Comments for the National Energy Regulator of South Africa on the Ministerial Determination on the procurement of 2500 MW new generation capacity from nuclear

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Introduction

The objective of this paper is to provide comments as requested by NERSA and set out in *the consultation paper*, titled: *Concurrence With The Ministerial Determination On The Procurement Of 2500 MW Generation Capacity From Nuclear*, published on 23 November 2020.

The Energy Systems Research Group (ESRG) at the University of Cape Town combines modelling of energy and economic systems to generate and enhance knowledge of energy systems at sectoral, regional, national and sub-continental scales. Modelling helps to study the interaction of multiple components under changing conditions over longer time periods, and in SATIM, the group holds the only full energy sector model for South Africa, combining electricity and liquid fuels sectors on the supply side with industrial, transportation and residential users on the demand side. A dynamic linking of this energy systems model with a macroeconomic general equilibrium model allows for social and economic analysis of energy-system decisions and ensures that inputs to SATIM are based on economic forecasts rather than arbitrarily specified.

The group in its current format evolved out of the 2019 restructuring of the University of Cape Town's Energy Research Centre (ERC) and holds a combined experience of over 70 person-years.

Our expertise and our comments concern the questions raised in the first two of these sections of the consultation paper, namely: Capacity allocation (section 2) and Technology costs (section 3), as well as the questions in part G of the section on the Procurement process (section 6) regarding the socio-economic impact of the nuclear new build programme on South Africa.

We show, using previous studies and new modelling (included in a Technical Annex) that the pursuit of new nuclear power at this stage is not necessary to meet demand, is not cost effective, and is not required for climate change reasons. There is limited evidence that nuclear will provide better economic outcomes than alternative supply options, especially as regards affordability, industrialisation, or job creation. While the IRP states that nuclear is a "no-regret" option, scant evidence for this claim is provided by the Department of Mineral Resources and Energy, and in fact substantial evidence exists to counter such a claim, with multiple studies showing that nuclear power raises costs for consumers and is accompanied by negative economic impacts on GDP and employment. We are not the only independent experts to note the limited evidence provided for the nuclear determination. CSIR (2019) also noted that several decisions, the nuclear decision (decision 8 in the IRP 2019) amongst them, "lack evidence-base or are contradictory to the available evidence-base".[1]

[1] https://researchspace.csir.co.za/dspace/bitstream/handle/10204/11200/22850_GWDMS%20279138%20CSIR-IRP2019.pdf?sequence=1&isAllowed=y

Therefore, as these comments will show:

i) the rationale for new nuclear as outlined in the NERSA questions (for example, the stated need for baseload power) is baseless
ii) the IRP 2019 does not provide a basis for new nuclear capacity as nuclear does not feature in the IRP plan; hence, the procurement of new nuclear capacity is irrational and inconsistent
iii) best available information currently, including all of our own analysis, as well as the IRP itself, indicates that new nuclear capacity is not cost effective, does not feature as part of a least cost system, and is not competitive with other options;
iv) new nuclear is not a least cost or effective way to meet climate policy or development goals.

Before engaging in answering the specific question raised by the Consultation paper as we will do here below, we would like to take advantage of the possibility offered by the consultation paper to comment on "other issues" than the ones raised by the questions, as indicated on p.19. We use this opportunity because we see it as our obligation to make very clear to all decision makers involved that the operation of power systems around the world has changed and that modern power systems can no longer be organised in terms of "baseload" and "peak" capacity.

General comment concerning the concept of 'baseload' capacity

Baseload in essence is the idea that only certain kinds of plants can supply power in large, continuously available quantities. The term stems from historical alignment between minimum electricity demand (the 'base' demand or 'load'), and the profile and economics of generators such as large coal and nuclear plants. In the past it was cheapest to run these large generators at close to their maximum capacity, with limited variance in output. This led to these base supply generators dominating many electricity systems. Today, the rapid and widespread uptake of gas and renewable generators worldwide has shown that electricity systems can function effectively with many smaller plants supplying similar power generation capacity. That "baseload" has become outdated and that flexibility is the new imperative for electricity systems has been recognized by leading organisations: including the International Energy Agency[2] and by the leaders of large power grids, including the UK's National Grid[3]; the California Independent System Operator,[4] and the Australian Electricity Market Operator[5],

[2] https://www.iea.org/reports/status-of-power-system-transformation-2019
[3] Steve Holliday CEO National Grid: baseload is outdated
[4] https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf
[5] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Future-Energy-Systems/2019/AEMO-RIS-International-Review-Oct-19.pdf

all of whom are actively managing grids with high and growing penetrations of renewables already.

A systems approach to electricity planning ensures that a reliable supply of electricity is generated from complementary resources across the system, with the aim of meeting demand at lowest cost. In the past, it was cheapest to meet most demand from base supply plants, but as the costs of renewables have fallen rapidly in recent years, the economically optimal combination of technologies has changed. Now, renewable energy plus other flexible resources is often the cheapest combination.

While in some countries minimum demand may still be met cheaply from coal or nuclear plants that run continuously, this is not a technical requirement for power system operations. It is an historical artefact of how systems have evolved that is increasingly becoming obsolete. Many real-world examples show that large, industrialised countries can maintain a stable supply of electricity even as coal and nuclear provide smaller and smaller annual average shares, while renewables increase their shares to become the biggest supplier of electric power.[6]

In Europe for example, Denmark, Ireland and Germany are examples of countries with average shares of wind and solar energy in total power generation of over 1/3rd (Figure 1), with Denmark and Germany managing 100% renewable electricity at some times.[7] [8] Overall, only 14% of electricity comes from coal in the EU today, halving since 2015; while nuclear has either fallen or stagnated over the same period, and fell 10% in 2020. European nuclear power generation fell by 10% in 2020, as French and Belgian technical problems added to permanent closures in Sweden and Germany. Nuclear generation will continue to fall in Europe as countries phase-out nuclear: Germany by 2022, Belgium by 2025, Spain by 2030, and a reduction to half its electricity mix in France by 2035, compared to 67% in 2020.[9] Similarly, in the USA, coal use has fallen quickly and dramatically, and has been replaced by gas and renewables, while nuclear has remained at the same output levels of around 800TWh per year since 2007[10]. This illustrates once more that the operation and economics of power systems are changing and that there is no need to impose limits to the speed by which

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[6] https://www.reuters.com/article/us-eu-renewables-idUSKBN29T0T8 (accessed 2 February 2021)

[7] https://www.bloomberg.com/news/articles/2016-05-16/germany-just-got-almost-all-of-its-power-from-renewable-energy (accessed 2 February 2021)

[8] https://renewablesnow.com/news/wind-meets-denmarks-100-power-demand-on-sep-15-669566/ (accessed 2 February 2021)

[9] Agora and Ember (20210): https://ember-climate.org/wp-content/uploads/2021/01/Report-European-Power-Sector-in-2020.pdf

[10] www.eia.gov electricity data browser

wind and solar power generation capacities should be added to the power grid due to the idea that 'baseload' is needed.

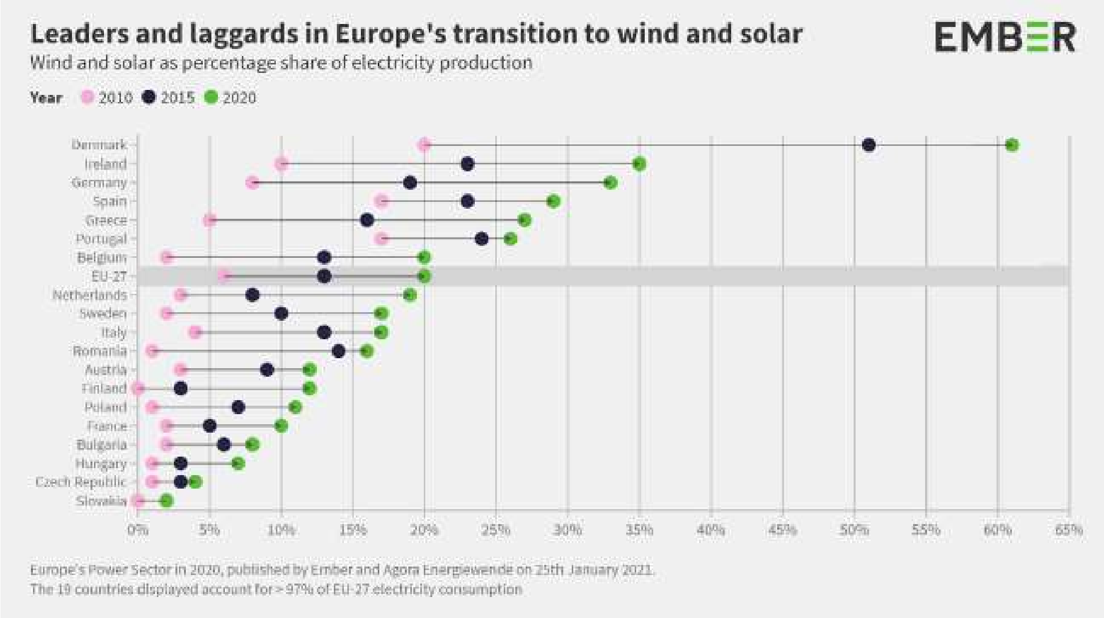

Figure 1 Wind and solar percentage share of electricity production (Agora & Ember, 2021)

Of course, as the share of renewables grows, some operational changes to systems are needed[11], and it helps if systems have more flexible generators available. A stable or reliable electricity system requires the system operator to ensure that supply meets demand at every moment, regardless of how much demand fluctuates. It is these changes in demand and increasingly, in supply (because renewables are dispatched by the weather), that underpin the need for flexibility in the system.

