CSIR Response

Consultation Paper on Concurrence with the Ministerial Determination on the procurement of 2 500 MW generation capacity from nuclear

v2.0

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Touching lives through innovation

Summary of comments

Gazetted IRP 2019* does not include 2500 MW of new nuclear in the planned energy mix but does include life extension of Koeberg to 2044 and a decision to include 2 500 MW of new-build nuclear capacity

Decision 8 in the IRP 2019 is a deviation from IRP 2019* not justified/supported by published scientific evidence in the NERSA Consultation Paper on concurrence with DMRE Ministerial Determination

Published evidence would aid NERSA & other stakeholders to make a sufficiently informed decision surrounding concurrence with the Ministerial Determination for policy adjustment of 2500 MW of new nuclear capacity

As VRE penetration increases as part of the IRP 2019 there is an increasing need for flexible capacity and a decreasing need for base-supply capacity

The CSIR has again confirmed least-cost future energy mix in South Africa (also confirmed by DMRE and others) is a mix of VRE (solar PV, wind) and flexible capacity including storage as existing coal capacity decommissions. The quantified cost impact of deviation from gazetted IRP 2019 is:

- The inclusion of imported hydro capacity (Inga) in the IRP 2019 is a deviation from least-cost & results in an additional ~R 1.6-3.3 bln/yr more than least-cost (+10% to +20%)
- The displacement of 2 500 MW of imported hydro (Inga) with 2 500 MW of nuclear results in an additional cost of ~R 6.7 bln/yr (+37%)
- The inclusion of 2 500 MW of nuclear capacity results in an additional cost of ~R 8-10 bln/yr relative to least-cost (+50% to +70%)

*As per Table 5 in the IRP 2019 report

Summary of comments

When deployment of 2.5 GW of new-build nuclear in any year (insensitive to year of deployment) - anticipated cost premium for nuclear replacing Inga is just over R7 bln/yr and relative to least-cost is R9-11 bln/yr

New-build nuclear construction costs will need to be 30-50% lower than assumed in the IRP 2019 in order to break-even with the already planned imported hydro (Inga) or the least-cost portfolio of technologies

When considering low financing costs for prospective new-build nuclear, CAPEX costs still remain higher than the break-even analysis undertaken for imported hydro and the least-cost portfolio of technologies

Broader economic impacts associated with policy adjustment have not been published by DMRE or Nersa and should be made available to stakeholders for consideration (CSIR have quantified costs impact only)

- CSIR have quantified cost impact of prospective 2 500 MW imported hydro (Inga) or nuclear deployment relative to least-cost
- Impacts in other dimensions including CO_2 emissions, water usage, localised emissions (PM, SOx, NOx), employment and economic impact of these options and prospective localisation needs to be undertaken and published for all stakeholder consideration

Fundamental energy planning principles have demonstrated how base-demand does not need to be met with base-supply capacity but instead by a portfolio of options - which could be least-cost or a combination of other technologies that deviates from least-cost

Summary of comments

Global experience with new-build nuclear capacity (whether large-scale or SMR) indicates it is unlikely that 2500 MW of nuclear capacity will come online by 2030 as indicated in IRP 2019

- Initial construction time for new nuclear capacity of ~6 years on average in the 1970s (range of 4-7 years) escalated to 8-9 yrs in the three decades thereafter
- In the 2010s, average construction times of 8.0 yrs have been seen with ranges of 5-13 years being experienced (lower end dominated by China)

CSIR have demonstrated that even under very ambitious CO_2 emissions trajectories for the South African power sector, nuclear does not from part of the least-cost energy mix and is instead met by VRE technologies and flexible capacity (including storage)

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  1.1 NERSA Consultation paper

  1.2 Global context

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Background

Invitation to comment on the concurrence with the ministerial determination on the procurement of 2 500 MW new generation capacity from nuclear

According to section 34 of the Electricity Regulation Act, 2006 (Act No. 4 of 2006), NERSA is required to appropriately apply its regulatory reviews and make decisions prior to the conclusion of the determination process by the Minister of the Department of Mineral Resources and Energy (DMRE)

- NERSA received Section 34 determinations from Minister of DMRE for the procurement of 2 500 MW of new generation capacity from nuclear technology
- This is in line with Decision 8 of the Integrated Resource Plan for Electricity - published as GN 1360 of 18/10/2019 in Government Gazette No. 42784 (IRP 2019)
- The determined 2 500 MW nuclear capacity is assumed to reach commercial operation by 2030 in the IRP 2019
- The capacity is to provide clean base supply capacity in response to the approximately 11.0 GW of coal capacity being decommissioned by 2030 as well as to maintain supply demand balance and improve energy security.

This submission forms the CSIR's written comments on the consultation paper published by NERSA in November 2020 on the prospective concurrence with the ministerial determination on the procurement of 2 500 MW generation capacity from nuclear technology

