NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

In the matter regarding

Concurrence with the ministerial determination on the procurement of 2 500MW new generation capacity from nuclear

By

DEPARTMENT OF MINERAL RESOURCES AND ENERGY (DMRE)

DECISION

Based on the available information and analysis conducted on the draft determination submitted by the Minister of Mineral Resources and Energy in terms of section 34 of the Electricity Regulation Act, 2006 (Act No 4 of 2006), at its meeting held on 26 August 2021, the Energy Regulator decided to concur with the following:

1. The commencement of the process to procure the new nuclear energy generation capacity of 2 500MW as per Decision 8 of the Integrated Resource Plan for Electricity 2019 – 2030 (published as GN 1360 of 18 October 2019 in Government Gazette No. 42784) (IRP 2019) subject to the following suspensive conditions:

   1.1. Satisfaction of Decision 8 of the IRP 2019 which requires that the nuclear build programme must be at an affordable pace and modular scale that the country can afford because it is no regret option in the long term. This will require the following to be satisfied:

      1.1.1 Recognition and taking into account technological developments in the nuclear space.

      1.1.2 To further establish rationality behind the 2 500MW capacity of nuclear, a demand analysis aimed at determining the envisaged load profile post 2030, to derive the generation mix that would be needed to meet the envisaged demand. This will assist to determine the capacity and the scale at which the country would need to procure additional power generation from various technologies, including nuclear.

2. The generator of the electricity produced will be Eskom Holdings (SOC) Limited (Eskom), or any other organ of state, or in partnership with any other juristic person.

3. The buyer of the electricity will be Eskom Holdings (SOC) Limited or any entity determined through the Eskom's unbundling process as the future buyer of electricity.

4. The procurer of the nuclear new build programme will be the Department of Mineral Resources and Energy, or any other organ of state, or in partnership with any other juristic person.

5. The procurer designated above will be responsible for determining the procurement process, which will be established through a tendering procedure that is fair, equitable, transparent, competitive and cost-effective, subject to

   5.1 the new nuclear power being procured on an Engineering Procurement and Construction (EPC) contract rather than through fragmented contracts.

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ABBREVIATIONS AND ACRONYMS

CCGT	combined cycle gas turbines
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated Solar Plant
DEA	Department of Environmental Affairs
DMRE	Department of Mineral Resources and Energy
Dx	Distribution
EIA	Environmental Impact Assessment
ERA	Electricity Regulation Act, 2006 (Act No. 4 of 2006)
ESI	Electricity Supply Industry
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
GWh	Gigawatt hour
HELE	High efficiency low emissions
IAEA	International Atomic Energy Agency
IDC	Interest During Construction
INPO	Institute of Nuclear Power Operators
IPP	Independent Power Producer
IRP	Integrated Resource Plan
ISMO	Independent System and Market Operator
MCR	Maximum Continuous Rating
MW	Megawatt
NNBP	Nuclear New Build Programme
NERA	National Energy Regulator Act, 2004 (Act No. 40 of 2004)
NERSA	National Energy Regulator of South Africa
NPP	Nuclear power plant
OCGT	Open cycle gas turbine

PV	Photovoltaic
PWR	Pressurised Water Reactor
RfD	Reasons for Decision
RFI	Request for Information
RE	Renewable Energy
SAPP	Southern African Power Pool
SMR	Small Modular Reactors
SO	System Operator
SOE	State-Owned Enterprise
TWh	Terawatt hour
Tx	Transmission
VRE	Variable Renewables Energy
WANO	World Association of Nuclear Operators

DEFINITIONS

In this document, any word or expression shall have the meaning assigned below, unless the context indicates otherwise.

'Ancillary services'[1] means services supplied to the national transmission company by generators, which are necessary for the reliable and secure transport of electricity from generators to distributors and customers.

'Base load plant'[2] refers to energy plants or power stations that are able to produce energy at a constant, or near constant, rate, i.e. power stations with high capacity factors.

'Base load demand'[3] the baseload demand (also base load) on a grid is the minimum level of demand on an electrical grid over a span of time, for example, one week.

'Buyer'[4] means, in relation to a new generation capacity project, any organ of state designated by the Minister of Mineral Resources and Energy ('the Minister') in terms of section 34(1)(c) and (d) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) ('the ERA').

[1] Definition obtained from New Generation Regulation 2011
[2] IRP 2010
[3] www.merriam-webster.com. Merriam Webster Dictionary. Retrieved 2021-09-22
[4] Definition obtained from New Gen Regs

'Capacity[5]' means, in relation to a Unit or the Facility, at any time and from time to time, the output power (expressed in megawatts or MW) of such unit, as the case may be.

'Capacity Factor[6]' refers to the expected output of the plant over a specific time period as a ratio of the output if the plant operated at full-rated capacity for the same time period.

'Dispatch'[7] means the scheduling, coordination and management of the flow of electricity produced by generation facilities or consumed by the demand-side resource into and out of the national transmission power system, including the start-up and shut-down of those facilities.

'Dispatchable'[8] means the System Operator (SO) is authorised to influence the dispatch of the generator or demand-side resource, and the generator or demand-side resource is able to respond to automatic or manual SO dispatch instructions.

'Energy'[9] means the electricity produced by, flowing through or supplied by an electric circuit over a particular time interval, being integral with respect to the time of the instantaneous power, measured in units of watt-hours (Wh) or standard multiples thereof, i.e.:

a) 1 000 Wh = 1kWh
b) 1 000 kWh = 1 MWh
c) 1 000 MWh = 1 GWh
d) 1 000 GWh = 1 TWh

'Energy Storage?'[10] is the capture of energy produced at one time for use at a later time[1] to reduce imbalances between energy demand and energy production.

'Eskom'[11] means Eskom Holdings Limited contemplated in section 3(1) of the Eskom Conversion Act, 2001 (Act No.13 of 2001).

'Government'[12] means the Government of the Republic of South Africa.

'Independent Power Producer (IPP)'[13] means any person in which the Government or any organ of state does not hold a controlling ownership interest (whether directly or indirectly), which undertakes or intends to undertake the development of new generation, pursuant to a determination made by the Minister in terms of section 34(1) of the ERA.

[5] Definition obtained from Schedule 2 of the Electricity Regulation Act
[6] Definition obtained from IRP 2019
[7] The Scheduling and Dispatch Rules, Rev. 7.2, 2016
[8] The Scheduling and Dispatch Rules, Rev. 7.2, 2016
[9] The Scheduling and Dispatch Rules, Rev. 7.2, 2016
[10] https://en.wikipedia.org/wiki/Energy_storage
[11] Definition obtained from New Gen Regs
[12] Definition obtained from New Gen Regs
[13] Definition obtained from New Gen Regs

'Inertia'[14] is a property of large synchronous generators, which contains large synchronous rotating masses, and which acts to overcome the immediate imbalance between power supply and demand for electric power systems, typically the electrical grid.

'Minister'[15] means the Minister of Mineral Resources and Energy.

'National transmission company or NTC[16]' means the person licensed to execute the national transmission responsibility, in its capacity as such, including the transmission network service provider, which maintains and develops the transmission network, but excluding the system operator.

'New generation capacity'[17] means:

a) electricity generation capacity other than the capacity of existing generation facilities;
b) the electricity derived from the capacity referred to in (a); and
c) ancillary services relating thereto, individually or in any combination thereof, and including an increase in the electricity generation capacity of existing generation facilities.

'New generation capacity project'[18] means a project for the development of new generation capacity, pursuant to a determination made by the Minister in terms of section 34 of the ERA.

'Organ of state'[19] bears the meaning ascribed to it in section 239 of the Constitution.

'Peaking plant'[20] means the energy plants or power stations that have very low capacity factors, i.e. generally produce energy for limited periods, specifically during peak demand periods, with storage that supports energy on demand.

'Power Purchase Agreement (PPA)'[21] means an agreement concluded between a generator and a buyer for the sale and purchase of new electricity generation capacity or electricity derived therefrom, or both.

'Procurer'[22] means the person designated by the Minister in terms of section 34 of the ERA as being responsible for the preparation, management and implementation of the activities related to procurement of new generation capacity under an IPP procurement programme, including the negotiation of the applicable power purchase agreements. The procurer may or may not be a buyer.

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[14] https://en.wikipedia.org/wiki/Inertial_response
[15] New Gen Regs
[16] New Gen Regs
[17] New Gen Regs
[18] New Gen Regs
[19] New Gen Regs
[20] Definition obtained from the IRP 2019
[21] Definition obtained from New Gen Regs
[22] New Gen Regs

'Self-dispatched generation unit'[23] refers to an operating regime where a generating unit or facility output is determined by the generator under normal system conditions except where curtailment rules apply.

'The Act' means the Electricity Regulation Act, 2006 (Act No. 4 of 2006).

[23] The Scheduling and Dispatch Rules, Rev. 7.2, 2016

1. LEGAL MANDATE TO CONSIDER THE DRAFT DETERMINATION

1.1 NERSA Application of its Legal Mandate

1.1.1 The National Energy Regulator of South Africa (NERSA) has been established as the custodian of the electricity supply industry (ESI) regulatory framework. The participation of NERSA as the custodian of the regulatory framework can be derived by proactively developing mechanisms to enable regulation, implementing existing legal framework or participating in the development of the framework.

1.1.2 Section 34 of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) ('the ERA') locates the powers to initiate new generation capacity. NERSA does not have the powers to initiate the need for new generation capacity. Despite not having the powers to initiate the need for new generation capacity, the process cannot move forward without an approval by NERSA. Section 34 of the Act re-emphasises the powers of NERSA as the custodian of the regulatory framework. It must also be clear from the onset that section 34 of the Act does not generate the powers to NERSA similar to the mandate outlined in Section 34 of the Act.

1.1.3 Section 34 of the ERA designates the Minister of Mineral Resources and Energy ('the Minister') as the authority that must generate the determination. The powers of the Minister are not without a proviso. The section goes further to demand that, in order to implement the determination decision, such exercise must be in consultation with NERSA. The 'in consultation' principle carries the power to the finalisation of the draft determination.

1.1.4 The ERA does not expand on how NERSA should go about meeting the dictates of section 34 of the ERA. The silence of the section on how NERSA should address the dictates of section 34 is pivoted on the existing application of the 'in consultation' principle. In consultation demands that the concurrence of NERSA must be sought by the Minister before exercising delegated powers. This known legal principle has generated a mandate to NERSA to process the determination.

1.1.5 The absence of concurrence by NERSA with regard to the draft determination renders the proposition by the Minister unachievable. It is also clear that when NERSA concurs, our consideration is on what has been provided in the draft determination and within the provisions of section 34 of the ERA.

1.1.6 Is the Minister bound by the IRP in making a section 34 determination? This aspect has been examined and it has been widely acknowledged that there is a settled distinction between law and policy. For policy to find its way into law, if the law has recognised and incorporated its applicability, the IRP does not equate to the new generation capacity provided for in section 35(4)(j) of the ERA.

1.1.7 What is an IRP? It is a coordinated schedule for generation expansion and demand-side intervention programmes, considering multiple criteria to meet electricity demand including least-cost electricity supply and demand balance, security of supply and the environment. It is also acknowledged that the IRP is a Government policy approved by the Cabinet, with the Minister as its custodian.

1.1.8 The IRP has not created a hard and fast rule that must be implemented as planned. It recognises that while the purpose of the IRP is to balance supply and demand on a least-cost basis, implementation lead times for various generation technologies limit the options available for deployment immediately and in the short term. Therefore, the Minister cannot avoid considering the IRP when proposing new generation capacity but whatever basket of factors at his disposal, the objectives of the IRP must be at the forefront. The IRP provides that *Following the promulgation of the IRP 2010–2030, implementation followed in line with Ministerial Determinations issued under Section 34 of the Electricity Regulation (Act No. 4) of 2006. The Ministerial Determinations give effect to planned infrastructure by facilitating the procurement of the required electricity capacity*[24].

1.1.9 The key question that emerges is *if the Minister is bound by the IRP in making determinations, how does the Minister grant deviations therefrom in respect of Section 10(2)(g) of the NERA?* As alluded to above, the IRP is not law but a Government policy which the Government must adhere to with regard to electricity-related matters. Section 10(2)(g) is a statutory provision recognising and enabling investor participation in generation. Despite the fact that section 10(2)(g) enables the Minister to deviate from the IRP, the approach towards the approval is not beyond legality reproach.

1.1.10 The objects of the ERA, as stipulated in section 2, are to:

a. *Achieve the efficient, effective, sustainable and orderly development and operation of electricity supply infrastructure in South Africa;*
b. *Ensure that the interests and needs of present and future electricity customers and end users are safeguarded and met, having regard to the governance, efficiency, effectiveness and long-term sustainability of the*

[24] IRP 2019, Pg. 14

ESI within the broader context of economic energy regulation in the Republic;

c. *Facilitate investment in the ESI;*
d. *Facilitate universal access to electricity;*
e. *Promote the use of diverse energy sources and energy efficiency;*
f. *Promote competitiveness and customer and end user choice; and*
g. *Facilitate a fair balance between the interests of customers and end users, licensees, investors in the ESI and the public.*

The objects of the ERA define the outcomes that all actions and decisions undertaken by NERSA in respect of its functions, seek to achieve. In concurring with the Minister's section 34 determination, the determination is gauged in relation to how closely it aligns with the objects of the ERA.

2. BACKGROUND

2.1 Ministerial Section 34 Determination

2.1.1 On 6 August 2020, NERSA received the proposed determination from the Minister in terms of section 34 of the ERA, as detailed below and attached hereto as **Annexure A**.

2.1.2 According to the DMRE, the 2 500MW for the Nuclear New Build Programme (NNBP) is informed by **Decision 8** of the Integrated Resource Plan (IRP 2019) to 'Commence preparations for a nuclear build programme to the extent of 2 500 MW at a pace and scale that the country can afford because it is a no-regret option in the long term'.

2.1.3 Furthermore, the DMRE stated that the 2 500MW for the NNBP is further informed by South Africa's Nuclear Energy Policy of 2008. Principle 3 of the policy states that 'Nuclear Energy shall form part of South Africa's strategy to mitigate climate change'.

2.2 Determination under Section 34(1) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006)

2.2.1 The Minister, in consultation with NERSA, acting under section 34(1) of the ERA and the Electricity Regulations on New Generation Capacity (published as GNR. 399 in Government Gazette No. 34262 dated 4 May 2011) ('the Regulations'), has determined as follows:

2.2.2 To commence the process to procure the new nuclear energy generation capacity of 2 500MW as per Decision 8 of the Integrated Resource Plan for

Electricity 2019 – 2030 (published as GN 1360 of 18 October 2019 in Government Gazette No. 42784) (‘IRP 2019’);

2.2.3 The generator of this electricity produced will be Eskom Holdings (SOC) Limited, or any other organ of state, or in partnership with any other juristic person.

2.2.4 The buyer of the electricity will be Eskom Holdings (SOC) Limited or any entity determined through the Eskom’s unbundling process as the future buyer of electricity.

2.2.5 The procurer of the nuclear new build programme will be the Department of Mineral Resources and Energy, or any other organ of state or in partnership with any other juristic person. The procurer designated above will be responsible for determining the procurement process, which will be established through a tendering procedure that is fair, equitable, transparent, competitive and cost-effective.

3. THE DECISION-MAKING PROCESS

3.1 Process Followed by NERSA to Arrive at the Decision

3.1.1 On 6 August 2020, NERSA received a proposed determination for the procurement of 2 500MW of new generation capacity from nuclear from the Minister in terms of section 34 of the ERA.

3.1.2 On 11 November 2020, NERSA’s Electricity Subcommittee (ELS) approved the NERSA Consultation Paper on the proposed procurement of new generation capacity.

3.1.3 On 23 November 2020, NERSA published the consultation paper, requesting stakeholders to submit written comments. This enabled NERSA to appropriately apply its regulatory reviews and decision-making prior to concurrence with the Minister.

3.1.4 The closing date for the submission of comments was 5 February 2021.

3.1.5 NERSA conducted public hearings virtually on 23 and 24 February 2021 to solicit comments from interested and affected stakeholders.

3.1.6 NERSA received 304 comments from individual stakeholders. Out of the 304 individual stakeholder comments, 235 comments were opposed to NERSA concurring with the ministerial determination, 59 were supportive and 10 were on the fence.

3.1.7 NERSA received 53 substantive comments from several organisations. Comments were received from municipalities, energy specialists, energy developers, mining houses, environmentalist organisations, consulting engineers, lawyers, state-owned enterprises (SOEs) – including Eskom and the South African Nuclear Energy Corporation Ltd (NECSA) – universities, unions, consumer associations, research institutions, nuclear organisations and nuclear developers.

3.1.8 Out of the 53 stakeholders, 28 were supportive of the determination by the Minister and 24 were opposed to it with some indicating that they were objecting to it entirely, one stakeholder was on the fence. The written comments from organisations are summarised in **Annexure B**.

3.1.9 NERSA sourced the services of Senior Council (SC) to obtain legal counsel on the determination, due to several legal concerns that surfaced during the processing thereof.

3.1.10 The Energy Regulator made a determination on the concurrence on **26 August 2021**.

4. ISSUES RAISED IN ASSESSING THE DETERMINATION

4.1 Classification of Stakeholder Comments

4.1.1 Section 10 of NERA states that every decision made by the Regulator (NERSA) must be taken within a procedurally fair process in which affected persons have the opportunity to submit their views and present relevant facts and evidence to the Energy Regulator.

4.1.2 During the public hearings and from the stakeholders that submitted comments, a number of issues were raised concerning the Minister’s nuclear section 34 determination. Issues raised by those who supported the determination included the following:

- **Generating capacity** – the country needs baseload capacity to replace the 24 100MW of baseload coal that will be decommissioned post 2030.
- **Job creation** – the nuclear power build programme will create manufacturing and construction jobs during the build as well as during operation, including the mining of the fuel. It will also have major long-term benefits on our industry, including industrialisation and manufacturing, leading to further job creation in the future.

- **Varied energy mix** – most modes of production should be included in the 'energy mix', subject to everything being contextually and economically rational.

4.1.3 Issues raised by those who did not support the Minister's determination included the following:

- **Affordability** – the country cannot afford the project and renewables are a cheaper alternative.
- **Alignment with the IRP 2019** – the Minister's determination is not aligned with the IRP 2019. There is a need for studies to confirm the energy path post 2030, as per the IRP recommendation. Furthermore, there is a need to update the IRP.
- **Invalidity of the baseload term** – the concept of baseload is no longer valid in today's modern power systems. What is needed is a flexible grid that can support increased penetration of renewables. Baseload does not equate to energy security.
- **Availability of cheaper alternatives** – the availability of cheaper, renewable energy and the fact that the country cannot afford the project at present.
- **Risk of the project becoming a white elephant** – due to cost overruns during construction and unaffordability in a long run.
- **Environmental concerns** – the waste-disposal facility at Vaalputs is producing radioactive waste and harming the environment and the people dwelling in the area.
- **Need for a flexible, decarbonised grid –** the present and future demand for electricity can be met by an appropriate mix of least-cost renewable energy technologies (which exclude nuclear as the most expensive form of electricity generation), storage and demand-side management.

4.1.4 NERSA is the regulatory authority established in terms of the National Energy Regulator Act, 2004 (Act No. 40 of 2004) (NERA). The mandate of NERSA is to 'undertake the functions of the National Electricity Regulator as set out in the Electricity Regulation Act, 2006 (Act No. 4 of 2006)'. The legal mandate of the Energy Regulator to concur with the Minister is derived from the Electricity Regulation Act, 2006 (Act No. 4 of 2006) and NERA.

4.1.5 NERSA notes the issues raised by stakeholders above. However, issues raised by stakeholders that are not in line with NERSA's mandate, termed 'out-of-scope' issues will be referred to other relevant government bodies that are mandated to deal with them. Issues that are in line with NERSA's mandate termed 'in-scope' issues will be dealt with in the following sections. However, it is sufficient to state that in evaluating this determination, NERSA has steered away from matters that are out of scope in its analysis. This ensured that the analysis is not clouded with issues that are outside of NERSA's jurisdiction.

5. NUCLEAR TECHNOLOGY ASSESSMENT

5.1 Baseload Demand in South Africa

5.1.1 Baseload, as seen from the demand side, is the constant, non-variable energy consumed on a 24/7/365 basis. Base-load customers are prevalently high load factor, large industrial customers with operations that operate continuously. This demand is characterised by continuous consumption, with some load factors as high as 99%.

5.1.2 Baseload demand emanates mostly from industrial processes that require consumption of electricity at high load factors (>90%). Examples of industrial processes that run at nearly 99% load factor include aluminium smelters, ferrochrome smelters and residential applications such as refrigerators, freezers and electronics in stand-by mode. Large industrial operations sustain local economies with jobs and facilitate the growth of downstream beneficiation in the country.

5.1.3 Figure 1 below shows how the electricity demand curve varies over different periods throughout the year, from hours to seasons (left). The load duration curve (right) is derived by sorting the load curve (left) in descending order according to load duration (load factor). Using this method, different parts of the load can be distinguished, i.e. baseload, intermediate and peak load (right).

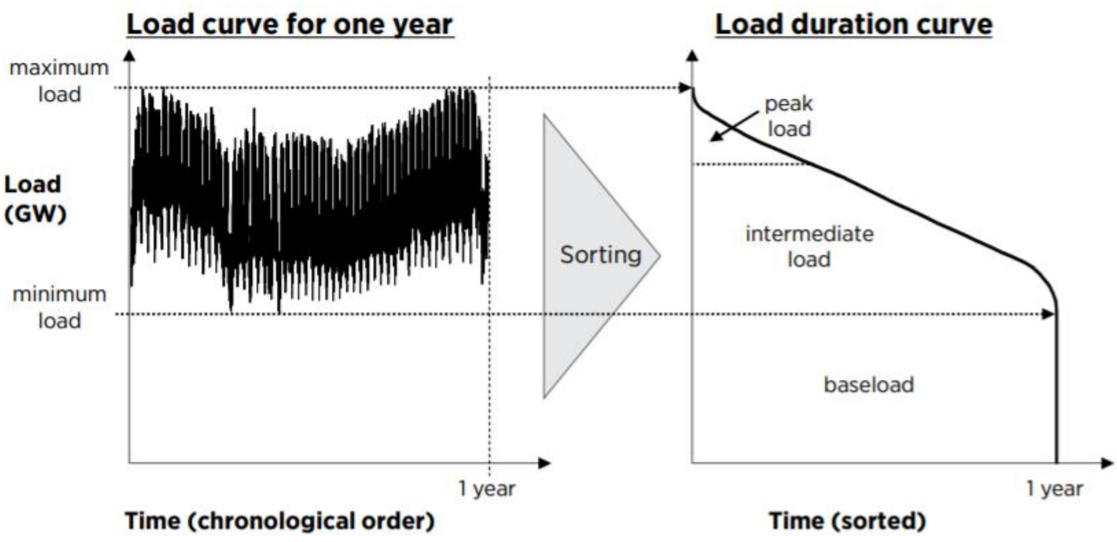

Figure 1: Load curve sorted according to time durations (load factor)
Source: IRENA (2015)

5.1.4 As shown in Figure 1 above, baseload demand is constant throughout the year and needs to be matched with baseload supply that is correspondingly constant throughout the year. Renewables cannot effectively match baseload demand since their output varies throughout the year.

5.1.5 Industry is the main electricity consumer at 40% down from 56% just over 10 years ago. Within the industrial sector, manufacturing accounts for the largest share of annual industrial energy consumption, followed by mining, construction, and agriculture. The National Development Plan 2030 envisages that adequate investment in energy infrastructure will promote economic growth and development and that an additional 29GW of electricity will be needed by 2030.[25] The NDP goal is to secure primary steel production capability and support the downstream steel sector and to raise domestic vehicle production to 1% of global output, including building 20% hybrid electric vehicles by 2030.

5.1.6 It is for this reason that baseload supply needs to be maintained on the grid to protect industrial sector jobs that make up at least 22.31%[26] of the South African workforce. To meet baseload demand to feed South Africa's industrialised economy, various options are available and the feasible options should be those that are suitable for the South African scenario and should be sustainable.

5.2 Base Load Supply Options to Meet Base Load Demand

5.2.1 According to Eskom's Integrated Results of 2018, the net maximum generating capacity as at March 2018 amounted to 48GW. Coal-fired power stations are still dominant at 83% of total sent-out capacity until such time that other means of power generation such as nuclear are ascertained.[27] Nuclear currently only contributes 4% of total baseload supply while hydro contributes 2%.

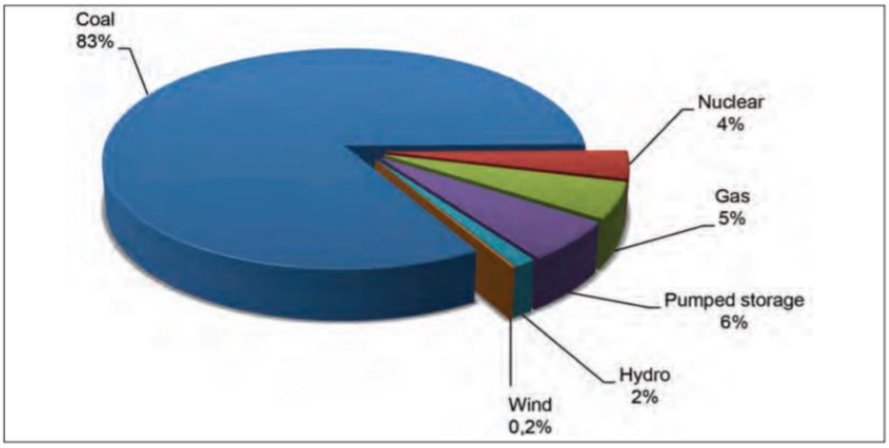

Figure 2: Generation energy mix
Source: Eskom Integrated Results, 2018

[25] https://www.nationalplanningcommission.org.za/National_Development_Plan
[26] Statssa 2019
[27] http://www.energy.gov.za/files/media/explained/2019-South-African-Energy-Sector-Report.pdf

5.2.2 Generation sources can be classified as either intermittent/self-dispatch or dispatchable. Intermittent sources, such as wind and solar, only produce power when the wind is blowing within the optimal speed range or the sun is shining, respectively. Although hydropower is dispatchable, it is only available when excess water is available.

5.2.3 Baseload supply consists of dispatchable capacity that is characterised by generators that maintain a close to constant output 24 hours a day, seven days a week, resulting in high load factors >80%. Power plants such as coal-fired plants, nuclear power plants (NPPs) as well as hydro, to name a few, constantly provide this electricity to ensure that there is a minimum amount of electricity on the grid to support loads with corresponding high load factors.

5.2.4 Figure 3 below depicts the energy sent out on an arbitrary day in South Africa (24 September 2021). The various sources that were used to meet baseload demand are coal (thermal generation) (83%), nuclear (3%) and hydro (5%). Baseload demand is therefore met with baseload supply, which is 91% of the total sent-out energy throughout the year. The rest of the demand, i.e. mid-merit and peaking, is met with renewable energy sources and dispatchable open cycle gas turbine (OCGT).

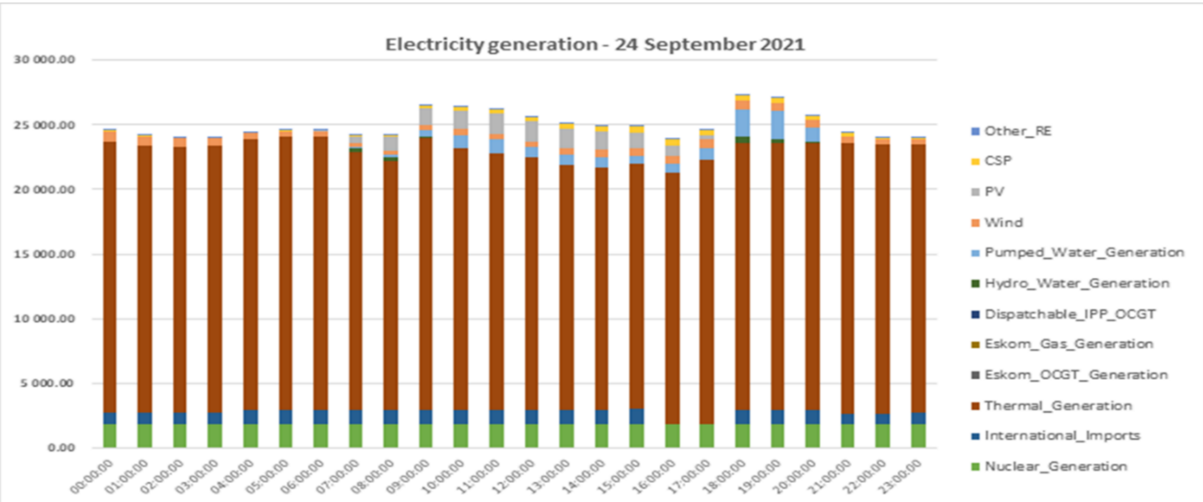

Figure 3: Energy sent out over 24 hours
Source: Eskom

5.2.5 Around 2035, when the new nuclear capacity is expected to come online, the total baseload demand according to the IRP is projected at around 38.5GW with a system load factor of 80%, [(266,500GWh)/ (8 760 hrs x 79%)= 38,509MW].