Concerning other flexible sources, one must keep in mind that one cannot speak of a need for 'renewables back-up', as all systems require reserves to 'back up' the running generators, whether they're based on renewables or not. What variable renewable energy technologies do need is to be accompanied by complementary resources with particular characteristics. These complementary resources must be able to be turned on and off quickly, or to supplement particular weather patterns. For example, as levels of solar start to drop in the late afternoon, a system may need high levels of flexible technologies which can ramp up to full power quickly, or incentives to shift load to match variable generation. Suitable resources for complementing VRE can include concentrating solar power, pumped storage or hydro, batteries, geothermal, or demand side management, depending on the system in question and the type of electricity market.

[11] https://newclimate.org/wp-content/uploads/2019/10/Report_Transition_Towards_A_Decorbanised_Electricity_Sector_A2A_2019.pdf

In the short to medium term, making existing coal plants more flexible can contribute to maintaining reliability while systems transition from the current operations to another in the coming years. There may also be the need for longer-term or seasonal storage, such as gas, although of course this should ideally be from a low-carbon source such as green hydrogen. Having suitable transmission infrastructure is also essential, in order to move electricity from where it is being generated to where it is being used.

All of this underlines that power system investment decisions are to be informed by full sector modelling of the entire economy. This enables decision makers to have a complete picture of options for supply, as done in many of the studies discussed in our comments, and as we have done for this particular request for comments by NERSA, in the Technical Annex below.

Comments on questions raised by NERSA (section 2, capacity allocation)

***Question 1*:**
Is this 2500MW of nuclear capacity section 34 determination compliant with the IRP 2019 as gazetted by the Minister of Mineral Resources and Energy?

Comment:
The question here is whether the 2500 MW of the nuclear capacity determination is compliant with the IRP 2019. Here our answer is "no". The procurement of nuclear energy does not correspond to the objective of providing affordable electricity to the people of South Africa, neither is it necessary to provide stable and secure electricity supply. Multiple studies undertaken for South Africa have demonstrated this, the details of which are delineated below.

Furthermore, IRP processes, underpinned by correctly undertaken optimisation modelling, provide a framework to assess the costs, benefits, and trade-offs of different resources to meet demand reliably and at lowest cost. Regardless of the DMRE's claim that nuclear is a "no-regret" option in Decision 8 in the IRP 2019, new nuclear power is not part of a least-cost supply suite to meet demand reliably and at lowest cost, nor was it included in the modelling results in the IRP 2019 itself. That is, whether nuclear is a no-regret option was not in fact assessed in the IRP 2019. A compliant determination could only follow a full assessment of supply and demand in the post-2030 period, and cannot be pursued without this.

Question 2:
In light of the decommissioning of a significant amount of base load capacity by 2030, and South Africa's reliance on natural resources extraction and beneficiation as significant drivers of economic development, should this baseload capacity be added post 2030 and why?

Is this an important consideration in the broader integrated industrial policy and why?

Comment:
The role and purpose of the integrated resource plan (IRP) for the electricity system is to assess how to meet future electricity demand growth across the economy. The retirement of coal plants is considered, and new capacity options are represented in the model. The aim of such modelling is to then *ensure that supply matches demand*, from the available resources, over time, into the future, at lowest cost.

As mentioned in our general comment above, the concept of baseload is no longer relevant in modern electricity systems, while flexibility and agility have become the new imperatives for power system management. The right question to ask therefore is what options South Africa has in order to achieve reliable and affordable use of electricity while coal power plants are decommissioned into the future.

To answer this question multiple studies should be considered which have assessed the question of the future electricity supply mix for South Africa. All recent studies found that a least-cost and reliable future power generation consists primarily of new wind and solar, complemented and supplemented by flexible options (batteries, hydro, gas etc). This ranges from research by the Centre for Scientific and Industrial Research (Wright et al, 2017[12]; Wright et al 2018[13];Wright & Calitz, 2020)[14] (amongst many other analyses undertaken by the CSIR Energy Centre); Meridian Economics (Steyn et al, 2017;[15] Steyn et al, 2020)[16]; research by the ESRG at UCT (Ireland & Burton, 2018[17]; Burton et al, 2018;[18] Mccall et al, 2019[19]; Merven et al, 2020;[20] Merven et al, 2019[21]), as well

[12] http://meridianeconomics.co.za/wp-content/uploads/2017/11/20171121-IEEFA-SACoalGen-Report-FINAL.pdf

[13] http://researchspace.csir.co.za/dspace/bitstream/handle/10204/10492/Wright_Formal%20comments_slide.pdf?sequence=5&isAllowed=y

[14] https://researchspace.csir.co.za/dspace/bitstream/handle/10204/11483/Wright_2020.pdf?sequence=4&isAllowed=y

[15] https://meridianeconomics.co.za/wp-content/uploads/2017/11/CoalGen-Report_FinalDoc_ForUpload-1.pdf

[16] https://meridianeconomics.co.za/wp-content/uploads/2020/07/Ambition.pdf

[17] https://cer.org.za/wp-content/uploads/2018/05/ERC-Coal-IPP-Study-Report-Finalv2-290518.pdf

[18] https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Rapport/20180609_ReportCoal_SouthAfrica.pdf

[19] https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP29_February_2019_McCall_Burton_Marquard_Hartley_Ireland_Merven.pdf

as international analyses of South Africa, for example NREL (2017)[22] and Oyewo et al (2019)[23].

Several studies have thus already demonstrated that new nuclear power is not necessary or competitive for South Africa. These studies include the many listed above, as well as the Department of Mineral Resources and Energy's own analysis in the IRP 2019 (notwithstanding some policy adjustments e.g. the inclusion of new coal power that were not least-cost). The IRP itself acknowledges that renewable energy is the least-cost option, and the modelling supports this. Previous iterations of the IRP (2013, 2016, and 2018) also delayed the nuclear on the grounds of scale and affordability, with nuclear not required before the late 2030s at the earliest. Since those studies, the economics of alternatives have continued to improve (see for example, Lazard and system analyses listed above).

As well as the general power system studies above, independent analyses have, in particular, assessed the role of nuclear power in South Africa's electricity system, and whether it forms part of the suite of technologies to meet demand at lowest cost, and hence whether it should be included in a capacity expansion plan. Some studies have also assessed the economic implications of committing to new nuclear on the broader economy. In brief:

ERC (2013), even using older and conservative cost assumptions on renewable energy, nonetheless found that nuclear would not be required before 2040.[24]

ERC (2015) examined the effects of a committed nuclear fleet approach under conditions of uncertainty (on costs, demand, etc.). The study found that in conditions of lower demand, adopting a more flexible approach to capacity expansion is less risky, and less likely to incur costs for electricity consumers, compared to a scenario with higher use of nuclear power. The study found that if economic growth is lower, and nuclear costs are high, the impacts of a committed fleet of nuclear plants are substantial, and negative. Electricity prices will be higher over the period 2030-2040 and could be 20% higher in 2040 when compared to a flexible planning approach; similarly, GDP growth will be lower in 2040. The investment required will be significant, with impacts on investment in other sectors and the electricity price. This leads to substantial job losses if the nuclear commitment goes ahead compared to a flexible planning approach, with up to 75 000 jobs lost as the economy contracts in response to higher electricity prices. Given high levels of unemployment amongst unskilled workers, they are

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[20] https://sa-tied.wider.unu.edu/article/modelling-costs-constraining-transition-renewable-energy-in-south-africa

[21] https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP84_Merven_Hartley_McCall_Burton_Schers_October_2019.pdf

[22] https://www.nrel.gov/docs/fy18osti/70319.pdf

[23] https://www.sciencedirect.com/science/article/abs/pii/S0038092X19309144?via%3Dihub

[24] http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2013/13ERC-Towards_new_power_plan.pdf

most likely to face the worst impacts of growing unemployment. In turn, household consumption will drop for all consumer groups, with potentially serious ramification on welfare.[25]

Furthermore, the authors used the Monte Carlo method, (i.e. simulated a thousand scenarios), and in each scenario "drew" an internally consistent set of assumptions from a distribution for each of the uncertain parameters (e.g. costs, demand, etc.). The 1000 different combinations were tested with and without the forced nuclear build plan. In each case the electricity price is compared over the modelling horizon. The results showed that under almost all circumstances, new nuclear capacity raises costs in the power system. The results show that in 2030 if South Africa commits to a full fleet of nuclear there is a 94% chance that electricity prices will be higher than if we adopted a flexible planning approach. They also show that the risks of sustained higher electricity prices are very high. An investment of this magnitude could have significant risks on the South African economy and the lock-in associated with an investment in the full fleet will result in South Africa foregoing investment in other, more cost-effective electricity generation technology options (ERC, 2015).