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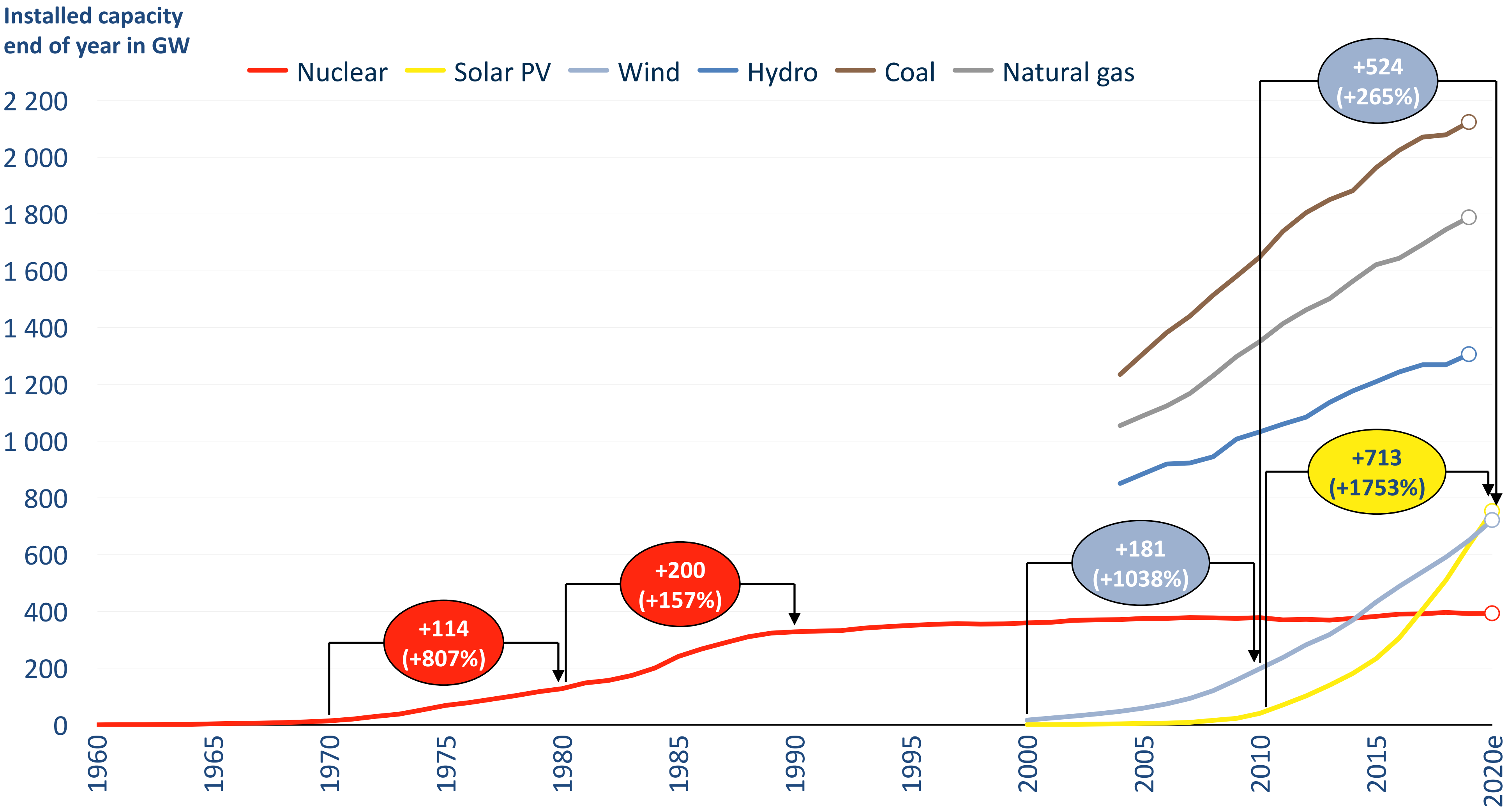
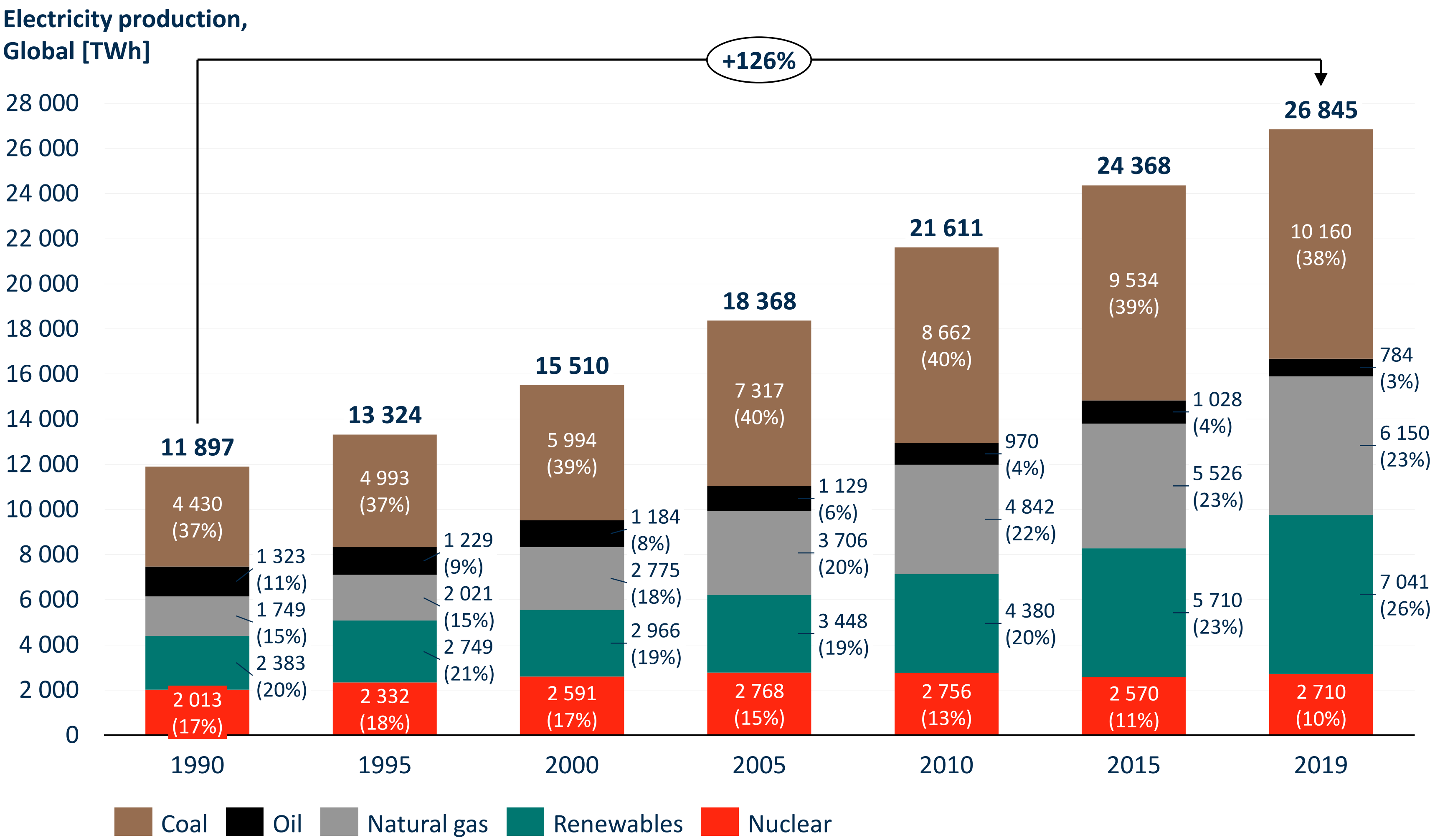
Following 1970-1990 growth, nuclear stabilised whilst other technologies growing - PV and wind exponential growth

Installed capacity end of year for nuclear, wind and solar PV (1960-2020)



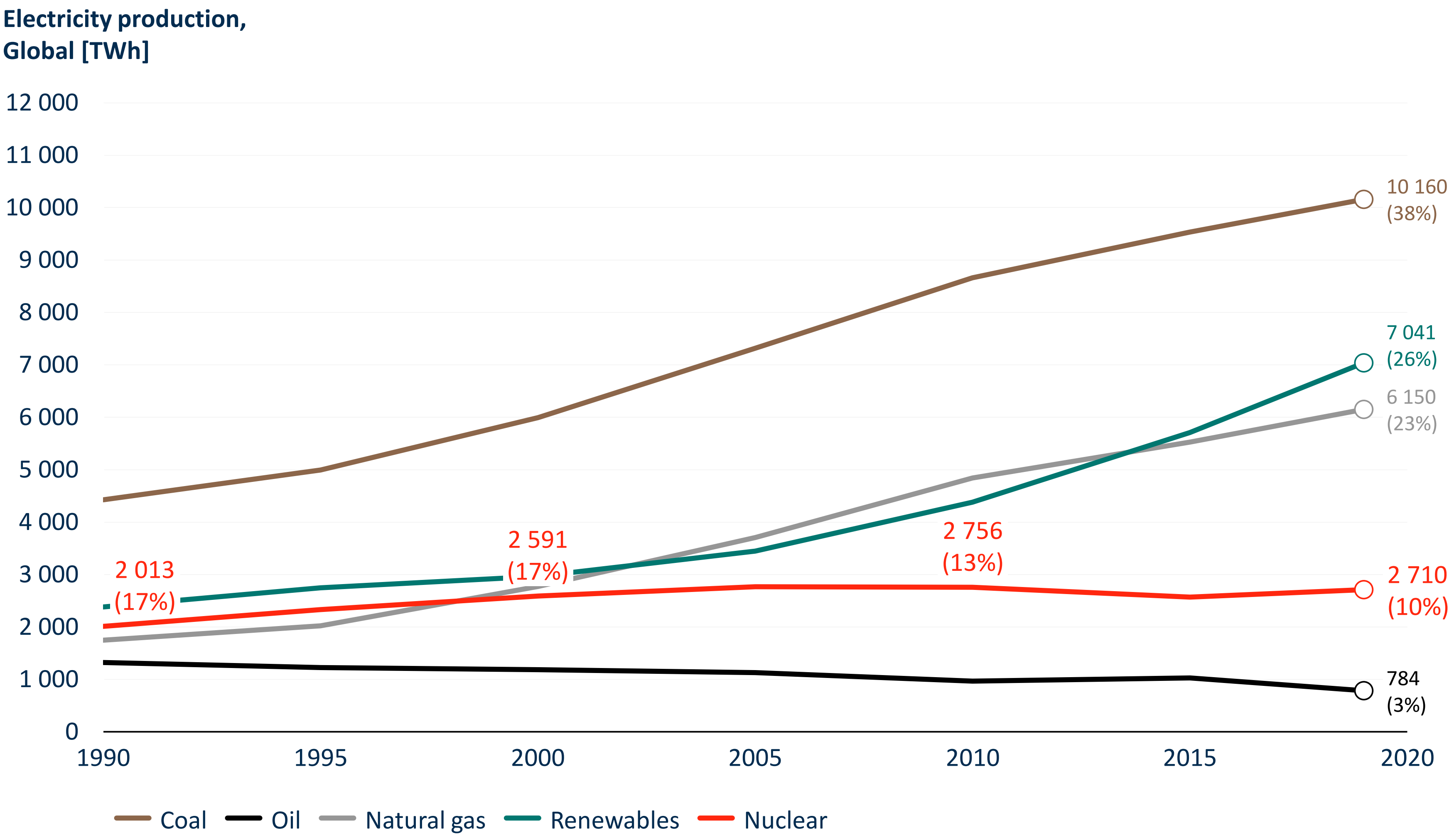
Sources: IEA; World Nuclear Association - Reactor database; SolarPowerEurope; GWEC; CSIR analysis

Electricity production has more than doubled since 1990 (CAGR 2.8%, ~30 yrs) – marginal nuclear growth (CAGR 1.0%, ~30 yrs)