5.2.6 In 2020, the total coal fleet installed capacity was 36.8GW with sent-out energy of 185.6GWh. According to the IRP 2019, this will decrease by 24,1GW post 2030 to 12.8GW, [(36.9GW – 24.1GW = 12,8GW)]. Beyond 2030, the total installed baseload capacity will drop to 12,8GW, which will be insufficient to supply the total projected baseload demand of 38.5GW as indicated above.

5.2.7 It must be noted, however, that the projected demand of 38.5GW is a scenario that did not take into account the announcement recently made by the President of South Africa to increase the threshold of licensing requirements of SSEGs from 1MW to 100MW.

5.2.8 It is therefore envisaged that many industrial establishments are likely to develop their own capacity, which could cause the baseload generation gap of 25.7GW, indicated above, to drop significantly. Hence, a moderate additional baseload capacity of 2.5GW that the Minister is proposing will go a long way to close this generation gap.

5.2.9 As the proposed capacity of 2 500MW will only cover 10% of the envisaged generation gap, one of the suspensive reasons for the conditional concurrence is for the Minister to do a further demand analysis to ensure that the country will have sufficient baseload capacity post 2030 in light of the new developments. It is important to establish this fact before commencing the nuclear build programme in case additional baseload capacity is required. Different options available to South Africa to meet baseload demand with the associated pros and cons, are discussed in the following sections.

5.2.10 South Africa’s option to meet baseload demand is mainly through coal and nuclear. Geothermal energy can generate a stable supply of electricity throughout the year because it is not dependent on weather conditions. Furthermore, as no fuels are burned above the ground and only extremely small amounts of carbon dioxide are released, it is environmentally friendly. However, the restricting factor with geothermal generation is that it is only feasible at locations where sources of hot underground water are available at 3 to 5km below the surface.[28]

5.2.11 Hence, coal and nuclear remain the most feasible options with nuclear being the most preferred option because it proliferates the least amount of greenhouse gases (GHG). Coal also remains the largest source of power globally and, given its wide availability and relatively low cost, it is likely to remain so for the foreseeable future.[29]

5.2.12 The High-Efficiency, Low-Emissions (HELE) Coal-Fired Power Generation Roadmap describes the steps necessary to adopt and further develop technologies to improve the efficiency of the global fleet of coal.[30] To generate the same amount of electricity, a more efficient coal-fired unit will burn less fuel,

[28] http://sustainable.org.za/userfiles/geothermal.pdf
[29] https://www.iea.org/reports/technology-roadmap-high-efficiency-low-emissions-coal-fired-power-generation
[30] https://www.iea.org/reports/technology-roadmap-high-efficiency-low-emissions-coal-fired-power-generation

emit less carbon, release less local air pollutants, consume less water and have a smaller footprint.[31]

5.2.13 HELE technologies in operation already reach a thermal efficiency of 45%, and technologies in development promise even higher values.[32] Since South Africa holds 35,053 million tons (MMst) of proven coal reserves as of 2016, ranking 8th in the world and accounting for about 3% of the world's total coal reserves of 1,139,471 million tons (MMst),[33] coal remains the second most viable option for baseload generation.

5.2.14 The use of abundantly available coal and uranium resources in the country will ensure that the country has sufficient energy to support economic growth leading to the creation of much-needed jobs. This will strengthen the sovereignty of the country and ensure energy security.

5.3 Advantages and Disadvantages of the Two Approaches

5.3.1 The pros and cons of retaining the traditional use of baseload generators versus VRE backed with flexible generation, are discussed below to provide a picture of what is being circumvented by employing diverse technologies in the energy mix. The reason for the diversified energy mix is to maintain system inertia and balance in the grid.

5.3.2 A diverse combination of energy sources is a more prudent approach than decommissioning baseload capacity suddenly without putting plans in place to replace it. Australia took the same approach and has not experienced grid failure or blackouts, (see Geopolitical Study in **Annexure C**). Diversifying is also in line with section 2(e) of the ERA, which supports NERSA's mandate of promoting the use of diverse energy sources.

5.4 Advantages of VRE Backed by Flexible Generation

5.4.1 The proponents of this new approach state that the combination of widely distributed variable wind and solar PV generation, backed up with flexible power generation such as gas and storage, provides reliable, flexible, dispatchable, quasi-baseload power at least cost (10% – 20% cheaper) when compared with the alternatives of coal and nuclear power.[34] At the same time, it delivers the lowest CO_2 emissions (65% less emissions than the current IRP 2016 base case), least water usage (70% less fresh water consumption) and the most jobs (10 – 20% more jobs).[35]

[31] https://www.iea.org/reports/technology-roadmap-high-efficiency-low-emissions-coal-fired-power-generation
[32] https://www.iea.org/reports/technology-roadmap-high-efficiency-low-emissions-coal-fired-power-generation
[33] https://www.worldometers.info/coal/south-africa-coal/#:~:text=Coal%20Reserves
[34] https://www.ee.co.za/article/end-baseloadism-south-africa-need-flexible-power-generation.html
[35] https://www.ee.co.za/article/end-baseloadism-south-africa-need-flexible-power-generation.html

5.4.2 The other notable benefits of the new approach ensure operational flexibility, but also provide construction flexibility in small unit sizes to meet the uncertain future demand for electricity using simple, proven technology that lends itself to localisation.[36] Furthermore, short, reliable and proven construction times eliminate the risk of cost, time overruns associated with complex coal, and nuclear mega-projects, reduce the risk of future demand uncertainty, and avoid the need for long-term contractual commitments to foreign countries and governments.

5.4.3 Unlike in the conventional form of generation, instead of meeting the normal demand curve, the new system calculates the 'net-load' on a minute-by-minute basis by subtracting the forecast renewable production from the current load. The system operator (SO) then determines the net demand ramping variability over a three-hour period, which is needed to maintain reliability.[37]

5.5 Disadvantages Due to Unlimited Use of VRE Technology

5.5.1 The majority of embedded generators are likely to be predominantly made up of PV plants. The increase in variable technologies in the grid, particularly PV, gives rise to the 'duck curve' phenomenon. The duck curve refers to the phenomenon where increased solar PV penetration on the grid significantly depresses demand during daytime hours. This results in the required ramp rate during the hours when solar PV decreases output (usually coinciding with the early evening peak) becoming ever steeper.

5.5.2 The tariff restructuring would be required to ensure that additional peaking plant requirements that arise as a result of the duck curve explained above, are not socialised, that is, other customers not benefiting from having embedded generation are not forced to carry additional peaking capacity, which is usually more expensive.

5.5.3 There will also be an issue of upgrading the Distribution (Dx) networks infrastructure to be smarter and better developed/integrated to deal with the added complication of increased self-generation. At the very least, each end-user with variable embedded generator would need to install a time-of-use meter and be on a time-of-use tariff.

5.5.4 The grid design and operating configurations were designed and established to ensure correct voltages and frequencies on the system. However, when VRE penetration is increased this may result in inadequately analysed grid operating

[36] https://www.ee.co.za/article/end-baseloadism-south-africa-need-flexgeneration.htmlible-power-
[37] https://renewables-grid.eu/activities/best-practices/database.html?detail=154&cHash=fb2c81dd950619c92d5a5b8282456dcc

configurations due to ill-equipped municipalities that will need to connect a number of these generators on their networks.

5.5.5 Failure to analyse the grid under changing conditions and reconfiguration of the grid to support renewables and avoid adverse configurations could result in the following:

- When there is a large concentration of renewables on the network, due to their self-dispatch nature, it will be difficult for the System Operator (SO) to control voltage within specific limits so that voltage variation at customer points of supply are within limits specified in the South African Grid Code (SAGC) for electricity Quality of Supply (QoS) standards.
- In situations of maximum generation and minimum load, the reverse flow of power from embedded generators may cause voltage rise in networks, particularly in equipment that is designed to mitigate the effects of voltage drop, e.g. transformers. Moreover, sudden voltage reduction can be experienced when an embedded generator is disconnected due to a fault or for maintenance purposes.
- The consequences of voltage sags and swells caused by the factors above are numerous, including production plant downtime, premature equipment failure, automatic resets, data errors, equipment failure, circuit board failures, power supply problems, UPS alarms, software corruption and overheating of electrical distribution systems.
- Furthermore, connecting a generator to a network has the effect of increasing the fault level in the network close to the point of embedded generator connection. This may result in the violation of equipment fault level ratings, leading to improper operation of protection equipment.
- Generator transient instability is not normally an issue with generators connected to the distribution system. However, generators connected to long lines, subject to long protection clearance times, could experience transient instability. Multiple generator installations could be particularly prone to instability.
- Technical losses may increase or decrease due to changes in equipment loading. Connecting an embedded generator to a weak network and thereby forcing power flow through a weak network, can increase losses.
- Large private ownership of generators and networks could also raise pressures to keep electricity rates competitive, resulting in a reduction of grid maintenance or reluctance to invest in transmission system upgrades that are needed to preserve the present level of grid reliability.

5.5.6 To highlight other disadvantages associated with VRE technology unbacked by adequate baseload, a case in point is that of the State of Texas in the USA, which has similar conditions as South Africa. Texas is the nation's leader in wind-powered electricity generation, producing almost 30 percent of the U.S. total.[38] It is the only one of the 48 states with its own stand-alone electricity grid,[39] (South Africa also has a stand-alone grid with few exceptions, i.e. Cahora Basa and other SAPP interconnections). The Electric Reliability Council of Texas, or ERCOT, manages the Texas Interconnection, which covers 213 of the 254 Texas counties.

5.5.7 In 2009, coal-fired plants generated nearly 37 percent of the state's electricity while wind provided about 6 percent.[40] Since then, three Texas coal-fired plants have shut down and the use of wind power has more than quadrupled, as more transmission lines bringing electricity from remote wind farms to urban market centres came online.

5.5.8 In February 2021, Texas faced record-low temperatures, snow and ice made roads impassable, the state's electric grid operator lost control of the power supply, leaving millions without access to electricity.[41] As the blackouts extended from hours to days, top state lawmakers called for investigations into the ERCOT, and Texans demanded accountability for the disaster.[42]

5.5.9 To avoid a similar disaster, South Africa, which has similar conditions as Texas, needs to take heed to these lessons and ensure that it has a mix of technologies that can withstand any weather conditions by continually providing energy to the grid regardless of the severity of the weather. Both nuclear and coal are able to do this.

5.5.10 This is especially important where the harshest weather conditions have been witnessed in the last century due to climate change causing the weather to become more and more unpredictable, and colder winter days can extend unprecedented.

5.5.11 In South Africa for a period of days, e.g. winter peaks, base load generation would be required. Detailed studies are required to quantify how much VRE penetration can be tolerated based on our local conditions and, thereafter, how much baseload capacity is required to effectively support that percentage of VRE penetration to avoid grid instability, especially after retiring 24 100MWe of Eskom's obsolete coal plants post 2030. Thus, the growing view that fossil fuels are a thing of the past is false because many countries around the world still use fossil fuel-based, baseload generators. This is vitally important to maintain grid stability, inertia and reliability.

[38] https://comptroller.texas.gov/economy/fiscal-notes/2020/august/ercot.php
[39] https://comptroller.texas.gov/economy/fiscal-notes/2020/august/ercot.php
[40] https://comptroller.texas.gov/economy/fiscal-notes/2020/august/ercot.php
[41] https://www.texastribune.org/2021/02/19/texas-power-outage-winter-storm-deaths/
[42] https://www.texastribune.org/2021/02/19/texas-power-outage-winter-storm-deaths/

5.5.12 Energy curtailment is another issue that affects the revenues of IPPs during periods of low demand, i.e. during sunny days. These are primarily issued against wind turbine generators.[43] This results in the payment of deemed energy by Eskom to compensate the wind turbines for the unserved energy. During the lockdown of 2020, when demand was very low, Eskom proceeded to advise some IPPs that during certain times, the power they produce would not be used nor paid for by the utility, until the energy demand returns to normalised levels.

5.5.13 To mitigate curtailment and the fruitless payment of deemed energy, battery solutions are being proposed to absorb the additional energy from wind turbines during off-peak times and then discharging the energy during peak times when demand is high. A case in point is Eskom's battery energy storage system (BESS) project that is being deployed in the Humansdorp area near Gqeberha. This area is a production hub for wind generators and often energy from the area has to be curtailed because it cannot be evacuated to the national grid due to low demand.

5.5.14 South Africa has to lean towards a healthy mixture of all technologies in various percentages because of the following reasons:

5.5.14.1 Limited gas resources

In Europe and the US, affordable gas has become baseload, as aged coal-fired power stations are retired. In Europe, gas is combined with old investments in nuclear to supply baseload. South Africa on the other hand does not have ready access to gas. Therefore, policy makers and planners in South Africa cannot pin their hopes on gas until it is a fact and is readily available.

5.5.14.2 *Limited interconnections with countries that have baseload generation*

South Africa is a net exporter of electricity. Studies conducted by NERSA (see Geopolitical survey in **Annexure C**) show that unlike countries in Europe whose grids are inter-linked for flexibility and to assist with grid stabilisation, South Africa has limited access to alternative supplies from nearby countries. Grand Inga, which is yet to be developed in Congo and the inter-connection with the Mozambican Cahora-Basa, is an example of the kind of inter-connection that is needed to support grid stability. However, this is insufficient. The Southern African Power Pool (SAPP) has much work to do to realise the goal of effectively sharing energy in the SADC region. Australia, for example, has 26 interconnections with its neighbours giving it a lot more flexibility than South Africa.

[43] https://www.futuregrowth.co.za/insights/the-energy-curtailment-dilemma-for-ipps/

5.5.14.3 Limited battery storage

With sufficient battery storage capacity, renewable energy could transition from being variable to baseload.[44] To reach this stage, renewable energy will require gigantic batteries.[45] What will be the cost of building such batteries for South Africa, bearing in mind the skyrocketing costs of the basket of minerals required to make batteries?[46] Furthermore, in the absence of empirical evidence of this working elsewhere in the world, South Africa cannot plan based on hypothesis rather than fact.

5.5.15 To address the issue of those who say that baseload demand can be met by a combination of renewables and flexible generation such as gas, we further submit that: on a macro level, 1MW of 'green' active power may be seen as equal to 1MW of baseload active power. However, on a micro level, 1MW of 'green' energy cannot be equated to 1MW of baseload capacity due to the variable nature of VRE. Since there is a relationship between active and reactive power, if the amount of power being consumed in an area is doubled, the reactive power demand quadruples. In general, decreasing reactive power causes voltage to fall while increasing it causes voltage to rise. To compensate for voltage variations, networks dominated by VREs may require additional compensating such as by static VAR compensators (SVC) to ensure voltage stability, which will increase cost and the need to maintain additional equipment.

5.5.16 This means that vast amounts of land in South Africa would need to be used to erect wind turbines, and many solar panels would also need to line arid desserts to ensure adequate capacity. This is not an ideal situation seeing that South Africa has some of the most beautiful landscapes in the world and the impact this could have on wild life is unimaginable. Furthermore, wind turbine blades cannot be recycled, so they are piling up in landfills and companies are searching for ways to deal with the tens of thousands of blades that have reached the end of their lives.[47]

5.5.17 Thus, in light of the above, if 24 100MWe of baseload is decommissioned as envisaged and replaced with green energy, loads such as ferrochrome smelters that demand a continuous constant supply of electricity will not be able to run at their expected load factors, i.e. > 95%. As shown by the dotted line in Figure 3 below, loads below the dotted line are baseloads whose demand must be met by consistent baseload supply.

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44 https://www.news24.com/citypress/business/energy-puzzle-for-south-africa-20210701
45 https://www.news24.com/citypress/business/energy-puzzle-for-south-africa-20210701
46 https://www.news24.com/citypress/business/energy-puzzle-for-south-africa-20210701
47 https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills

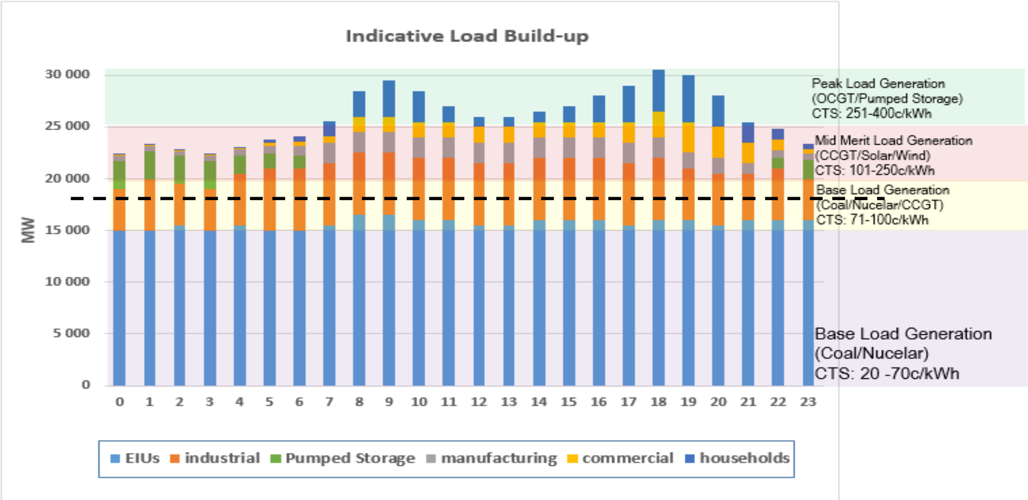

Figure 4: Indicative load build-up

5.5.18 The demand pattern used to motivate for renewables is aggregated across different customer demand patterns, thus the matching of demand type to supply is lost. With aggregated demand patterns, baseload demand is no longer matched with base load supply.

5.6 Advantages of the NNBP and How it Meets the Objectives of ERA

5.6.1 **Low cost of operation** – after the initial cost of construction of a nuclear power plant (NPP), nuclear energy has the advantage of being one of the most cost-effective energy solutions available. The cost to produce electricity[48] from nuclear energy is much lower than the cost to produce energy from gas and coal, unless those resources are located near the power plant they supply[49]. Nuclear energy also has the benefit of facing comparatively low risks for cost inflation, unlike traditional fossil fuels that regularly fluctuate in price.[50] These characteristics of the NNBP meet the requirements of section 2(a) and (b) of the ERA.

5.6.2 **Reliable technology with a reliable source of energy** – South Africa is among the top countries in the world with uranium reserves and accounted for a significant reserve base of an estimated 433 364t of uranium, or around 7% of global proven reserves in 2010.[51] Koeberg, the NPP owned by Eskom, is among the safest and reliable world's top ranking PWRs of its vintage and is the most reliable Eskom power station. This makes the option of a new NPP a reliable option in South Africa as it is a reliable technology with enough uranium in the country to generate power for the foreseeable future. This feature of the NPP fulfils objectives stated in section 2(a), (b) and (d) of the ERA.

[48] https://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx
[49] https://springpowerandgas.us/the-pros-cons-of-nuclear-energy-is-it-safe/
[50] https://springpowerandgas.us/the-pros-cons-of-nuclear-energy-is-it-safe/
[51] https://www.miningweekly.com/article/uranium-rich-south-africa-good-environment-for-nuclear-plants-2012-04-06

5.6.3 **Stable and efficient base load energy** – NPPs are not only reliable but also an efficient source of energy. The stable production of power created by nuclear power plants means that they can be ideally used in conjunction with other forms of renewable energy. For example, wind turbines generate significant amounts of power when the wind is blowing strongly. When the wind is blowing strongly, nuclear plants can adjust energy output to be lower. Conversely, when the wind is not blowing and greater energy is needed, nuclear energy can be adjusted to compensate for the lack of wind (or solar) generated power.

5.6.4 The existing coal plants do not perform well under sever fluctuating conditions and a modern NPP can relieve major fluctuations through effective load following.

5.6.5 The load following capability of new NPPs is particularly inherent in small modular reactors (SMRs), which are a novel technology among the suite of nuclear technologies. The agility of NPPs and the ability to integrate better with VREs than coal fulfils objectives stated in section 2(a), (b), (d) and (e) of the ERA. In particular, NPPs promote the use of diverse energy sources and are energy efficient.

5.6.6 **High energy density** – nuclear fission (the process used to generate nuclear energy) releases much greater amounts of energy than burning fossil fuels such as coal or gas, which also produce methane. Nuclear fission is nearly 8 000 times more efficient at producing energy than traditional fossil fuels. That is a considerable amount of energy density. Since nuclear energy is more efficient, it requires less fuel to power the plant and therefore creates less wastage as well. This feature of NPPs meets the objectives stated in section 2(a), (b) and (e) of the ERA.

5.6.7 **Produces low pollution** – when it comes to pollution, it is clear that there are pros and cons of nuclear energy save the issue of radioactive waste. However, the overall output of pollution from a nuclear power plant is quite low compared with the ash waste from fossil fuels such as coal. The current consumption of nuclear energy already reduces over 555 million metric tons of emissions every year.[52] This reduction in greenhouse gases (GHG) is a good indicator of how switching to nuclear energy can help reduce the effect on global climate change in the long run. This feature of NPPs satisfies the objectives stated in section 2(a) and (b) of the ERA.

5.6.8 **Public-private partnerships** – since the NPP is likely to be owned and built through a public-private partnership, this will attract private investors into the ESI. Furthermore, the NPP will serve as a means to facilitate a fair balance between the interests of customers and end-users, licensees, investors in the

[52] https://springpowerandgas.us/the-pros-cons-of-nuclear-energy-is-it-safe/

ESI and the public. Customers want cheap reliable energy, which nuclear offers; the case in point being Koeberg that provides the cheapest electricity in the Eskom fleet. Due to the large capital required to build an NPP, there is a high probability that investors will be given the opportunity to invest their capital in the NPP. This element of the NPP fulfils the objectives stated in section 2(c) and (g) of the ERA.

5.6.9 Therefore, nuclear fulfils the objectives of the ERA because it has, by far, the highest capacity factor (<90%), requires minimal land and natural resources, features the most price-stable fuel and has very low and predictable operating costs. NERSA supports this technology based on the fact that it fulfils the objectives of the ERA.

5.7 Nuclear NPP Disadvantages

5.7.1 **Expensive to build** – despite being relatively inexpensive to operate, nuclear power plants are expensive to build, and the cost keeps rising. In addition to the expense of building a power plant, nuclear plants must also allocate funds to protect the waste they produce and keep it in cooled structures with security procedures in place. All of these costs make nuclear power expensive.

5.7.2 **Prone to accidents** – one of the first things most people think of when they hear nuclear is the disaster at Chernobyl. Although we do not know exactly how many people died as a result of the Chernobyl incident, it is estimated that there have been as many as 10 000 deaths from the long-term effects of radiation in the region. The Fukushima power plant crisis in 2011 also showed that no matter how safe NPPs are designed to be, accidents can and do happen. Eskom is, however, affiliated to the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operations (INPO). South Africa remains a member of the International Atomic Energy Agency (IAEA). These affiliations advocate for defining standards, sharing best practices, conducting periodic safety reviews, training personnel and benchmarking performance, which have facilitated the safe operation of Koeberg since 1976.

5.7.3 **Produces radioactive waste** – although nuclear energy production produces minimal emissions, it does produce radioactive waste that must be securely stored so that it does not pollute the environment. While radiation may sound scary, we are constantly exposed to small amounts of radioactivity from cosmic rays or radon in the air we breathe. In small quantities, radiation is not harmful, but the radioactive waste from nuclear energy production is incredibly dangerous. Storage of radioactive waste is a major challenge facing NPPs. Since there is no way to destroy nuclear waste, the current solution is to seal it securely in containers and store it deep underground where it cannot contaminate the environment. As the technology improves, better ways of storing radioactive waste may emerge in the future.

5.7.4 In conclusion, the South African load profile is dominated by baseload industrial and mining demand. Hence, baseload supply is the most appropriate supply to efficiently meet baseload demand at least cost. If South Africa is to realise its industrialisation goals envisaged in the NDP 2030, reliable baseload supply will be an indispensable ingredient to drive the economy and to secure the country's competitiveness on a global scale.

5.7.5 On a global scale, economies in Europe depend on network interconnectivity to secure baseload supply, especially those whose grid is dominated by renewables. Case in point is Germany, which decommissioned its nuclear plants and ramped up renewables but still taps into France's nuclear capacity to stabilise the grid.

5.7.6 South Africa does not have access to alternative baseload capacity like Germany; hence based on this and the analysis above, it is imperative that South Africa develops its own baseload capacity expediently. Therefore, it is recommended that the Energy Regulator should concur with the nuclear capacity of 2 500MW proposed by the Minister. Doing so will ensure that NERSA fulfils the following objectives of the ERA:

a. *Achieve the efficient, effective, sustainable and orderly development and operation of electricity supply infrastructure in South Africa;*
b. *Ensure that the interests and needs of present and future electricity customers and end users are safeguarded and met, having regard to the governance, efficiency, effectiveness and long-term sustainability of the ESI within the broader context of economic energy regulation in the Republic;*
c. *Facilitate investment in the ESI;*
d. *Facilitate universal access to electricity;*
e. *Promote the use of diverse energy sources and energy efficiency;*
f. *Promote competitiveness and customer and end user choice; and*
g. *Facilitate a fair balance between the interests of customers and end users, licensees, investors in the ESI and the public.*

6. TARIFFS THAT EMERGE FROM THE TWO GENERAL APPROACHES

6.1 Financial Analysis and Impact on Tariffs

6.1.1 The energy prices of different technologies from various public sources are analysed in comparison to nuclear. The energy prices of nuclear are estimated from existing power plants and cannot be determined accurately except through a procurement process that will provide firm costs.

6.2 Cost of Nuclear and the Tariff Impact

6.2.1 The DMRE conducted benchmark studies towards the implementation of the nuclear new build programme ranging from cost, financing and procurement framework, amongst others. The study into nuclear costs was undertaken by Ingerop Consulting Engineers and was submitted to the then Department of Energy (DoE) on 21 October 2013. The document is publicly available. The purpose of the study was to provide the DoE with a comprehensive survey of the cost of nuclear power based on available information. The most useful information from the report is nuclear's Levelised Cost of Electricity (LCOE) compared with a range of renewables (wind, solar PV and CSP) and fossil fuel technologies (gas and coal).

6.2.2 In simple terms, LCOE calculates the present value of the total cost of building and operating a power plant over an assumed lifetime. LCOE can be used as a metric to determine whether to invest in a project or as a means to compare different energy costs of projects. The cost component of LCOE includes the following:

(a) Overnight costs
(b) Fuel costs
(c) Long-term fuel waste management costs
(d) Operation and maintenance costs
(e) Decommissioning and dismantling costs.

6.2.3 Furthermore, the unit power and efficiency, fuel burn-up, and discount rates were considered in the study to perform LCOE calculations.

6.2.4 The DMRE cited that the Ingerop benchmark cost of nuclear study was based on data collected from around the world and not specific to South Africa, and it concluded that nuclear is competitive compared with other technologies as measured by the LCOE.

6.2.5 Majority of stakeholders have indicated that nuclear investment costs are high, and this is caused by high upfront investment costs and high decommissioning costs. They have indicated that the investment costs are between R3 000$/kW to $10 000/kW. The DMRE stated that in the IRP 2019 it used an average overnight cost of US$5 000/KW as an inflation-adjusted value from the data in the Ingerop study.

6.2.6 Some stakeholders raised a concern that when considering costs of nuclear, the costs of decommissioning and costs of nuclear waste storage and disposal are not being taken into account despite this being required by law.

