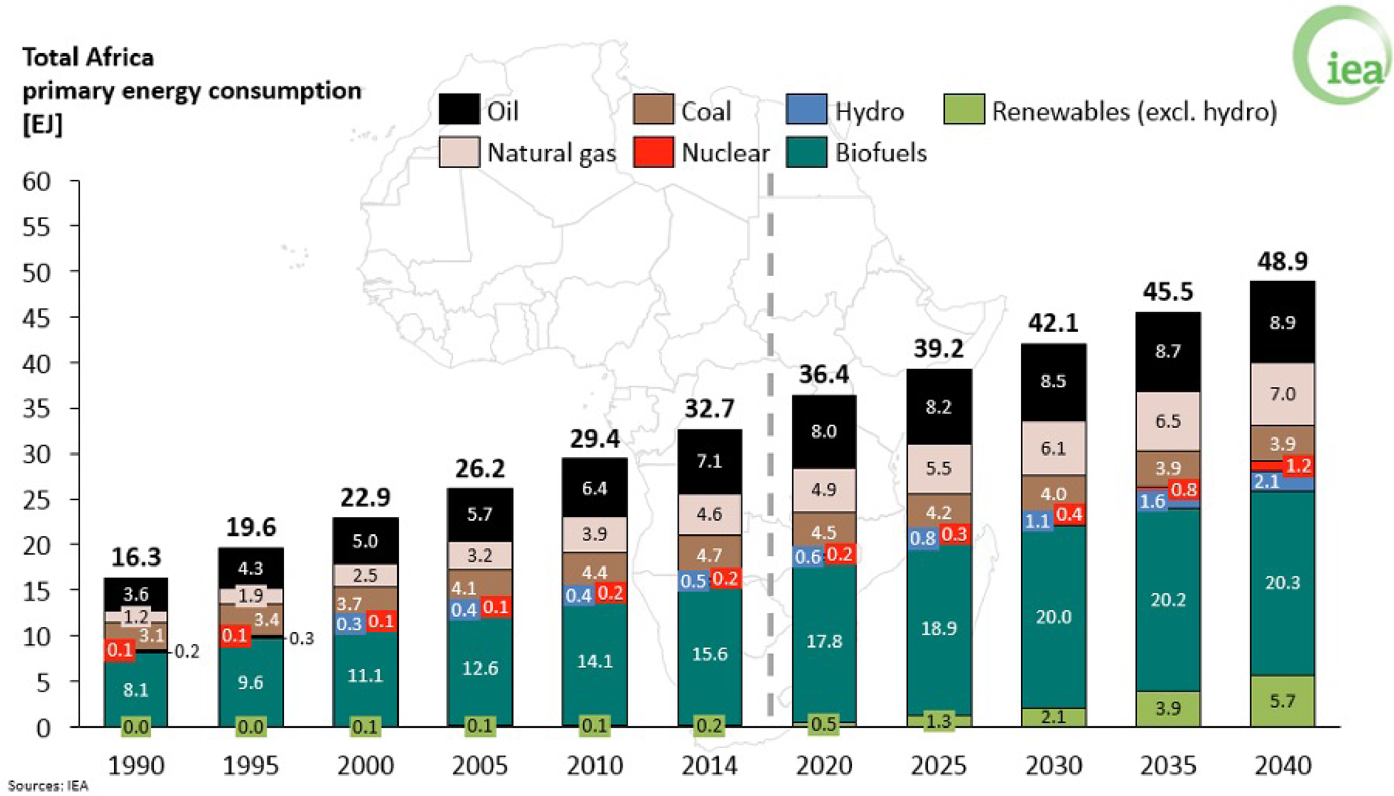
Sources: IEA

Figure 21. Breakdown of change in primary energy consumption in Africa to 2040 (IEA World Energy Outlook, New Policies)



Sources: IEA

Figure 22. Relative growth expected in primary energy suppliers globally and in Africa to 2035 (IEA World Energy Outlook, New Policies)