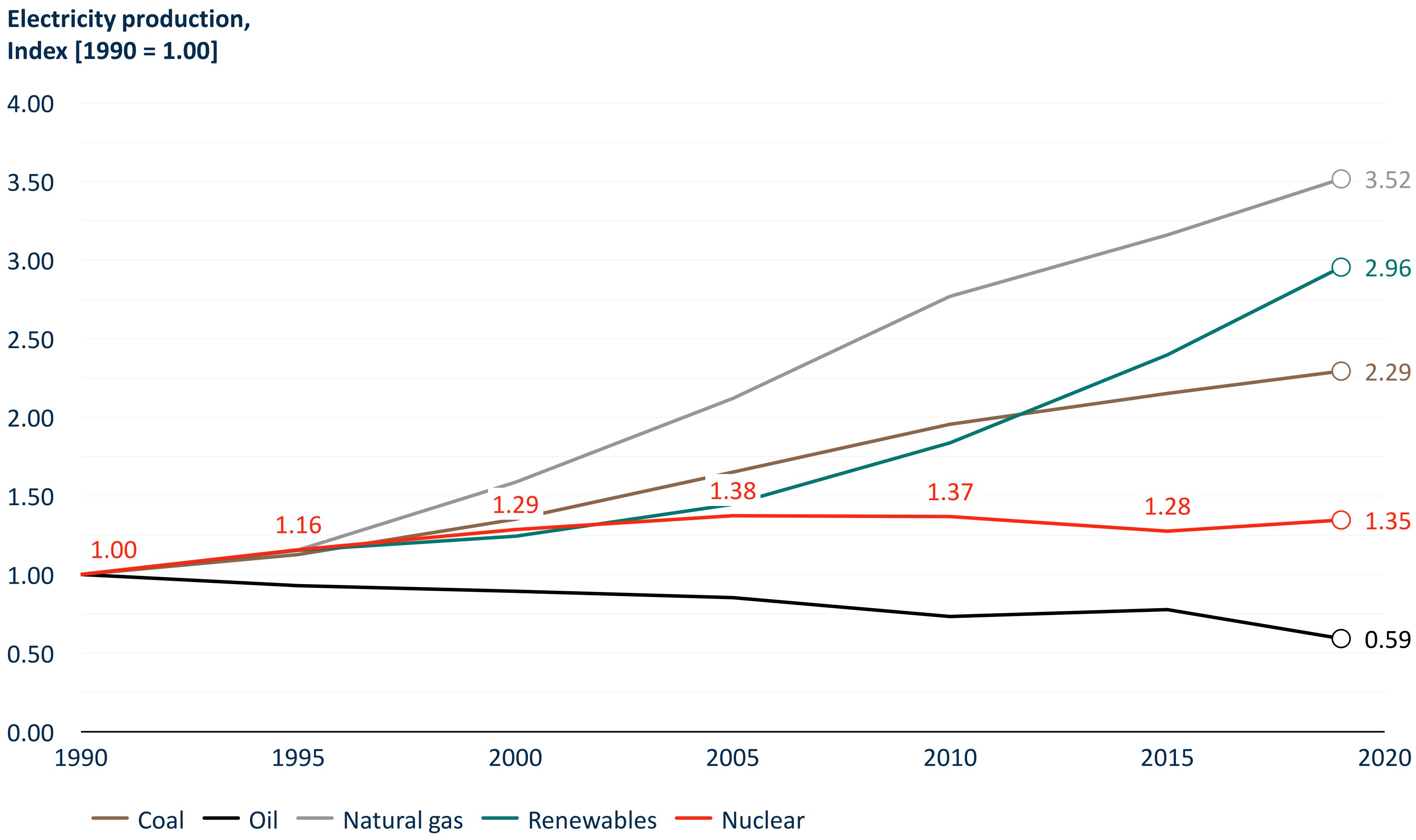
Sources: IEA; CSIR analysis

Nuclear from ~2000 TWh (1990) to ~2600 TWh (2000) but stagnant since with ~2700 TWh (2019), relative contribution in decline since 2000s



Sources: IEA; CSIR analysis

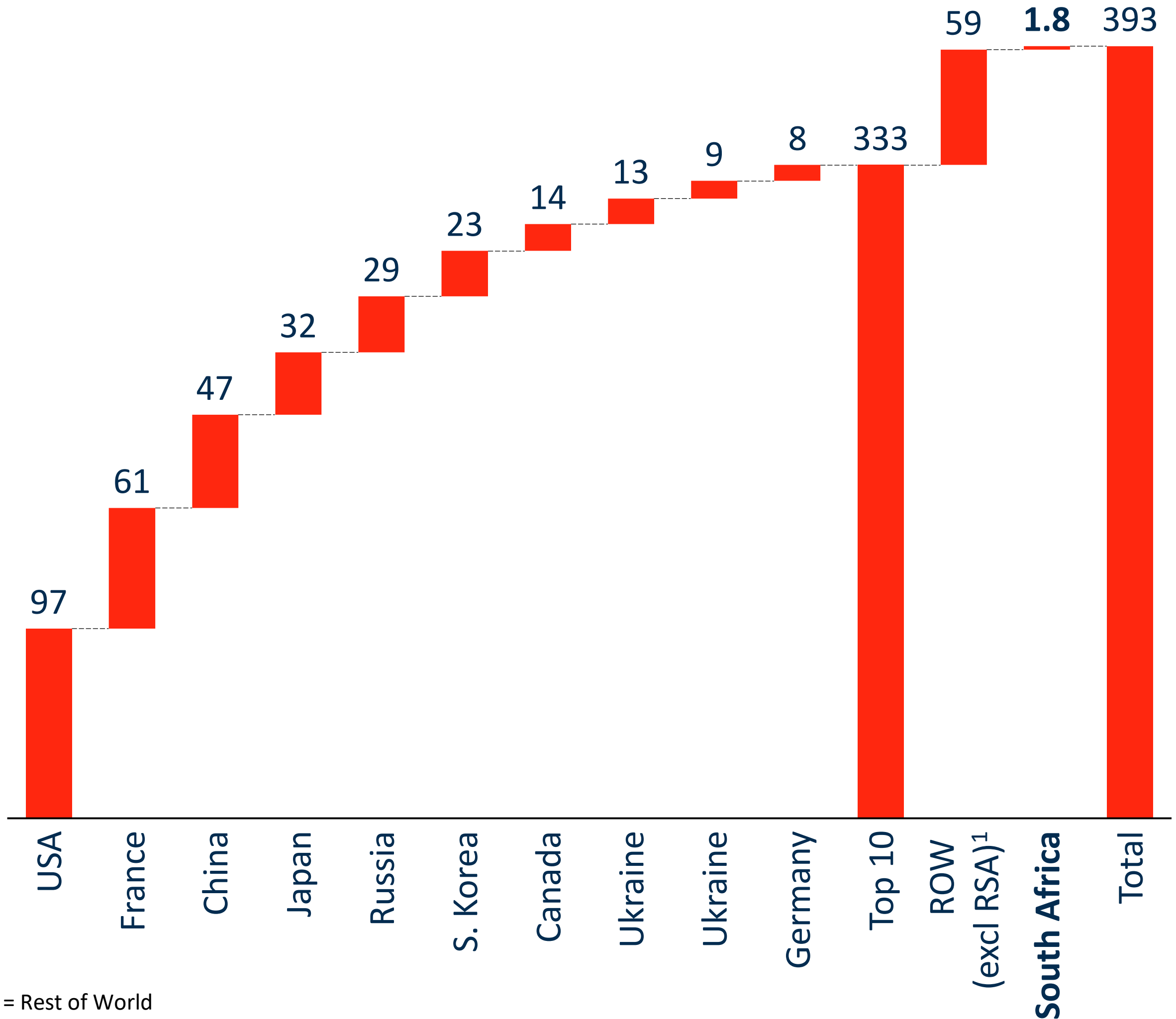
Nuclear has shown marginal growth from 1990 of 40% by mid 2000s but declined slightly since then to ~35% growth by 2019



Sources: IEA; CSIR analysis

Top 10 nuclear-power countries host 85% of all operating nuclear capacity (393 GW) – RSA comprises 0.5% of this

Nuclear operational capacity, 2019 [GW]