6.2.7 Some stakeholders have indicated that recent investments have almost always resulted in higher than anticipated costs due to cost overruns normally caused by delays in construction. Recent delays related to funding, cost overruns and construction delays in UK and Turkey have been cited as a concern for nuclear build. There is evidence based on research that nuclear has not realised positive learning rates on recently built power plants around the world

6.2.8 Stakeholders, who performed studies, have indicated that scenarios that include nuclear do not lead to a least cost option. They have indicated that, in fact, it would result in unnecessary high costs for consumers as other options, including storage, renewable energy (RE) and imported hydro, would be comparatively cheaper than a solution including nuclear. Furthermore, stakeholders have indicated that based on the results obtained from scenario 7 in the IRP 2019, which includes nuclear, the price trajectory would be significantly higher than other scenarios without nuclear.

6.2.9 There were also stakeholders who indicated that further studies and a future IRP update are needed for the period beyond 2030, for a decision to be taken by government on whether nuclear is necessary.

6.2.10 Some stakeholders were concerned that the costs of nuclear is not being shared with the public. Stakeholders within the energy industry proposed that the RFI that was undertaken by the DMRE should be used as a source of actual costs of nuclear, and that the ‘pace and timing’ of introducing nuclear would only be possible once those costs are known.

6.2.11 There is a consensus that fuel costs of nuclear are lower compared to other technologies such as fossil fuel-based technologies. Some concern was that the price of nuclear would be lower in the long term as plants have a longer lifetime (60+ years).

6.2.12 The IRP 2019 is supporting modular units as opposed to fleet size units. Some stakeholders’ concern is related to the fact that SMRs are not yet commercially available; implying that only matured nuclear power would be able to reduce investment risks. There is an agreement from most stakeholders that SMRs are capable of being distributed around the network and do not require as much water as it is the case with matured nuclear power plants.

6.2.13 Some stakeholders have also indicated that nuclear power plants would only be viable if the government absorbs the risks associated with nuclear, and this would result in a more affordable price of electricity.

6.2.14 Most stakeholders with inputs of price (R/kWh) indicated that consumers are expected to pay above R1.80kW/h (current year) with nuclear included in the energy mix. Some also indicated that the costs of nuclear would be above the blended tariff, but less than high RE average prices of about R2.20.

6.3 NERSA Analysis of Comments on Cost of Nuclear

6.3.1 NERSA notes the concerns raised regarding the high capital costs of nuclear technology as well as the tendency for such projects to be prone to delays as well as cost overruns. However, extensive upfront planning and sufficient time being allocated to design and following an appropriate procurement process to mitigate delays and cost overruns, could mitigate this.

6.3.2 NERSA notes the concern regarding making this determination in the absence of actual costs. This means that NERSA had to resort to postulating and utilising abstract information to assess how the phrase *at the pace and scale that the country can afford* has been explained in the Determination. This concern was taken into account when the decision was made.

6.3.3 NERSA also notes the concern regarding the cost of nuclear that can be expected to be above R1.80/kWh. However, it must be noted that in the recent past the country adopted RE technologies when costs were above R3/kWh, and are still currently blended at R2.20/kWh. Based on the IEA cost of generation report of 2020, the cost of nuclear will most certainly be lower than these costs due to higher load factors and longer plant lifetime. The cost of nuclear is also comparable to storage and gas costs.

6.3.4 The cost of nuclear is determined by the following cost elements:

(a) Capital costs of construction, including finance costs
(b) Fuel costs
(c) Operation and maintenance (O&M) costs
(d) Decommissioning and waste-disposal costs.

6.3.5 Nuclear power plant costs are dominated by capital costs, which can be up to 70% of the energy costs. Fuel costs are relatively low in nuclear plant's LCOE[53] (typically less than 20% of total costs). Consequently, the cost of electricity from a nuclear plant is very sensitive to construction costs and interest rates but relatively insensitive to the price of uranium. This fuel cost advantage is due to the enormous energy content of each unit of nuclear fuel compared to fossil fuel.

6.3.6 The operation and maintenance (O&M) costs of nuclear plants are higher than those of coal O&M fossil fuel plants because of the complexity of a nuclear plant and the regulatory issues that arise during the power plant's operation.[54] Costs for decommissioning and waste disposal are normally included in the fees charged by electrical utilities.

6.3.7 The IEA 2020 cost report estimates these costs to be about 15% of the overnight costs.

6.3.8 Regarding waste handling, the DMRE stated that it has drafted a Radioactive Waste Management Fund Bill and is consulting various structures in Government before approaching the Cabinet. This Bill provides for the establishment of a Radioactive Waste Management Fund within the National Radioactive Waste Disposal Institute, introducing an additional mandate to:

a) manage and invest money received by the Fund;
b) ensure sufficient financial provision to cover the costs required by the Institute for the long-term management of radioactive waste; and
c) ensure that the waste from the decommissioning activities will in the future be covered by the fund.

6.3.9 Cost overruns in nuclear construction have been experienced in the recent past. According to the TNO nuclear cost update report[55] of 2018, the uncertainties in the cost of nuclear energy are as a result of recent nuclear power plant developments that became more expensive than initially planned. The report indicates that after an idle period of roughly 20 years, three projects in Western Europe started construction, i.e. Oilkiluoto-3 (Finland), Flamanville 3 (France), and Hinkley Point C (UK), in 2005, 2007 and 2017, respectively.

6.3.10 The major projects that were faced with an upward revision of costs were one EPR unit (1650 MW) in Olkiluoto and in Flamanville, as well as, two EPR units at Hinkley point C. The report also indicated that both Olkiluoto and Flamanville costs were three times more than their initially planned budget and construction periods stretched from the planned period of four to five years to 15 years. However, according to the World Nuclear Performance Report 2020[56], not all new nuclear reactor designs experienced construction delays. The report indicated that Yangjiang 6 was completed in 66 months, and it is the second ACPR-1000 unit to be built after completion of its sister unit, Yanjiang 5, in 2018.

[54] https://www.britannica.com/technology/nuclear-power/Economics
[55] TNO Report, 2018, nuclear energy economics:
An update to Fact Finding Nuclear Energy
[56] World Nuclear Association, 2020, *World Nuclear Performance Report 2020*

6.4 Recently Published International Cost Data

6.4.1 Analysis of the publicly available international data is based on Projected Costs of Generating Electricity – 2020 edition (9th edition), which discusses the levelised costs of generating electricity (LCOE). The basis for using this report is that it is produced every five years by the International Energy Association (IEA) and the OECD Nuclear Energy Agency (NEA) under the oversight of the Expert Group on Electricity Generating Costs (EGC Expert Group). It publishes plant-level costs of generating electricity from various regions and countries for both baseload electricity generated from fossil fuels and nuclear power stations, and a range of renewable energy generation.

6.4.2 Table 1 shows the published EIA costs of nuclear in 2020. From the table, it can be seen that the overnight cost of nuclear technologies varies between US$2 157 (in Korea) and US$6 920 (in Slovak Republic). In addition to this source, the STATISTA 2020 report[57] indicated that the overnight cost of existing nuclear technology (light water reactor) is US$6 034, while SMR nuclear overnight cost is US$6 183/kW. NERSA's assessment is that the investment cost of nuclear varies widely, depending on the type of technology used, region and discount rates. This conclusion on the wide variety of the overnight and investment costs is also in line with the input costs submitted by various stakeholders during the public participation process.

Table 1: Overnight and investment costs of nuclear

Nuclear generating technologies – New build						
Country	Technology	Net capacity	Overnight costs	Investment costs (USD/kWe)		
		(MWe)	(USD/kWe)	3%	7%	10%
France	EPR	1 650	4 013	4 459	5 132	5 705
Japan	ALWR	1 152	3 963	4 402	5 068	5 633
Korea	ALWR	1 377	2 157	2 396	2 759	3 066
Russia	VVER	1 122	2 271	2 523	2 904	3 228
Slovak Republic	Other nuclear	1 004	6 920	7 688	8 850	9 837
United States	LWR	1 100	4 250	4 721	5 435	6 041
Non-OECD Contries						
China	LWR	950	2 500	2 777	3 197	3 554
India	LWR	950	2 778	3 086	3 552	3 949

Source: EIA Report, 2020

6.4.3 Figure 5 shows the plots indicating the range of investment costs and fixed O&M costs of various technologies, including nuclear (see red arrows), as published in the IEA 2020 report. Also shown are the averages and medians of the investment costs and fixed O&M. The mean values for investment and fixed O&M costs for nuclear technology are about R3 607/kW and R80/kW/year, respectively.

[57] STATISTA 2020, Online: https://www.statista.com/statistics/519118/power-plant-base-overnight-costs-in-the-us-by-technology/

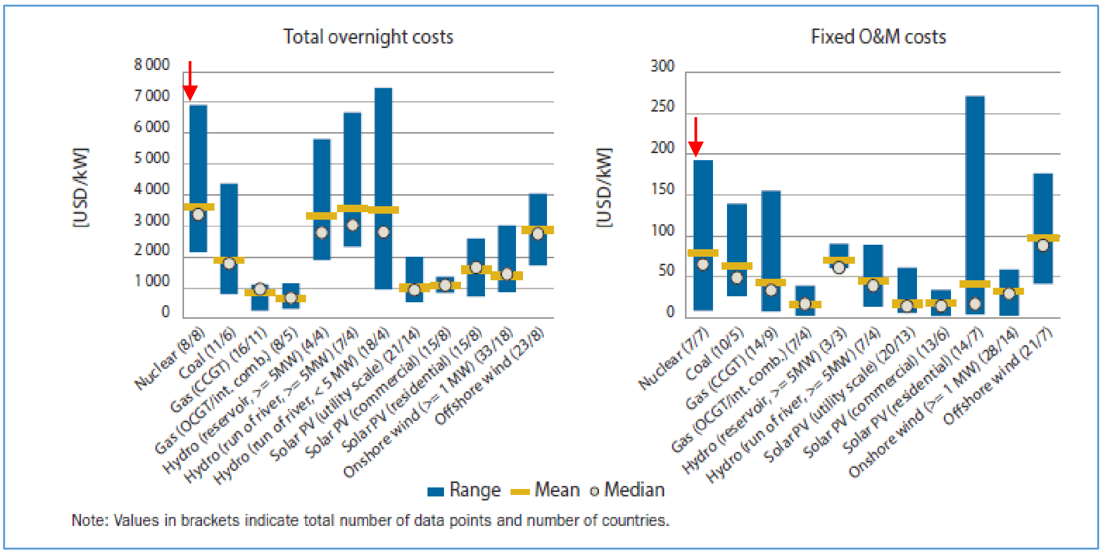

Figure 5: Overnights costs and fixed O&M costs of electricity of different technologies in 2020
Source: IEA Report, 2020

6.4.4 Figure 6 below shows the box plot of LCOE value from the 2020 IEA report, calculated at 7% discount rate and for various power generation technologies. As can be seen in the plot, the median of nuclear lies within the distribution of gas (CCGT) technology, but lower than the distribution of coal.

6.4.5 A horizontal line drawn across the plot illustrates that there are other technologies with LCOE values that fall within the same range as LCOE values of nuclear. These technologies are utility scale PV (with lower median) and hydro-reservoir >=5MW (with wider range of LCOEs). According to the 2020 EIA report, the calculated scenarios of LCOE at different discount rates result in a median LCOE of $69/MWh at 7% discount rate, and increases to $89/MWh at 10% discount rate.

6.4.6 For comparison, Table 2 lists the LCOE comparison values of various technologies from the 2020 IEA and 2020 Lazard reports. From the table, nuclear costs are comparable to CCGT (at 85% capacity factor). Figure 7 illustrates the impact of discount rate on the LCOE for nuclear technologies. From the plot, it is evident that the increase in the discount rate results in an increase of the LCOE.

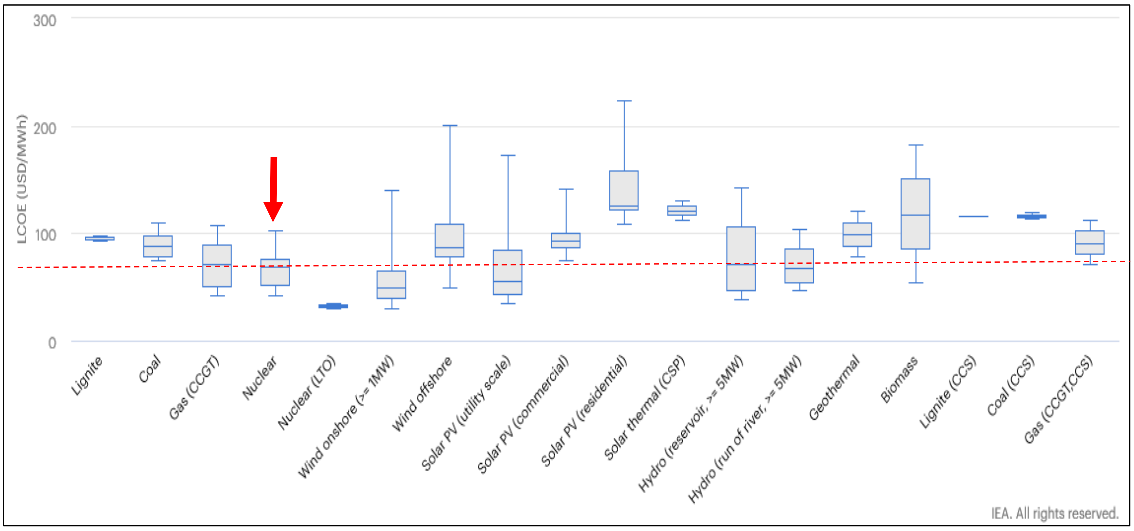

Figure 6: Levelised cost of electricity of different technologies in 2020
Source: IEA report, 2020

Table 2: Global average energy costs of various technologies at 7% discount rate

Technology	**Mean energy costs ($/MWh)**	**R/kWh (at R14.5 per USD)**
Solar PV plus battery storage*	111	1.61
Nuclear	69	1.00
Coal	103	1.49
Hydro	80	1.16
CCGT	72	1.04

Source: IEA 2020, * Lazard 2019 Estimates

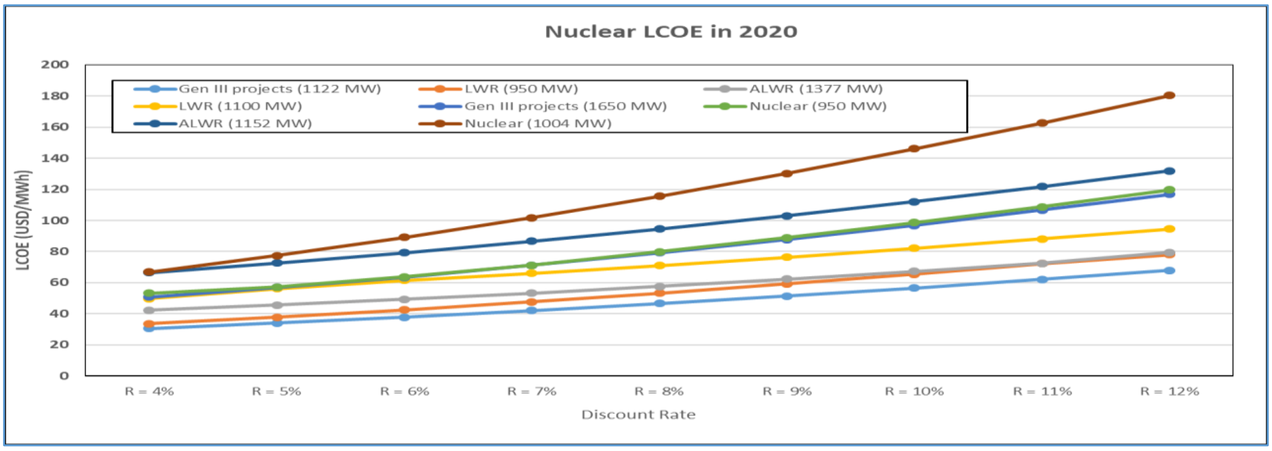

Figure 7: Levelised cost of electricity at various discount rates for nuclear technologies from different regions in 2020
Source: IEA report, 2020

6.4.7 NERSA notes the study undertaken by the DMRE in 2013, which was not specific to South Africa but was aimed at providing a generic view of nuclear costs. The study referenced an IEA report as its main source. The report was released around the same time as the Lazard report on levelised cost of energy. The nuclear costs provided in the recently published 2020 IEA report illustrate the updated costs of nuclear from various countries, and give a comprehensive cost benchmark similar to the one provided in the Ingerop report that was released in 2013.

6.5 NERSA Analysis of Investment and Nuclear Energy Cost

6.5.1 Table 3 shows the assumptions used for the calculation of indicative energy price. It should be noted that the costs are based on current and published nuclear cost information, and are merely a benchmark of existing nuclear technology, and are not necessarily costs of nuclear technology type that would be selected by the country. This is complicated by the fact that these nuclear technologies are mostly vendor-specific, hence a bidding process will reveal suitable technology type(s) and corresponding costs.

Table 3: Key financial inputs for nuclear energy costs

Parameter (Unit)	Value
Rand exchange rate for 1USD (December 2020)	14.5
Life, years	60
Overnight capital cost, (USD/kW) (2020)*	4 147
Load Factor (%)	95%
Adjusted Capex (including IDC at 8% discount rate) {(USD/kW) (2020)*}	5 943
Construction lead time (years)	7
Fixed O&M (USD/kW/year)**	95
Variable O&M USD/MWh**	3.02
Efficiency(%)	34
Fuel cost & water cost (USD/MWh)***	9.64

**Overnight Includes 15% Decommissioning costs.*

***Fixed and Variable O&M sourced from Statista report 2020*

****Fuel costs includes $7.0/MWh for front-end fuel costs and $2.33/MWh for storage*

6.5.2 Table 4 below shows the calculated estimates of energy cost components that are based on the financial and technical assumptions of Table 3 above. Total estimated energy cost of nuclear at 95% load factor is about R1.12/kWh. Also shown in the table are the corresponding annual amounts of estimated cost components of the energy cost of a 1000 MW plant size.

Table 4: Calculated nuclear energy costs per year at 8% discount rate (1 000MW)

Energy price component	R/kWh	ZAR (million)
Capital	0.775	6 447
Fixed O&M	0.166	1 378
Variable O&M	0.044	364
Fuel	0.140	1 167
Total costs	**1.124**	**9 356**

6.5.3 The capital portion of the energy price compensates for the project financing principal and interest payments, working capital, corporate income tax paid and the profit used to achieve a return for equity holders. The fixed component compensates fixed costs of the project. The variable is the tariff that compensates variable costs of the project that depend on how the power plant is run.

6.5.4 It is important to note that nuclear energy price varies with applicable discount rates, and this has been demonstrated in the published 2020 IEA report. The median energy costs in 2020 were between $69/MWh (about R1.00/kWh) at 7% discount rate and US$89/MWh (R1.29/kWh) at 10% discount rate.

6.5.5 In line with section 15 (1)(a), (c) and 15(2) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) ('the ERA'), NERSA will evaluate the energy prices/tariffs of nuclear power plant(s) emerging from the bidding process to ensure that prices are affordable for customers and viable for the licensee(s).

6.5.6 Depending on the indexation method chosen post the bidding process, energy rates may be fully indexed or partially indexed to Consumer Price Index (CPI) annually at the beginning of each financial year.

6.5.7 Estimated revenues and energy costs for the first five years for a 1 000MW capacity NPP, at 8% discount rate, are shown in Table 5 below. The assumption made for this analysis is that the portion of the tariff related to O&M would be escalated with a CPI of 5%. The remaining portion of the energy price would be dependent on interest rates, while the fuel component would be dependent on the prevailing market prices.

Table 5: Nuclear power plant calculated indicative energy and revenue for a capacity of 1 000MW

Operation over a year	Year 1	Year 2	Year 3	Year 4	Year 5
Total electricity production (GWh)	8 322	8 322	8 322	8 322	8 322
Annual combined revenues (R'm)*	9 356	9 443	9 534	9 630	9 731
Effective revenues per energy output (ZAR/kWh)	**1.124**	**1.135**	**1.146**	**1.157**	**1.169**

*Assumes O&M (excluding Fuel) is adjusted annually with CPI of 5%

6.5.8 Other options that have been suggested by stakeholders include a combination of batteries, solar PV and wind. The costs of solar PV and wind around the world continue to drop and are estimated to be around R1.00/kWh. However, both variable solar PV and wind power plants will require optimised battery storage systems and other backup generators since their resources are not always available (i.e. load factors of solar PV are below 30% and about 37% for onshore wind), and do not match peak demand periods.

6.5.9 Furthermore, additional grid management equipment will be needed to run the power system in an optimal manner. It is also important to note that the lifetime of battery storage systems is shorter (i.e. up to 10 years) compared to conventional generators, hence, periodical investments would need to be made in order to sustain security of power supply.

6.5.10 According to the Lazard October 2020 report [58], the energy cost of battery storage for a size of 100MW (running for four hours), varies between $158/MWh (R2.29/kWh) and $245/MWh (R3.55/kWh). These Lazard 2020 energy cost figures are lower than those published in the US Department study[59] report of December 2020. Table 6 shows the battery energy costs for various lithium-ion technologies in 2020 and projected to 2030. As can be seen in the table, costs varied between $326/MWh (R4.73/kWh) and $457/MWh (R6.63/kWh) in 2020, depending on the type of lithium-ion battery technology used i.e. lithium-ion: iron phosphate (LFP) or lithium-ion: nickel manganese cobalt (NMC).

Table 6: Stand-alone battery storage energy costs

	Lithium-ion: LFP		**Lithium-iron: NMC**	
	2020	**2030**	**2020**	**2030**
Installed cost range ($/kW)	1 302 - 1 752	944 – 1 249	1 320 – 1 827	965 - 1279
Energy storage cost ran ($/MWh)	326 - 438	236 - 312	330 – 457	241 - 320

Source: US Department energy storage assessment, 2020

6.5.11 The energy cost analysis above shows that the costs of the possible flexible option, such as batteries, are still quite high, and would need additional investment in grid management equipment. Furthermore, large-scale renewables are often located in remote areas where the grid is not available, and this would result in additional costs due to investment in grid extensions.

6.5.12 To conclude, it is important to note that the calculated nuclear energy cost of R1.12/kWh, at 95% load factor, is an estimated tariff based on available information. The benchmark analysis is based on existing nuclear technology costs, and may not give the exact costs of nuclear technology to be deployed in the country. As indicated previously, the costs for nuclear vary widely depending on the region, type nuclear technology, discount rate used, and delays in completing construction.

[58] Lazard (October 2020), Levelized Cost of Storage Analysis—Version 6.0, Available Online, https://www.lazard.com/media/451566/lazards-levelized-cost-of-storage-version-60-vf2.pdf.
[59] US Department (December 2020), Energy Storage Grand Challenge Cost and Performance Assessment 2020

6.5.13 Furthermore, since ‘the pace and scale’ of nuclear are not fully outlined in the IRP 2019 post 2030, the annual and specific costs would be difficult to estimate with confidence. It is therefore clear that the DMRE would need to source these costs from vendors of the specific nuclear technologies to be certain of the size and the pace at which the NNBP project should be rolled out.

7. EX ANTE ECONOMIC IMPACT ASSESSMENT

7.1 Cost Benefit Analysis of the NPP in South Africa

7.1.1 The new nuclear energy generation capacity of 2 500MW in South Africa may be evaluated in context through a cost and benefit analysis. This entails consideration of its private financial costs, opportunity costs and social costs invoked by possible externalities. Such costs are then weighed against potential private-public benefits and spill over or knock-on effects driven by positive externalities arising from construction and operation of the project forthwith.

7.1.2 On balance, a marginal analysis was conducted through a priori rational expectation to check if in total, marginal economic and social benefits outweigh marginal economic and social costs for the project to be declared worthwhile. This forms the basis of an ex ante regulatory impact assessment of the project to assist decision makers, including the Energy Regulator, with important insights to consider.

7.2 Key Findings of the Economic Assessment

7.2.1 South Africa’s predicted impact response elasticities at 2500 MWH(e) not so far from the 2500 MWe capacity installation in question, are benchmarked against those of other emerging markets such as Malaysia. This is because the two economies have similar characteristics, especially considering that they are more or less of the same size and are also both emerging markets.

7.2.2 Findings from this empirical ex ante assessment are that the predicted impact responses elasticity ranges for South Africa are more than double to ten times those of Malaysia under similar specifications. A key assumption is that South Africa will construct the nuclear plant in six years whereas Malaysia will take up to thirteen years.

7.2.3 Another key finding was that economic and social impacts of building and operating additional nuclear power plants are considerable. South Africa, Croatia, Tunisia, and Uruguay, as they earmark to complete construction over six to eight years, have higher predicted impacts on GDP, total output value, disposable incomes and employment compared to their counterparts on the sample with construction periods exceeding 13 years, as the case with Malaysia and Poland.

7.2.4 On balance, the benefits that are anticipated to accrue from this project outweigh economic, social and environmental costs that can be carefully managed to ensure improved security of supply of electricity and economic development in South Africa. (The full economic impact study is attached as **Annexure D**).

8. STAKEHOLDER ANALYSIS

8.1 Analysis of Written Stakeholder Comments

8.1.1 The written comments from organisations are analysed and summarised in **Annexure B.** Out of the 53 stakeholders, 28 are supportive of the determination by the Minister and 24 are opposed to it with some indicating that they object to it entirely, one stakeholder is on the fence.

8.2 Analysis of 'In-Scope' Issues in Support of the Determination

8.2.1 Stakeholders who raised issues that are within NERSA's scope and are supportive of the determination, highlighted that nuclear is a well-established technology that provides efficient, reliable and dispatchable baseload capacity that would ensure security of supply. They further highlighted that nuclear is a clean technology that supports the reduction of the country's carbon footprint and has a positive socio-economic impact. The following sections detail the comments and each comment is analysed by NERSA.

8.2.2 Stakeholders expressed the need for baseload capacity post 2030 when coal capacity is retired from 2025 onwards (the country needs reliable and clean baseload capacity). Based on studies conducted by NERSA, it was confirmed that there is a need for baseload capacity post 2030 when coal capacity is decommissioned. The country needs reliable and clean baseload capacity, particularly due to lack of gas resources and the variability of renewable sources.

8.2.3 Furthermore, baseload capacity is needed to avoid incidences like the one that took place in Texas where wind turbines froze and there was no sunshine, resulting in the collapse of the national grid due to extreme cold weather. South Africa also needs to develop its own baseload due to the lack of grid interconnectivity with other countries with sufficient baseload capacity to support the grid if renewables are not able to generate energy due to weather conditions.

8.2.4 Stakeholders further highlighted that the retirement of South Africa's coal baseload capacity should be paralleled with the phasing in of comparable dispatchable sources of energy to replace it concurrently. NERSA agrees with the statement that as coal capacity is being decommissioned, new dispatchable capacity should be developed alongside to avoid lack of capacity in the future, which will result in load-shedding or even blackouts that could have a detrimental impact on the economy of South Africa.

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8.2.5 A stakeholder highlighted his support for a Nuclear Built Programme in South Africa, particularly small modular reactors (SMRs) or pressurised water reactors (PWRs). NERSA supports this view; however, due to the early development of SMRs, it will be difficult to obtain funding for them. Nevertheless, the procurement process that will ultimately be conducted by the DMRE will determine what technologies are viable and the corresponding costs.

8.2.6 Some stakeholders affirmed that there is very likely a need for baseload power before 2030 as Eskom's coal-fired power plant's Energy Availability Factor (EAF) is on the decline. NERSA agrees with this statement and has subsequently concurred with the Minister's determination, albeit with conditions. This is to ensure that the nuclear build programme is initiated promptly and that capacity studies are done to ensure that there will be enough capacity to meet demand before and after 2030, and to guarantee the availability of the capacity as close as possible after 2030.

8.2.7 In addition, other stakeholders confirmed what NERSA articulated in its ex ante economic impact analysis that a New Nuclear Power Programme will not only create manufacturing and construction jobs during the build, but will also have major long-term benefits to the nuclear industry with knock-on positive effects on other industries as well. NERSA, therefore, agrees with the stakeholders.

8.2.8 Finally, stakeholders in support of the determination alluded to the fact that many, if not most modes of generation, should be included in the 'energy mix', subject to everything being contextually and economically rational. As stated in the technical analysis in section 5, NERSA agrees with this statement as it acknowledges that including all viable technologies in the energy mix is one of the surest ways to minimise the risk of grid instability, lack of inertia and grid imbalance. In fact, one of NERSA's legal objectives according to the ERA is to encourage a diverse energy mix where it is economically rational to do so.