Also, important to note is that nuclear is not necessary to cost effectively achieve climate policy goals. Merven et al (2020)[26] examined how to achieve climate policy goals, assumed to be an electricity carbon budget consistent with the middle range of South Africa's current Peak, Plateau, and Decline trajectory, when annual additions of new renewable capacity are limited in the long-term (as currently specified in national planning). New nuclear capacity was only selected as a supply option when additions to solar PV and wind capacity were capped at 1 GW and 1.8 GW respectively per annum, RE was restricted to 15% share of peak demand, and a greenhouse gas emissions cap was imposed. Imposing these annual build constraints on solar PV and wind capacity decreased solar PV and wind capacity included in the future energy system by 50%, replaced by 800 MW of solar CSP and 6 GW of nuclear, as well as new coal. This investment programme would result in a 2050 electricity price that is 14% higher than when a least cost renewable build plan is pursued. This is equivalent to 16c/kWh when using conservative assumptions on renewable energy and 18c/kWh, when using more optimistic future renewable energy costs

The study highlights that a least cost renewable energy generation build plan will have a positive impact on real GDP, employment, and real household income in South Africa when compared to a scenario with higher coal and nuclear power plants forced into the build plan. These gains are substantial, in the range of 5-6% by 2050. New coal and nuclear therefore has a directly negative effect on real GDP, employment across the economy, and household income.

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[25] https://zivahub.uct.ac.za/articles/dataset/Nuclear_Study_-_Reports/7246820

[26] https://sa-tied.wider.unu.edu/article/modelling-costs-constraining-transition-renewable-energy-in-south-africa

Finally, to inform our comments we analysed a few new scenarios to explore whether there might be room for nuclear power generation under certain circumstances and given recent developments in South Africa's energy policy. These scenarios are presented in the Technical Annex below, and show that the conclusions of the studies above still hold. Nuclear remains too expensive as a source for power generation, with no sign of new nuclear technology becoming competitive before the mid to late 2030s. Hence, commissioning of 2500 MW of new nuclear power generation by 2030 or shortly thereafter leads to an unnecessary increase in power system investment costs and an unnecessary claim on South Africa's current financial means. Under different market configurations, and different levels of engagement of the state in the electricity sector, these investments could

i) become profitable at the expense of an increased regulated electricity price (3-4% higher in 2030, see the Technical Annex), or
ii) risk requiring further subsidisation of power generation by government, or
iii) risk turning new nuclear power generation into a stranded asset due to its lack of competitiveness.

Based on the considerable body of evidence described above, we would argue that there is limited or no role for nuclear power in an integrated industrial policy for South Africa at this stage. Indeed, pursuing the least cost option for new electricity generation capacity is the most viable option for industrialisation in South Africa. High renewable energy uptake is accompanied by better GDP and employment outcomes, both through direct growth and job creation and through minimising electricity price increases across the economy[27]. If minerals-based industrialisation is to be pursued, low-cost electricity becomes even more important given the energy-intensity of such production processes.

Question 3:
What other base load options are available that the country could invest in? Justify the preferred option?

Comment:
As mentioned in our general comment on the Consultation paper above, the concept of baseload is no longer relevant in modern electricity systems. The right question to ask here is what options exist for South Africa to achieve reliable and affordable use of electricity, for which the answer to Question 2

[27] For further analysis see Hartley et al (https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/); Meridian Economics (ttps://meridianeconomics.co.za/wp-content/uploads/2020/07/Ambition.pdf) and Trade and Industrial Policy Strategies (https://www.tips.org.za/policy-briefs/item/3804-a-case-for-renewable-energy-in-south-africa-s-post-lockdown-economic-recovery-stimulus-package) on the role of renewable energy in employment, industrialisation, just transition, mitigation, and post-covid economic recovery. Cognisance should also be taken by NERSA of the South African Renewable Energy Masterplan process which shows the direction being pursued as regards industrialisation in the energy sector.

above showed that all recent studies found that a least-cost and reliable future power generation is primarily comprised of new wind and solar, complemented and supplemented by flexible dispatchable capacity options.

Question 4:
Comment of the type of technology in the determination in line with the following:

- **i. Energy security considering both security of supply and security of demand.**
- **ii. Efficient, effective, sustainable and orderly development and operation of the electricity supply industry from production through to consumption.**
- **iii. The interest of present and future electricity customers is safeguarded against, inter alia, stranded assets, environmental impact and energy security.**
- **iv. Use of diverse energy sources and energy efficiency.**
- **v. International best practices.**
- **vi. Mitigation of climate change by the reduction of greenhouse gasses and other environmental imperatives.**

Comment:
Points (i.) to (v.) have been sufficiently addressed in our prior comments. We therefore focus our comment here on point (vi.) regarding the relation between the technology determination and mitigation of climate change.

In brief, new nuclear capacity is not necessary to meet climate policy objectives as currently outlined in the National Climate Change Response White Paper and the current Nationally Determined Contribution (NDC) under the Paris Agreement.

Indeed, even in ambitious mitigation scenarios, nuclear power does not feature unless renewables are forced out of the modelling results (as in Merven et al, 2020 above), and the inclusion of nuclear is accompanied by negative economic outcomes. In modelled mitigation scenarios that are even more ambitious than the low trajectory of the Peak, Plateau and Decline long-term target, nuclear is still not a least cost option (McCall et al, 2019)[28]. Even in studies that assess a more rapid phase out of coal power (eg Burton et al, 2018) nuclear does not feature. Similarly, research by the CSIR (Wright & Calitz, 2020) on a 2040 coal power phase out pathway, still does not include new nuclear despite the rapid reduction in so-called 'baseload' power stations in the 2030s.

[28] https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP29_February_2019_McCall_Burton_Marquard_Hartley_Ireland_Merven.pdf

These studies are consistent with global analysis that seeks to understand how to meet the goals of the Paris Agreement, namely to limit global warming to below 1.5°C and achieve net-zero emissions in the future. In the Intergovernmental Panel on Climate Change Special Report on 1.5C (IPCC, 2018), global scenarios on future energy systems show a penetration of renewable energy in the order of 63-77% share of electricity in 2050. The higher levels of renewable energy are found in scenarios with more realistic (ie lower) uptake of negative emissions technology; for example, in scenario P1, RE makes up 77% of electricity in 2050 and 60% of electricity in 2030.[29]

Until high ambition/1.5°C-compatible scenarios for South Africa have been developed (e.g. net zero economy-wide analysis), including 100% non-fossil scenarios, there is no basis on which to assume that nuclear power is necessary to meet demand or address climate change mitigation goals cost effectively. While nuclear may play a role in future power systems (e.g. through the still faraway commercialisation of small modular reactors), this does not yet offer a competitive alternative to renewables and is unlikely to by 2030 given the level of commercial activity in the sector. Right now, we have other commercialised, widespread, and cost effective technologies for power sector climate change mitigation that can be easily and cheaply rolled out to address emissions reductions and energy shortage requirements in the short and medium term.

Question 5:
Provide what you consider to be the risks and challenges associated with the allocated capacity in terms of the objects of the Electricity Regulation Act mentioned in question 3 above.

Comment:
The first risks of the capacity allocation of 2500 MW of nuclear to be added to the South African power grid is of financial nature, as an estimated additional 77 to 97 billion more Rand likely need to be invested until 2030 in power generation capacity compared to a least-cost reliable power supply (see Technical Annex). These investments come without any benefits in terms of greenhouse gas emission reductions or socio-economic benefits compared to a least-cost alternative. As discussed extensively above, the reason is that nuclear power is not the least-cost power generation option, not even in a full system perspective that takes into account the requirements for supplementary power generation options. It is furthermore likely that such an investment will require public investments or loans, while public debt is already high at 80% of GDP.[30] Secondly, the mentioned allocation risks requiring an increase of South Africa's electricity price unnecessarily, as mentioned above.

[29] https://www.ipcc.ch/sr15/
[30] See http://www.treasury.gov.za/documents/national%20budget/2020S/review/Chapter%204.pdf (accessed 3 February 2021)

Question 6:
Comment on the lead time for the deployment of nuclear power plant of circa 10 years, from design, licensing, construction, and commissioning.

Comment:
There is of course a considerable risk in undelivered electricity from the delayed commissioning of a nuclear plant. The nuclear industry worldwide is notorious for going over budget (further adding to the financial burden as above) and going over the construction deadline. A delay in commissioning new nuclear plant, especially if the power expansion plan relies on the capacity to meet demand, is a shortage in the supply of electricity. South Africa knows well the economic costs of insufficient supply of power and the risks of large plants not being commissioned on time. Generally long lead times also come with economic and financial implications for consumers who must bear this risk.

Long lead time technologies also paradoxically contribute to supply insecurity through causing supply-demand mismatches when high demand forecasts do not materialise, with large plants becoming stranded assets. In both cases, the large, inflexible supply and potentially long lead times are the root cause of risk. Retaining optionality through smaller, more flexible, and more quickly and easily procured technologies, with shorter lead times, can allow planners to more easily respond to changes in demand going forward. Planners and system operators can respond to higher demand through responsive and quickly built technologies, and slow down new procurement if realised demand is lower than expected, without already built capacity being under-utilised (also a risk for consumers in terms of capital repayments).

Question 7:
Considering the lead time above, what would be the most suitable time to commence preparations if nuclear was to be a no-regret option to replace the base load capacity to be decommissioned post 2030?

Comment:
As discussed in our comment to Question 4, several scientific studies show that if there is any need for nuclear power generation, then only at the earliest in the 2040s. Given the mentioned lead-time, this implies that preparations for procurement of a nuclear power plant are not required to begin before 2030, if at all.

Question 8:
What would be the advantages brought about by SMRs, and is it possible for these to complement intermittent technologies such as renewables?