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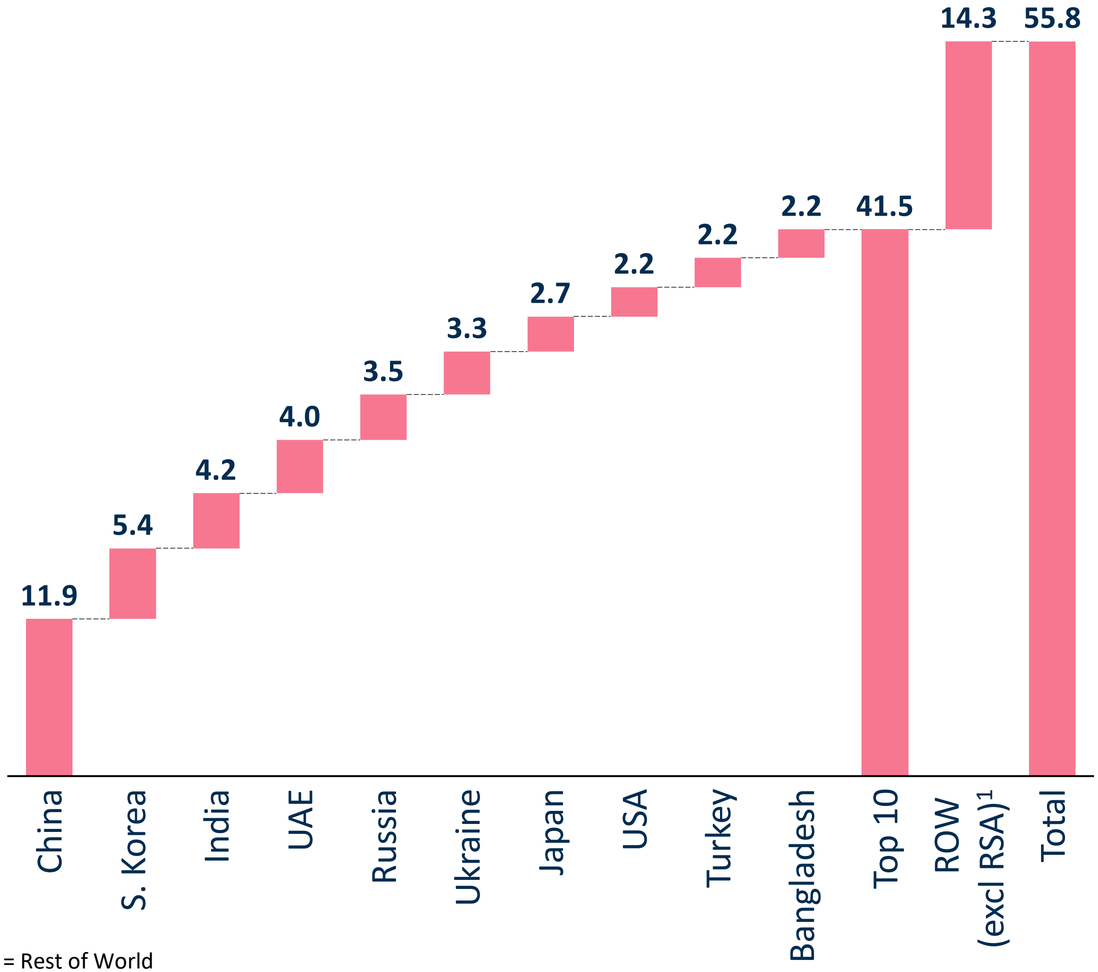
[1] ROW = Rest of World

Sources: World Nuclear Association - Reactor data base, CSIR analysis

19 countries have nuclear reactors under construction (56 GW) – dominated by China (12 of 52) making up 21% of global capacity under construction

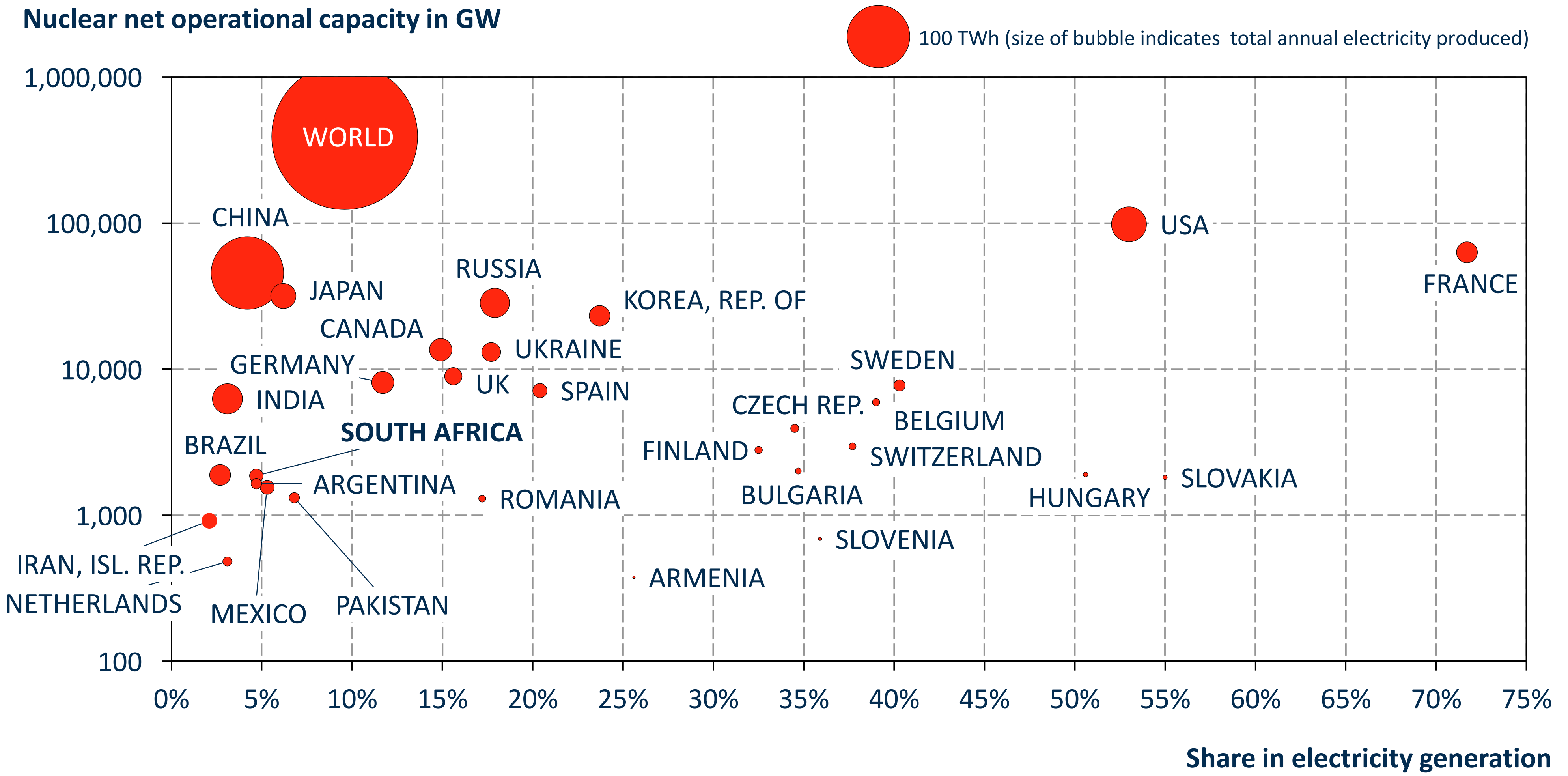
Nuclear reactors
Under construction, 2019 [GW]



[1] ROW = Rest of World

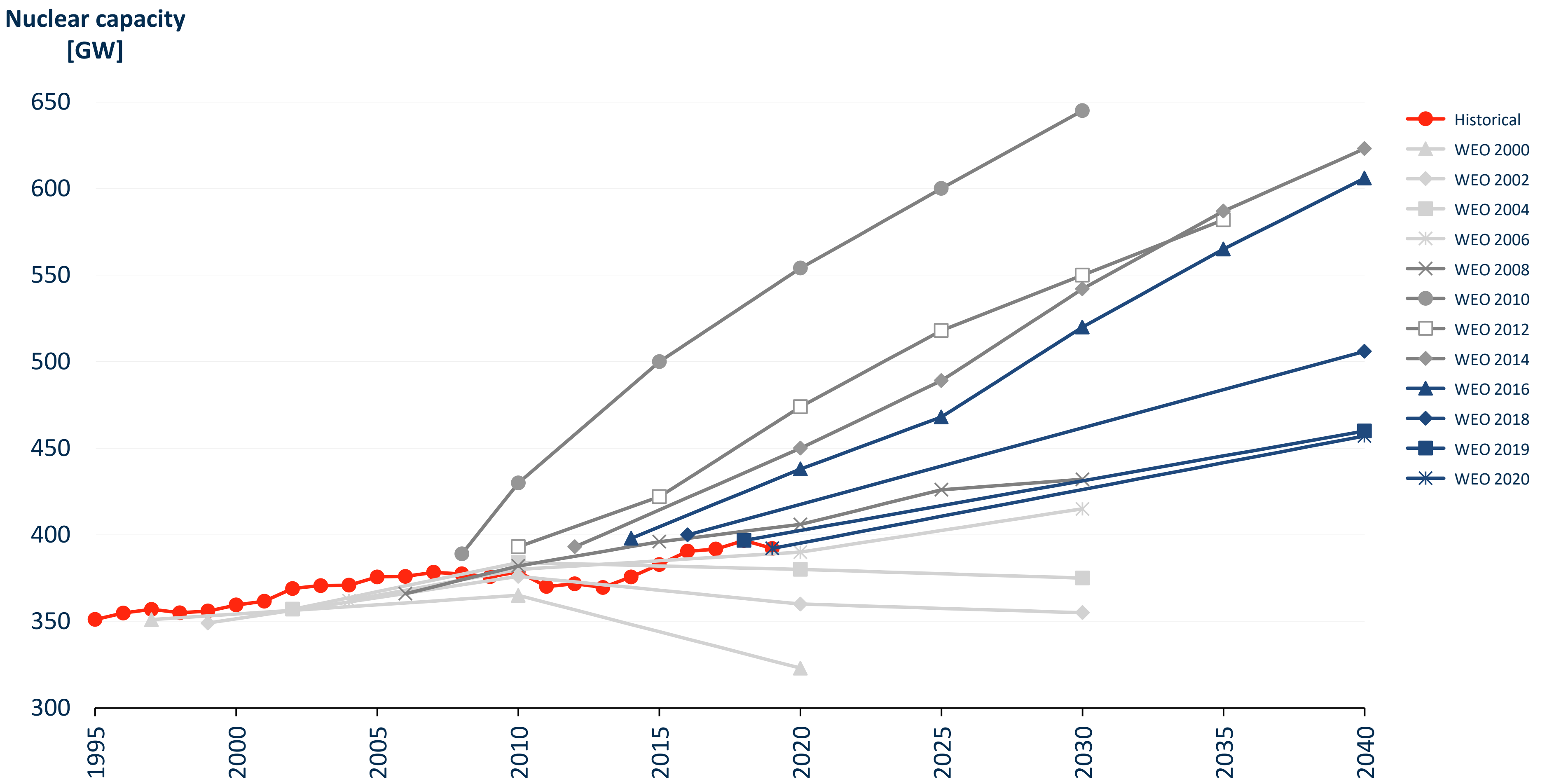
Sources: World Nuclear Association - Reactor data base, CSIR analysis