8.3 Analysis of 'In-Scope' Issues Not in Support of the Determination

8.3.1 Stakeholders, who raised issues that are within NERSA's scope and are not supportive of the determination, highlighted that the nuclear build programme in South Africa would not be affordable and that renewables are a cheaper alternative. Other stakeholders stated that the Minister's determination is not in line with decision 8 of the IRP and that there is a need to upgrade the IRP. Lastly, some stakeholders stated that the concept of baseload is no longer valid and that a combination of variable renewable energy (VRE) sources and flexible generation such as gas and storage can meet baseload demand. NERSA analysed these comments as follows:

8.3.2 Stakeholders raised the issue of affordability and the availability of renewables as a cheaper alternative. NERSA acknowledges the validity of the stakeholders' concern as the country is currently constrained financially. However, creative ownership techniques such as public-private ownership methods can be adopted to raise capital for the project, thus limiting the government and the consumers' exposure in the investment.

8.3.3 Other stakeholders pointed out that the Minister's determination is not aligned to the IRP 2019 and that there is a need for studies to confirm the energy path post 2030 as per the IRP recommendation. Furthermore, there is a need to update the IRP. NERSA has acknowledged this concern and put a suspensive condition for concurrence in its decision. The suspensive condition is that the determination should be aligned with decision 8 of the IRP 2019. This concern has therefore been taken into consideration by the Energy Regulator.

8.3.4 Stakeholders further suggested that the concept of baseload is no longer valid in today's modern power systems. They highlighted that what is needed is a flexible grid that can support increased penetration of renewables and that baseload does not equate to energy security. To test the validity of the stakeholders' assertions, NERSA conducted a geopolitical study to locate countries around the world where this works in practise. The study showed that even countries with high penetration levels of renewables, such as Germany, still use baseload capacity such as coal or nuclear through domestic and international suppliers. Thus, the concept of baseload capacity is still valid whenever reliable, constant capacity with high load factors is required where variable renewable energy (VRE) sources fail to meet demand during unfavourable weather conditions.

8.3.5 A stakeholder pointed out the risk of the project becoming a white elephant due to cost overruns and unaffordability during construction in a long run. NERSA acknowledges this concern as valid and a possibility. However, to mitigate this risk, one of the suspensive conditions for concurrence was that the Engineer Procure and Construct (EPC) contract method should be adopted when procuring this capacity. The contract will include payment penalties where there are cost or time overruns. Furthermore, the project will be rolled out at a pace and scale that the country can afford, as per decision 8 of the IRP. This will ensure that cost overruns are minimised.

8.3.6 Some stakeholders are of the view that present and future demand for electricity can be met by an appropriate mix of least-cost renewable energy technologies (which exclude nuclear as the most expensive form of electricity generation), storage and demand-side management. NERSA is cognisant of the fact that this sentiment echoes what is detailed in the IRP 2019, which states that the path post 2030 should not be confirmed but be validated by further studies. It is for this reason that NERSA has asked the Minister to do a capacity analysis to confirm whether the country will have enough capacity post 2030 with or without the proposed nuclear power plant or whether this capacity shortage can be met by alternative sources.

8.4 Stakeholder Inputs on 'Out-Of-Scope' Issues

8.4.1 Issues raised by stakeholders that are beyond NERSA's scope included environmental issues and other safety concerns. NERSA has a duty to ensure a sustainable and orderly development and operation of the electricity supply industry (ESI). NERSA must therefore ensure that the system is able to deliver electricity to the South African economy sustainably without adversely affecting the environment.

8.4.2 The Department of Forestry, Fisheries and Environment (DFFE) is a governmental institution that deals with environmental issues. NERSA is of the opinion that the DFFE is best suited to respond thereto thoroughly. However, environmental issues and other issues of concern raised by stakeholders will be dealt with succinctly in Section 10.

9. NERSA AREAS OF CONCERN

9.1 Legality of the Determination

9.1.1 In their written comments and during the oral presentations at the public hearings, stakeholders raised legal concerns. Following the public hearings, NERSA decided to approach Senior Counsel (SC) for a legal opinion to address the legal issues that were raised. The following legal issues were highlighted:

9.2 Inconsistency of the Determination with Decision 8 of the IRP 2019

The perceived inconsistency with decision 8 of the IRP 2019 was due to the wording/differences between the IRP decision 8 and the section 34 determination issued to NERSA. Several stakeholders highlighted that the determination is not compliant with the gazetted IRP 2019. The 2 500MW capacity of nuclear is not listed in Table 5 of the IRP 2019, which outlines the capacities to come online until 2030.

9.2.1 The stakeholders cited that the IRP 2019 was for the horizon up to 2030, while this determination indicates that this nuclear capacity will be for the horizon beyond 2030.

9.3 Pace and Scale

9.3.1 Decision 8 refers to the 'pace and scale that the country can afford'. This lack of clarity on the proposed timing and scale of the nuclear build may make it difficult to perform a proper analysis on the factors relating to the mandate of NERSA, i.e. to assess impact on tariffs, affordability, orderly development of the industry and securing the interests of current and future customers.

9.4 No-Regret Option

9.4.1 Regarding the notion that nuclear is a 'no-regret option', stakeholders indicated that other combinations of technologies had not been considered before reaching that conclusion. They indicated that a combination of renewable energy plants and storage technologies (i.e. batteries) would be a cheaper alternative and, therefore, qualifies better as 'no-regret options' for the time horizon beyond 2030.

9.4.1 Stakeholders further indicated that nuclear is not a 'no-regret option' as the price of nuclear is higher than that of other alternatives. This high cost, combined with the South African SOEs' poor track record in project management, would result in this being the 'highest regret option' due to cost overruns and delays in completion that are likely to occur. Stakeholders further indicated that the history of nuclear determinations by the government renders this determination suspicious as well.

9.4.2 Stakeholders further indicated that the combination of variable renewable energy (VRE) and flexible generation is the better 'no-regret option' as it is more cost-effective than nuclear technologies, has shorter lead times to construct and emits no greenhouse gases during operation.

9.5 Further Studies

9.5.1 Stakeholders raised the concern that further studies must be conducted to determine the exact capacity of nuclear post 2030. Stakeholders indicated that further comprehensive studies must be done to clearly determine the *rate and pace* that the country can afford. They indicated that simply stating 'at the pace and scale that the country can afford' is not a sufficiently articulated business case to give assurance that the chosen pace would be affordable for the country.

9.6 Conditions in Dealing with Stakeholder Concerns

9.6.1 To address the concerns above, NERSA concurred with the section 34 determination of the Minister subject to the following suspensive conditions:

9.6.1.1 *Satisfaction of Decision 8 of the IRP 2019, which requires that the nuclear build programme must be at an affordable pace and modular scale that the country can afford because it is a 'no-regret option' in the long term.*

9.6.2 The sustainability of the decisions of the Energy Regulator is premised on the provisions of sections 9 and 10 of the NERA. The mutual interface between exercising its powers and the substantive applicability of the IRP pivots the decision-making.

9.6.3 It has been espoused in the document that rationality is not based on the totality of meeting the absolute requirements but its minimum. The information provided by the Minister enables NERSA to take a decision but NERSA would have been remiss to the public interest aspect, which is one of its obligation.

9.6.4 Not adding the condition in the decision would have eroded the overall dictates of the existence of the regulatory framework cited in section 2 of the Electricity Regulation Act. NERSA could not have ignored the applicability and the binding nature of the IRP in the new generation space.

9.6.5 The suspensive condition therefore ensures that the principles defined in the IRP 2019 are realised in any procurement that the Minister will undertake. The fulfilment of this condition and further expounding on the suitable pace and scale that the country can afford, will ensure that the NNBP is indeed a no-regret option.

9.6.5.1 Recognition of and taking into account technological developments in the nuclear space.

9.6.6 Concurrence under section 34 has the parameters outlined to disable ultra vires exercise of power by NERSA. What is inherent in the exercise of public power is the principle of legality and this principle requires NERSA to ensure that its decisions are not only related to the purpose but they are also reasonable.

9.6.7 Reasonability relates to the consideration in the broader nature of the decision and noting that the means to the usage of nuclear as an added capacity has greater dependence on technology as one of the components. To progress to procurement, the DMRE needs to be alive to the requirement of the IRP and to be persuaded by its evaluation to ascertain pace and scale.

9.6.8 The decision of the Energy Regulator would not have been reasonable had the evaluation of the draft been only limited to the language of the ERA if the reasonability of the decision was not considered.

9.6.9 The suspensive condition again ensures that the principles defined in the IRP 2019 are realised in any procurement that the Minister will undertake. The advancement in the nuclear space in recent years has brought improvement to the technology, which allows it to play a much more diverse role in the energy mix, particularly in light of the energy transition.

9.6.10 This advancement must therefore be leveraged on to bring to life the objective of the IRP 2019 of implementing this programme to ensure a net benefit to the customer. Therefore, technologies such as SMRs must be considered.

9.6.10.1 *To further establish the rationality behind the 2 500MW capacity of nuclear, conducting a demand analysis aimed at determining the envisaged load profile post 2030, to derive the generation mix that would be needed to meet the envisaged demand, which will assist in determining the capacity and the scale at which the country would need to procure additional power generation from various technologies, including, inter alia, nuclear.*

9.6.12 The role of baseload capacity in an industrial economy like South Africa has been discussed in this document. Given that the IRP 2019 is only fully studied up to 2030, and due to the fact that the 2 500MW capacity will only cover 10% of the envisaged baseload generation gap as discussed in section 5 above, a demand analysis to ensure that the country will have sufficient baseload capacity post 2030 in light of new developments, is needed.

9.6.13 Having an understanding of the demand make-up post 2030 ensures that satisfaction can be asserted on whether the envisaged baseload will adequately respond to future baseload demand if South Africa is to remain an industrial economy.

9.6.14 Having concurred with the Minister with the suspensive conditions above, NERSA analysed each section of the section 34 determination and concluded as follows:

9.7 The Generator

9.7.1 The generator of the electricity produced will be either Eskom Holdings (SOC) Limited, or any other organ of state, or in partnership with any other juristic person.

9.8 NERSA Conclusion on the Generator

9.8.1 NERSA concurs with the determination on the Generator; however, the Government will decide on the choice of the Generator and the construction approach after a cost/benefit analysis of the received bids and also conducting other relevant studies. The analysis could include the impact of the NNBP on key country financial metrics, as discussed in the economic study section.

9.9 The Buyer

9.9.1 In terms of the draft section 34 determination, the buyer of the electricity will be Eskom Holdings (SOC) Limited or any entity determined through Eskom's unbundling process as the future buyer of electricity.

9.10 NERSA Conclusion on the Buyer

9.10.1 NERSA notes the uncertain position that Eskom is currently in due to its poor balance sheet, but cannot make any conclusive analysis on the effects of unbundling nor on the impact of the future Independent System and Market Operator (ISMO), as there are no solid facts or policy decisions that have been taken to enable NERSA to do so. Until Eskom and Eskom's shareholder, the DPE, conclude on the unbundling policy, including other government departments that are involved in the unbundling process; NERSA cannot comment on the matter.

9.10.2 When the entity is unbundled, NERSA will be in a position to determine the regulatory requirements and the licensing conditions of the three separate entities. Assuming a position while these processes are unfolding may be regarded as pre-empting the process that is currently unfolding and NERSA may be seen as usurping the executive powers of the DPE.

9.10.3 According to the ERA, the powers to determine the buyer belong to the Minister. It is therefore concluded that the determination of the buyer is a policy issue that is in the hands of the DPE, in consultation with the DMRE. However, the Energy Regulator will use its rules and other regulatory instruments to ensure that only efficiently incurred costs of the NNBP are paid for by the end-users.

9.11 The Procurer

9.11.1 The section 34 determination indicates that the procurer of the NNBP will be the Department of Mineral Resources and Energy, or any other organ of state or in partnership with any other juristic person. The procurer designated above will be responsible for determining the procurement process, which will be established through a tendering procedure that is fair, equitable, transparent, competitive and cost-effective.

9.11.2 NERSA agrees with the stakeholder comments indicating that nuclear vendors are likely to offer, as their most cost-effective model, a single structured turnkey EPC model for the engineering, procurement and construction of the nuclear power plant (NPP). NERSA also agrees with the stakeholder comment that the EPC model places full project delivery responsibility in the hands of the vendor consortium and mitigates against corrupt practices.

9.12 NERSA Conclusion on the Procurer

9.12.1 In conclusion, a number of stakeholders raised the fact that decision 8 of the IRP 2019 speaks of ‘preparations’ whereas this section 34 determination refers to ‘procurement’. NERSA notes the response of the DMRE during the public consultation process that preparation in the IRP 2019 included procurement, and further recognises that a large amount of preparatory work has gone into preparations for the 9 600MW nuclear programme.

9.12.2 Furthermore, the preparatory work that was done since 2010 included securing of sites, environmental impact assessments (EIAs) and various independent studies. However, the success of a competitive tender bidding process is highly dependent on the quality of the documentation and the management of the process. Bidders prefer good quality detailed information on which to base a sound bid. The quality of information provided will have an impact on the quality of the bids received. Therefore, quality technical, financial, commercial and legal documentation should be in place to ensure quality responses. NERSA therefore concurs with the proposed procurement process with the following suspensive condition:

9.12.2.1 That the new nuclear power be procured on an Engineering Procurement and Construction (EPC) contract rather than through fragmented contracts.

9.12.3 The benefit of using an EPC turnkey model is that it allows the principal to engage one contractor, which will make it easier for the owner to oversee the project. It also ensures that there is a single point of responsibility, which will make it easier to take legal action due to any eventuality. The EPC approach, as opposed to fragmented contracts, will mitigate against time delays and cost overruns during project execution.

10. LEGAL FRAMEWORK AND POLICY GOVERNING NUCLEAR

10.1 Energy Legal Framework

10.1.1 Every decision made by NERSA must be taken within a procedurally fair process in which affected persons have the opportunity to submit their views and present relevant facts and evidence to the Energy Regulator. NERSA also needs to apply its mind to and critically review all proposals made by various stakeholders in the industry.

10.1.2 An example where NERSA failed in its duty to do this was in the Earthlife Africa and South African Faith Communities' Environment Institute v Minister of Energy and Others. Therefore, all pieces of legislation that affect this nuclear determination were considered to ensure that the decision made by NERSA is within the ambit of the law, thereafter, the issues raised by stakeholders that are out of NERSA's scope were considered in light of the legal framework.

10.2 The Constitution of the Republic of South Africa

10.2.1 The Constitution provides that the state must establish a national energy policy that will ensure that national energy resources are adequately utilised and developed to cater for the needs of the nation. Energy should therefore be available to all citizens at an affordable cost.

10.2.2 Energy production and distribution should not only be sustainable, but should also lead to the improvement of the standard of living for all the citizens of South Africa.[60] The Constitution provides a legal framework that has created new organs of government and demarcated specific powers and functions to the various spheres of government. The following sections outline the legislation under the following categories:

- Legislation that is applicable to energy generally
- Environmental legislation, in particular, NEMA and the Environmental Impact Assessment Regulations (EIA Regulations)[61]
- Dedicated nuclear legislation
- Administrative legislation, in particular the Promotion of Administrative Justice Act, 2000 (Act No. 3 of 2000) (PAJA) and the Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) (PAIA).

[60] Department of Energy (n 92)
[61] Environmental Impact Assessment Regulations GN R982 in GG 38282 of 4 December 2014.

10.3 The Integrated Resource Plan (IRP)

10.3.1 The IRP is the lodestar policy that was created to guide the Minister when new capacity is needed and the type of technology from which the capacity should be met. It was put forward as a methodology for energy planning in 1998 and was reiterated in the NDP of 2012. The IRP is a decision-making process concerned with the acquisition of least-cost energy resources, which takes into account the need to maintain adequate, reliable, safe and environmentally sound energy for all. The IRP approach includes:

- the evaluation of all candidate energy supply and demand resources in an unbiased manner;
- the systematic consideration of a full range of economic, environmental, social, and technological factors;
- the consideration of risks and uncertainties posed by different resource portfolios and external factors, such as fluctuations in fuel prices and economic conditions; and
- the facilitation of public consultation in the utility planning process.

10.3.2 The compulsory use of IRP methodologies ensures that utilities avoid delaying electricity supply investments unnecessarily or delay decommissioning decisions when it is economical to do so. This is accomplished by optimising the utilisation of existing capacity and increasing the efficiency of energy supply and consumption. The use of the IRP also contributes to meeting the Electricity Supply Industry's environmental performance and allows for public participation.

10.4 The National Energy Act

10.4.1 The National Energy Act, 2008 (Act No. 34 of 2008) was promulgated in November 2008. It was administered by the Department of Energy, which is now the DMRE. The National Energy Act only makes mention of nuclear energy in chapter 4, clause 7(2)(b), to exclude it from the South African National Energy Development Institute's energy research and development.[62] The relevant objects of the National Energy Act are to:[63]

- ensure uninterrupted supply of energy to the Republic;
- promote diversity of supply of energy and its sources;
- facilitate effective management of energy demand and its conservation;
- ensure collection of data and information relating to energy supply, transportation and demand;

[62] Section 10 of the National Energy Act.
[63] Section 6 of the National Energy Act.

- provide for optimal supply, transformation, transportation, storage and demand of energy that are planned, organised and implemented in accordance with a balanced consideration of security of supply, economics, consumer protection and sustainable development; and
- ensure effective planning for energy supply, transportation and consumption.

10.5 The Nuclear Energy Act

10.5.1 The Nuclear Energy Act, 1993 (Act No. 131 of 1993) establishes South African Nuclear Energy Corporation Ltd (NECSA) as a state-owned company. The Nuclear Energy Act defines NECSA's powers and functions, and provides governance and its management by a board of directors and a chief executive officer. It sets out the responsibilities for the application and implementation of the Safeguards Agreement and any other agreements entered into by South Africa in support of the nuclear Non-Proliferation Treaty consented to by South Africa.

10.5.2 It regulates the ownership, purchase, import and export of nuclear fuel, nuclear and related material and equipment.[64] Chapter 4 sets out the Minister's responsibilities regarding source material, special nuclear material, restricted material, radioactive waste and irradiated fuel.[65]

10.6 The National Nuclear Regulator Act

10.6.1 The National Nuclear Regulator Act, 1999 (Act No. 47 of 1999) (NNR Act) was assented to in December 1999. It provides for the establishment of an NNR to regulate nuclear activities and sets out how it will be managed. The function of the Regulator is to exercise regulatory control by granting and amending nuclear authorisations. The function of the Regulator is to exercise regulatory control by granting and amending nuclear authorisations.

10.6.2 It should also provide for the protection of persons, property and the environment against nuclear damage through the establishment of safety standards and regulatory practices.[66]

10.7 The National Energy Regulator Act

10.7.1 The National Energy Regulator Act, 2004 (Act No. 40 of 2004) (NERA) was promulgated to establish the Energy Regulator, a single body to regulate gas, electricity and petroleum, which led to the establishment of NERSA. It set out

[64] Section 36 of the nuclear Energy Act
[65] Section 54 of the nuclear Energy Act.
[66] Section 5 of the NNR Act.

the duties, role and responsibility of the Energy Regulator as well as how the regulator makes decisions. NERA was administered by the DoE and was later amended by the ERA. The duties of the Regulator are set out in section 9 of NERA as follows: Duties of members *of Energy Regulator must act in a justifiable and transparent manner whenever the exercise of their discretion is required; act independently of any undue influence or instruction; act in the public interest.*[67]

10.8 The Electricity Regulation Act

10.8.1 The Electricity Regulation Act, 2006 (Act No. 4 of 2006) (ERA) was promulgated in 2006 to establish a national regulatory framework for the electricity supply industry and to make the National Energy Regulator of South Africa (NERSA) the enforcer and custodian of this framework. It amends NERA of 2004, which was amended in 2006 by the Electricity Regulation Amendment Act, 2007 (Act No. 28 of 2007).

10.8.2 It sets out the powers and duties of the regulator, the provisions for new generation capacity and remedies against decisions by the regulator. One of the objects of this Act is to ensure that the interests and needs of present and future electricity customers and end-users are safeguarded and met, having regard to the governance, efficiency, effectiveness and long-term sustainability of the ESI within the broader context of economic energy regulation in the Republic.[68]

10.8.3 The ERA allows the Minister of the Mineral Resources and Energy, in consultation with NERSA, to make ministerial determinations for new generation capacity if the Minister believes that it is required to secure the continued uninterrupted supply of electricity.[69]

10.8.4 The ministerial determinations may also outline the type of energy sources from which electricity must be generated. To make a determination for new generation capacity:[70]

(1) the Minister may, in consultation with the Regulator –
   (a) determine that new generation capacity is needed to ensure the continued uninterrupted supply of electricity;
   (b) determine the types of energy sources from which electricity must be generated, and the percentages of electricity that must be generated from such sources.

[67] Section 9 of NERA
[68] Section 2(b) of the ERA.
[69] Section 34(1)(a) of ERA.
[70] Section 34(1) of the Electricity Amendment Act 28 of 2007

10.8.5 In 2013 and 2016 the Minister of Energy made two determinations in terms of section 34 of the ERA that South Africa required 9.6GW of nuclear power, to be procured by the then DoE, and Eskom respectively. In the case of Earthlife Africa Johannesburg and South African Faith Communities' Environment Institute v the Minister of Energy and Others, these two determinations were challenged and found to be unlawful and unconstitutional and were set aside.

10.9 The Promotion of Access to Information Act

10.9.1 The Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) (PAIA) is the national legislation that enacts section 32 of the Constitution. The latter section reads as follows:

Access to information:

32(1) Everyone has the right of access to –

(a) any information held by the state; and
(b) any information that is held by another person and that is required for the exercise or protection of any rights.
(2) National legislation must be enacted to give effect to this right, and may provide for reasonable measures to alleviate the administrative and financial burden on the state.

10.9.2 The purpose of PAIA is 'to give effect t to the constitutional right of access to any information held by the state and any information that is held by another person and that is required for the exercise or protection of any rights'. PAIA gives effect to the constitutional right of access to information held by the State or another person, subject to justifiable limitations, in a manner that balances that right with other rights, including the rights in the Bill of Rights.[71]

10.9.3 In the case of Earthlife Africa (Cape Town) v Director-General (DG) not granted the access to the information that was sought despite showing that the requested information was necessary to protect the constitutional environmental right,[72] the applicants launched an urgent court case to gain access to information that was placed before the DG in support of their application and a reasonable opportunity to make representation to the DG before the decision was made, but this case was struck off the roll. The respondent successfully established that various grounds of refusal listed in PAIA were present and the authorisation was granted for Eskom to proceed.[73]

[71] Section 11 of PAIA.
[72] 2005 (3) SA 156 (C) para 47.
[73] 2005 (3) SA 156 (C) paras 79–80.

10.10 The Promotion of Administrative Justice Act

10.10.1 The Promotion of Administrative Justice Act, 2000 (Act No. 3 of 2000) (PAJA) was assented to in 2000 and gazetted in 2009 but was only promulgated in 2016. The delay was due to extensive training that had to be undertaken by judicial officers and court officials before the new procedure was brought into the court space.[74] The Bill of Rights section on the Just Administrative Action requires national legislation to be enacted[75] to give effect to the rights to:

a. provide for the review of administrative action by a court, or where appropriate, an independent and impartial tribunal;
b. impose a duty on the state to give effect to the rights stated in 33(1) which is the right to administrative action that is lawful, reasonable and procedurally fair and 33(2) the right to be given reasons when rights have been adversely affected by administrative action; and
c. to promote an efficient administration.[76]

10.10.2 PAJA gives effect to these rights to administrative action that is lawful, reasonable and procedurally fair, and to the right to written reasons for administrative action as contemplated in section 33 of the Bill of Rights in the Constitution of South Africa. PAIA and PAJA are similar in that they both codify common-law administrative legal principles, with an individual requesting access to information from institutions seeking to determine how that institution arrived at a particular decision.[77]

10.10.3 PAJA gives requirements for procedurally fair administrative action affecting any individual or the public. It directs how reasons for administrative action should be provided. It stipulates when a judicial review of an administrative action may be done, the procedures of such review, and how these proceedings may, during the judicial review, remedy the administrative action taken. PAJA allows for judicial review of administrative action by a court or tribunal if –[78]

(b) a mandatory and material procedure or condition prescribed by an empowering provision was not complied with;
(d) the action was materially influenced by an error of law;
(e) the action was taken –
  (iii) because irrelevant considerations were taken into account or relevant considerations were not considered;
(f) (ii) the action itself is not rationally connected to:

[74] Promotion of Access to Information and Promotion of Administrative Justice Rules: Deliberations, https://pmg.org.za/committee-meeting/23162/, accessed 24 July 2019
[75]Bill of Rights that deals with just administrative action states: National legislation must be enacted to give effect to these rights.
[76] Section 33 of the Constitution.
[77] PAIA Rules (n 148).
[78] Section 6(2) of PAJA.

aa) the purpose for which it was taken;
bb) the purpose of the empowering provision;
cc) the information before the administrator; or
dd) the reasons given for it by the administrator;

10.10.4 Both PAIA and PAJA were used to challenge the nuclear determination by the Minister of Energy and the intergovernmental agreements with China, Russia and Korea in Earthlife Africa and South African Faith Communities' Environment Institute v Minister of Energy and Others. PAJA was also used to challenge the environmental authorisation granted to Thabametsi Power Company in Earthlife Africa Johannesburg v Minister of Environmental Affairs and four others ('Thabametsi case') to build their 1200 MW coal-fired plant.

10.10.5 In Earthlife Africa (Cape Town) v Director-General: Department of Environmental Affairs and Tourism and Eskom Holdings, the applicant took the decision of the DG on review, invoking provisions in the ECA and PAJA. The Court dismissed the respondent's argument that since Eskom could only commence with construction after obtaining further authorisations, there was no need to launch review proceedings at the first stage of public participation. The Court held that just because this was the first stage in the process 'does not mean that the audi rule is inapplicable, nor does it mean that an aggrieved party must await 'the final step' before it can seek to review the decision'. It thus found that procedural fairness required that the audi rule be applied at the second stage.

10.11 The National Environmental Management

10.11.1 The National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) is the statutory framework to enforce section 24 of the Constitution of the Republic of South Africa. It is the primary environmental management and implementation framework act in South Africa. NEMA is intended to promote cooperative governance and ensure that the rights of people are upheld, but also recognising the necessity of economic development. Environmental legislation, in particular NEMA and the EIA Regulations,[79] require public participation as a requirement for environmental authorisation.

10.11.2 Furthermore, NEMA will be considered insofar as it illustrates public participation as a legal requirement, looking at case law, for example, the Thabametsi case where public participation processes were challenged.

[79] Environmental Impact Assessment Regulations GN R982 in GG 38282 of 4 December 2014.

10.11.3 Chapter 5 of NEMA replaced the environmental assessment provisions in the Environment Conservation Act, 1989 (Act No. 73 of 1989) (ECA) and lays down the legislative basis for environmental assessment in South Africa.[80] Chapter 5 of NEMA lays out the objectives to achieve integrated environmental management.[81]

10.11.4 The September 1997 regulations were replaced by a new and more complex set of regulations during 2006.[82] They were later replaced by the June 2010 regulations,[83] and subsequently by the current set of Environmental Impact Assessment Regulations dated 4 December 2014 (as amended).[84] The latest version of the list of activities, the Listing Notices, is contained in the Government Gazette GNR 324 – 327 of 7 April 2017[85] and is referred to as the December 2014 regulations as amended.[86]

10.11.5 NEMA flashes out the constitutional right of everyone to have an environment that is not harmful to his or her wellbeing while allowing for sustainable development. Sustainable development is defined in NEMA as 'the integration of social, economic and environmental factors into planning, implementation, and decision-making so as to ensure that development serves present and future generations.'[87]

10.11.6 This Act empowers the Minister of Mineral Resources and Energy to issue environmental authorisations, while the Minister of Environmental Affairs will be the appeal authority. Section 24 of NEMA provides that the Minister of Environmental Affairs must list those activities for which an environmental authorisation is required. Further, the potential consequences for or impact on the environment of listed activities or specified activities must be considered, investigated, assessed and reported to the competent authority or the Minister responsible for mineral resources to obtain an environmental authorisation in terms of this Act.