Comment:

As the studies about economy-wide, energy-system wide or power-system modelling mentioned above have shown, and as the IRP 2019 has recognised, there is currently and in the near future no cost-efficient mature nuclear power technology.
Whether nuclear can play a technical role in providing flexible capacity in the future, using for example small modular reactor technology, is not yet known. Few studies assess the commercial costs of Small Modular Reactors or other reactor types as an alternative to currently mature nuclear power generation technology. One such study observes that no R&D spending and projects have managed to materialize promises of reduced costs for SMRs in comparison to conventional (large scale PWR) reactors, and that so far no appetite for large scale public funding has been found around the world that would give SMRs the possibility to experiment and develop in the real world (see Thomas, et al., 2019).[31] Given the stage of its development, commercial viability of SMRs might not arrive before 2035.

Question 9:
Comment on the impact of nuclear technology on the electricity tariff and how this may affect demand for electricity in the longer term, and how this may affect future investment decisions and how long the investment cycle is, where applicable.

Comment:
As mentioned, multiple sources confirm that power generation from nuclear technology – given all requirements to meet electricity demand and the characteristics of competing technologies, as shown by full-sector analysis of the South African economy – is currently not an affordable or necessary option. This situation will continue in the coming decades, even when assuming conservative changes in alternative renewable energy sources for power generation, as shown in many of the mentioned system-wide studies in our Comment to Question 2, in the IRP 2019 itself, and in the Technical Annex to these comments.

As mentioned above, we updated existing analyses with an analysis of a scenario with the most beneficial circumstances for nuclear power generation presented in the Technical Annex. In our additional analysis we assumed conservative future cost reductions for renewable energy and explored a scenario in which the South African economy sees very high economic growth rates, while South Africa's coal power plants would continue to operate at recently observed low energy availability factors (EAF). Even in this circumstance, nuclear power adds unnecessary investment costs to the South African power system to the height of R77 to R97 billion over the coming decade. To recover these investments, the electricity price (excluding charges for transmission and distribution and taxes),

[31] Thomas, S., Dorfman, P., Morris, S. & Ramana, M.V. (2019) 'Prospects for Small Modular Reactors in the UK & Worldwide' NFLA, Manchester, available at https://www.nuclearpolicy.info/wp/wp-content/uploads/2019/07/Prospects-for-SMRs-report-2.pdf (accessed 4 February 2021)

should increase by 2,7 to 3,8% by 2030. Alternatively, government will have to subsidise nuclear power from public means, leading to economic disadvantage elsewhere in the economy.

Comments on questions raised by NERSA (section 3, technology costs)

"B. The IRP proposes that the nuclear power programme must be implemented at an affordable pace and modular scale (as opposed to a fleet approach) and taking into account technological developments in the nuclear space."

Question 9:
Comment on the costs of mature and commercially available nuclear power generation technologies. Provide your comments in line with a mandate to ensure that:

- **i.** **investment in the electricity supply industry is facilitated;**
- **ii.** **universal access to electricity is facilitated; and**
- **iii.** **competitiveness, customer and end-user choice are promoted.**

Comments on costs should incorporate overall cost of the technology and must not be limited to overnight cost.

Comment:
Taking into consideration our comments above and our analysis presented in the Technical Annex, it must be concluded that:

- (i) procurement of nuclear power generation currently poses an unnecessary investment burden by adding an estimated 77-97 billion Rand to power sector investments from 2021 to 2030 (see Annex);
- (ii) procurement of nuclear power thus probably draws on public finance that could be directed to other more useful purposes, and that the likely consequence of an increased electricity price complicates the objective of achieving universal access to electricity;
- (iii) nuclear power would not stand the test of competitiveness or survive if customers would have free end-user choice in regarding their electricity supplier.

Question 10:
What would constitute modular scale and at what cost would it be affordable for the South African economy?

Comment:
See our comments to Questions 4 and 8 above: While a modular scale, (which the World Nuclear Association defines as reactors of 300MWe or less)[32] would be in line with the demands for flexibility of future power systems, there is no clarity yet of near future affordability of nuclear SMRs for power systems, or indeed for breakthroughs that would make them competitive with mature nuclear technology.[33] Without such prior knowledge, the government should be prudent, and act in accordance with one of the findings of IRP 2019, namely "Accordingly, long-range commitments are to be avoided as much as possible, to eliminate the risk that they might prove costly and ill-advised."

Rather than already deciding to commence procurement of either mature but uncompetitive, or not yet proven technologies, the South African government should rather decide to survey and possibly research these future nuclear technologies to maintain an eye on their maturity in the medium to long term. In the interim, spending more cost-effectively on already proven, cheap and reliable options for power supply, such as renewable energy, would deliver better outcomes for the electricity sector and the economy, in terms of pricing, affordability, and jobs.

Question 11:
Comment on the cost of other suitable base load technology options the country can consider – whether referenced in the IRP 2019.

Comment:
See our answers to Questions 2, 3 and 4 above. The most suitable options for new power generation are solar PV and wind energy, supplemented by flexible dispatchable capacity options such as batteries, hydro, concentrating solar power, and gas (although uptake of fossil gas is subject to the ambition of long-term climate mitigation targets).

Finally, integrated resource planning should also include demand side options as resources for balancing supply and demand. Energy efficiency and demand side management (e.g. flexible loads) should be included to respond to variability in supply, e.g. through managing household electricity demand, electricity demand for charging electric vehicles, and channelling surplus renewable energy for the industrial production of chemicals or steel via hydrogen/ammonia production.

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[32] https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx (accessed 2 February 2021)
[33] https://www.nuclearpolicy.info/wp/wp-content/uploads/2019/07/Prospects-for-SMRs-report-2.pdf

Question 12:
Comment on the most suitable pace (timing between power units) at which South Africa should implement the nuclear build programme.

Comment:
From all of our comments above one can conclude that we advise NERSA and the government of the Republic of South Africa to put the idea of procurement of new nuclear power generation on hold until after 2030, or until such time that a commercial SMR becomes available internationally. In this time, South Africa's government agencies specialised in energy technology, like CSIR, can monitor whether technological breakthroughs take place in SMRs that could make them cost-effective in an evolving power generation system. If a commercially viable SMR becomes available, then when a new IRP is undertaken, that analysis could incorporate this new information to test and identify *if* SMRs are a least cost option. However, on current evidence, this is not the case, and for now mature nuclear power generation is no longer a cost-effective power generation technology for modern-day electricity systems.

Question 13:
Comment on the procurement of this capacity now for build beyond 2030.

Comment
From all of our comments above one can conclude that we advise NERSA and the government of the Republic of South Africa to put the idea of procurement of new nuclear power generation on hold until after 2030, or until such time that a commercial SMR becomes available internationally. In this time, South Africa's government agencies specialised in energy technology, like CSIR, can monitor whether technological breakthroughs take place in SMRs that could make them cost-effective in an evolving power generation system. If a commercially viable SMR becomes available, then when a new IRP is undertaken, that analysis could incorporate this new information to test and identify *if* SMRs are a least cost option. However, on current evidence, this is not the case, and for now mature nuclear power generation is no longer a cost-effective power generation technology for modern-day electricity systems.

Comments on questions raised by NERSA (section 6, procurement process)

G. The IRP 2019 highlights that 'Taking into account the 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 road map for future expansion programme'.

Question 32:
Comment on the socio-economic impact of nuclear new build programme on South Africa (e.g. job opportunities and localisation).

Comment:
Many of the studies mentioned in our Comment to Question 2 above evaluate the socio-economic impacts of the expansion of nuclear power generation within South Africa's electricity system for the total economy in a full-sector model . The scenarios adapted to NERSA's request for comments presented in the technical annex to this document were also evaluated for socio-economic impacts. Both previous studies and the analysis in the Annex show that the increased need for power sector investment in the run up to commissioning of a new nuclear power plant causes too much of a draw on South Africa's savings and hence reduces economic growth and employment. This occurs even before the unnecessary increase in the electricity price. Our most recent analysis shows that the impacts on South Africa's GDP of procurement of 2500 MW of nuclear power generation by 2030 could amount to -0,5% to -0,8% of GDP compared to a future with least-cost power generation, while employment could be between 71 and 158 thousand jobs lower for the entire economy. These jobs would be lost in the entire economy, including many low skill jobs. Furthermore, Merven et al (2019)[34] already found that nuclear power itself does not offer any specific advantage over other renewable power generation technologies for direct job creation.

Question 33:
Do you agree with the determination as provided by the Minister?

From all of our comments above one can conclude that we do not agree with the determination as provided by the Minister. We advise NERSA and the government of the Republic of South Africa to put the idea of procurement of new nuclear power generation on hold until after 2030, or until such time that a commercial SMR becomes available internationally. In this time, South Africa's government agencies specialised in energy technology, like CSIR, can monitor whether technological breakthroughs take place in SMRs that could make them cost-effective in an evolving power generation system. If a commercially viable SMR becomes available, then when a new IRP is undertaken, that analysis could incorporate this new information to test and identify *if* SMRs are a least cost option. However, on current evidence, this is not the case, and for now mature nuclear power generation is no longer a cost-effective power generation technology for modern-day electricity systems.