Nuclear share varies widely with RSA at ~6% (3/4 of countries produce more from nuclear than RSA on a relative basis)



Note: Size of bubble indicates total annual electricity produced from nuclear
Sources: World Nuclear Association - Nuclear generation by country; IEA; https://web3.moeaboe.gov.tw/ECW/english/content/wHandMenuFile.ashx?menu_id=2110; CSIR analysis

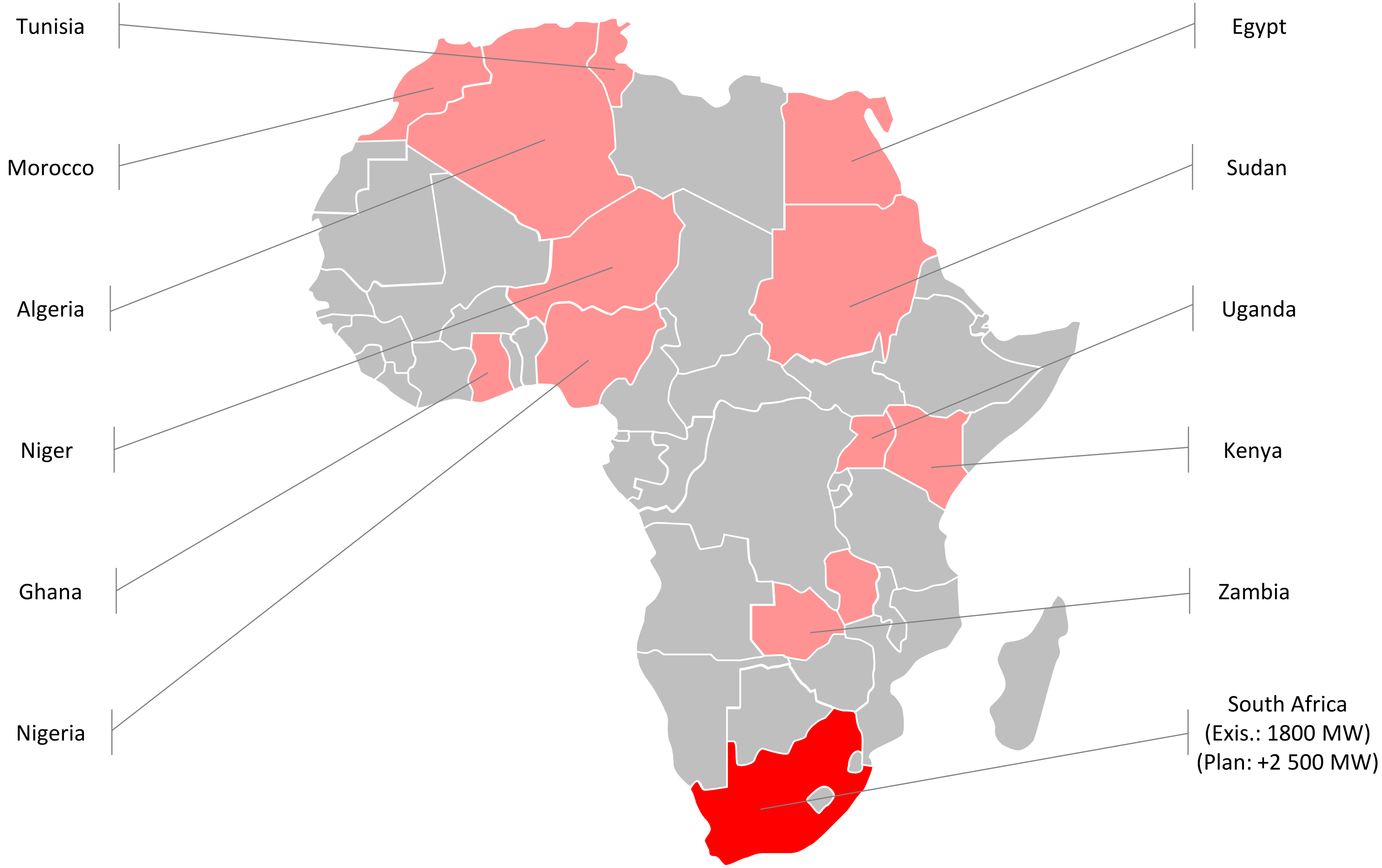
Despite stagnant nuclear capacity for more than two decades - IEA has been forecasting significant growth in nuclear since 2010



Sources: Updated and supplemented from M. Metayer, C. Breyer, and H.-J. Fell, "The projections for the future and quality in the past of the World Energy Outlook for solar PV and other renewable energy technologies," in 31st European Photovoltaic Solar Energy Conference (EUPVSec), 2015; World Nuclear Association - Reactor database; CSIR analysis

No African nation other than RSA currently uses nuclear power whilst 11 are considering ≈30 GW new nuclear power by 2030

African countries with announced nuclear plans and operational reactors (1,800 MW) in South Africa



Sources: https://www.iaea.org/newscenter/news/is-africa-ready-for-nuclear-energy

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2 CSIR comments

- 2.1 Overarching policy guidance (NDP)
- 2.2 IRP 2019 policy adjustment - transparency
- 2.3 Energy planning fundamentals
- 2.4 Delivery timeframe (lead times)
- 2.5 New-build nuclear learning rates (global experience)
- 2.6 Power sector decarbonisation
- 2.7 Fill the gap

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The NDP puts emphasis on energy empowering South Africa

Having an energy sector that promotes economic growth, social equity and environmental sustainability

Of the 15 Chapters in the NDP 2030, four chapters speak directly to energy:

Chapter 3: Economy and Employment
Chapter 4: Economic Infrastructure
Chapter 5: Environmental sustainability and resilience
Chapter 7: SA in the region and the world

Of the 119 actions in the NDP 2030, no explicit mention of nuclear power

However, this may be deemed to be captured more generally in actions 3 and 5 as well as in the main body of the NDP 2030:

3. Remove the most pressing constraints on growth, investment and job creation, including energy generation and distribution, urban planning etc.