10.11.7 Depending on the impact of an activity, it will require a Basic Assessment or a full Environmental Impact Assessment (EIA). Nuclear installations require a full EIA before they can proceed. Thus, NEMA is of particular relevance to the nuclear industry. While NEMA[88] limits investigation of mitigation measures to the need to 'keep adverse consequences or impacts to a minimum', the need

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[80] 'Environmental Assessment' in J Glazewski & S Brownlie (eds) Environmental Law in South Africa (2018) para 10.3.1
[81] 'Environmental Assessment' in Glazewski & Brownlie (n 112) 18
[82] GN 385–GN 387 in GG28753 of 21 April 2006.
[83] GN R 543–GN R546 in GG 33306 of 18 June 2010.
[84] 'Environmental Assessment' in Glazewski & Brownlie (n 112)
[85] In terms of GN 326, GN 327, GN 325 and GN 324 (respectively) in GG 40772 on 7 April 2017.
[86] 'Environmental Assessment' in Glazewski & Brownlie (n 112).
[87] Section 1 of NEMA.
[88] Sections 23 and 24(4) of NEMA.

to go beyond minimising impacts to 'remedy' them is absent. The 2014 EIA Regulations, as amended, go one step further by defining mitigation as to 'anticipate and prevent negative impacts and risks, then to minimise them, rehabilitate or repair impacts to the extent feasible'.[89]

10.11.8 The principles of NEMA state that environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably. Environmental management should pursue the selection of the best practicable environmental option.[90]A further principle is that 'pollution and degradation of the environment are avoided, or, where they cannot altogether be avoided, are minimised and remedied.'[91]

10.11.9 It lists the regulations of environmental assessments, the EIA Regulations and sets out the process to be followed in applying for an environmental authorisation and the consequences of unlawful commencement of an activity. In the EIA Regulations Listing Notice 2 of 2014, nuclear is identified as a listed activity (Listed Activity 3 of LN2): The development and related operation of facilities or infrastructure for nuclear reaction including energy generation, the production, enrichment, processing, reprocessing, storage or disposal of nuclear fuels, radioactive products, nuclear waste or radioactive waste.[92] The EIA process includes:

1. scoping report;
2. public participation;
3. draft EIA, including specialist studies;
4. public participation, including hearings, detailed commentary and submissions;
5. final EIA and public comments submitted;
6. the decision on application and issue or refusal of application;
7. environmental authorisation issued, with conditions; and may include:
   a) appeal to the Minister; and
   b) judicial review.

10.12 Concerns Raised by Stakeholders Opposed to the Nuclear Determination

10.12.1 The analysis of the issues raised by stakeholders, who opposed the proposed Nuclear New Build Programme (NNBP), is detailed in the following sections. The analysis focuses on the proposed determination in light of the legal framework above and examines 'out-of-scope' and other issues raised by

[89] EIA Regulations (n 103) as amended by GN 326 in GG 40772 of 7 April 2017.
[90] EIA Regulations (n 103) 11.
[91] Section 2(4)(a)(ii) of NEMA.
[92] EIA Regulations (n 103) 7.

various stakeholders. The stakeholder concerns are quoted and then analysed in light of the laws that are applicable thereto.

10.12.1.1 Invalidity of the baseload term

10.12.1.1.1 ‘The concept of baseload is no longer valid in today’s modern power systems. What is needed is a flexible grid that can support increased penetration of renewables. Baseload does not equate to energy security.’

10.12.1.1.2 ‘The present and future demand for electricity can be met by an appropriate mix of least-cost renewable energy technologies (which excludes nuclear as the most expensive form of electricity generation), storage and demand-side management.’

10.12.1.1.3 The piece of legislation that deals with the above concerns is the National Energy Act. According to this act, when considering possible sources for meeting future energy demand, cost is not the only consideration but also the need to ensure that the supply of energy is uninterrupted as legislated in the National Energy Act. NERSA has determined that the way to ensure an uninterruptible supply is through the promotion of a diverse supply of energy sources. This is in line with object 2(e) of the ERA that is to promote the use of diverse energy sources and energy efficiency. The notion that baseload is no longer required and that baseload can be met with a combination of VRE and flexible generation, is risky if it means that certain technologies are excluded from the energy mix purely based on cost. Therefore, although NERSA acknowledges that nuclear is capital intensive, its legal mandate dictates that it promotes diverse energy sources to ensure an uninterrupted supply of energy in the future.

10.12.1.2 Availability of cheaper energy alternatives

10.12.1.2.1 ‘The availability of cheaper, Renewable energy and the fact that the country cannot afford the project at present.’

10.12.1.2.2 Although considered the cheaper alternative, the exclusive use of renewables does not find support in law and in practical application as it shall be seen in the following section (Section 11). A healthy and sustainable energy mix is the one that includes diverse energy sources.

10.12.1.2.3 The life span of an NPP (60 years) is typically three times that of wind or solar (20 years). Thus, nuclear is required to meet long-term, stable requirements of energy while wind and solar provide intermittent energy for the medium to long term (20 years).

10.12.1.2.4 Therefore, one NPP will survive three lifetimes of a wind or solar plant. Thus, although the country might not be able to exclusively afford an NPP, a private-public partnership could be forged to share the risk. Hence, as stated above, the best way to ensure an uninterruptible supply is through the promotion of a diverse supply of energy sources. This is also in line with the object 2(e) of the ERA, which is to promote the use of diverse energy sources and energy efficiency.

10.12.1.3 Risk of the project becoming a 'white elephant'

10.12.1.3.1 'Due to cost overruns during construction and unaffordability in a long run.'

10.12.1.3.2 The Nuclear New Build Programme (NNBP) will be procured through an Engineering Procurement and Construction (EPC) contract rather than through fragmented contracts. NERSA included this suspensive condition in its decision to minimise the risks brought to its attention. Furthermore, the project will be rolled out at a pace and scale that the country can afford, as per decision 8 of the IRP. The EPC contract method was chosen to minimise the impact of project delays and possible cost overruns to reduce the possibility of the project becoming a 'white elephant'.

10.12.1.4 Environmental concerns

10.12.1.4.1 'The waste-disposal facility at Vaalputs is producing radioactive waste and harming the environment and the people dwelling in the area.'

10.12.1.4.1 Nuclear installations require a full EIA before they can proceed. Thus, NEMA is of particular relevance to the nuclear industry. The concern raised by the stakeholder is noted, however, these issues will be directed to the relevant departments. The Department of Fisheries, Forestry and Environment (DFFE) will handle this concern. Any other concerns around nuclear safety will be directed to the National Nuclear Regulator (NNR), which is a body that is established to ensure nuclear safety (see section 10.6 above).

11. BENCHMARKING STUDIES

11.1 Assessment of Other Countries' Regarding Nuclear

11.1.1 Countries benchmarked include Brazil, China, Czech Republic, Finland, India, Japan, Russia, South Korea, Turkey, UAE, United Kingdom, USA and Vietnam. The fact that was highlighted is that countries with larger shares of VREs in their energy mix, like Germany and United Kingdom, import baseload electricity from other countries. The UK imports hydro capacity from Norway and nuclear from France, while Germany, with its coal-dominated energy mix, also imports nuclear-generated electricity from France. South Africa does not have neighbours from which it can import baseload power. Therefore, South Africa must develop its own baseload power to balance the effects of VRE and ensure security of supply.

11.1.2 While first world countries are moving towards zero carbon economies, no country has demonstrated that industrialisation can be increased and maintained by an energy mix that excludes solid baseload capacity and only consists of renewable technologies and flexible generation yet. Australia's energy mix, for instance, still consists of 79% fossil fuels even though they began integrating VREs as early as in the 1990s. This is in spite of the fact that >25% of Australia's domestic homes have solar power.

11.1.3 Furthermore, Australia has not decommissioned its fossil fuel-based plants quickly and suddenly. Fossil fuels make up 86% of Italy's primary energy consumption, with 38% in crude oil and 38% in gas. Italy, which has approximately 26 interconnections with its neighbours, also imports 10% baseload electricity in the form of nuclear from France, and hydropower and nuclear from Switzerland. Therefore, countries with larger shares of VRE, e.g. Italy (41.7% in 2020) and Germany (19.3% in 2020), are able to maintain grid stability by accessing baseload capacity from neighbouring countries through inter-linked grids.

11.1.4 South Africa, on the other hand, does not have this interconnectivity with neighbouring countries that have baseload generation and must, therefore, produce its own baseload capacity. Thus, like Australia, for South Africa to support its industrial baseload and to support future industrialisation goals through Foreign Direct Investment (FDI), it must develop solid baseload supply. Given that South Africa's industrialisation appears to be halted and has declined over the past decade, it may be a risk to push the above assertion for a third world country.

11.1.5 China had 48 nuclear reactors in operation and 11 under construction at the beginning of 2020. China is one of the few countries that have included nuclear power, along with renewables, in the low emissions strategy in its Nationally

Determined Contribution under the Paris Agreement. Significant programmes are underway in Russia, India and the Middle East that will add to the expansion of nuclear power globally.

11.1.6 Some 20GW of new nuclear power capacity was under construction at the start of 2020 in Finland, France, Japan, Korea, Slovakia, Turkey, the United Kingdom and the United States – there is otherwise limited projected additional capacity over the next decade in advanced economies.

11.2 Role of Natural Gas

11.2.1 Natural gas is often considered as a transition fuel to a low-carbon economy and could be a game changer in South Africa's energy mix for use in a range of end-use sectors (not just for power generation).[93] Furthermore, to assist with a just transition from coal to renewables, investigations should be done whether coal power stations that are due to be retired by 2025 can be repurposed by converting them from coal to gas, particularly because gas is not as intensive in producing greenhouse gases (GHG) as coal. This assessment and possible sources of gas and the designs can be initiated before these units are decommissioned around 2025 so that they can immediately be repurposed after they are decommissioned.

11.2.2 Infrastructure for liquefied natural gas (LNG) imports at strategic port locations should be prioritised in the short- to medium-term. Additional regional pipeline natural gas imports should be considered for use in the short- to medium-term with unconventional domestic natural gas resources as long-term options only if environmental concerns are alleviated (coal bed methane (CBM) and shale gas).[94]

[93] https://static.pmg.org.za/180101NPC_Energy_Paper.pdf
[94] https://static.pmg.org.za/180101NPC_Energy_Paper.pdf

12. ANNEXURE A: DRAFT DETERMINATION

GOVERNMENT NOTICES

DEPARTMENT OF MINERAL RESOURCES AND ENERGY

DETERMINATION UNDER SECTION 34(1) OF THE ELECTRICITY REGULATION ACT, 2006 (ACT NO. 4 OF 2006)

The Minister, in consultation with the National Energy Regulator of South Africa ("NERSA"), acting under section 34(1) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) (as amended) (the **ERA**) has determined as follows:

1. To commence the process to procure the new nuclear energy generation capacity of 2 500 MW as per decision 8 of the Integrated Resource Plan for Electricity 2019 - 2030 (published as GN 1360 of 18 October 2019 in *Government Gazette* No. 42784)("IRP 2019");
2. The generator of this electricity produced will be either Eskom Holdings (SOC) Limited, or any other organ of state, or in partnership with any other juristic person.
3. The buyer of the electricity will be Eskom Holdings (SOC) Limited or any entity determined through the Eskom's unbundling process as the future buyer of electricity.
4. The procurer of the nuclear new build programme will be the Department of Mineral Resources and Energy, or any other organ of state, or in partnership with any other juristic person.
5. The procurer designated above will be responsible for determining the procurement process which will be established through a tendering procedure which is fair, equitable, transparent, competitive and cost effective.

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Concurrence to this Determination given by the National Energy Regulator of South Africa on the below mentioned date:	Determination made by the Minister of Energy on the below mentioned date:
Signed: ___________________ **MR JACOB MODISE** **CHAIRPERSON: NERSA** **DATE:**	**Signed:** ___________________ **MR GWEDE MANTASHE, MP** **MINISTER: MINERAL RESOUCES AND ENERGY** **DATE:**

13. ANNEXURE B: SUMMARY OF STAKEHOLDER COMMENTS

13.1 SUMMARY OF STAKEHOLDER COMMENTS [NUCLEAR TECHNOLOGY]

Out of the 53 stakeholders 28 are supportive of the determination by the minister and 24 are opposed to it with some indicating that they object to it entirely, one stakeholder is on the fence.

STAKEHOLDERS SUPPORTING

No.	ORGANISATIONS/STAKEHOLDERS	REASONs FOR SUPPOTING	NERSA ANALYSIS
1.	Stakeholders	Need for baseload capacity post 2030 when coal capacity is decommissioned (Country needs reliable and clean baseload capacity).	Based on studies conducted by NERSA, it was indeed confirmed that there is a need for baseload capacity post 2030 when coal capacity is decommissioned. The country needs reliable and clean baseload capacity, especially due to lack of gas resources and the variability of renewable sources. Furthermore, in order to avoid incidences like the one that took place in Texas where wind turbines froze and there was no sunshine, resulting in the collapse of the national grid due to extreme cold weather. South Africa also needs baseload due to lack of interconnectability with other

			countries with sufficient baseload capacity. South Africa is a net exporter of electricity.
2.	Stakeholders	The retirement of our coal baseload capacity should be paralleled with the phasing in of comparable dispatchable sources of energy to concurrently replace it.	Nersa agrees with this sentiment. As coal capacity is being decommissioned, new dispatchable capacity should be developed alongside in order to avoid lack of capacity in the future resulting in load shedding or blackouts.
3.	Stakeholder	Support for a Nuclear Programme in South Africa, particularly SMRs and PWRs.	NERSA supports this view, however, due to the early development of SMRs, it will be difficult to obtain funding for them. However, the procurement process that will ultimately be conducted by the DMRE will determine what technologies are viable and the corresponding costs.
4.	Stakeholder	There is very likely a need for baseload power before 2030 looking at Eskom's coal-fired power plant most expected further decline in availability.	NERSA agrees with this statement and has therefore concurred with the minister's determination albeit with conditions, in order to ensure that the nuclear build program is initiated speedily to ensure availability of the 2.5GW capacity as close as possible after 2030.

5.	Stakeholder	A new Nuclear Power Build program will not only create manufacturing and construction jobs during the Build, but will have major longer term benefits to our industry.	NERSA agrees with this statement as recorded in its Reason for Decision.
6.	Stakeholders	The responder is a service provider specialising in nuclear and is therefore biased towards supporting any nuclear programme.	
7.	Stakeholder	Many if not most modes of production should be included in the “energy mix”, subject to everything being contextually and economically rational.	NERSA agrees with this statement. In fact, one of NERSA’s legal mandate is to encourage a diverse energy mix where it economically rational to do so.

Summary:

The majority of stakeholders supported due to the country’s need for baseload capacity post 2030 in order to prevent grid imbalance, load shedding and blackouts in the future.

STAKEHOLDERS NOT SUPPORTING

No.	ORGANISATIONS	REASON FOR NOT SUPPOTING	NERSA ANALYSIS
1.	Stakeholders	Affordability and the availability of renewables as a cheaper alternative.	The stakeholder's concern is valid as the country is currently constrained financially. However, creative ownership methods such as public-private ownership methods can be adopted to limit government's risk in the investment.
2.	Stakeholders	The minister's determination is not aligned with the IRP 2019. There is a need for studies to confirm the energy path post 2030 as per the IRP recommendation. Furthermore, there is a need to update the IRP.	One of the conditions for concurrence with the minister was that the determination should be in alignment with decision 8 of the IRP 2019. Hence this concern has been taken into consideration by the regulator.
3.	Stakeholder	The concept of baseload is no longer valid in today's modern power systems. What is needed is a flexible grid that can support increased penetration of renewables. Baseload does not equate to energy security.	The geopolitical studies conducted by NERSA show that countries with high penetration levels of renewables still utilise baseload capacity such as coal or nuclear through domestic and international suppliers. Thus, the concept of baseload capacity is still valid whenever reliable, constant capacity with high load factor in needed.

4.	Stakeholders	The availability of cheaper Renewable energy and the fact that the country cannot afford the nuclear project at present.	All sources of energy should be equally considered in order to ensure a balanced power system. The price of the energy source should not be the only factor that is considered for inclusion in the energy mix. Therefore, NERSA concurred with the minister on condition that he does a capacity analysis precisely to determine exactly how much nuclear will be required in light of the projected load requirements post 2030. The affordability issue was dealt with above.
5.	Stakeholder	Risk of the project becoming a white elephant due to cost overruns and unaffordability in a long run.	This concern is valid; however, one of the conditions for concurrence was that the EPC contract method be adopted. The contract will include payment penalties where there are cost or time overruns. Furthermore, the project will be rolled out at a pace and scale that the country can afford as per decision 8 of the IRP. This will ensure that cost overruns are minimized.
6.	Stakeholders	Environmental Concerns & Cost of Nuclear	The concerns are valid, however, government and Eskom is doing all it can to ensure that the waste-disposal

			facility at *Vaalputs* is controlled such that the Radioactive Waste does not harm the environment and the people dwelling in the area. This c
7.	Stakeholder	SAFCEI and ELA-JHB are of the view that present and future demand for electricity (for whatever purposes) can be met by an appropriate mix of least-cost renewable energy technologies (which excludes nuclear as the most expensive form of electricity generation), storage and demand-side management.	This sentiment echoes what is detailed in the IRP 2019, which states that the post 2030 path should not be confirmed but be validated by further studies. It is for this reason that NERSA has asked the minister to do a capacity analysis to determine the need for the inclusion of nuclear which is not the least cost path according to the IRP 2019 based on the projected demand post 2030.

Summary:

The majority of stakeholders objected due to the determination not being aligned to the IRP 2019, affordability of the NNBP and environmental concerns.

14. ANNEXURE C: GEOPOLITICAL STUDY

1. Introduction

In December 2015, 174 countries and the European Union agreed to reduce their greenhouse gas emissions to limit the global average temperature increase to well below 2°C above pre-industrial levels.[95] As electricity generation produces about 40% of the world's CO2 emissions, this sector will be at the centre of efforts to reduce carbon emissions[96]. Meeting these ambitious climate goals means reducing the carbon intensity of the electric power sector by as much as a factor of ten.[97] The increasing electrification of industry, transport and buildings will only further reinforce the pivotal role of electricity generation. It is therefore crucial that the electricity being used comes from clean-energy sources. Many countries are therefore shifting from the traditional thermal plants that burn millions of tons of coal to produce electricity and are incrementally adding renewable energy sources (RES) in order to meet demand in a way that does not affect the environment negatively. South Africa, according to the promulgated IRP2019, plans to decommission some 11 400MW of coal plants by 2030 and about 24 100MW before 2050.[98]

The fate of thermal plants therefore raises an important question for scenario modelling and for policy-making that ensures that the grid remains stable post the fossil-fuel era. In power systems with high shares of renewables, flexibility needs are going to increase considerably, therefore assessing the economics of fuel conversion for existing coal generation units is an option that needs to be considered and compared with other possibilities, including storage, demand-response and nuclear. Recently, attention has focused on the possibility of developing power-to-gas-to-power (by using hydrogen as an interim fuel or adding an additional step of methanation to use synthetic methane) or of importing decarbonised synthetic gases. These options could rely on existing thermal power plants; if it is proven that fuel switching can be implemented in a cost-effective way.

Scenarios aiming at net zero emissions by 2050 with high shares of renewables tend to rely on those technologies. For example, the SNBC projects that hydrogen and decarbonised gas (before conversion into electricity) would be available for electricity generation by 2050 to a limited extent. Nevertheless, generating some dozens of terawatt hours of electricity from synthetic gas, only as back-up solutions when wind or solar availability is low, would still require significant installed capacities. In South Africa, this option could require at least a few dozens of OCGTs and CCGTs running

[95] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[96] https://www.hindawi.com/journals/je/2013/845051/
[97] https://www.hindawi.com/journals/je/2013/845051/
[98] IRP2019

as back-up units with synthetic or decarbonised fuels, i.e. significantly more than the existing fleet of such units.

It is promising that governments have committed to an ambitious global temperature goal and national actions to limit emissions. This study examines not only the benefit of including nuclear in the energy mix but also looks to answer questions facing policymakers today, i.e.: "how can we achieve our ambitious carbon reduction targets in a cost-effective manner? Does nuclear energy have a role to play? What is the right energy mix that is suitable for the country – leading to meeting our decarbonisation targets, at the least cost and meet demand reliably?" Answering these questions correctly will help design, develop and deliver better, cost-effective, environmentally sound policies, for better lives. In order to answer these questions, South Africa's NERSA embarked on a number of bilateral talks to enquire from countries that are ahead in their quest towards decarbonising their electricity grids. Bilateral talks were held with Australia, Italy and other countries. Informal engagements were also held with other nations including France (see appendix A for the Questions and Answers received). A brief study on Germany's energy transition was also conducted and the lessons learned are included in Appendix B. Nuclear policies of major countries are outlined in appendix C and Appendix D examines the assistance provided by IAEA to nations that are investing in nuclear. Finally, an important NEA study is included in Appendix E, which examines different scenarios (percentages) of RES penetration combined with nuclear in terms of cost and viability.

Bilateral Meeting NERSA-Australia High Commission

7th May 2021

NERSA held a meeting with the High Commissioner of Australia in order to learn some lessons from their journey towards decarbonising the grid and their use of Nuclear energy. Australia is similar to South Africa in the sense that it is dominated by baseload due to Intensive Energy Users (IEU) i.e., mines. The commissioner stated that international forces are driving major country's choice of energy sources. This is driven through the instruments of terms of trade, favouring the financing of clean energy sources and climate change agreements, such as the Paris Agreement (The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change, on climate change mitigation, adaptation, and finance, signed in 2016). The question that needed to be answered was: can the right mix of technologies (excluding traditional baseload generators such as Coal and Nuclear), meet base load demand?

2. Australia's Energy Mix excludes Nuclear

The high commissioner admitted that nuclear energy gets you over many problems related to energy supply. He highlighted that the downside of nuclear is the environmental issues due to nuclear waste and security issues, as it is prone to accidents as perceived from experiences around the world. In Australia, nuclear support fell out since the 1970s due to nuclear incidences mainly in Japan. As shown in Figure 1 below, Australia started engaging in renewable energy sources more than 20 years ago, yet they have been very steady in decommissioning their coal based generators and introducing more and more renewable energy. (This is a good strategy to ensure that you do not pull the carpet suddenly from under the grid such that it loses stability. Instead, you steadily reduce coal and introduce renewables incrementally over the years).

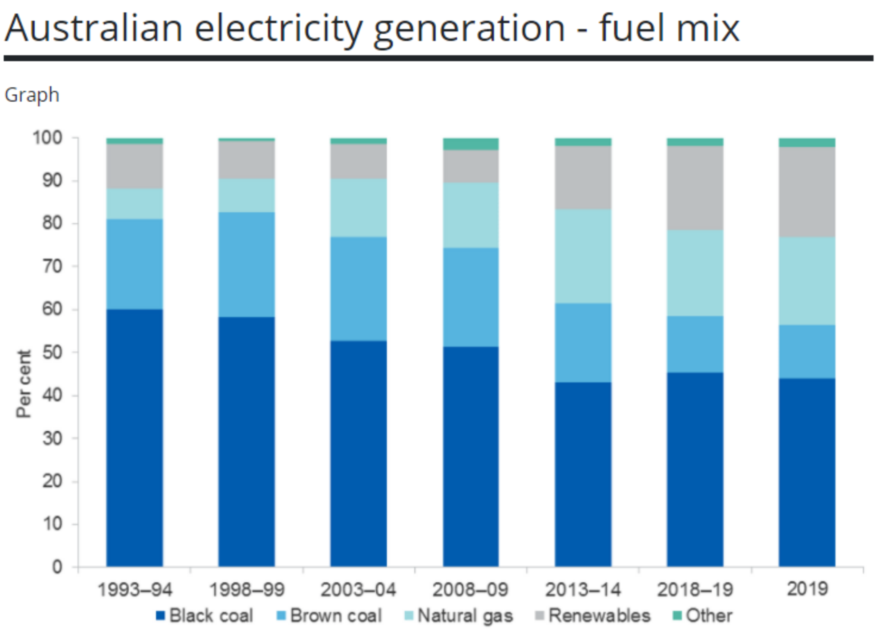


Figure 1: Australia current energy mix (Source: Australia department of Energy website)

Figure 1 shows Australia's electricity generation fuel mix in shares from 1993–94 to 2018–19 and calendar year 2019. Fossil fuels contributed 79 per cent of total electricity generation in 2019, including coal (56 per cent), gas (21 per cent) and oil (2 per cent). Renewables contributed 21 per cent of total electricity generation in 2019, specifically hydro (5 per cent), wind (7 per cent), and solar (7 per cent).

- As can be see form Figure 1 above, Australia currently does not have any nuclear power generators.
- The commissioner said that politically, nuclear is not acceptable in Australia.
- He also mentioned that in making the decision to develop nuclear, one should consider the cost of managing nuclear waste and the decommissioning costs of the plant.

3. Baseload Supply and introduction of Renewables into the grid

- There is a growing view that fossil fuels are a thing of the past, however, Australia's energy mix still consists of 79% from fossil fuels.
- This is in spite of the fact that >25% of homes have solar power.
- Australia also has a National Hydrogen Strategy in place. The aim is to incorporate hydrogen into the energy mix by developing technologies needed to transition into renewable energy.
- The commissioner further stated that Australia's goal is to retire ¾ of coal by 2040.
- This capacity will not be replaced by new coal or gas.
- The commissioner further stated that countries transitioning to renewable energy is an issue of staying competitive and relevant in the global context.

4. Australia and the Integrated Resource Plan (IRP)

- The commissioner stated that the Australia Government does not engage in IRPs. Government policy is to allow the Market to determine the type of technology utilised per time based on economies of scale.
- The government only provides the targets to be met.
- Therefore, the prevailing energy mix is based on a competitively developed solution. This ensures that the least cost option is developed.
- The role of the government is to develop policy that ensures that the market understands that Australia wishes to decarbonise energy supply.

Bilateral Meeting NERSA-ARERA

28th May 2021

5. Introduction

The purpose of the bilateral engagement was to learn valuable lessons from the Italian authorities who are at the coalface of the energy transition process about the challenges they have faced in the path towards energy transitioning and how they are overcoming the challenges. This included ARERA the Italian Energy Regulator, Terna Energy the Italian Transmission System Operator and GES, which is the Italian government agency for promoting and incentivising RES and energy efficiency. The following valuable lessons were learned from the delegates from each organisation:

6. ARERA Energy Regulator

The Italian Regulatory Authority for Energy, Networks and Environment (ARERA) carries out regulatory and monitoring activities in the sectors of electricity, natural gas, water services, the waste cycle and district heating. Established by Law no. 481 of 1995, and operational since 1997, the Authority is a collegial body whose five members are chosen among people with high and recognised professionalism and competence.

Italy's Energy policy is strongly pro-renewables. The country has experienced an impressive growth in the renewable energy sector and has been successful in integrating large volumes of variable renewable energy into the national grid. Containing costs is a priority, and policies are focused on bringing deployment costs towards international benchmarks. Italy has also progressed in terms of market liberalisation and infrastructure development through market coupling (interconnection of the grid with other nations), and this has resulted in price convergence throughout the country.

6.1 Prices and Tariffs

6.1.1 Electricity

In 2019, the average price of electricity (weighted with quantities sold), net of taxes, charged by sales companies to domestic customers was 21.50 c€/kWh in the standard offer service and 24.21c€/kWh in the free market. The difference between the two markets, which can be explained in part by large differences in the types of contracts available on the two markets, was therefore 2.7 €cent, which drops to 2.6 €cent if we only consider the cost component for energy (10.19 €cents/kWh in the standard offer market against 12.81 €cents/kWh in the free market).

6.1.2 Gas

In 2019, the average price of gas (weighted with the quantities sold), net of taxes, charged by companies selling to end customers, was 39.2 c€/m3 (39.9 c€/m3 in 2018). The decrease in the average price (-1.9%) is actually due to the decrease in the price for the largest consumers (over 20 million cubic meters/year), which showed a sharp drop (-6.8 cent €/m3 , -23.3%). The price for all other classes increased. As for LPG4, on the same date, the price for an Italian household that consumes 200 m3 of LPG was 353 c€/m3 (361 c€/m3 in 2018) and is composed of components to cover costs (71.3%) and taxes (28.7%). The cost of raw materials accounts for 21.1% of the total value of LPG, retail sales account for 5.1%, local distribution accounts for 25.2%, while transmission costs upstream of the distribution plant account for 19.8%.

7. Terna Energy

Terna Energy is responsible for planning, developing and maintaining the national transmission grid and managing the electricity flows that pass through it. It ensures that the supply of electricity released into the grid constantly matches demand in terms of power consumption. In addition to this, it designs and develops the grid following a ten-year development plan.