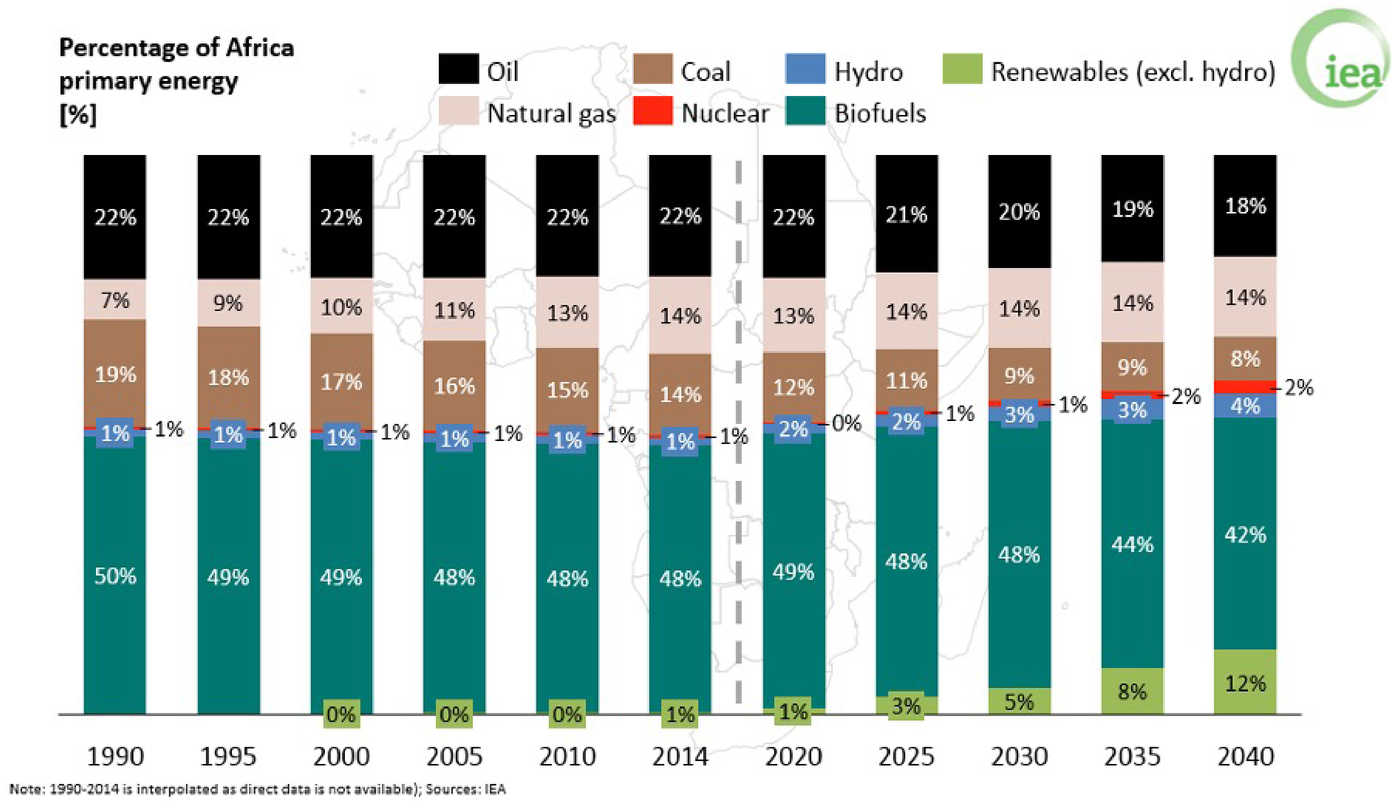
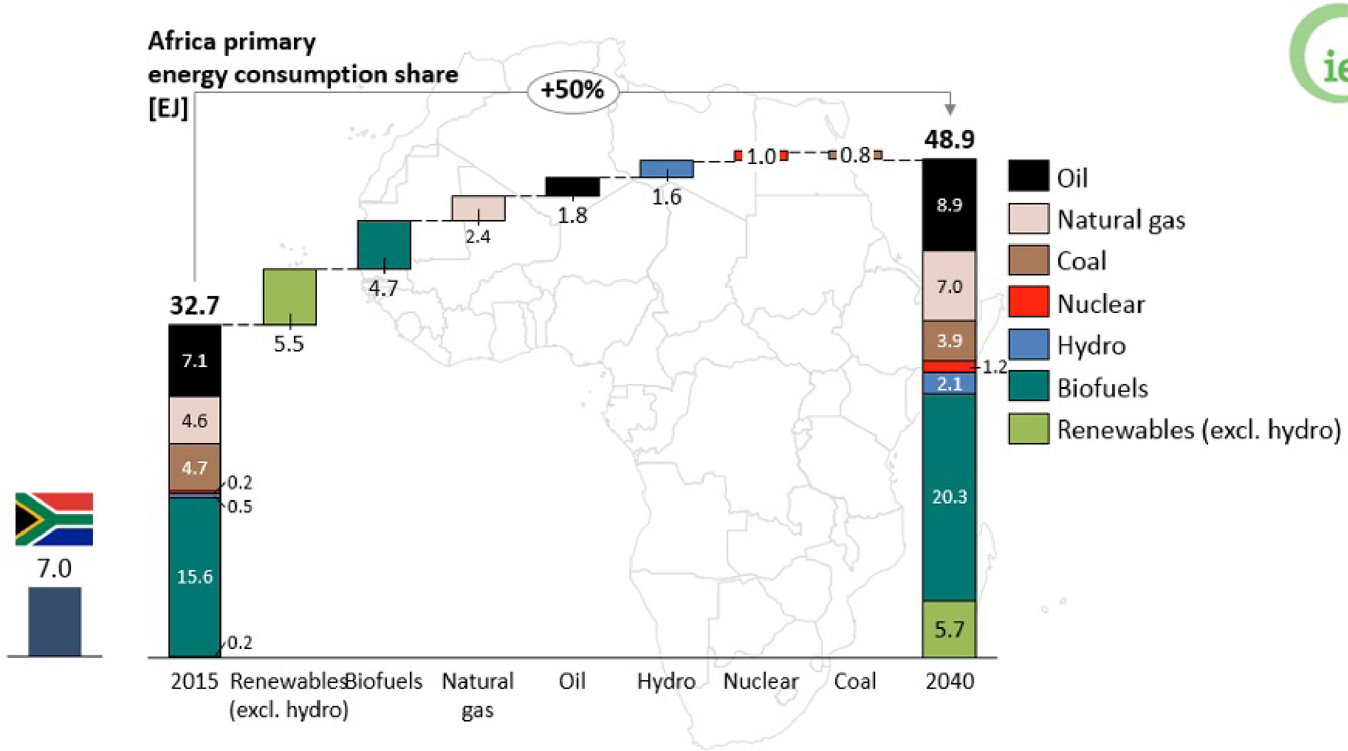
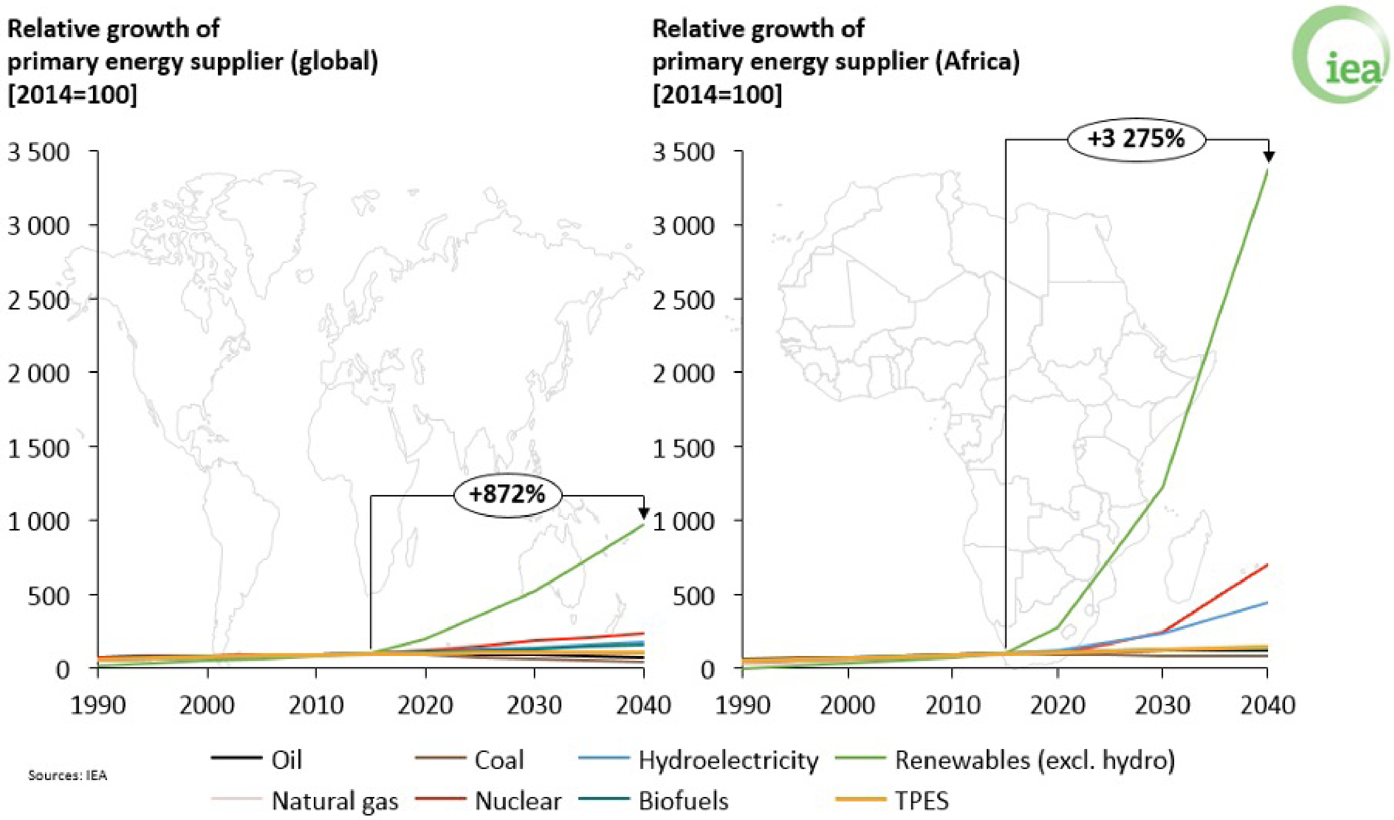


Figure 23. Total Africa primary energy consumption and share to 2040 (IEA Annual Energy Outlook, 450 scenario)



Sources: IEA

Figure 24. Breakdown of change in primary energy consumption in Africa to 2040 (IEA World Energy Outlook, 450 scenario)



Sources: IEA

Figure 25. Relative growth expected in primary energy suppliers globally and in Africa to 2035 (IEA World Energy Outlook, New Policies)

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