5. Increase the benefit to the country of our mineral resources by:

- *Giving clear certainty over property rights (the right to mine)*
- *Increasing rail, water and energy infrastructure*
- *Structure a taxation regime that is fair, equitable and predictable and that recognises the non-renewable nature of mineral resources.*

Sources: https://nationalplanningcommission.wordpress.com/the-national-development-plan/

Future nuclear power is almost always referred to as an option that requires further consideration on various aspects

The level of investment in one procurement programme is unprecedented in South Africa

"The ***timing and/or desirability of nuclear power*** *and a new petrol refinery need to be considered."*

– Chapter 4, NDP 2030 (pp. 65)

"According to the Integrated Resource Plan, more nuclear energy plants will need to be commissioned from 2023/24. Although ***nuclear power does provide a low-carbon base-load alternative, South Africa needs a thorough investigation on the implications of nuclear energy, including its costs, financing options, institutional arrangements, safety, environmental costs and benefits, localisation and employment opportunities, and uranium enrichment and fuel-fabrication possibilities****. While some of these issues were investigated in the IRP, a potential nuclear fleet will involve a* ***level of investment unprecedented in South Africa.*** *An in depth investigation into the financial viability of nuclear energy is thus vital. The National Nuclear Energy Executive Coordinating Committee (NNEECC), chaired by the Deputy-President, will have to make a final "stop-go" decision on South Africa's nuclear future, especially after actual costs and financing options are revealed."*

– Chapter 4, NDP 2030 (pp 172)

"Ensuring the ***nuclear regulator has sufficient capacity*** *for proper regulation of the industry, commensurate with the risks involved."*

- Chapter 5, NDP 2030 (pp. 213)

"Power generation plants contribute about half of South Africa's current greenhouse gas emissions. If the sector follows the proposed carbon emissions scenario of peak, plateau and decline, ***the balance of new capacity will need to come from gas, wind, solar, imported hydroelectricity and possibly a nuclear programme from about 2023.****"*

– Chapter 4, NDP 2030 (pp. 168)

*"****South Africa needs an alternative plan – 'Plan B' – should nuclear energy prove too expensive****, sufficient financing be unavailable or timelines too tight.* ***All possible alternatives need to be explored, including the use of gas,*** *which could provide reliable base-load and mid-merit power generation through combined-cycle gas turbines. Gas turbines can be invested in incrementally to match demand growth. While their operational costs are arguably higher than those of nuclear stations, their unit capital costs are cheaper, they are more easily financed and they are more able to adjust their output to make up the shortfall from variable renewable energy sources. "*

– Chapter 4, NDP 2030 (pp 172)

NATIONAL DEVELOPMENT PLAN 2030

Sources: https://nationalplanningcommission.wordpress.com/the-national-development-plan/

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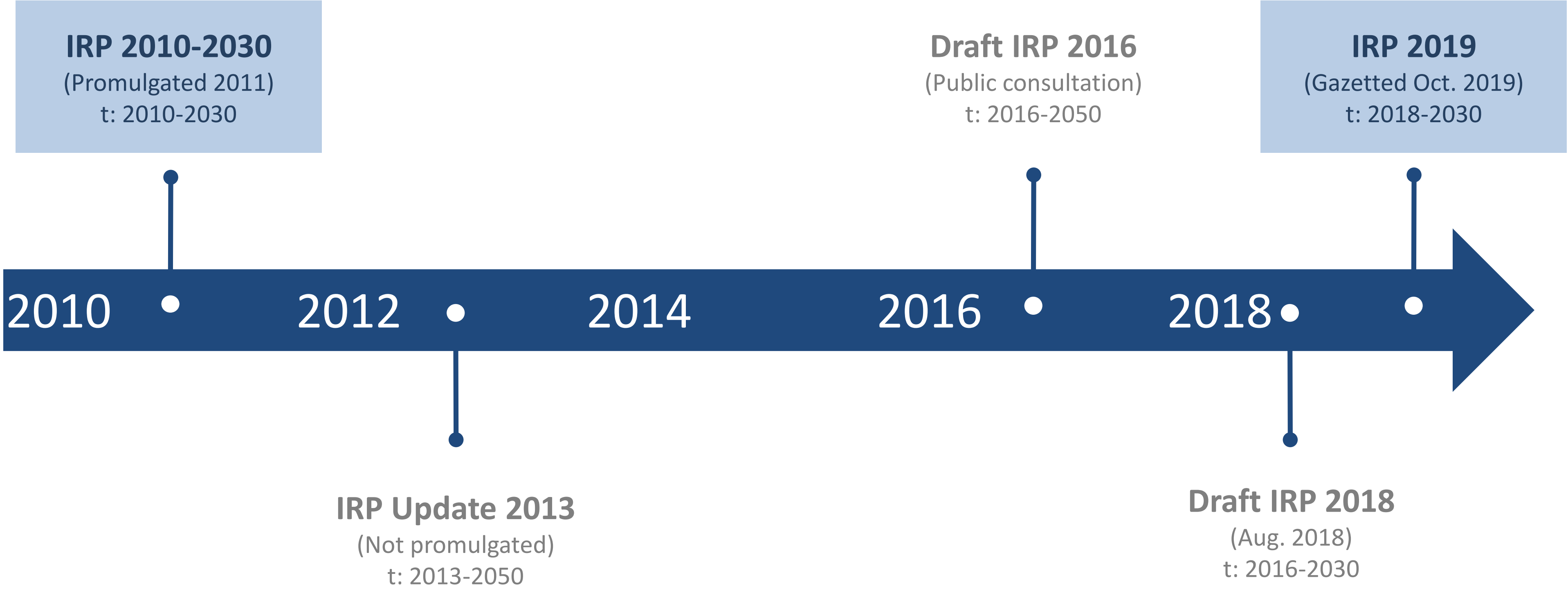
Following a notable gap and resulting outdated IRP 2010-2030 we now have a gazetted IRP 2019



IRP 2010-2030
(Promulgated 2011)
t: 2010-2030

Draft IRP 2016
(Public consultation)
t: 2016-2050

IRP 2019
(Gazetted Oct. 2019)
t: 2018-2030

IRP Update 2013
(Not promulgated)
t: 2013-2050

Draft IRP 2018
(Aug. 2018)
t: 2016-2030

Sources: CSIR Energy Centre analysis

Focus areas for nuclear capacity have shifted as iterations of the IRP have been developed to end with the IRP 2019

	IRP 2010-2030 (Promulgated 2011) t: 2010-2030	**IRP Update 2013** (Not promulgated) t: 2013-2050	**Draft IRP 2016** (Public consultation) t: 2016-2050	**Draft IRP 2018** (Aug. 2018) t: 2016-2030	**IRP 2019** (Gazetted Oct. 2019) t: 2018-2030
Expected energy mix	Scenario-based; **Big**: Coal, nuclear **Medium**: VRE, gas **Small**: imports (hydro)	Decision trees; **Big**: Coal, nuclear **Medium**: VRE, gas, CSP **Small**: Imports (hydro, coal), others	Scenario-based **Big**: Coal **Medium**: Nuclear, Gas, VRE **Small**: Imports (hydro), others	Scenario-based **Big**: Coal, VRE **Medium**: Gas **Small**: Nuclear, DG/EG imports (hydro), others	Scenario-based; **Big**: Coal, VRE **Medium**: Gas, DG/EG **Small**: Nuclear, Imports (hydro), Storage, others
Demand	454 TWh (2030)	409 TWh (2030) 522 TWh (2050)	350 TWh (2030) 527 TWh (2050)	313 TWh (2030) 392 TWh (2050)	307 TWh (2030) 382 TWh (2050)
Emissions (CO$_2$-eq)	Peak only, EM1 (275 Mt from 2025)	PPD (Moderate)	PPD (Moderate)	PPD (Moderate)	PPD (Moderate)
Nuclear options	**Commit to 9.6 GW**	**Delay option (2025-2035)**	**No new nuclear pre-2030; 1st units (2037)**	**No new nuclear pre-2030; (pace/scale/affordability) 1st units (2036-2037)**	**No new nuclear pre-2030; (pace/scale/affordability) 2.5 GW (≥2030)**
Import options	Coal, hydro/PS, gas (fuel)	Coal, hydro/PS, gas (fuel)	Hydro, gas (fuel)	Hydro, gas (fuel)	Hydro, gas (fuel)

[1] Performance (energy production & cost level/certainty); [2] For each technology option; EM1 – Emissions Limit 1 (whilst other scenarios EM2/EM3/CT (carbon-tax) with increasingly stricter CO2 emissions limits were explored non were adopted); PPD - Peak-plateau-decline; EAF – Energy Availability Factor; Sources: LC – least-cost; MES – minimum emissions standards; LT – long-term; ST – short-term; Tx – transmission networks; Dx – distribution networks; DG – distributed generation; EG – embedded generation;
Sources: DoE; CSIR Energy Centre analysis