In summary:

v) the rationale for new nuclear as outlined in the NERSA questions (for example the need for baseload power) is baseless;

[34] https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP84_Merven_Hartley_McCall_Burton_Schers_October_2019.pdf

vi) the IRP 2019 does not provide a basis for new nuclear capacity as nuclear does not feature in the IRP plan; hence, the procurement of new nuclear capacity is irrational and inconsistent;

vii) best available information currently, including all of our own analysis, as well as the IRP itself, indicates that new nuclear capacity is not cost effective, does not feature as part of a least cost system, and is not competitive with other options;

viii) new nuclear is not a least cost or effective way to meet climate policy goals.

Technical Annex

Introduction

In this technical annex we will show that even in circumstances beneficial to nuclear power generation there currently is no scale or suitable pace, and no case to be made based on affordability, for new nuclear power generation in South Africa. We arrive at this finding even when assuming the circumstances to be beneficial for nuclear power, including recently observed low Energy Availability Factors (EAFs) for thermal coal power plants and higher GDP growth rates than can reasonably be expected for the coming decade. Nevertheless, even under such beneficial circumstances we find that there is no need for the procurement of nuclear power in South Africa in the coming years.

To arrive at this conclusion we use the SATIM-GE energy model, which is a linked energy-economic model representing the full South African economy and energy system (Arndt et al., 2016;[35] Merven et al., 2017)[36]. SATIMGE combines an optimisation TIMES model (SATIM) with an economy-wide CGE model (SAGE):

- SATIM identifies the least-cost technology mix for the energy system subject to constraints such as emissions limits, committed build plans, technology costs and availability characteristics, and energy demand (up to an hourly level of detail for power generation);
- SAGE allows for the analysis of economic impacts of different energy system choices, including inter alia, analysis of investment costs and mitigation policy, by modelling the economic development trade-offs associated with the energy system.

The models are set to converge and SAGE interacts with SATIM by considering energy intensity in economic activity, energy investment and energy prices as required by SATIM, which in turn receives feedback on household income and consumption decisions, as well as direct energy demand by sector from SAGE. An overview of the model was also presented recently at the International Energy Agency's ETSAP online workshop in December 2020.[37] Key developments in SATIMGE of recent years are documented in Merven et al. (2018;[38] 2019a;[39] 2019b;[40] 2020a;[41] 2020b[42]) and Hartley et al. (2019).[43]

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[35] Arndt, C., Davies, R., Gabriel, S., Makrelov, K., Merven, B., Hartley, F. and Thurlow, J. 2016. A sequential approach to integrated energy modelling in South Africa. Applied Energy 161: 591-599.

[36] Merven, B., Arndt, C. and Winkler, H. 2017. The development of a linked modelling framework for analysing the socioeconomic impacts of energy and climate policies in South Africa. Working Paper 2017/40, United Nations University World Institute for Development Economics Research (UNU-WIDER).

[37] The IEA-ETSAP workshop presentation of the SATIMGE model can be found at: https://www2.slideshare.net/IEA-ETSAP/satimge2020 (accessed 2 February 2021)

[38] Merven, B., Ireland, G., Hartley, F., Arndt, C., Hughes, A., Ahjum, F., McCall, B. and Caetano, T. 2018. Quantifying the macro- and socio-economic benefits of a transition to renewable energy in South Africa. Working Paper 19, Southern Africa – Towards Inclusive Economic Development (SA-TIED).

What is important to notice is that the model is a full-sector model of the South African economy, meaning that South Africa's economic activity has been modelled with a great level of detail (52 sectors in the economic model), and that the model has a great level of detail for energy demand per time slice – with a check on the appropriateness of the match between power generation (electricity supply) and electricity demand evaluated using IRENA's FlexTool Model (IRENA, 2018)[44]. In this way the model tests on the one hand the macro-economic need for future power generation, with e.g. taking into account the introduction of electric vehicles, new technologies in residential electricity demand, or the electrification of parts of the industry sector, and on the other hand the detailed technical requirements of supply and demand in the electricity sector.

Highlights

- Procurement of new nuclear power to be commissioned by 2030 will lead to unnecessary additional power sector investment needs in the period 2020 – 2030 of R80 bn in the most likely case, and still R77 bn in the best case, and R97 bn in the worst case;

- These additional investments will only reduce fuel consumption for gas to a limited extent because these investments mainly replace additions of wind and solar energy in the years before and after the year 2030, and only for a minor part replace power generation from gas turbines. As a result, the electricity price is expected to be required to increase in 2030 between R 0,04 and R 0,055 per kWh (or 2,7 to 3,8%), relative to a future without procurement of 2500 MW of new nuclear power generation;

- The limited extent to which new nuclear would substitute power generation from gas turbines also implies that the benefits for South Africa's climate change mitigation ambitions are limited, and forthcoming analysis by our research group has shown that energy efficiency

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[39] Merven, B., Hartley, F. and Ahjum, F. 2019a. Road freight and energy in South Africa. Working Paper 60, Southern Africa – Towards Inclusive Economic Development (SA-TIED).
[40] Merven, B., Hartley, F., McCall, B., Burton, J. and Schers, J. 2019b. Improved representation of coal supply for the power sector for South Africa. Working Paper 84, Southern Africa – Towards Inclusive Economic Development (SA-TIED).
[41] Merven, B., Hartley, F. and Schers, J. 2020a. Long term modelling of household demand and its implications for energy planning. Working Paper 99, Southern Africa – Towards Inclusive Economic Development (SA-TIED).
[42] Merven, B., Hartley, F., Schers, J. and Ahjum, F. 2020b. Private transport modelled in SATIMGE and the socio-economic impacts of electric vehicles in South Africa. Working Paper 121, Southern Africa – Towards Inclusive Economic Development (SA-TIED).
[43] Hartley, F., Merven, B., Arndt, C. and Ireland, G. 2019. Part 2 — Quantifying the macro and socioeconomic benefits of a transition to renewable energy in South Africa. Working Paper 26, Southern Africa – Towards Inclusive Economic Development (SA-TIED).
[44] : IRENA (2018), Power System Flexibility for the Energy Transition, Part 2: IRENA FlexTool methodology, International Renewable Energy Agency, Abu Dhabi.

measures or increased power sector investment in solar PV and wind energy could lead to higher levels of greenhouse gas emission reductions relative to a least-cost power system. Moreover, increased electricity prices could have some limited negative trade-offs for climate policy due to slower electrification of transport or industrial applications that currently use fossil fuels;

- The additional need for power sector investment in the case of procurement of 2500 MW new nuclear power generation competes with other more productive investments in the South African economy, and combined with the increased electricity price leads to a lower GDP of minus 0.5% to minus 0.8% by 2030 compared to a future without procurement of new nuclear power;

- Lower GDP has ramifications for employment that go beyond employment effects within the power generation sector, with in the most likely case minus 0.5% jobs in 2030, or roughly 100 thousand jobs. This number includes the jobs generated directly from constructing and maintaining a nuclear power plant in South Africa, which by the way are already estimated to be slightly lower than those that would be generated for their renewable alternatives (see Merven et al., 2019b);

- Delaying the decision around procurement of new nuclear power generation by several years, meaning until ample and reliable information around the costing and maturity of smaller modular reactors and other competing technologies becomes available, is strongly recommended.

Detailed analysis

Scenarios & main assumptions

We have modelled three scenarios to test the effects of the inclusion of new nuclear power. In each scenario there is a case *with* and a case *without* procurement of 2500 MW of nuclear energy to be commissioned by 2030. An overview is given in Table 1, and details are given below.

Table 1 Naming of scenarios with assumptions and whether 2500 MW of new nuclear is enforced

Assumptions Case	Moderate GDP growth + historic EAF for coal	Moderate GDP growth + Low EAF for coal	High GDP growth + Low EAF for coal
Without 2,5 GW new nuclear	Reference	LowEAF	LowEAF-HiGr
Commissioning of 2,5 GW nuclear by 2030	Reference_ wNewNuclear	wNewNuclear_ LEAF	wNewNuclear_ LEAF-HiGr
Estimated likeliness of scenario	*Fairly possible*	*Most likely*	*Unlikely*

Assumptions about technology costs

For the analysis to comment on questions of NERSA's Consultation paper several modelling assumptions are worth mentioning.

We have assumed the lower cost estimate of currently mature nuclear power technology, as given by the IRP 2019, while we assumed conservative estimates of future cost reductions in renewable power generation (solar PV, wind energy, and solar CSP) based on Ireland and Burton (2018)[45]. National wind and PV temporal energy production profiles and the removal of total resource constraints are based on (DoE REDIS, 2018)[46] and (CSIR et al, 2016)[47].

Few studies exist that can estimate the commercial costs of Small Modular Reactor's or other reactor types as an alternative to currently mature nuclear power generation technology. One such study observes that no R&D spending and projects have managed to materialize promises of reduced costs for SMRs in comparison to conventional (large scale PWR) reactors, and that so far no appetite for large scale public funding has been found around the world that would give SMRs the possibility to experiment and develop in the real world (see Thomas, et al., 2019).[48] In other words, there is no reasonable prospect for SMRs to have developed and demonstrated to be cheaper than conventional nuclear technology by 2030 or any year soon thereafter.