7.1 Terna's role in the Italian Electrical System Supply Chain

Regulated activities account for about 85% of its business, but it also conducts non-regulated activities to support the energy transition as an energy solutions provider and through international activities. Terna also exports its expertise and technological expertise, developed in Italy, making it available to international operators for the development of electricity grids and the management of complex systems, transmission, integration of renewable sources and storage systems.

7.1.1 Dispatching Energy to the Grid

Renewable energy technologies for electricity generation can be grouped into dispatchable renewables, such as hydropower, geothermal power and biomass power and non-dispatchable renewables that are referred to as "variable" or "intermittent" renewables, such as wind power, solar photovoltaics and wave and tidal power. The dispatchability of an electricity generation source refers to the source's ability to be controlled in response to system requirements, such as variation in demand (i.e. at request of the power grid operator). In general, dispatchable sources are constantly available (apart from maintenance needs) for production and offer high capacity factors (i.e. close to those obtained from fossil fuels or nuclear power plants, though with certain limitations). In contrast, electricity generation from non-dispatchable renewables depends on meteorological conditions. Consequently, capacity factors are modest and grid operators cannot fully plan the electricity generation from these sources; only a fraction of the installed capacity can be considered as statistically dispatchable and an appropriate amount of back-up capacity is needed in power grids with a significant share of variable renewables. The typically small size and capacity of variable renewable power generation technologies is particularly suited to distributed power generation systems where many small power plants are connected to the distribution network and produce electricity close to demand sites. This may reduce the need for centralised power generation and high-voltage transmission lines, as well as transmission and distribution costs. However, appropriate adaptation and control of the electricity system (i.e. generation plants and transmission / distribution lines) are needed to ensure reliable operation (i.e. supplying electricity upon demand with required frequency and voltage, and balancing active and reactive power) of grids with a high share of variable renewables.

7.2 Energy Transition Targets

Italy has an ambitious target of increasing Renewable Energy Sources contribution by 85% by 2050. This means that by 2050 solar and wind will account for 60% of the total electricity generated. From 2008 to 2020, Italy managed to add 28,2 GW of Solar and wind energy to the total energy mix. The minimum reserve margin decreased from 25 GW in 2014 to only 2GW in 2020. The summary of Italiay's ambitious goal towards a fossil-fuel free grid is summarised in Figure 2.

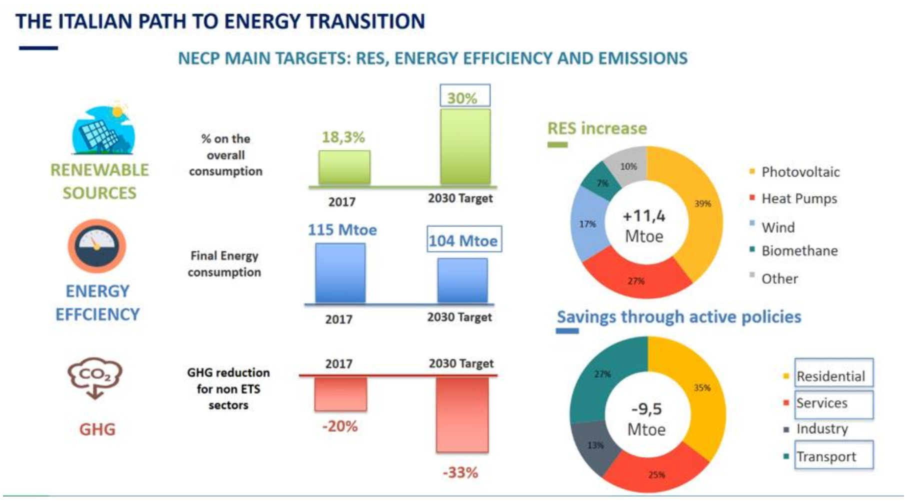


Figure 2: Production target towards 2030

7.2.1 Challenges with RES integration

VRE has four characteristics that require specific measures to integrate these technologies into current power systems: 1) variability due to the temporal availability of resources; 2) uncertainty due to unexpected changes in resource availability; 3) location-specific properties due to the geographical availability of resources; and 4) low marginal costs since the resources are freely available.

7.2.1.1 Main effects on the system

1. **Increasing congestion**

   - This is due to the concentrated development of RES sources in areas where primary sources such as sun and wind are abundant.

2. **Steeper Evening Ramp (Duck Curve)**

   - The steeper evening ramp is due to the sudden reduction of solar production.

3. **Voltage Regulation Resources Reduction**

   - As a result of increased shares of RES capacity on total installed capacity.

4. **Short Circuit Power Reduction**

   - Due to the replacement of synchronous rotating generators with non-synchronous inverter-based generators.

5. **Lower system Inertia**

   - Due to limited contribution of RES to grid inertia.

Each of the factors outlined above will be examined in detail below.

7.2.1.2 Dealing with challenges associated with RES penetration

The integration of a significant share of variable renewables into power grids requires a substantial transformation of the existing networks in order to:

a) Allow for a bi-directional flow of energy; that is top-down (from generators to users) and bottom-up (with end-users contributing the electricity supply) aimed at ensuring grid stability when installing distributed generation;
b) Establish an efficient electricity-demand and grid management mechanisms aimed at reducing peak loads, improving grid flexibility, responsiveness and security of supply in order to deal with increased systemic variability;
c) Improve the interconnection of grids at the regional, national and international level, aimed at increasing grid balancing capabilities, reliability and stability;
d) Introduce technologies and procedures to ensure proper grid operation stability and control (e.g. frequency, voltage, power balance) in the presence of a significant share of variable renewables; and
e) Introduce energy storage capacity to store electricity from variable renewable sources when power supply exceeds demand and aimed at increasing system flexibility and security of supply.

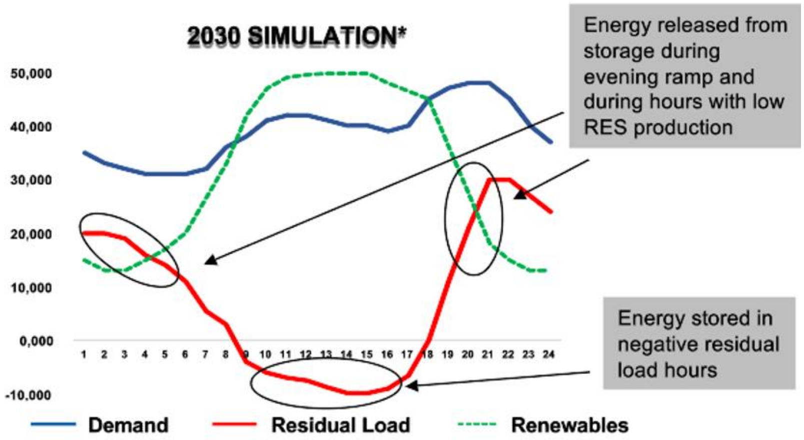


Figure 3: Net load curve with increased RES penetration

To combat the effect of the duck curve on the Residual Load (difference between the total load minus VRE generation), the details of the solutions stipulated above are elaborated below:

7.2.1.3 Electricity Storage

In power grids with a significant share of variable renewables, storage is needed to allow energy to be captured and retained when renewable sources are available for production and this production exceeds the current demand. The stored energy can then be supplied upon demand, even when renewable production is not available. The electricity storage plants can also help to ensure the required grid voltage and frequency stability, at various timescales and operating conditions. Since electricity cannot be stored as it is, electricity storage involves the conversion of electricity into other forms of energy using several technological options with different characteristics and performance, i.e. pumped-storage hydro; compressed air energy storage; electric batteries (e.g. lead-acid, lithium- and nickel-based, flow batteries, etc.); superconducting magnets; flywheels; super-capacitors; chemical storage (e.g. electricity conversion into hydrogen by electrolysis); and thermal storage (e.g. heat storage in concentrating solar power plants. Electricity storage can also be obtained from end-user technologies, such as plug-in electric vehicles (EV) batteries this could be charged overnight using excess electricity, and used during the day. The technical feasibility of this approach is being carefully investigated as it could also contribute to the grid demand-supply balance. Among electricity storage technologies, pumped-storage hydro plants are currently the only commercial option for large-scale electricity storage (in the form of potential energy). Although electricity storage plays a key role for renewable integration in power grids, the global potential for pumped-storage hydro is limited and largely exploited worldwide since these plants require specific sites, with natural or artificial water reservoirs located at different geodetic elevations. New, cost-effective storage technologies are still under development. Near-term applications for advanced battery storage systems can be found in islands and off-grid systems and have started to penetrate the residential market coupled to rooftop solar PV systems.

7.2.1.4 Grid Interconnection

Increased grid interconnection at regional, national and international level would enable more flexibility in power transmission from regions with an ample availability of renewables to other regions with high electricity demand. Another advantage is the integration of variable renewables with conventional power and the possibility for variable renewables to complement each other at different times (e.g. solar power during the day, wind power overnight) and/or in different regions (South, North). Higher interconnection and transmission capacity also enables the optimal use of surplus generation, alleviates the problem of daily and seasonal demand peaks, reduces the requirements for regulation reserves, enhances congestion management and reduces the need for new (and back-up) generation capacity. Modern, high-voltage, direct-current (HVDC) transmission lines for long distances are highly efficient though their implementation takes time and involves significant upfront investment.

Grid interconnection also requires full integration of the grid management systems. Grid interconnection of several operating areas requires high levels of synergy among the system operators in order to achieve a single virtual control area. The technology implemented to achieve grid interconnection allows grid operators to optimise their control energy use through intelligent communication between the grid operators' load-frequency controllers. Moreover, there are some market based mechanisms that facilitate the efficient operation of grid interconnection, such as market coupling, market splitting and market balancing between neighbouring operating areas.

South Africa does not have the advantage of European countries that have neighbours with strong Electricity grids. However, the Southern African Power Pool (SAPP), which is a cooperation of the national electricity companies in Southern Africa under the auspices of the Southern African Development Community (SADC), is one platform that has the potential to be used for grid-interconnection purposes. The members of SAPP have created a common power grid between their countries and a common market for electricity in the SADC region and this platform is an opportunity for SADC countries to work together to achieve each countries decarbonisation goals.

7.2.1.5 Low System Inertia

Massive integration of inverter-based renewable energy systems has been displacing conventional generating units (mainly synchronous generators) and causing a reduction in power system inertia. As a result, the emerging grid is known as low-inertia power systems. Renewable energy systems are integrated into power systems through power electronics (PE) inverters. These can be generally categorized as (i) grid-following (GFL) and (ii) grid-forming (GFM). The GFL is currently the most commonly used technology and synchronizes with the grid and follows the grid's voltage and frequency. On the other hand, the GFM is a promising emerging technology that generates its own voltage signal and has the capability to regulate the frequency and voltage at the point of interconnection, independent of the grid conditions.[99] The GFM is gaining more attention given that as we move towards a low to no inertia grid, frequency regulation becomes challenging. It is presently well taken care of by the synchronous machines in hydro and thermal power plants. The issue at hand is to understand what happens when we move towards a power grid that is dominated by power electronics-based generation and to develop technologies that would mitigate the subsequent challenges and enable this transition. This changing landscape of the power grid causes a broad range of challenges for system modelling, planning, stability, and control. We are working on a range of problems in this area including high-fidelity modelling of GFM and GFL, their parallel operation and control, low inertia systems small-signal and large-signal stability analysis, and developing analytical and computational tools for low inertia systems planning and operation.

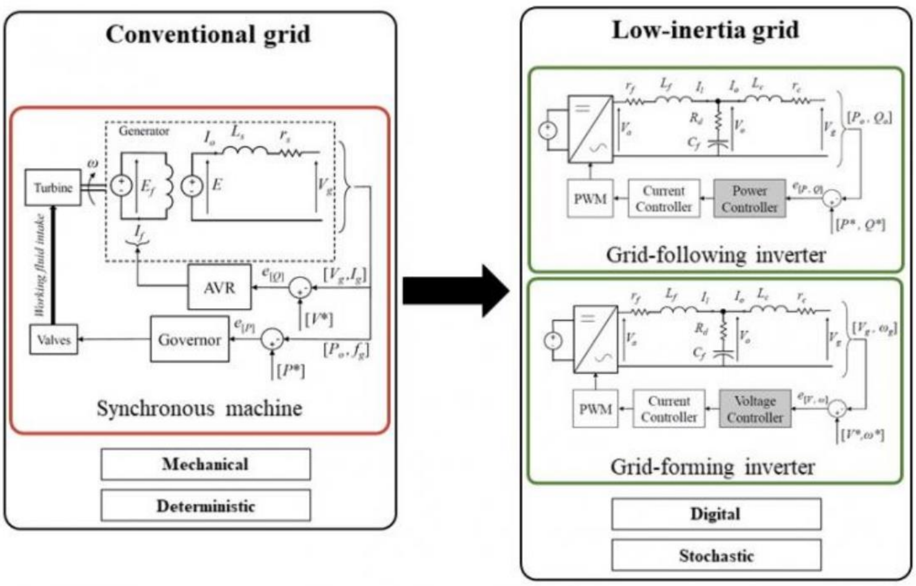


Figure 4: Old grid and new grid (inertia)[100]

[99] https://www.colorado.edu/faculty/hodge/research/low-inertia-power-systems
[100] https://www.colorado.edu/faculty/hodge/research/low-inertia-power-systems

7.2.1.6 Digitilisation & Changes in power system planning and operation

Due to the low-cost and abundant resources of wind and solar energy, it is inevitable that there will be a rise in the integration of technologies that harness these resources into the power grid. South Africa already has some 10% contribution from wind and Solar and this is expected to rise to about 30% by 2030. The rise of distributed energy resources means that there needs to be an accompanying increase in digitalisation of the grid in order to improve system operation and planning.

These factors are leading to a structural shift in the way power systems are planned and operated. In particular, they call for increased flexibility of power systems. Power system flexibility encompasses all relevant characteristics of a power system that facilitates the reliable and cost-effective management of variability and uncertainty in both supply and demand. The need to balance supply and demand is a strong constraint on the operation of the power system. To maintain this balance, several resources can be used to provide flexibility, whether on the production side (most current resources), the demand side (load shaping) or the storage side (batteries and hydro storage). The balance and use of these flexibility sources should be largely be determined at the central System Operator level, taking into account interconnection capacities between countries. Flexibility needs depend on several factors, including the level and types of load (new power uses, thermal sensitivity), the generation mix, and in particular the share of non-dispatchable energies (run-of-river hydropower, wind and solar PV production). They also depend on the country’s load profile and geo-spatial spread of load and generation. Therefore, integrating large shares of renewables could require increasingly decentralised power systems with greater flexibility needs and a shift from synchronous to converter-based technologies; it is particularly important to study the implications of this shift. Given the complexity of accounting for all these factors, integration studies often focus on one or a subset of these. Most studies take a development perspective and focus on system costs and overall system adequacy. Each has its own assumptions, model limitations, strengths and weaknesses. The integration of a high share of VRE technologies faces some challenges that have been clearly identified in January 2021 by RTE (the French transmission system operator) and IEA (the International Energy Agency of the OECD) in a study on the technical conditions for a power system with a high share of renewables. The full study is available here: **https://www.rte-france.com/actualites/rte-aie-publient-etude-forte-part-energies-renouvelables-horizon-2050**

8. GSE Agency

GES is the Italian governmental agency for promoting and incentivising RES and energy efficiency. GSE manages 10 nationwide incentive mechanisms aimed at promoting the development of energy efficiency and renewable sources in Italy. It is allocated about 15 billion Euros in incentives every year, equal to 1% of the Italian GDP. GSE purchases the renewable energy from private suppliers and resells it on the electricity market. Italy is among the countries that reached it 2020 goals set by the European mandatory directive 2009/28/EC, well before the 2020 deadline since 2014. In 2019, the share of renewables in gross final energy consumption was around 18%, above the 2020 Italian mandatory target of 17%. Figure x below depicts the current RES penetration in terms of percentage, the energy consumed and the GHG targets. RES electricity contribution is expected to increase from 115 TWh in 2015 to about 187 TWh by 2030. The highest increase will come from Solar Energy with an additional 50TWh, followed by wind energy at an additional 23 TWh. The production target for each source of renewable energy is indicated in Figure 5 below.

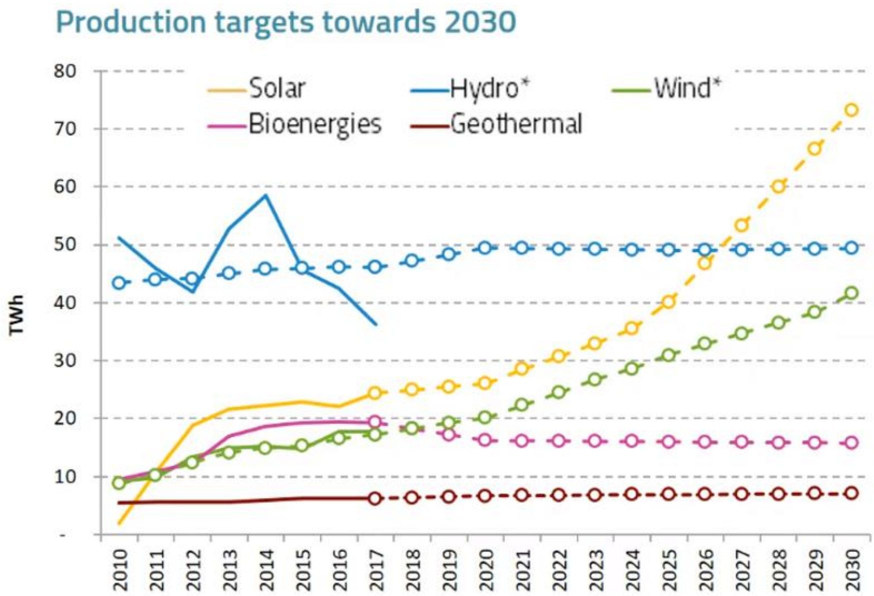


Figure 5: Production target towards 2030

9. Conclusions and Recommendations

It has been established that nuclear as a technology still features significantly in the energy mix of many countries around the world. Countries like Germany that have hurried to decommission their nuclear plants due to incidences in foreign countries, have suffered severely through increased tariffs and dependency on other countries to ensure grid stability. The middle east is currently pursuing nuclear build programs and the development of such plants elsewhere in the world is of particular interest for South Africa since upfront planning with regard to additional nuclear capacity is a requisite given the long (>10-year) lead time, for timely decision making and implementation. Based on the above the following conclusions can be drawn:

- Australia started embarking on the journey of incorporating renewable energy sources more than 20 years ago, (see Figure 1) yet still has 79% of fossil fuels in their energy mix.

- Based on their plans, it will take Australia another 20 years (until 2040) before it retires ¾ of its coal fleet. This will be based on whether they are able to develop hydrogen technology and be able to implement it at utility scale.

- Australia has not decommissioned its fossil fuel based plants quickly and suddenly despite the fact that > 25% of the population utilises solar energy in their homes.

- All the above is due to the fact that Australia, like South Africa has a large base load which needs large base load generators to effectively meet demand.

- South Africa wishes to accomplish the same goal as Australia in less than half the time i.e., by 2040 we aim to retired 73% of coal capacity (20 years). Whether this goal is realistic remains to be seen.

- Australia's IRP is determined by market forces to ensure that the least cost solution is developed according to economies of scale. South Africa on the other hand develops the IRP proactively and the market participates based on the minister's determinations as time progresses. According to the IRP policy, the minister determines which technology to develop according to the least cost solution with the shortest lead times as and when needed.

- Politically, nuclear is not acceptable in Australia. South Africa on the other hand has plenty of experience with operating and maintaining a nuclear plant. Unlike Australia, South Africa does not have sufficient gas reserves to support VRE and is not planning to use hydrogen-based technology as per the IRP.
- Italy's government has put energy and climate at the centre of its political agenda. The national energy and climate plan sets very ambitious targets for renewables by 2030; aiming to reach 30% in total energy consumption and 55% in electricity generation.
- Italy has continued to progress in terms of market liberalisation and infrastructure development, notably in the electricity market where transmission improvements between the north and South, as well as market coupling, have resulted in price convergence throughout the country.
- An important share of electricity comes from import, mainly from Switzerland and France. The share of primary energy dedicated to electricity production is above 35%, and grew steadily since the 1970s.

- Electricity is produced mainly from natural gas, which accounts for the source of more than half of the total final electric energy produced. Another important source is hydroelectric power, which was practically the only source of electricity until 1960. Wind and solar power grew rapidly between 2010 and 2020 thanks to high incentives.
- Italy has few energy resources, and most of supplies are imported, in this way it differs to South Africa which produces nearly all of its electricity requirements.

Ancillary services in the form of reserve capacity normally comes in the form of gas, hydro and storage. These are not yet readily available technologies in South Africa and gas particularly is not available in large quantities. This means that if the country's grid was to be dominated by VRE, we would need to import electricity from hydro and import gas which will be expensive. We therefore need to ensure that over and above VRE sources we have stable clean nuclear and coal baseload to support VRE. Lessons from around the world prove that accelerated decommissioning of thermal base load generators due to incidences elsewhere or as a result of pursuing ambitious renewable energy programs has the potential to compromise the security of supply. Variable renewable energy sources penetration above 20% can cause challenges with maintaining grid stability requiring large capital injection to bolster additional ancillary services. There is therefore a need for base load generation in South Africa, particularly because unlike countries in Europe whose grids are interlinked and help to balance each other's energy supplies, South Africa on the other hand is a net exporter of electricity to SADEC and other regions. The question that was asked at the beginning of this study was whether there is an optimal mix of technologies excluding traditional baseload generators such as coal and nuclear that can meet base load demand. The short answer based on lessons learned particularly from Australia and Italy is yes, however this depends on the availability of alternative fast dispatchable sources such as gas and energy storage to assist with voltage and frequency control and curbing the "duck curve" effect of PV penetration. Both Italy and Australia are developing technologies such as hydrogen and storage technology in order to support VRE generation.

9.1 The following recommendations are therefore made:

Judging from experiences from other countries, there is a need for the country to consider building stable and clean nuclear capacity while decommissioning coal capacity in order to prevent the grid from collapsing in the future. This is due to the following reasons:

- South Africa has unique situation in that it is well developed and has a strong grid system but does not have strong neighbours to interconnect its grid with in order to facilitate for flexibility. The SAPP is a facility that could potentially facilitate for international collaboration, however this would require large investments in the network infrastructure. Italy is able to survive on a relatedly large penetration of renewables because of its ability to tap into the capacity of nearby countries i.e., France and Switzerland that have considerable reserves of nuclear energy.

- South Africa has existing human resource capacity, skills, technology and the economic potential that nuclear holds, consideration must be given to preparatory work commencing on the development of a clear road map for a future expansion programme.

- South Africa needs to pay attention to lessons from around the world when making the decision to decommissioning approximately 24 100 MW of coal fired power plants. This supports the need for additional capacity from clean energy technologies including nuclear.

- It is recommended that NERSA obtains the full picture of the cost of the nuclear option and not just the LCOE. The full costs including future cost of decommissioning nuclear power plants and nuclear waste handling costs should be determined. The total cost should be broken down and it should be clear what it would cost the country compared to other base load generator options such as clean coal.

- It is also recommended that a detailed study should be conducted which will compare the option of adding clean base load generation once coal is decommissioned as opposed to adding more VRE at the additional cost of ancillary services. This should be done in order to determine the approximate base load required and the ancillary services needed in order to maintain grid stability. The associated costs should also be indicated in the study.

- Finally, it is recommended that preparations should be made for new nuclear capacity. However, procurement should not be engaged prior to the studies above being concluded.

- It is recommended that the new nuclear plant should be placed at or near Cape Town as this will be required for grid stability since Koeberg is the only major plant located at the tail end of the grid backbone. Nuclear is the viable option to supply the grid in that area since Cape Town is far from the abundant coal reserves in Mpumalanga and the North end of the Country in Lephalale.

- Due to abundant reserves of coal in the country, it is further recommended that South Africa should strongly consider the options of HELE coal technologies including underground coal gasification, integrated gasification combined cycle, carbon capture utilization and storage, ultra-supercritical, super-critical and similar technologies for the exploitation of our coal resources. This will ensure that base load generation is adequately provided for.

- When considering investing in nuclear energy, the state needs to take into account industrial issues as well as socio-economic issues, which are specific to South Africa.

- Regarding public acceptance, several aspects are important:

  - A legal framework that guarantees transparency (on positive aspects as well as limitations and drawbacks) and access to information;
  - Public debates and consultations;
  - A nuclear safety authority (ASN), which must be independent from the government and provide public access to information including on their recommendations and prescriptive measures

Appendix A - Answers from the General Directorate for Energy and Climate (DGEC) of the French Ministry for the Ecological Transition to the questions from the South African energy regulator NERSA

1. **Please advise how countries still investing in nuclear are able to motivate for it given the high levels of anti-nuclear rhetoric as well as the rise of Renewable energy uptake.**

- Nuclear and renewables are not to be opposed. Both technologies can contribute to decarbonize the energy system and, for those countries that decide to use it, nuclear power, as a reliable and flexible technology, may also contribute to reach higher shares of renewables. In France, the stated priority is to fight global warming, and as a result there will be no additional fossil fuel power plant. Renewables and nuclear power are considered compatible and complementary in a diversified and clean electricity system.

- The integration of high share of variable renewables (solar and wind) in the electricity mix face some challenges that have been clearly identified in January 2021 by RTE (the French transmission system operator) and the IEA (the International Energy Agency of the OECD) in a study on the technical conditions for a power system with a high share of renewables. The full study is available in English: https://www.rtefrance.com/actualites/rte-aie-publient-etude-forte-part-energies-renouvelableshorizon-2050

- When considering investing in nuclear energy, a State needs to take into account industrial issues as well as socio-economic background, which may be specific to each country.

- Regarding public acceptance, several aspects are important:
  - A legal framework that guarantees transparency (on positive aspects as well as limitations and drawbacks) and access to information;
  - Public debates and consultations;
  - A nuclear safety authority (ASN), which must be independent from the government and provides public access to information including on their recommendations and prescriptive measures.

2. **What cost assumptions are used to justify the decisions and from which countries are these costs taken from as there has been a lot of talk about nuclear costing above >$5000/k?. Which countries have reactors coming out below $2000/kW? What Discount rates are used in the planning? Please provide articles that you can share that talk to costs.**

- The NEA (Nuclear Energy Agency of the OECD) has been working on these topics and has published several reports on the cost of nuclear energy. While those reports do not necessarily reflect the assessments carried out in France, these reports are providing very useful information and will help reply to these questions, including in the context of South Africa:

- Projected Costs of Generating Electricity: https://www.oecd-nea.org/jcms/pl_51110/projected-costs-of-generating-electricity-2020- edition?id=pl_51110&preview=true

  - Unlocking Reductions in the Construction Costs of Nuclear/A Practical Guide for Stakeholders (2020):

    https://www.oecd-ea.org/jcms/pl_30653/unlockingreductions-in-the-construction-costs-of-nuclear

  - The Costs of Decarbonisation/ System Costs with High Shares of Nuclear and Renewables: https://www.oecd-nea.org/jcms/pl_15000/the-costs-of-decarbonisation-system-costs-with-high-shares-of-nuclear-and-renewables

- Most recently, the IEA delivered its “Net Zero by 2050 – A Roadmap for the Global Energy Sector” report: https://www.iea.org/reports/net-zero-by-2050.

- The discount rate to be used depends on the financial structure of the project, its investors, the risks they hold, and, in case of public intervention in equity or subvention, the discount rate for public investment.

- When comparing technologies, a systemic analysis should be led as Levelized Costs Of Energy (LCOE) do not properly reflect all the costs associated with the use of some technologies, such as system costs.

3. **Do you have any studies that look at the appropriate level of RE penetration in the energy mix, given their tendency to being highly variable and can result in stability problems for the System Operator?**

- There is no “appropriate level”. Each country has its own technical constraints, depending also on the degree of interconnection with the neighbouring countries, and makes its own political choices.

- As far as technical considerations are concerned, see the January 2021 RTE and IEA study on the technical conditions for a power system with a high share of renewables (reference and link to the full study in question 1).

4. **Do you have articles / studies regarding stability risk for countries with high levels of RE like Germany, how are these mitigated, especially for a country like SA that is not as interconnected to other countries like Germany is? SA is a net exporter of power so it is effectively an island from an import perspective.**

   • See the January 2021 RTE and IEA study on the technical conditions for a power system with a high share of renewables (reference and link to the full study in question 1).