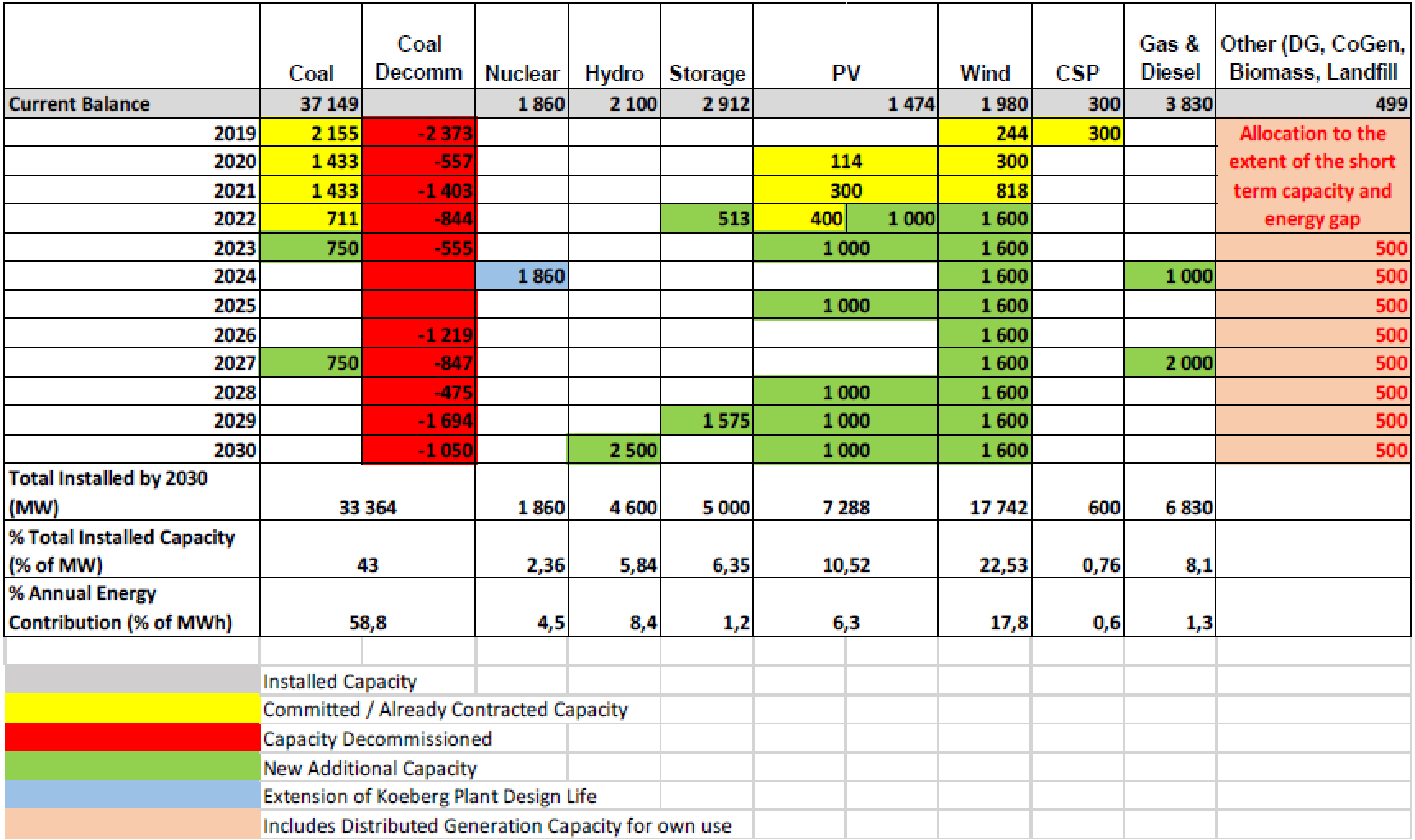
Other key considerations and focus areas have shifted in some dimensions but remained largely unchanged in others

	IRP 2010-2030 (Promulgated 2011) t: 2010-2030	**IRP Update 2013** (Not promulgated) t: 2013-2050	**Draft IRP 2016** (Public consultation) t: 2016-2050	**Draft IRP 2018** (Aug. 2018) t: 2016-2030	**IRP 2019** (Gazetted Oct. 2019) t: 2018-2030
Coal fleet performance	>85% EAF	~80% EAF; LifeEx (10 yrs)	72-80% EAF; MES delay (2020/25)	72-80%; MES delay (2020/25)	67-76%; MES delay (2020/25)
New-build coal	1st units forced earlier 1.0 GW (2014) 6.3 GW (2030)	Displaced by LifeEx (10 yrs) 1.0 GW (2025) <3.0 GW by 2030	1st 1.5 GW (2028) 4.3 GW (2030)	0.5 GW (2023) 1.0 GW (2030)	0.75 GW (2023) 1.5 GW (2030)
New technologies[1]	Uncertain VRE cost/perf. CSP (marginal); Annual constr.: 0.3-1.0 GW/yr (PV) 1.6 GW/yr (wind)	Uncertain VRE cost/perf. CSP (notable); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Battery/CAES (option); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Batteries (option); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Batteries (notable); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)
Security of supply	LT (reserve margin); ST (hourly dispatch); Immediate ST need; Research: Fuel supply, base-load, backup, high VRE	LT (reserve margin); ST (hourly dispatch); Research: Fuel supply, base-load, backup, high VRE	Assumed similar Research: None highlighted	Assumed similar Research: Gas supply, high VRE, just transition	Assumed similar; Immediate ST need; Research: Gas supply, high VRE, just transition
Network requirements2	Not considered; Tx/Dx research need	Not a concern (Tx power corridors) Dx networks research need (DG/EG)	None	Explicit Tx needs costed (per tech.)	Explicit Tx needs costed (per tech.)

[1] Performance (energy production & cost level/certainty); [2] For each technology option; EM1 – Emissions Limit 1 (whilst other scenarios EM2/EM3/CT (carbon-tax) with increasingly stricter CO2 emissions limits were explored non were adopted); PPD - Peak-plateau-decline; EAF – Energy Availability Factor; Sources: LC – least-cost; MES – minimum emissions standards; LT – long-term; ST – short-term; Tx – transmission networks; Dx – distribution networks; DG – distributed generation; EG – embedded generation;
Sources: DoE; CSIR Energy Centre analysis

Touching lives through innovation

Gazetted IRP 2019 does not include new nuclear capacity beyond the life extension of Koeberg



	Coal	Coal Decomm	Nuclear	Hydro	Storage	PV	Wind	CSP	Gas & Diesel	Other (DG, CoGen, Biomass, Landfill
Current Balance	37 149		1 860	2 100	2 912	1 474	1 980	300	3 830	499
2019	2 155	-2 373					244	300		Allocation to the extent of the short term capacity and energy gap
2020	1 433	-557				114	300			
2021	1 433	-1 403				300	818			
2022	711	-844			513	400 1 000	1 600			
2023	750	-555				1 000	1 600			500
2024			1 860				1 600		1 000	500
2025						1 000	1 600			500
2026		-1 219					1 600			500
2027	750	-847					1 600		2 000	500
2028		-475				1 000	1 600			500
2029		-1 694			1 575	1 000	1 600			500
2030		-1 050		2 500		1 000	1 600			500
Total Installed by 2030 (MW)	33 364		1 860	4 600	5 000	7 288	17 742	600	6 830	
% Total Installed Capacity (% of MW)	43		2,36	5,84	6,35	10,52	22,53	0,76	8,1	
% Annual Energy Contribution (% of MWh)	58,8		4,5	8,4	1,2	6,3	17,8	0,6	1,3	

⬜ Installed Capacity

🟨 Committed / Already Contracted Capacity

🟥 Capacity Decommissioned

🟩 New Additional Capacity

🟦 Extension of Koeberg Plant Design Life

🟧 Includes Distributed Generation Capacity for own use

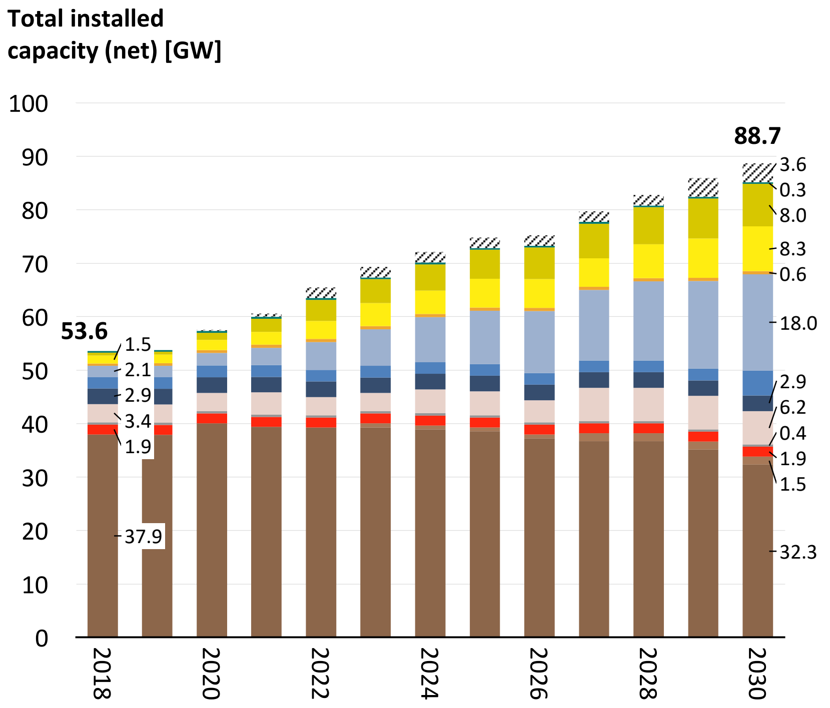
Sources: DMRE IRP 2019

IRP 2019 indicating an increasingly diversified energy mix away from coal predominantly towards solar PV, wind & gas