Assumptions for the need for additional power generation capacity
Electricity demand mainly follows from economic growth projections, with smaller changes due to structural and technological change in sectors. The two different assumptions used in the scenarios presented here are:

- Reference and Low-EAF scenarios: The growth rate is based on a combination of projections from the 2020 Supplementary Budget (National Treasury, 2020), the April 2020 Bureau for Economic Research extended forecast and extrapolations of these outlooks. Between 2020 and 2050, the average annual growth rate is 2.6%;

[45] Ireland, G. and Burton, J. 2018. An assessment of new coal plants in South Africa's electricity future: the cost, emissions, and supply security implications of the coal IPP programme. Energy Research Centre - University of Cape Town, South Africa
[46] DoE REDIS [Department of Energy]. 2018. Renewable Energy Data and Information Service. http://redis.energy.gov.za/national/
[47] CSIR, Fraunhofer-IWES, SANEDI, and ESKOM. 2016. Wind and Solar PV Resource Aggregation Study for South Africa. Final Report, 1 Nov 2016. Available at: https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf
[48] Thomas, S., Dorfman, P., Morris, S. & Ramana, M.V. (2019) 'Prospects for Small Modular Reactors in the UK & Worldwide' NFLA, Manchester, available at https://www.nuclearpolicy.info/wp/wp-content/uploads/2019/07/Prospects-for-SMRs-report-2.pdf (accessed 4 February 2021)

- The High Growth (HiGr) scenario takes into account the potential to successfully unlock key constraints to the economy, based on National Treasury (2019) and higher competition levels from SARB (2013). Between 2020 and 2050, the difference in average annual growth rate is about 0,5% until 2024, then about 1,5% in 2025 and increasing to about 2% in 2030, after which growth rates gradually converge to the same rate in 2050.

These growth assumptions lead to an electricity demand for 2050 in the Reference and LowEAF moderate growth scenarios just slightly higher than the Upper projection of the IRP 2019, and of about 50 TWh/year above the IRP's Median projection. The High Growth scenario reaches 480 TWh/year in 2050, or about 50 TWh/year more than the moderate growth scenarios (see Figure 2 below).

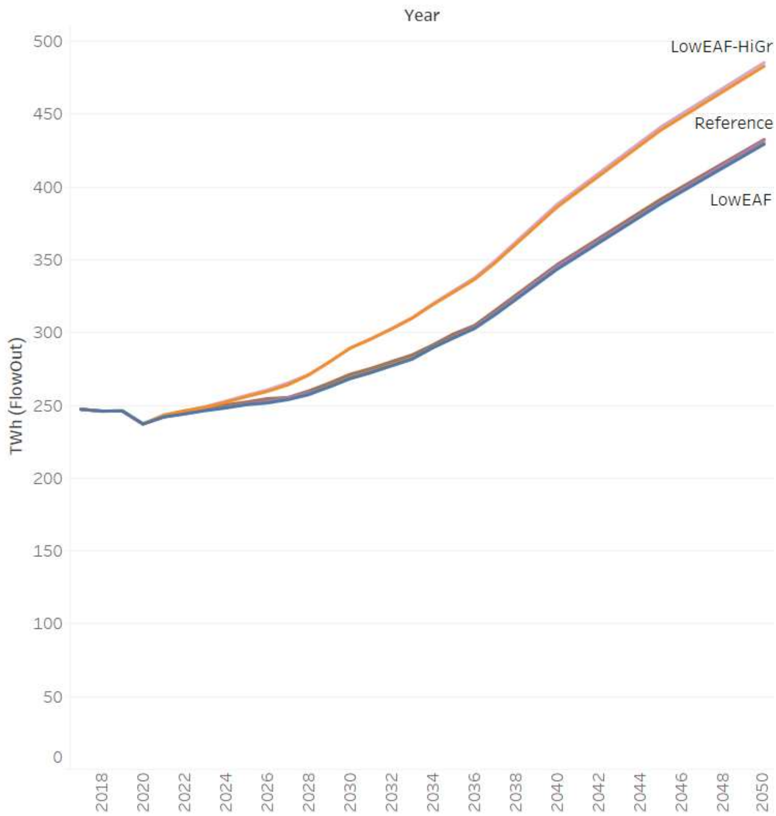

Figure 2 Evolution of electricity demand (in TWh/year) in High Growth and Reference scenarios

Assumptions on the Energy Availability Factor (EAF) of coal power plants

- Reference scenario assumptions are that the EAF of South Africa's existing coal-fired power plants is restored from a low 65% in 2020 to its level foreseen by the IRP 2019. The Medupi and Kusile power stations, together representing the largest share of new generation capacity in South Africa, have been reporting low availability factors while technical problems in construction and commissioning are addressed. We assume that their maximum availability factors rise from 55% and 40% respectively in 2020, to 80% each by 2025. Availability factors for power stations on the system are taken from IRP 2019;

- As mentioned, South Africa's coal power plants have been observing historically low EAF in 2019 (67%) and 2020 (65%) (see Figure 3, and CSIR 2020)[49]. The need for new power generation is higher if the EAF of the coal power plants that dominate South Africa's power supply is low. In the Low-EAF scenarios we therefore assume that coal EAF's stay at the recent low EAF of 2020, namely at 65%.

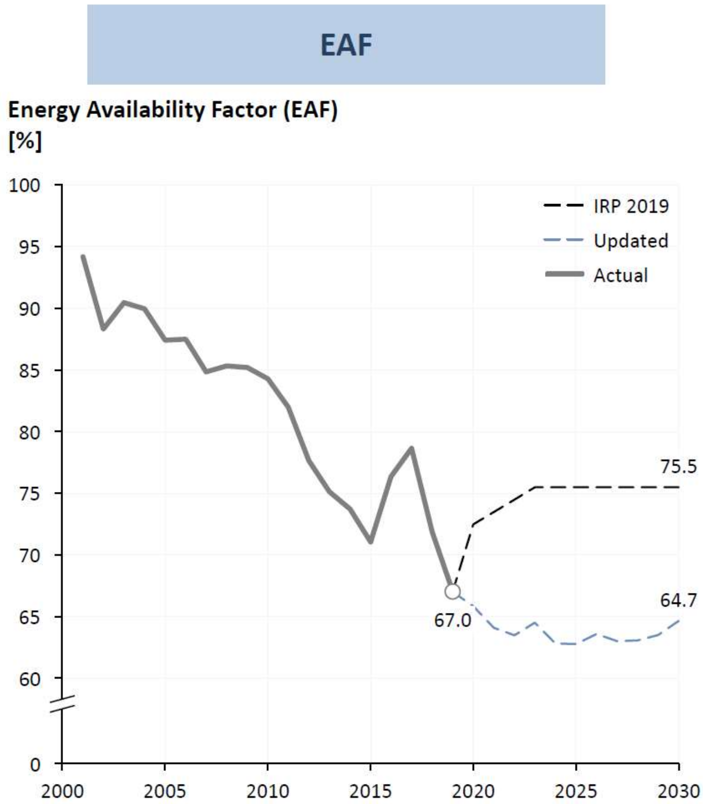

Figure 3 Estimated low EAF ("Updated") for coal power plants, from CSIR (2020)

[49] Wright, J. and Calitz, J., 2020. Setting up for the 2020s: Addressing South Africa's electricity crisis and getting ready for the next decade. Presentation by CSIR Energy Centre, Pretoria, January 2020. Available at: https://researchspace.csir.co.za/dspace/bitstream/handle/10204/11282/RS_Setting%20up%20for%202020.pdf%20version%201.1.pdf (accessed 4 February 2021)

Other assumptions relevant for the capacity allocation

- *Existing capacity:* Capacity values and decommissioning dates are taken from Eskom (2018)[50], NERSA (2018)[51], and the IRP 2019 reports. Availability for the plants has been taken from table 6 of the IRP 2019 report, combined with data from Eskom CDM webpage (Eskom , 2018);

- *Committed new capacity additions*: Beyond the existing power generation and decommissioning plans of the IRP 2019 we also add already committed capacity additions according to the schedule outlined in the IRP 2019 (see Table 2);

- *Further additions,* power generation capacity additions beyond the already committed new build (besides the 2500 MW of new nuclear being forced to be commissioned by 2030 or not) follow from least-cost optimisation decisions for the South African energy system over the entire modelling time horizon (2050). For solar PV and wind there is a gradual liberation of a constraint on new capacity, as in Merven et al (2019b), namely:
  - Wind: 1GW per year starting in 2020, ramping up gradually to 2GW/year by 2025, 3GW/year by 2030, and finally 4GW per year by 2040;
  - Solar PV: it is assumed that solar PV can be rolled out faster early on, with 2GW per year starting from 2020, increasing to 2.5GW/year by 2025, 3GW/year in 2030, and 4GW/year in 2040 and thereafter. These build rates are also applied equally to rooftop PV in residential and commercial sectors, and industrial rooftop PV each at 1 GW/year in 2020, 2GW/year in 2025, 3GW/year in 2030 onward.