5. **What ownership structures are considered in the implementation of the nuclear build programmes? Is there consideration for private/public partnerships, especially given the nature of nuclear and safety risks associated therewith?**

   - Due to its specificities (such as important upfront capital costs or very long asset lifetime), nuclear energy requires a State intervention, which can take several forms (which can be cumulative), for instance:

     - Equity participation or subsidies at the investment stage; o revenue regulation;
     - Various insurance schemes for political or legislative risks;
     - Sovereign backed guarantee.

The ownership structures depend on all the features of the State intervention.

6. **What kind of contracting is considered and has resulted in successful projects?**

   - Several contracting can be considered, depending on the specificities of the project. In any case, the risks taken by the private players must be limited to their field of competence.
   - See reports from NEA (references in question 2).

7. **In your regions, does the customer ever pay for a plant that is still being built, that is, part of the tariff paid by the customer include capital costs of stations that are still under construction?**

   • The State intervention may take many forms (cf. question 5), including a revenue regulation as soon as the construction phase, in order to facilitate the financing of the project by private players.

   • Today, public electricity tariffs in France do not include a regulation for stations that are being built.

8. **If not, how are the funds raised for a program like a nuclear build which is highly capital intensive?**

   • Refer to the previous answers: the ability to raise funds depends on the State intervention for the project, on the security and visibility given to the potential investors.

9. **Please comment on the notion that true costs of nuclear cannot be known until a procurement process is initiated. How do you then plan, if that is the case?**

   • A competitive process may indeed help to reveal the costs, but the fact that nuclear technologies may have significant differences (for instance as far as nuclear safety features are concerned) must be taken into account.

   • As far as the costs of decommissioning, waste management and spent fuel management are concerned, they should be considered before deciding on new build projects. An internal dedicated fund has to be set up to finance those costs as soon as the nuclear facility is commissioned (see below).

10. **Please comment on the decommissioning and waste management in terms of costs as well as infrastructure.**

   • In France, in compliance with the "polluter pays" principle, it is up to the nuclear licensees to take charge of the financing of those costs by setting up a dedicated portfolio of assets capable of meeting the expected costs as soon as the nuclear facility is commissioned. These assets must be clearly identified and managed separately from the company's other financial assets and investments.

   • The total amount invested in these dedicated assets has to exceed the discounted value of the costs of decommissioning nuclear facilities and managing the spent fuel and the radioactive waste. A specific discount rate is used, which must be compliant with applicable accounting standards and must be lower than a regulatory cap and then the expected rate of return on dedicated assets.

   • The Ministers in charge of Energy and Economy are closely monitoring this system and can prescribe any necessary measure.

   • Regarding infrastructures, the main challenge is the disposal of high-level and intermediate level long-lived wastes. The reference solution studied in France is the Centre Industriel de Stockage Géologique (Cigéo) project, which is a deep geological disposal site. This project is to be funded by radioactive waste producers and managed by the national radioactive waste management agency (ANDRA). It is internationally recognized as the best way to deal with those kinds of wastes.

11. **What are your comments on SMR, do you have information regarding the maturity of this technology and costs associated thereto?**

- Worldwide, several SMR projects or concepts are being developed. See IAEA booklet on SMR technologies: https://aris.iaea.org/Publications/SMR_Book_2020.pdf

- A French SMR is also under development. It is called Nuward.

- No SMR technology is ready to be built at large scale in the very short term but SMR may be built massively in the 2030s.

12. **What is the region's view on baseload demand requiring baseload supply? Do you believe that a system that is purely RE and flexible generation, can it support a country like SA that is trying to industrialise?**

- There are multiple assumptions regarding the evolution of electricity demand as it depends on industrialization, electric vehicle deployment, energy retrofit of buildings and electrification of final uses.

- See the January 2021 RTE and IEA study on the technical conditions for a power system with a high share of renewables (reference and link to the full study in question 1).

13. **Typically, how long does it take to develop a nuclear plant, i.e. cradle to grave? How much of that time should be for planning?**

- To do the detailed design of a new technology of nuclear plant may take several years or decades to a nuclear company. The question of the time needed for developing a nuclear plant usually refers to the time to adapt an existing technology to one site specificities, then the time needed to take a decision (which mostly depends on politics and on the time needed to implement a financial and regulatory framework), then the time to build after the investment decision.

- The NEA has been including these aspects in several of its reports (see references in Question 2), in particular some comparison of the past projects. However, recent FOAK projects have experienced multiple issues. The industry learned from this experience, and the planning of new projects is not to be strictly compared to the planning of a FOAK

Appendix B – Lessons from Germany on transitioning to renewable energy

Germany's Energiewende (energy transition) is a national program to change to a renewable-dominated energy system and phase out nuclear power. The government has estimated that the total cost of this could reach €1 trillion. Germany until March 2011 obtained one-quarter of its electricity from nuclear energy, using 17 reactors. Following the Fukushima accident in Japan in March 2011, eight reactors shut down immediately with the remaining reactors to be phased out by 2022.

While the main challenge in grid function is in transmission capacity, most solar PV systems are connected to the distribution grid, providing a distinct set of challenges for reliability at that level of distributed generation. Also, when in 2005 domestic sources were encouraged to feed surplus into the distribution grids it was assumed that this would be consumed locally, thus reducing the need for trans-regional transmission. However, it turned out *"that volatile renewables such as solar and wind power do not help eliminate the need for grid expansion; on the contrary, they create the need for it,"* according to the Federal Ministry for Economic Affairs and Energy of Germany.

Maintaining grid stability in 2018 cost more than €1.4 billion, due to redispatch* where prioritised renewable power causes transmission congestion and conventional power stations are paid to reduce output. The redispatch costs have risen since 2015 despite a new east-south grid link. The country's four transmission system operators (TSOs) said that redispatch costs could rise to €4 billion per year by 2020, and the German federal network agency and grid authority *Bundesnetzagentur* (BNetzA) agreed that this was not unrealistic, given the slow progress with transmission expansion. The Association of German Chambers of Industry and Commerce (*Deutscher Industrieund Handelskammertag*, DIHK) estimates redispatch costs at €30 billion over 2016 to 2025.

As well as redispatch, the grid operator can decide to curtail excessive renewable power from individual installations, in which case the producer is compensated with 95% of its lost FIT revenues. The number of such curtailments on the grid has increased significantly in recent years, so that balancing payments of €485 million were made by grid operators to renewable energy (mostly wind) producers between 2009 and the end of September 2015, with rising amounts anticipated for the future. The incurred costs are passed onto ratepayers. Curtailment of wind and solar energy in 2018 due to grid congestion amounted to 5.4 TWh, with compensation payments of €635 million. The figure had risen by around 50% in 2017 (5.5 TWh curtailments, with €610 million compensation payments).

In July 2012 *The Economist* opined:

"It is hard to think of a messier and more wasteful way of shifting from fossil and nuclear fuel to renewable energy than the one Germany has blundered into. The price

will be high, the risks are large and some effects will be the opposite of what was intended."

To mitigate this, Germany decided to implement rules that were aimed at limiting the share of electricity coming from renewables in 2025 to 45% and 60% in 2035 in order to synchronize with network expansion, to secure planning and development of the conventional power station fleet, and so that Germany's neighbours can adapt their own electricity systems to predictable renewable energy additions. South Africa must learn lessons from economies like Germany who are ahead in their program of transitioning to cleaner technologies in order to avoid making the similar mistakes.

Appendix C - Nuclear Policies of Major Countries

There are a number of reports from around the world on the implications of plans to close down nuclear generation and greatly ramp up the contribution of wind and solar sources. They strongly warn of resulting vulnerability to major failures and also unreliability. Grid stability was the major concern, along with generation and transmission capacity. Increased capacity from conventional thermal plants is essential to cope with occasional high input from wind and solar, and this will be very expensive but the average utilisation will be low. The following information was obtained:

Germany

Germany until March 2011 obtained one-quarter of its electricity from nuclear energy, using 17 reactors. Following the Fukushima accident in Japan in March 2011, eight reactors shut down immediately with the remaining reactors to be phased out by 2022.

Italy

Italy has had four operating nuclear power reactors but shut the last two down following the Chernobyl accident. About 6-8% of the electricity consumed in Italy is from nuclear– all imported.

Spain

Spain generates about a fifth of its electricity from nuclear power. Its first commercial nuclear power reactor began operating in 1968. There are plans for renewed uranium mining. Government commitment to nuclear power has been uncertain.

European Union

The EU depends on nuclear power for more than one-quarter of its electricity, and a higher proportion of base-load power. Nuclear provides over half the low-carbon electricity. Very different energy policies pertain across the continent and even within the EU.

Netherlands

The Netherlands has one nuclear reactor generating a small amount of its electricity. A previous decision to phase out nuclear power has been reversed. Public and political support is increasing for expanding nuclear energy.

Middle Eastern Countries

Saudi Arabia, the emirate of Abu Dhabi in the United Arab Emirates, and Iran – are currently pursuing nuclear power despite their large reserves of oil and gas. Why do many Middle Eastern countries view nuclear power more favourably than renewables such as solar power? How do state policies on energy pricing influence these decisions? What are the advantages of huge up-front investments when lower-cost power generation options are available? What will the presence of nuclear plants do to the relationship between the Gulf States and the West, not just in terms of economics but for geostrategy?

Appendix D - IAEA support for new nuclear programmes

The IAEA states that all countries governments need to create the environment for investment in nuclear power, including professional and independent regulatory regime, policies on nuclear waste management and decommissioning, and involvement with international non-proliferation measures and insurance arrangements for third-party damage.

In 2009 the IAEA began offering **Integrated Nuclear Infrastructure Review (**INIR**)** missions to evaluate the status of countries' nuclear infrastructure development, building on member states' self-evaluation. The first three were to Jordan, Indonesia and Vietnam. Since then, INIR reviews have been conducted in Bangladesh, Belarus, Egypt, Ghana, Kazakhstan, Malaysia, Morocco, Niger, Nigeria, Philippines, Poland, Saudi Arabia, Thailand, Turkey and United Arab Emirates. In 2013 an INIR mission was to South Africa – the first country with an operating nuclear power programme that has requested this service.

More broadly than these INIR missions are **Nuclear Energy System Assessments (NESA)**, using the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) methodology to help countries develop long-term national nuclear energy strategies. The INPRO methodology identifies a set of Basic Principles, User Requirements, and Criteria in a hierarchical manner as the basis for the assessment of an innovative and sustainable nuclear system. The NESA programme helps members "in gaining public acceptance, getting assistance in nuclear energy planning in their country, and increasing awareness of innovations in nuclear technologies". NESAs have been carried out in Belarus, Kazakhstan, Ukraine and Indonesia.

IAEA **Site and External Events Design (**SEED**)** missions review the design and siting of nuclear plants against external hazards specific to the site. The programme arose from the Fukushima accident and involves the IAEA's International Seismic Safety Centre (ISSC), which has conducted over 430 site external hazard evaluations since 1980.

The IAEA also has an **Integrated Regulatory Review Service (**IRRS**)** to scrutinise the regulatory structures in particular countries, upon invitation from the government. Though mostly used for countries with established nuclear power, it is also used for countries embarking upon nuclear power programmes, as in Iran in 2010, Poland early in 2013, Jordan and Vietnam in 2014, UAE and Indonesia in 2015, Bangladesh and Belarus in 2016.

In March 2020 the IAEA published new guidance to countries planning to adopt nuclear power in a document titled Initiating Nuclear Power Programmes: Responsibilities and Capabilities of Owners and Operators. It takes into account more than ten years of experience and good practices in countries that are introducing nuclear power, as well as lessons learned during INIR missions, and IAEA technical assistance activities to newcomer countries. Together with the nuclear energy programme implementing organization (NEPIO) and the nuclear regulatory body, the nuclear plant owner-operator is one of the three key organizations identified in the 'milestone' approach. The publication is a significant revision of a document first issued in 2009.

Nuclear build Program

In different countries, institutional arrangements vary. Usually governments are heavily involved in planning, and in developing countries also financing and operation. As emerging nuclear nations lack a strong cadre of nuclear engineers and scientists, construction is often on a turnkey basis, with the reactor vendor assuming all technical and commercial risks in delivering a functioning plant on time and at a particular price. Alternatively, the vendor may be set up a consortium to build, own and operate the plant. As the industry becomes more international, new arrangements are likely, including public-private partnerships.

The IAEA sets out a phased 'milestone' approach to establishing nuclear power capacity in new countries, applying it to 19 issues. In broad outline the three phase approach is (milestones underlined):

- **Pre-project phase 1** (1-3 years) leading to knowledgeable commitment to a nuclear power programme, resulting in set up of a nuclear energy programme implementing organization (NEPIO). This deals with the programme, not the particular projects after phase 2.
- **Project decision-making phase 2** (3-7 years) involving preparatory work after the decision is made and up to inviting bids, with the regulatory body being established. In phase 2 the government role progressively gives way to that of the regulatory body and the owner-operator.
- **Construction phase 3** (7-10 years) with regulatory body operational, up to commissioning and operation.

In this regard and as it is the case with coal, small nuclear units will be a much more manageable investment when compared to a fleet approach.

Appendix E – NEA study on System costs associated with combining Nuclear, Renewables & Storage

Today, system costs are no longer part of an unfamiliar concept but a universally accepted part of electricity system analysis. The first NEA study on system costs, published in 2012, was part of an early wave of studies that were instrumental in introducing and conceptualising the notion of system costs. While the initially developed concepts, as well as the basic methodology of working with residual load curves to assess profile cost, have proven robust, much has changed during the past five years. Among the changes that need to be accounted for are:

- The significant decline in the LCOE costs of renewable energies, in particular for solar PV, as documented in the changes in investment costs reported in the IEA/NEA reports on the Projected Costs of Generating Electricity for 2010 and 2015;
- The emergence of a broad and lively literature on the system costs of electricity systems, which includes the emergence of a widely shared methodological framework for assessing profile costs;
- A greater awareness and better understanding by policy makers of the importance of system costs;
- A clearer idea of the policy-relevant questions that can be usefully asked and answered by the available conceptual and modelling tools given the present state of knowledge.

From the outset, it was clear that any new study should not simply provide an update of the well-regarded 2012 study. In the present study, great care has been expended to construct a representation of the electricity sector in a manner as complete as possible. In this process, the NEA worked with a team of experienced power system modellers at the Massachusetts Institute of Technology (MIT). NEA modelling of the eight scenarios is thus built on the Optimal Electricity Generation Expansion (GenX) model developed at MIT, which provides the detailed, comprehensive and flexible representation of an integrated electricity system that was required. The electricity sector model that underlies this study thus includes not only hourly dispatch but also ramping constraints and reserve requirements that preserve both system stability and economic equilibrium. In addition, a carefully selected set of credible flexibility options has been added to the model. They include interconnections with neighbouring countries, a relatively high share of flexible hydroelectric resources, demand-side management (DSM) and several storage options. Both technological and flexibility options are important drivers of total system costs. This holds, in particular, if electricity generation includes a large share of wind and solar PV, since their variability challenges the workings of the system by increasing ramp costs and reserve requirements, and it also increases the demand for different flexibility options. The defining feature of this modelling effort is the fact that all scenarios include the same stringent carbon constraint of 50 gCO2 per kWh, which is consistent with a level that the electricity systems of OECD countries must achieve to contribute their share to limit the increase in global mean temperatures to 2°C. In order to allow for economic results that are as general, relevant and transparent as possible (and thus independent of the power generation mix of a particular country), this study has taken a "greenfield approach". This means that starting with a clean slate the electricity system evolves only as a function of electricity demand throughout the year and the specific costs of different technologies in an optimal fashion as if all plants were built from scratch on a green field. This approach is limited only by the exogenously imposed constraints, i.e. carbon emissions of 50 gCO2 per kWh and different shares of VRE generation that are specified ex ante. Only the share of hydroelectric resources has been set exogenously. The alternative – using a brownfield approach – would have yielded different results. In function of the existing mix, the results in this volume might help individual countries to better assess the cost of their transitions. However, the results of brownfield modelling would not allow drawing comparable general conclusions about the respective costs of electricity systems with different shares of nuclear and renewables. In particular, for variable renewables such as wind and solar PV, the total system costs are highly dependent on local conditions and the structure of the residual system. VREs, more specifically wind and solar PV, share some specific characteristics that make their integration into the electricity system particularly challenging. The IEA has identified six technical and economic characteristics that are specific to VRE and are a key element to explain and understand the system costs associated with their integration. The output of VRE is thus:

- **Variable:** the power output fluctuates with the availability of the resource (wind and solar) and not as a function of demand or system needs.

- **Uncertain:** the amount of power produced cannot be predicted with precision. However, the accuracy of generation forecast increases with approaching the time of delivery.

- **Location-constrained:** the available renewable resources are not equally good in all locations and cannot be transported. Favourable sites are often far away from load centres.

- **Non-synchronous:** VRE plants must be connected to the grid via power electronics and are not directly synchronised with the grid.

- **Modular:** the scale of an individual VRE unit is much smaller than other conventional generators.

- **With low variable costs:** once built, VRE generate power at little operational cost. The short-run marginal costs of wind and solar PV units are zero.

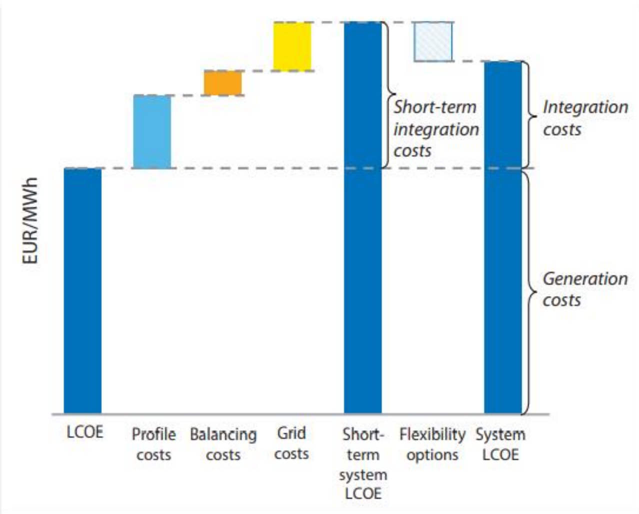
The concept of system effects, which are heavily driven by these six attributes of VRE, has been conceptualised and explored extensively by the NEA and the IEA, and has benefitted from a significant amount of new research from academia, industry and governments. System effects are often divided into the following four broadly defined categories of profile costs (also referred to as utilisation costs or backup costs by some researchers):

- Balancing costs,
- Grid costs,
- Connection costs,
- Profile costs (or utilisation costs) refer to the increase in the generation cost of the overall electricity system in response to the variability of VRE output.

They are thus at the heart of the notion of system effects. They capture, in particular, the fact that in most of the cases it is more expensive to provide the residual load (net load) in a system with VRE than in an equivalent system where VRE are replaced by dispatchable plants. A different way of looking at the profile costs of VRE is to consider that the electricity generation of wind or solar PV is concentrated during a limited number of hours with favourable meteorological conditions. This decreases value for the system of each additional VRE unit and corresponds to an equivalent increase in profile costs. In addition, the presence of VRE generation generally increases the variability of the residual load, which exhibits steeper and more frequent ramps. This causes an additional burden, also called the flexibility effect, to other dispatchable plants in terms of more start-ups and shutdowns, more frequent cycling and steeper ramping requirements, leading to lower levels of efficiency, an increase in the wear and tear of equipment and higher generation costs.

Balancing costs refers to the increasing requirements for ensuring the system stability due to the uncertainty in the power generation (unforeseen plant outages or forecasting errors of generation). In the case of dispatchable plants, the amount and thus the cost of operating reserves are generally given by the largest contingency in terms of the largest unit (or the two largest units) connected to the grid. In case of VRE, balancing costs are essentially related to the uncertainty of their output, which may become important when aggregated over a large capacity. Forecasting errors may require carrying on a higher amount of spinning reserves in the system. Grid costs reflect the increase in the costs for transmission and distribution due to the distributed nature and locational constraint of VRE generation plants. However, nuclear plants also impose grid costs due to siting requirements for cooling and transmission. Grid costs include the building of new infrastructures (grid extension) as well as increasing the capacity of existing infrastructure (grid reinforcement). In addition, transmission losses tend to increase when electricity is moved over long distances. Distributed solar PV resources may, in particular, require investing in distribution networks to cope with more frequent reverse power flows occurring when local demand is insufficient to consume the electricity generated. Connection costs consist of the costs of connecting a power plant to the nearest connecting point of the transmission grid. They can be significant especially if distant resources (or resources with a low load factor) have to be connected, as can be the case for offshore wind, or if the technology has more stringent connection requirements as is the case for nuclear power. Connection costs are sometimes integrated within system costs (see NEA, 2012), but are sometimes also included in the LCOE plant-level costs. This reflects commercial realities as different legislative regimes require connection costs either to be borne by plant developers or by the transmission grid operator. In the former case, they are part of the plant level costs and thus fully internalised, while in the latter case they are externalities to be accounted for in the system costs. The above list of four cost categories of system costs is not fully exhaustive. The provision of physical inertia, which is implicitly provided by dispatchable plants but not by VRE, is thus emerging as a topic of research. Together, the four categories nonetheless make up the bulk of system costs. Figure ES2 below summarises them.

Figure ES2. **Illustration of system cost**



Source: OECD, 2015.

Modelling results from the NEA system cost study

The NEA study shows that combining explicit targets for VRE technologies and a stringent limit on carbon emissions has important impacts on the composition of the generation mix and its cost. In particular, total generation capacity increases significantly with the deployment of VRE resources. Since the load factor and the capacity credit of VRE is significantly lower than that of conventional thermal power plants, a significantly higher capacity is needed to produce the same amount of electricity. While about 98 GW are installed in the base case scenario without VRE, the deployment of VRE up to penetration levels of 10% and 30% increases the total capacity of the system to 118 and 167 GW, respectively. The total installed capacity would more than double to 220 GW if a VRE penetration level of 50% must be reached. More than 325 GW, i.e. more than three times the peak demand, are needed if VRE generate 75% of the total electricity demand. In other words, as the VRE penetration increases vast excess capacity, thus investment, is needed to meet the same demand. The capacity mix of different generation technologies in the five main scenarios is illustrated in Figure ES3, while their respective electricity generation share is shown in Figure ES4 below.

Figure ES3. **The capacity mix with different shares of VRE**

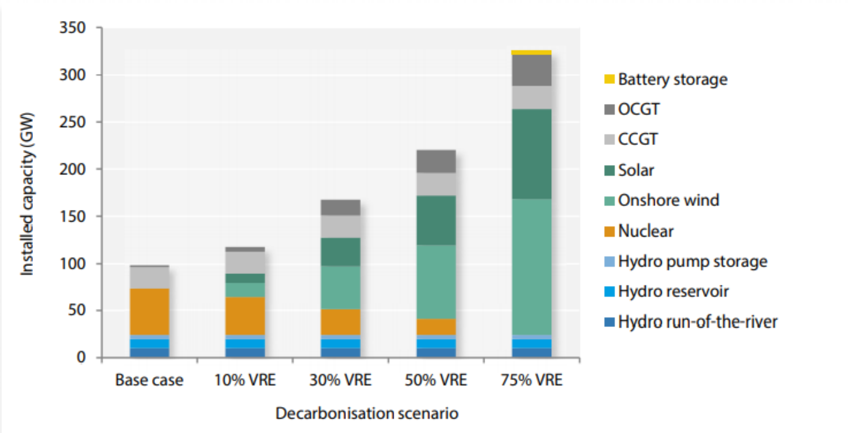
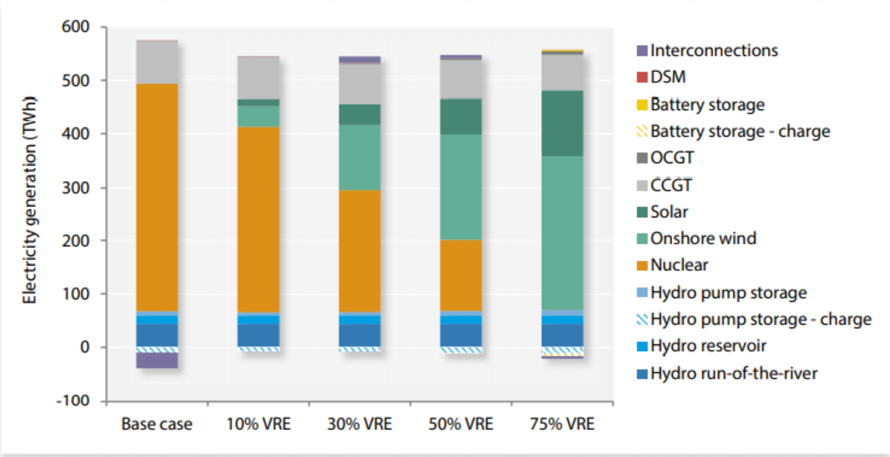
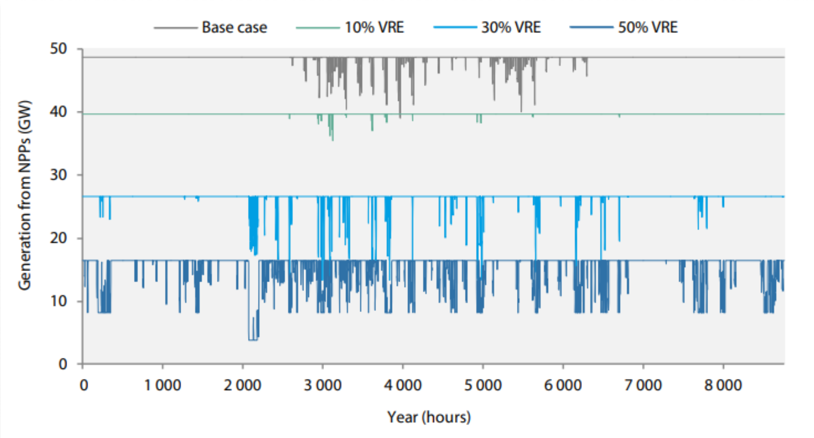


Figure ES4. **Electricity generation share in the main region (main scenarios)**



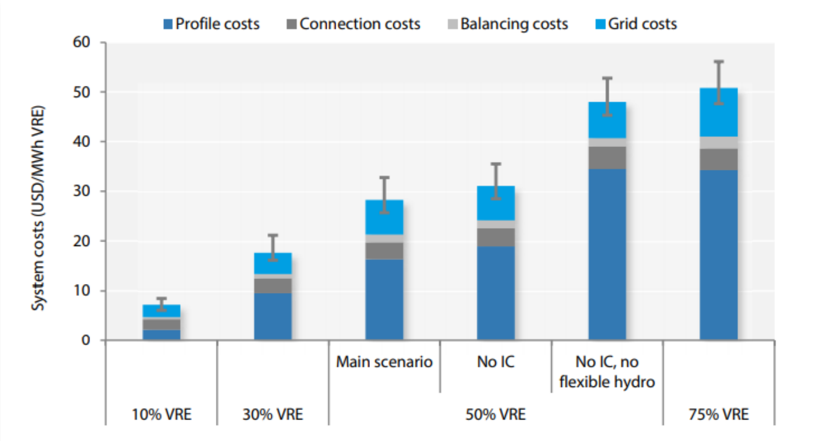
The integration of VRE changes the long-term structure of the thermal generation mix. The share of fossil-fuelled generation (open cycle gas turbine [OCGT] and combined cycle gas turbines [CCGT]) remains almost constant in all scenarios, as it is limited by the carbon cap. However, the structure of the capacity installed of gas plants and the relative share of generation from OCGT and CCGT changes significantly with the presence of VRE. While the capacity of CCGT power plants is almost constant in all scenarios considered, they are operated at lower load factor in the scenarios with more variable generation. Another important finding is that, under the stringent carbon constraint adopted for this study, coal is never deployed in any of the scenarios considered, despite being cheaper than the other technologies on a pure LCOE basis. In terms of generation, VRE displaces nuclear power almost on a one-to-one basis, which results from the fixed carbon constraint in combination with a fixed amount of hydroelectric resources. The way in which thermal plants operate also changes significantly, with a reduction of the average load factors and an increase of ramping and load-following requirements. Figure ES5 shows the projected hourly generation pattern of the nuclear fleet for four of the five main scenarios considered (there is no nuclear generation under the 75% VRE). This allows a visualisation of the increased flexibility requirements from nuclear plants, as well as the reduction in nuclear capacity associated with VRE deployment.