Table 2 Committed new capacity additions (GW)

	2012 - 2017	2018-19	2020	2021	2022	2023	Total
Medupi	1.44	0.72	0.72	0.72	-	-	**4.33**
Kusile	0.72	-	1.44	0.72	0.72	0.72	**4.33**
Pumped Storage - Ingula	1.32	-	-	-	-	-	**1.32**
DoE Peakers (Diesel)	1.01	-	-	-	-	-	**1.01**
Micro hydro	-	-	-	0.005	-	-	**0.005**
CSP 9 hrs storage	0.30	0.10	-	-	-	-	**0.50**
Solar PV Fixed	1.92	-	-	-	-	-	**1.92**
Solar PV tracking	0.51	-	0.11	0.30	0.40	-	**1.33**
Wind	2.64	-	0.24	0.30	0.82	-	**4.00**

Source: IRP 2019

[50] Eskom. 2018. Fuel consumption data 2010-2018. http://www.eskom.co.za/OurCompany/SustainableDevelopment/Pages/CDM_Calculations.aspx

[51] NERSA [National Energy Regulator of South Africa]. 2018. Electricity Generation Statistics by Licensee. Pretoria, South Africa

Results & Analysis

Since new nuclear power does not feature in least-cost optimisation of the power sector, in each case the new 2500MW must be 'forced in' to the model. We thus compare impact of procuring the 2500 MW of new nuclear on the power system, and observe the following differences due to the procurement and commissioning of 2500 MW of new nuclear power by 2030:

- A fifth to a quarter more power sector investment is required in the lead period 2021 to 2030 – equal to 80 billion Rand. New nuclear power requires significantly higher investments in the power generation sector throughout the 2020s, with only a smaller reduction in future power generation investment need to be expected from 2029 onwards in all cases: see Figure 4. The main forms of power generation capacity that would be substituted by that time by new nuclear power generation are: 1. Wind energy; 2. Solar PV; and 3. Gas turbines.

Figure 4 Changes in power sector investment between 2021 and 2050 due to commissioning of new nuclear power for the three scenarios

- Reflecting relatively small changes in the composition of electricity supply by 2030, and leading to an actually almost negligible contribution of nuclear energy by 2050 (see Figure 5).

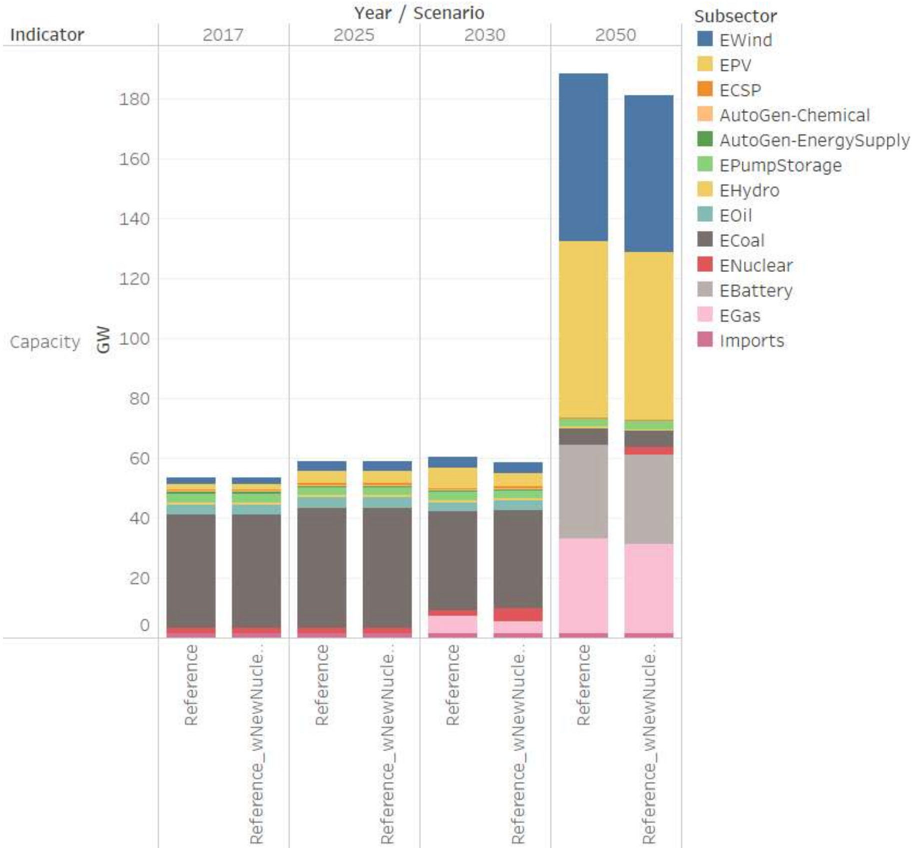

Figure 5 Installed capacity for selected years in the Reference scenario with and without forcing of 2500 MW new nuclear capacity

- This translates into higher average costs for power generation of around R 0,04 to R 0,055 per kWh of electricity, due to commissioning of new nuclear power in 2030 (see Figure 6) in comparison to to a corresponding least-cost scenario with similar assumptions (as indicated in Table 1 previously). This is equivalent to an increase of the average cost of power generation of 2,7% to 3,8%.

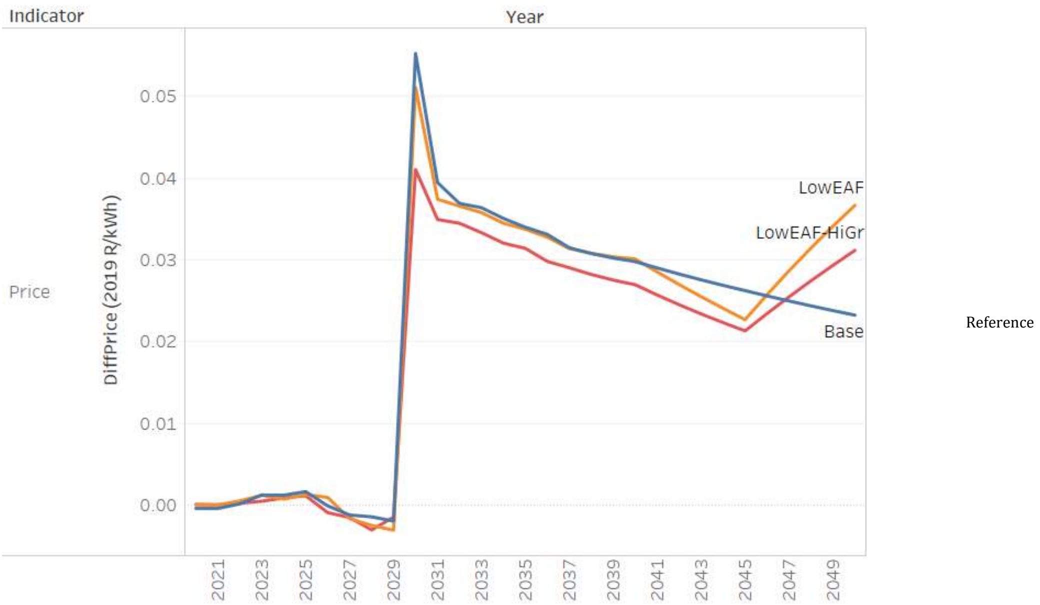

Figure 6 Change in the average cost of electricity in each scenario due to the commissioning of 2500 MW of new nuclear power generation

Levelised Cost of Electricity (LCOE)

Analysis of Levelised Cost of Electricity (LCOE) by technology shows that new nuclear power generation indeed causes higher electricity prices, because:

a. The LCOE of new nuclear at current proven mature technology costs is significantly higher than that of continuing to run existing nuclear power plant, Koeberg: See Figure 7, showing the difference between the Koeberg and possibly-to-be-procured nuclear LCOE's;

b. It is also higher than that of competing alternatives, i.e. New Coal, and New Variable Renewable Energy when combined with New Flexible Generation (see VRE+FlexibleGen in Figure 7).