Figure ES5. **Projected generation pattern from nuclear power plants**



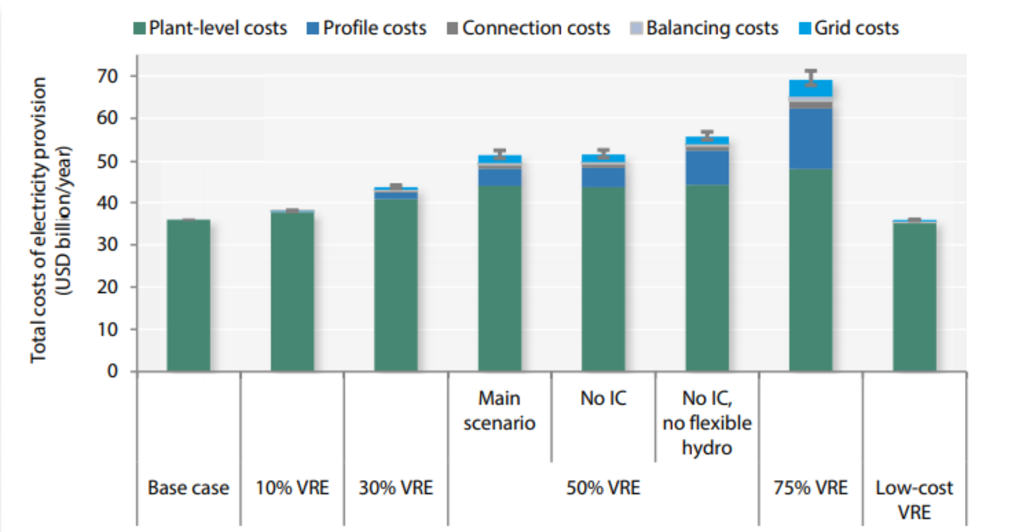
Nuclear capacity progressively decreases with the share of renewables. In the base case scenario with the lowest cost and no VRE, nuclear power is the major source of low-carbon electricity and produces about 75% of the total electricity demand with minimal demand on flexibility. At higher rates of VRE, the demand for nuclear flexibility increases progressively. In the 50% VRE case, nuclear units must ramp up and down by a maximal 30-35% of their installed capacity in one hour. The changes in the capacity mix, the generation mix and load factors of the different technologies can be captured in the system costs of the different scenarios. Additional grid costs, balancing and connection costs are thus added to the profile costs already implicitly calculated in the different optimised scenarios. As already mentioned, profile costs result from the de-optimisation of the residual system due to the variability of VRE. Total system costs, expressed in USD per unit of net electricity delivered by VRE to the grid are shown in Figure ES6 for the four scenarios of 10%, 30%, 50% and 75% VRE as well as for the two sensitivity scenarios. These system costs must be understood as the increase of the total costs to provide the same service of electricity supply above the costs of the least-cost scenario without any VRE. System costs in the reference system are zero since the issue of variability does not arise because all the electricity is generated by dispatchable technologies. The figure also provides a breakdown of the total system costs into the four main components. Also, an error bar provides an indication of the uncertainty range deriving from a range of possible assumptions on grid, connection and balancing costs.

Figure ES6. **System costs per MWh of VRE**



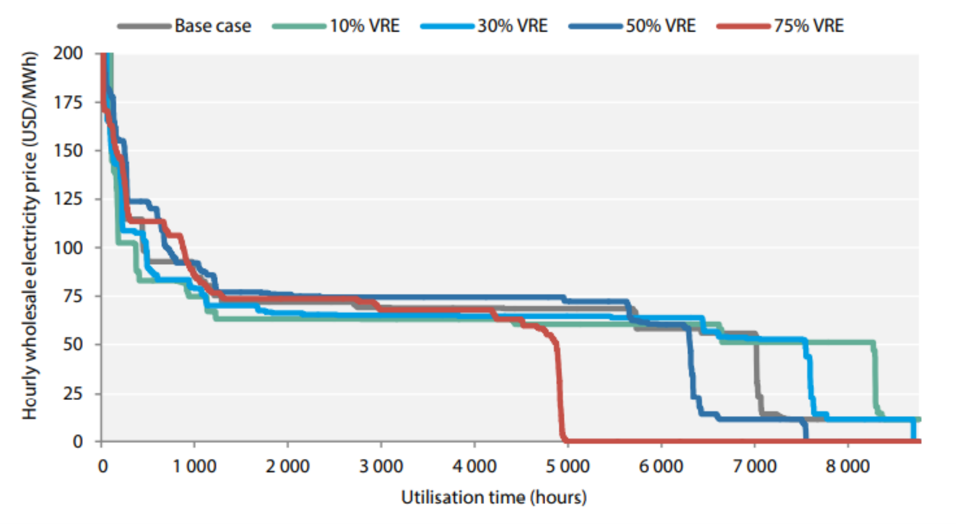
System costs vary between less than USD 10 per MWh of VRE for a share of 10% of wind and solar PV to more than USD 50 per MWh of VRE for a share of 75% of wind and solar PV. Almost as important is the increase of USD 28 per MWh of VRE to almost USD 50 per MWh of VRE, both at a share of 50% of wind and solar PV, as a function of the availability of flexibility in the system in the form of interconnections with neighbouring countries and flexible hydroelectric resources. While such estimates come with some degree of uncertainty, the order of magnitude provides clear indications for policy choices.

Figure ES7. **Total cost of electricity provision including all system costs**
(USD billion per year)



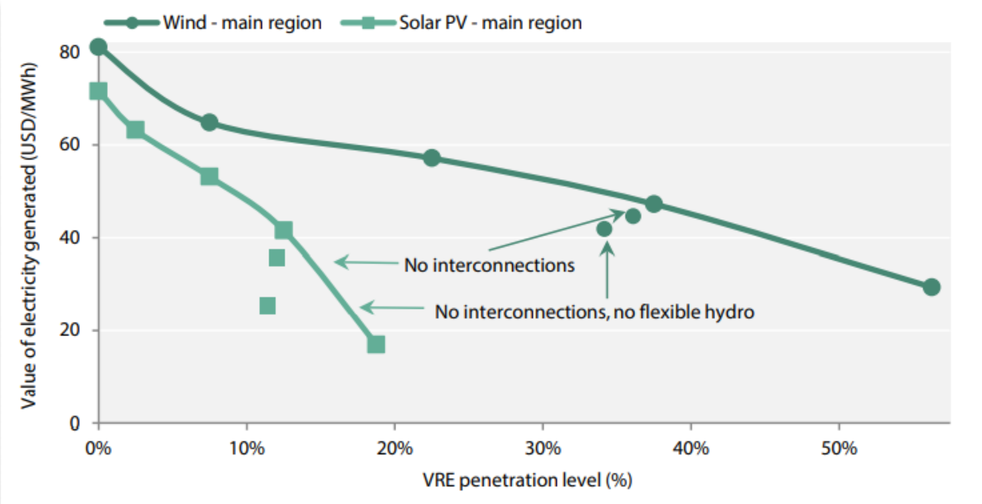
These values need to be compared to the plant-level generation costs of VRE, which range, depending on the scenario, from USD 60 per MWh for onshore wind to up to USD 130 per MWh for solar PV. It should also be noted that the system costs are largely unaffected by any declines in plant-level costs as long as the share of VRE remains exogenously imposed. Indeed, all four components of system costs (balancing, profile, connection and grid costs) increase with the deployment of VRE resources, but at different rates. By adding system costs to the costs of plant-level generation as assessed in LCOE calculations, one can calculate the total system costs of electricity provision for the eight scenarios analysed in this study (see Figure ES7 above). With 10% of VRE in the electricity mix, total costs increase only about 5% above the costs of a reference system with only conventional dispatchable generators, which in a mid-sized system such as the one modelled corresponds to additional costs of about USD 2 billion per year. At 30% VRE penetration, costs increase by about USD 8 billion per year, i.e. by 21% with respect to the base case. Reaching more ambitious VRE targets leads to considerably higher costs. Total costs increase by more than USD 15 billion per year if 50% of electric energy generation is provided by variable renewable resources, which corresponds to an additional 42% of costs compared to the base case. Reaching a 75% VRE target finally implies almost doubling the costs for electricity provision to almost USD 70 billion per year, representing more than USD 33 billion above the base case. A striking effect of the deployment of low marginal cost variable resources on the electricity market is the appearance of hours with zero prices, a substantial increase in the volatility of electricity prices and the commensurate increase in capital cost (not modelled here). Such zero prices are not observed in the two scenarios with no or low VRE deployment but start appearing for 60 hours per year when VRE reach a penetration level of 30%. The number of occurrences increases dramatically with the VRE penetration level; at 50%, more than 1 200 hours in a year feature zero-price levels, i.e. about 14% of the time. When VREs produce 75% of the demand, zero prices occur during 3 750 hours, i.e. more than 43% of the time (see Figure ES8). Since the model works under a financing constraint, the higher frequency of hours with zero prices is compensated by an increase in the number of hours with high electricity prices, which increases volatility. At 75% VRE penetration, the number of hours with prices above USD 100 per MWh is more than double that at zero or low VRE penetration rate.

Figure ES8. **Price duration curves of wholesale electricity prices in the five main scenarios**



Finally, yet importantly, the generation by VRE as a function of the availability of natural resources such as wind speed or solar radiation, is not only more variable than that from dispatchable plants but also more concentrated during a limited number of hours. Periods with high generation are followed by periods with lower or zero output. Because they all respond to the same meteorological conditions, wind turbines and solar PV plants tend to auto-correlate, i.e. produce disproportionally more electricity when other plants of the same type are generating and to produce less when other wind and solar PV plants are also running at lower utilisation rates. In combination with the zero short-run marginal costs of VRE resources, this causes a decrease in the average price received by the electricity generated by VRE as their penetration level increases, a phenomenon often referred to as self-cannibalisation. Figure 48 summarises this effect by showing the average market price received by wind and solar PV generators in the wholesale electricity markets as a function of their share in the electricity mix.

Figure ES9. **The market remuneration received by wind and solar PV as a function of their share in the electricity mix**



The average price received by solar PV and wind resources in the electricity market declines significantly and non-linearly as their penetration level increases, and this price decrease is much steeper for solar PV than for wind as its auto-correlation is higher. The value of the solar PV generation is almost halved even when a penetration rate of only 12.5% is reached. Further deployment of solar PV capacity to a penetration level of 17.5% would further halve its market value to below USD 20 per MWh. Thus, even if the generation costs of solar PV were divided by five, its optimal penetration level would not exceed 17.5%. A similar trend, although less pronounced, is observed for onshore wind, which has a higher load factor than solar PV and whose generation spans over a larger time period. At a penetration level of 22.5%, the value of a megawatt-hour of wind is reduced by 25%. For penetration levels above 30%, the market value of wind electricity is below USD 50 per MWh compared to an average price of all electricity of USD 80 per MWh. Offshore wind with its even higher load factor might show less pronounced declines but was not included in the study as its overall LCOEs were significantly higher than those of competing low-carbon technologies including nuclear. Last but not least, achieving more ambitious renewable targets also implies that VRE must be curtailed more frequently. Curtailment of VRE generation thus appears at 30% penetration level and increases sharply with their share. At 50% generation share, the curtailment rate of the marginal VRE unit deployed is above 10%. In the scenario featuring a 75% share of VRE generation, about 18% of the total VRE generation must be curtailed, and the curtailment rate of the last unit deployed is above 36%. Curtailment can be understood as an indicator that the system value of VRE is lower than its system costs, i.e. that reducing VRE output during certain hours constitutes the least-cost flexibility option.

What we have learned so far is that in the electricity systems of the future, all available low carbon generation options, nuclear energy, wind, solar photovoltaic (PV), hydroelectricity and, perhaps one day, fossil fuels with carbon capture, utilisation and sequestration, will need to work together in order to enable countries to meet their environmental goals in a cost efficient manner.

However, their intrinsic variability and, to a lesser degree, their unpredictability, imply that the costs of the overall system will continue to rise over and above the sum of plant level costs. What nuclear energy and hydroelectricity, as the primary dispatchable low carbon generation options, bring to the equation is the ability to produce at will large amounts of low carbon power predictably according to the requirements of households and industry. For the right decisions to be made in the future by governments and industry, these factors must be understood and addressed.

A cost-effective low carbon system would probably consist of a sizeable share of VRE, an at least equally sizeable share of dispatchable zero carbon technologies such as nuclear energy and hydroelectricity and a residual amount of gas-fired capacity to provide some added flexibility alongside storage, demand side management and the expansion of interconnections. Those of us working in the nuclear energy area are well aware that electricity markets are evolving and that nuclear energy must evolve to meet future requirements. Nuclear energy is well placed to take on these challenges but can also work together with all other forms of low carbon generation, in particular VRE, to achieve the ambitious decarbonisation targets NEA member countries have set for themselves.

15. ANNEXURE D: EX ANTE ECONOMIC IMPACT ASSESSMENT OF THE NUCLEAR ENERGY ELECTRICITY GENERATING UNIT TO BE CONSTRUCTED IN SOUTH AFRICA

1.1. Electricity supply in South Africa remains subdued and erratic as evidenced by sporadic load-shedding since 2014. However, there have been remarkable improvements in 2021, despite the fact that Eskom continues to supply below 80% of its capacity. Supply bottlenecks have also been aggravated by production breakdowns at Medupi and other sites. Therefore, load-shedding remains a persistent risk. In the outlook, private generation of electricity is expected to have a significant knock-on-effect on supply due to recently pronounced increase in allowable private generating capacity to 100MW. Other heavy power users, including mining companies, are expected to add 5MW to the national grid. The Risk Mitigation Independent Power Producer Procurement Program (RMIPPPP) may not bring the anticipated 2GW forthwith due various economic and legislative constraints in the economy.

1.2. The new nuclear energy generation capacity of 2500MW in South Africa may be evaluated in context through a cost and benefit analysis. This entails consideration of its private financial costs, opportunity costs and social costs invoked by possible externalities. Such costs are then weighed against potential private-public benefits and spill over or knock on effects driven by positive externalities arising from construction and operations of the project forthwith. On balance, a marginal analysis may be conducted through a priori rational expectations to check if in total, marginal economic and social benefits outweigh marginal economic and social costs for the project to be declared worthwhile. This forms the basis of an ex ante regulatory impact assessment of the project to assist decision makers including the Energy Regulator with important insights to consider. As part of such ex ante economic analysis, a comparative analysis is also done to compare anticipated knock-on effects to the South African economy against impacts of similar activities in other countries through desktop research.

1.3. Economic costs include the forecasted cost of constructing the nuclear power generating facility, its generation costs, financing costs, decommissioning costs including financial provisioning for land rehabilitation and operating costs as contained in relevant sections of the RfD. Social and environmental costs, including non-monetary losses inclined to perceived negative externalities. On the environment, social costs are understood within the context of climate change impacts, impacts on the ecosystem, waste generation, water use impacts and land use impacts. On the social dimension, impacts on human health, employment and standards of living, intergenerational issues of radioactive waste disposal, public perception and safety and non-proliferation are important to consider. In the South African context, the general public is very sceptical about the use of nuclear due to its association with accidents in several places around the world. The Fukushima incident of 2011 in Japan has created a global awareness of the need to consider safety and possible disastrous effects of expanded nuclear projects for electricity generation. However, South Africa has abundance of experience in handling Nuclear Power Plants such as Koeberg in the Western Cape.

1.4. Economic benefits are understood in the context of improved energy supply security, knock-on multiplied effects on gross domestic product (GDP), employment, imports, disposable incomes of households and public net savings. These are driven through positive externalities that the nuclear expansion project will bring to South Africa. Of paramount importance is the notion of energy returns on energy invested (EROEI) as illustrated by the International Atomic Energy Agency (IAEA)(2016)[101] report. The EROEI as a standard metric measurement of electricity generation efficiency from other sources of energy has illustrated that, nuclear energy is the most efficient as it leads to more electricity generated from a comparative unit of fuel supplied. It has an EROEI that may exceed 1 compared to other less efficient power supply technologies such as coal, hydro and renewable energies.

1.5. The IAEA (2021) report illustrates sectoral impacts of any new nuclear project in South Africa on identified economic fundamentals as well as cross-country analysis. Predicted empirical annual impact responses are shown in line with changing investment disbursements over varying construction periods in each country case. Based on rational expectations and deductive macro-economic analysis, predicted impact responses as elasticities to some extent on GDP and employment are increasing with model robustness. The scope of assessment begins with sub model A (depicting Direct and Indirect effects), sub model B(induced Impacts), before sub model ABC captures impacts of labour market responses. When feedback impacts of financing decisions on new nuclear project investments are considered, predicted impact responses are captured through sub model ABCD. Impact responses are largely dependent on sources of financing considered and strategies adopted to raise funds publicly into the required investment fund.

1.6. According to the IAEA (2021)[102] survey report, South Africa stands to benefit enormously from the proposed nuclear power project as predicted from 2020 to 2025. Data was obtained from Statistics South Africa and the OECD databases.

[101] IAEA(2016). Nuclear Power and Sustainable Development, Austria: Vienna International Centre. http://www.iaea.org/books

[102] IAEA TECDOC SERIES (2021). Assessing National Economic Effects of Nuclear Programmes – Final Report of a coordinated Research Project, Austria: Vienna International Centre

Historical data was utilized as forecasts were not readily available from literature sources. The IAEA survey obtained cost estimates data from the Nuclear Industrial Association of South Africa (NIASA) and the Department of Mineral Resources and Energy (DMRE). Table 1 below shows the predicted impact and response multipliers on seven key macroeconomic fundamentals namely; GDP at market prices, nominal disposable incomes at current prices, production output at current prices, public net savings, imports and employment. Data to calculate the export price elasticity of demand, the marginal propensity to consume, the wage reaction to the unemployment rate among other economic fundamentals excluded in this ex ante economic analysis could not be obtained.

Table 1: Predicted Impact Multipliers of a new NPP Construction in South Africa

Impact Mechanism	2021	2021	2022	2023	2024	2025
	Impacts on GDP at current prices					
Model A	0.6	1.2	1.2	1.5	2.2	1.3
Model AB	0.8	1.5	1.6	1.9	2.8	1.6
	Impacts on disposable incomes at current prices (%)					
Model A	0.4	0.9	1.0	1.3	1.9	1.1
Model AB	0.5	1.2	1.3	1.6	2.4	1.4
	Impacts on production output at current prices (%)					
Model A	0.7	1.4	1.6	2.0	2.9	1.7
Model AB	0.8	1.7	1.9	2.4	3.5	2.0
	Impacts on public net savings at current prices (%)					
Model A	-0.7	-1.9	-2.3	-3.3	-5.2	-3.7
Model AB	-0.8	-2.3	-2.8	-4.1	-6.6	-4.7
	Impacts on imports at current prices (%)					
Model A	0.5	1.1	1.0	1.2	1.8	1.3
Model AB	0.7	1.5	1.4	1.7	2.5	1.7
	Impacts on Employment (%)					
Model A	0.5	1.1	2.6	3.2	4.9	1.3
Model AB	0.6	1.4	2.9	3.6	5.4	1.7

Source: IAEA (2021)

1.7. Over the five-year time horizon, the predicted empirical impact of any new NPP project on GDP at market prices was estimated to range from 0.6 to 2.2% with annual contributions noted to the penultimate aggregate multiplier. This is the case considering strictly direct and indirect impacts (Model A). If induced impacts are considered (Model AB), the impact multiplier range increases to a magnitude stemming from 0.8 to 2.8% non-cumulative annual impact on GDP. Predicted feedback effects impact responses and other expansions of model

AB were not reported. Hence, it is crucial to note that construction of the nuclear power unit in South Africa is expected to boost economic growth up to 2.8% year on year from until 2025. This is quite significant given that economic growth has been adversely affected by Covid-19 and therefore the nuclear power project provides an opportunity for economic recovery.

1.8. Over the same period, the project is predicted to impact disposable incomes at current prices positively. Model A shows that there will be significant knock-on impact on disposable incomes in the South African economy between year 2020 and year 2025. Model AB has presented plausible positive impact responses on disposable incomes ranging from between 0.5 to 2.4%. In this regard, there is a clear demonstration that the construction of new nuclear power plant will increase disposable incomes in the economy by a magnitude up to 2.4%.

1.9. The IAEA (2021) survey report has also demonstrated that ex ante empirical evidence support the construction of the new NPP as it will boost productivity in the South African economy over the period 2020 to 2025. Impact responses on production output at current prices based on Model A are ranging between 0.7 and 2.9%. Model AB has revealed higher response impacts that are ranging between 0.8 to 3.5%, considering that direct and indirect effects as well as induced effects are considered.

1.10. Through the IAEA (2021) survey, an inverse relationship between nuclear project construction and its impact on public net savings at current prices has been revealed. Over the reference period, public net savings will decline by a magnitude between -0.7 to approximately - 5%, other things being equal, based on Model A. If Model AB is considered, impact on public net savings further subdues to a range between -0.8 to -6.6% in the South African economy.

1.11. Predicted impact response elasticities with respect to model A and AB on imports at current prices, given construction of a nuclear energy power generating facility, ranges between 0.5 to 1.8% and 0.6 to 2.5% respectively. Such a positive impact has a knock-on effect on other economic fundamentals such as trade openness and significant contribution to the country's foreign direct investment growth potential.

1.12. The estimated impact response elasticities on employment attributable to the NPP considering direct and indirect effects as well as induced impacts are positive. According to IAEA (2021), these notable impact multipliers are calculated disregarding feedback effects. There is an anticipation that employment elasticities on this new NPP project will increase gradually from 0.5 to 4.9% with respect to Model A, direct and indirect impacts. This is understood in the context that transitional employment due to the commencement of construction activities will lead to more permanent jobs that will be created in the energy sector and outside as a result of the impact multiplier effect. A similar trend is also depicted when induced impacts are considered in model AB, with elasticities ranging between 0.6 to 5.4% over the reference period.

1.13. Tables 2 and 3 below presents the predicted empirical impacts of NPP construction projects on GDP and employment in eight (8) selected countries, including South Africa based on the IAEA (2021) survey report[103]. This study considers country specific effects and how country size, level of development and electricity contexts account for notable heterogeneities. These countries include South Africa and other emerging markets such as Indonesia and Malaysia that are fairly comparable. Through this survey, an economic analysis is done to compare predicted benefits of nuclear power projects (NPP) on national outputs and employment. Country specific models have been utilized to conduct ex ante analysis of economic impacts of individual new build projects as additional nuclear energy power plants in the outlook. It is appreciated that employment created through construction activities is transitional and subsequently become permanent during operation phases on these additional electricity generating units.

1.14. To the greater extent, predicted reactive impacts of building a nuclear energy electricity generation project directly varies with size of the economy of a country, holding constant number or size of nuclear reactors to be installed. Comparative analysis is conducted on the basis of ratios of GDP volumes at prevailing nominal exchange rates and hence at purchasing power parity.

Table 2: Impacts of NPP Construction on GDP in selected countries including South Africa

Country	Impacts on GDP according to impact mechanisms (modules)(%)			
	A	AB	ABC	ABCD
Croatia	0.35-0.40	0.67-0.75	0.75-0.81	-
Indonesia	0.001-0.035	0.001-0.054	0.002-0.065	0.002 – 0.065
Malaysia	0.28	0.31	0.31	0.31
Poland	0.02-0.11	0.03 - 0.015	-	-
South Africa	***0.6-3.2***	***0.8 - 2.8***	***0.8 – 3.0***	***-0.025 – 0.61***
Tunisia	0.03-0.13	0.04 - 0.18	0.03 – 0.17	0.02 – 0.12
Uruguay	1.1	1.6	1.6	-

[103] IAEA TECDOC SERIES (2021). Assessing National Economic Effects of Nuclear Programmes – Final Report of a coordinated Research Project, Austria: Vienna International Centre

Vietnam	0.267	0.375	0.409	0.37

Source: IAEA (2021)

1.15. Predicted impact multipliers on the South African output are estimated to range between 0.6 to 3.2 % if direct and indirect effects are considered before feedback effects or induced effects. If induced impacts are considered, the minimum multiplier impact of the NPP on GDP increases from 0.6 to 0.8. However, the multiplier effect becomes ambiguous with further extensions of the model to include feedback effects with predictions indicating a minimum of -0.025% to a maximum of 0.61%. Countries that depict similar trends include Croatia, Malaysia and Vietnam. However, South Africa has shown that it has the highest NPP impact multipliers on GDP compared to other countries included in the sample.

1.16. Table 3 below shows the predicted impact response multipliers of nuclear power programs on employment according to stipulated impact mechanisms. Given direct and indirect effects, induced impacts extended further to labour market impact responses and economy wider knock on effects on employment, South Africa has the highest impact multipliers on employment across the four models. The labour market impact multiplier, considering direct and indirect effects is predicted to range between 0.5 to 4.9% under specified conditions. The predicted multiplier impact increases to 0.6 to 5.4% if induced impacts are considered simultaneously with direct and indirect effects, as shown through the AB model. The impact multiplier is relatively stable at 0.6 basis points as the model is expanded to included wider economy knock-on effects on the wider economy. Overall, among the countries considered in the sample, South Africa has demonstrated a greater potential to boost employment through any nuclear power program that the Minister may initiate through the section 34 of the Electricity Regulation Act.

Table 2: Predicted Impacts of NPP construction on employment in selected countries including South Africa

Country	Impacts on employment according to identified mechanism (modules)(%)			
	A	AB	ABC	ABCD
Croatia	0.46 - 0.51	0.72 – 0.79	0.47 – 0.62	-
Indonesia	0.000 – 0.027	0.001-0.051	0.002 – 0.055	0.002 -0.065
Malaysia	-	-	-	0.31
Poland	0.02 - 0.1	0.03 – 0.14	-	-
South Africa	***0.5 – 4.9***	***0.6 – 5.4***	***0.6 – 4.9***	***0.6 - 4.8***
Tunisia	0.02 – 0.15	0.03 – 0.26	0.03 – 0.26	0.02 – 0.22
Uruguay	1.1	1.6	1.5	-
Vietnam	0.2	0.3	0.322	0.292

Source: IAEA (2021)

1.17. South Africa's predicted impact response elasticities at 2500 MWH(e) not so far from the 2500 capacity installation in question are benchmarked against those of other emerging markets such as Malaysia. This is because the two economies have similar characteristics, especially considering that they are more or less of the same size and also they are emerging markets.

1.18. Findings from this empirical ex ante assessment are that the predicted impact responses elasticity ranges for South Africa are more than double to ten times those of Malaysia under similar specifications. A key assumption is that South Africa will construct additional nuclear plant in six years whereas Malaysia will take up to thirteen years.

1.19. The ex ante predicted impact response elasticities with respect to employment creation have indicated that South Africa has a higher propensity to create more jobs as it makes a decision to build the new nuclear power plant. Such predictions are influenced by demographic and socio-economic characteristics of countries in the sample. These are crucial when comparing South Africa to other countries in terms of how these socio economic fundamentals act as employment creation catalysts in the nuclear development program. Hence the 2500 W nuclear project has a knock-on effect on the labour force participation Rate, human capital development and total factor productivity in South Africa, even beyond 2030. The ABCD model has shown a prediction impact response ranging from 0,5 to 4,8% annually with a potential multiplier effect on various Job market segments and also impacting on wage rate. Directly job opportunities for skilled and semi-skilled personnel will open up in construction works and in other sectors providing ancillary services as inputs into the project.

1.20. With a population estimated at approximately 58 million, South Africa compared to Malaysia at 32 million, the predicted impacts on employment significantly differ. The impact predictions are twice to ten times as high in South Africa than Malaysia under varying model specifications. The employment impact of Vietnam with a population exceeding that of South Africa by about 60% is predicted at the upper limit of the South African range of between 0,6 to 4,9 % under the ABC model. This comparison is made disregarding sizes of nuclear reactors to be installed in South Africa and Vietnam at more or less similar construction periods. Therefore, the impulse on the South African labour market is exceeding those of countries like Malaysia, Indonesia and Vietnam because of its relatively shorter construction period.

1.21. A key finding was that economic and social impacts of building and operating additional nuclear energy power plants are considerable. South Africa, Croatia, Tunisia, and Uruguay as they earmark to complete construction over six to eight years have higher predicted impacts on GDP, total output value, disposable incomes and employment compared to their counterparts on the sample with construction periods exceeding 13 years as the case with Malaysia and Poland.

1.6 On balance, the benefits that are anticipated to accrue from this project outweighs all economic, social and environmental costs which can be carefully managed to ensure improved security of supply of electricity and economic development in South Africa.