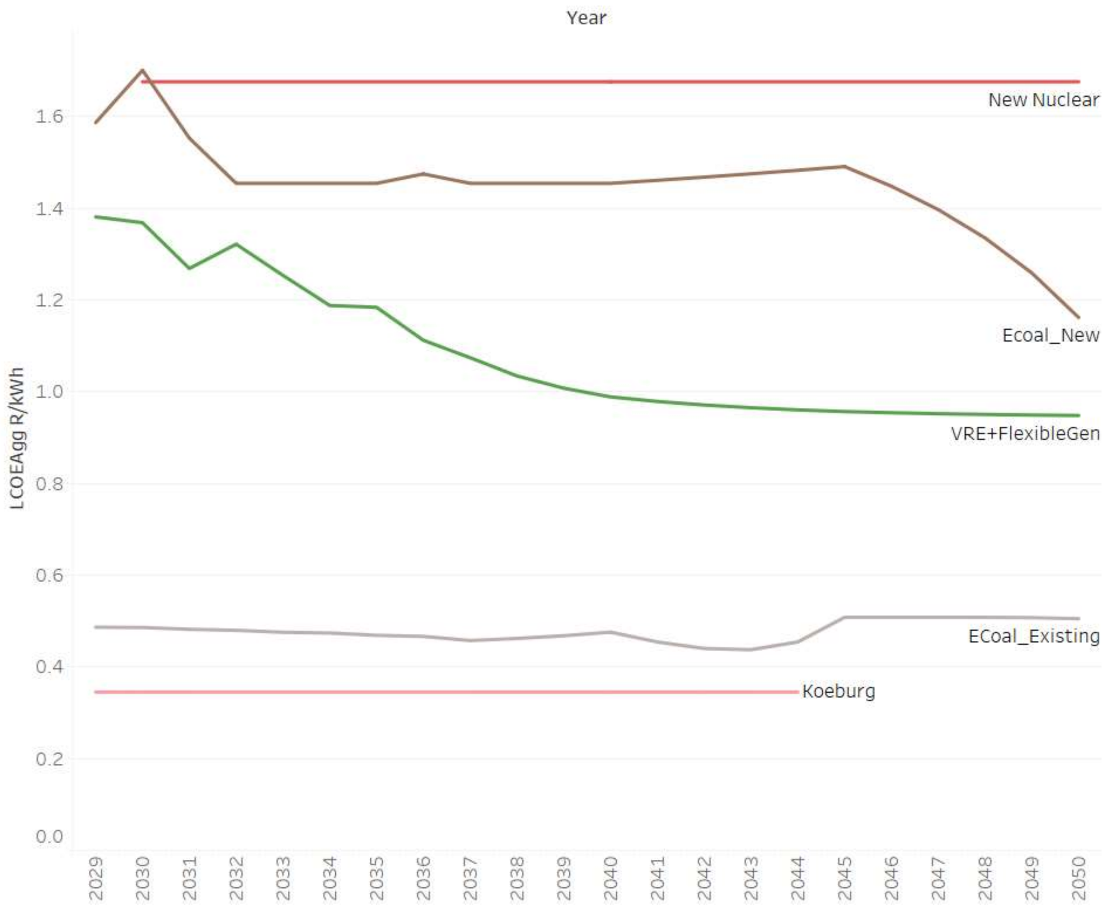

Figure 7 LCOE's in the Reference scenario with 2,5 GW new nuclear

This result is obtained despite new nuclear running at full loads in our scenarios. Note also that the combination of solar PV and wind energy renewable power generation with supplementary technologies like batteries or gas are still cheaper than nuclear, explaining the overall finding that the electricity price is higher in scenarios with nuclear compared to scenarios without nuclear, for which the differences were shown in Figure 6 above.

Environmental and socio-economic impacts

For the environmental impacts we find that adding nuclear power generation has no significant impact on Greenhouse Gas (GHG) emissions. There is a small negative impact on GHG emissions Figure 8, because of lower GDP meaning that lower economic activity causes the entire economy to emit less GHG emissions. However, as Merven et al. (forthcoming)[52] show, implementing energy efficiency measures, and investing in more solar PV and wind power generation is capable of reducing South Africa's GHG emissions much more at a comparable cost as the commissioning of 2500 MW of new nuclear power of the Consultation Paper's proposed capacity allocation.

[52] Merven, B., Hartley, F., et al. (forthcoming). Moving beyond a least-cost energy system: Assessing the trade-offs between increased mitigation ambition and economic development in South Africa.

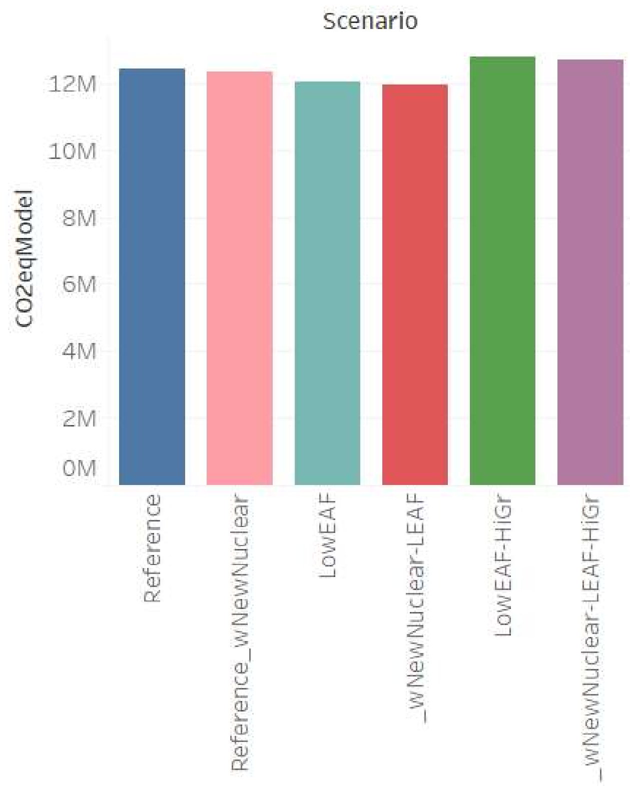

Figure 8 Cumulative CO2-eq GHG emissions for the period 2020-2050 for all 3 scenarios with and without forced commissioning of 2500 MW of new nuclear power by 2030

The economic cost of the procurement and commissioning of 2500 MW of new nuclear power by 2030 increases from 2021 to 2030 as the additional investment need for new nuclear power compared to a least-cost energy scenario (as shown in Figure 4 above) draws on South Africa's national savings, thus competing with other more productive investment goals. These negative economic impacts take place even in the scenario with the highest need for new power generation capacity additions, namely in the LowEAF-HiGr (high growth) scenario: In this best case, GDP in 2030 is 0,5% below that of a least-cost energy future. In the worst case, the Reference scenario, it could be 0,8% below that of a least-cost energy future (see Figure 9).

After 2028, the nuclear new build starts to substitute for other power generation investments that would else have been required by that time. This means that the economy recovers somewhat relative to the no-nuclear case. However, the recovery is incomplete because the technologies that nuclear substitutes are cheaper new power generation options.

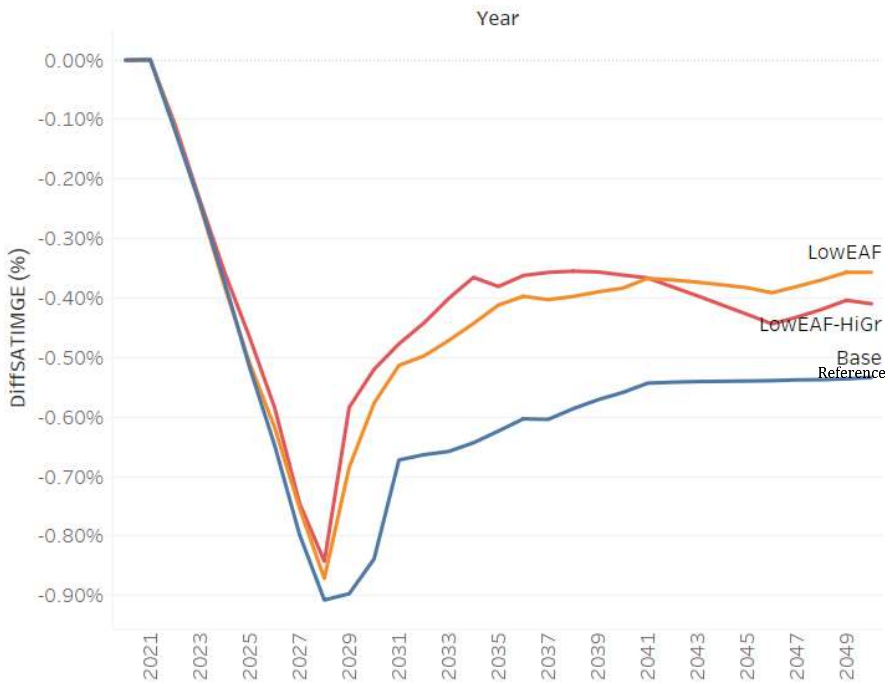

Figure 9 Change in Gross Domestic Product due to the procurement and commissioning of 2500 MW nuclear power in the 3 scenarios

Lower GDP leads to less employment in all three scenarios ranging from -0,3% employment in 2030 in case of adding 2500 MW of new nuclear to the LowEAF-High Growth scenario, up to a loss of 0,8% of employment in 2030 were new nuclear to be added under Reference scenario circumstances (see Figure 10). These numbers correspond to an expected 71 to 158 thousand jobs compared to the about 20 million people we expect to be in employment by 2030 in the three different scenarios. These employment impacts are economy-wide and therefore touch upon all regions and skills, and therefore also on a large number of low-skilled workers.

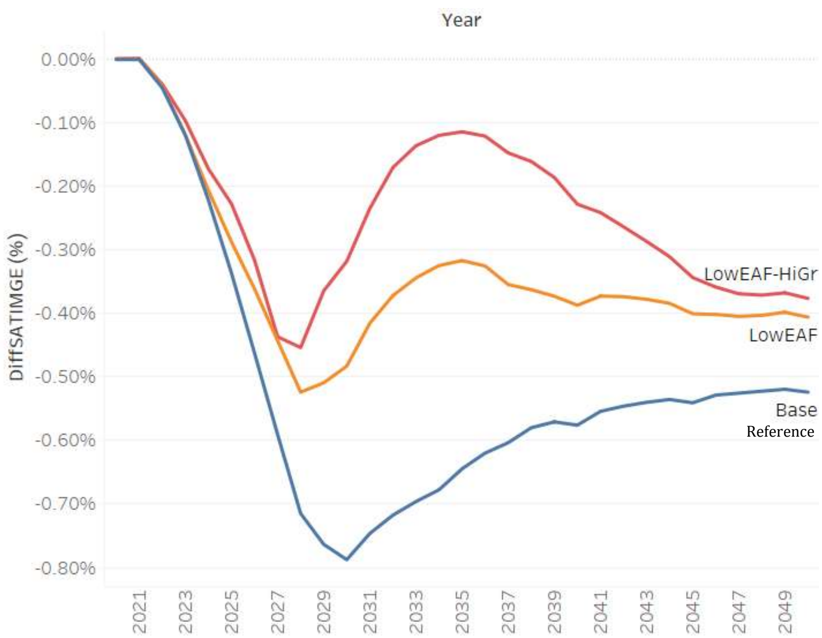

Figure 10 Change in employment due to the procurement and commissioning of 2500 MW nuclear power in the 3 scenarios

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