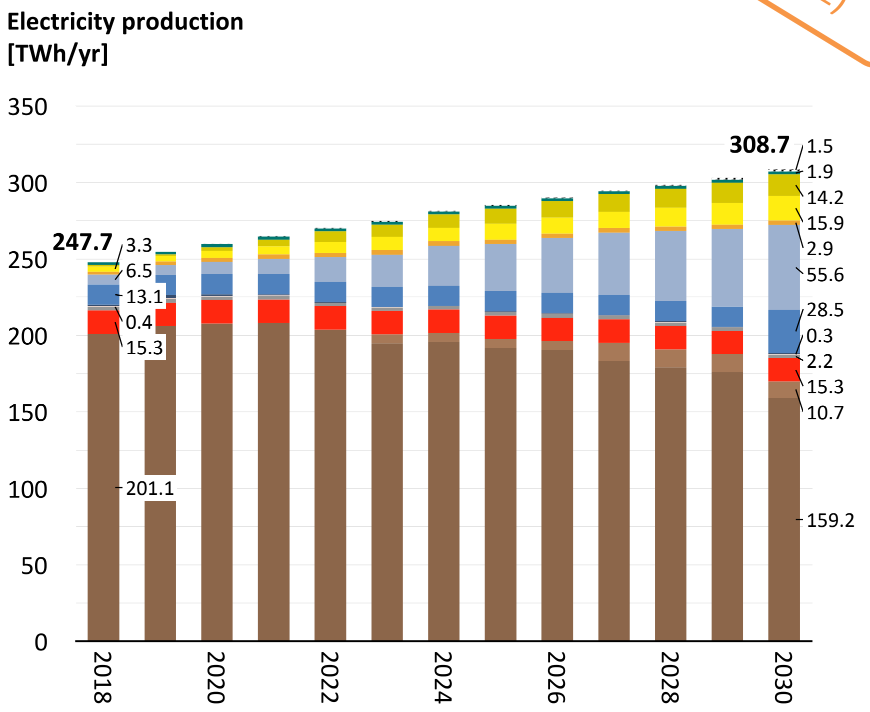
Installed capacity and electricity supplied from 2018 to 2030

IRP 2019 (DMRE)

Installed capacity



Energy mix



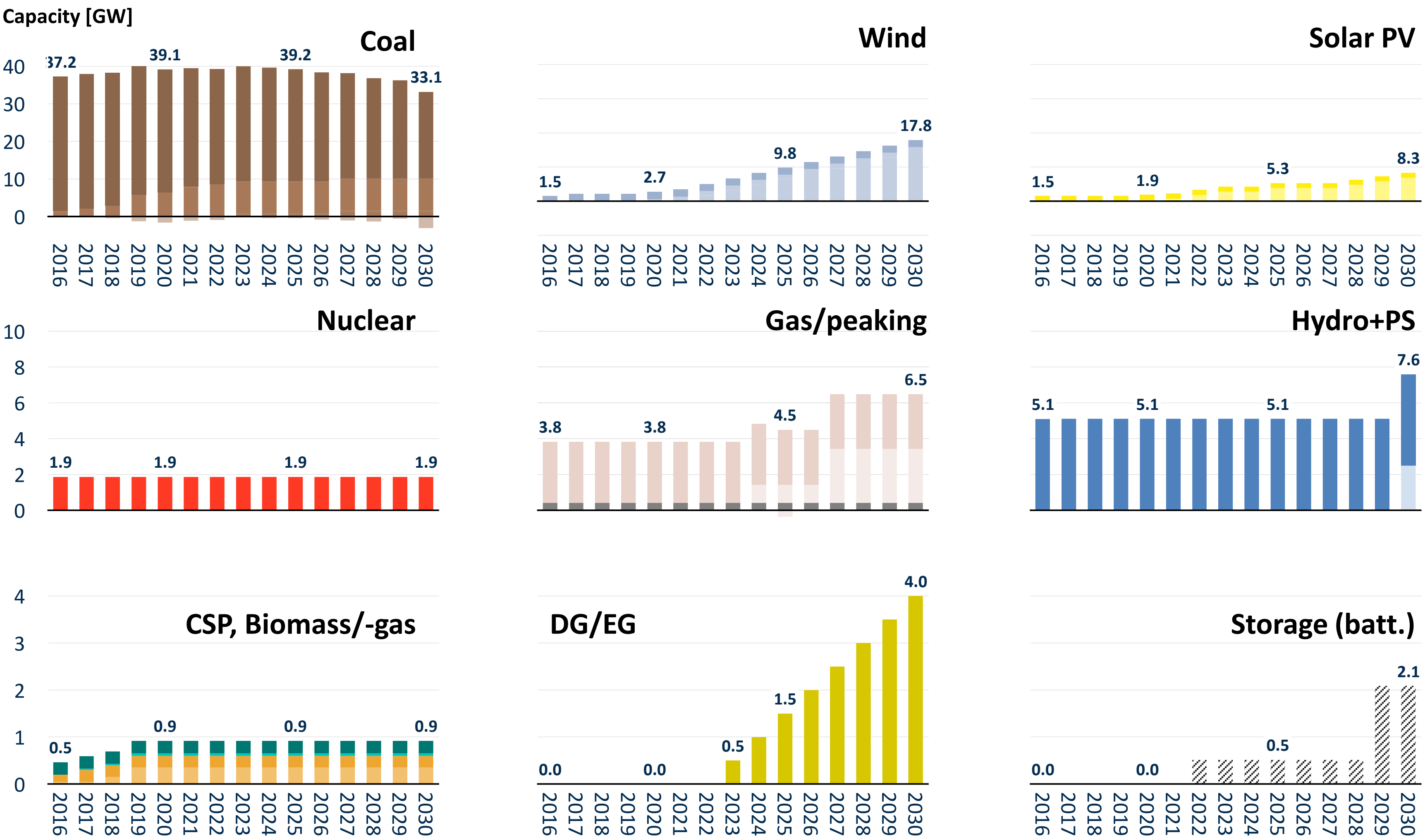
▨ Other Storage ■ DG ■ CSP ■ Hydro ■ Peaking ■ Nuclear (new) ■ Coal (New)
■ Biomass/-gas ■ Solar PV ■ Wind ■ PS ■ Gas ■ Nuclear ■ Coal

First new-builds:

Wind (2022)	*1.6 GW*
PV (2022)	*1.0 GW*
Storage (2022)	*0.5 GW*
Coal (2023)	*0.75 GW*
Gas (2024)	*1.0 GW*

DG = Distributed Generation; PS = Pumped Storage
NOTE: Energy share is a best estimate based on available data)
Sources: IRP 2019. CSIR Energy Centre analysis

Increasingly diversified energy mix shifting away from coal and predominantly towards solar PV, wind, DG/EG and gas



NOTE: Dark shade indicates existing capacity whilst light shade indicates under construction/committed and new-build capacity (negative values indicate decommissioning);
DSR (Demand Side Response) not included

Sources: IRP 2019. CSIR Energy Centre analysis

Decisions in IRP 2019 are far reaching but sometimes lack evidence-base or are contradictory to established evidence-base

Decision 1

Undertake a power purchase programme to assist with the acquisition of capacity needed to supplement Eskom's declining plant performance and to reduce the extensive utilisation of diesel peaking generators in the immediate to medium term. Lead-time is therefore key.

Decision 2

Koeberg power plant design life must be extended by another 20 years by undertaking the necessary technical and regulatory work.

Decision 3

Support Eskom to comply with MES over time, taking into account the energy security imperative and the risk of adverse economic impact.

Decision 4

For coherent policy development in support of the development of a just transition plan, consolidate into a single team the various initiatives being undertaken on just transition.

Decision 5

Retain the current annual build limits on renewables (wind and PV) pending the finalisation of a just transition plan.

Decision 6

South Africa should not sterilise the development of its coal resources for purposes of power generation, instead all new coal power projects must be based on high efficiency, low emission technologies and other cleaner coal technologies.

Decision 7

To support the development of gas infrastructure and in addition to the new gas to power capacity in Table 5, convert existing diesel-fired power plants (Peakers) to gas.

Decision 8

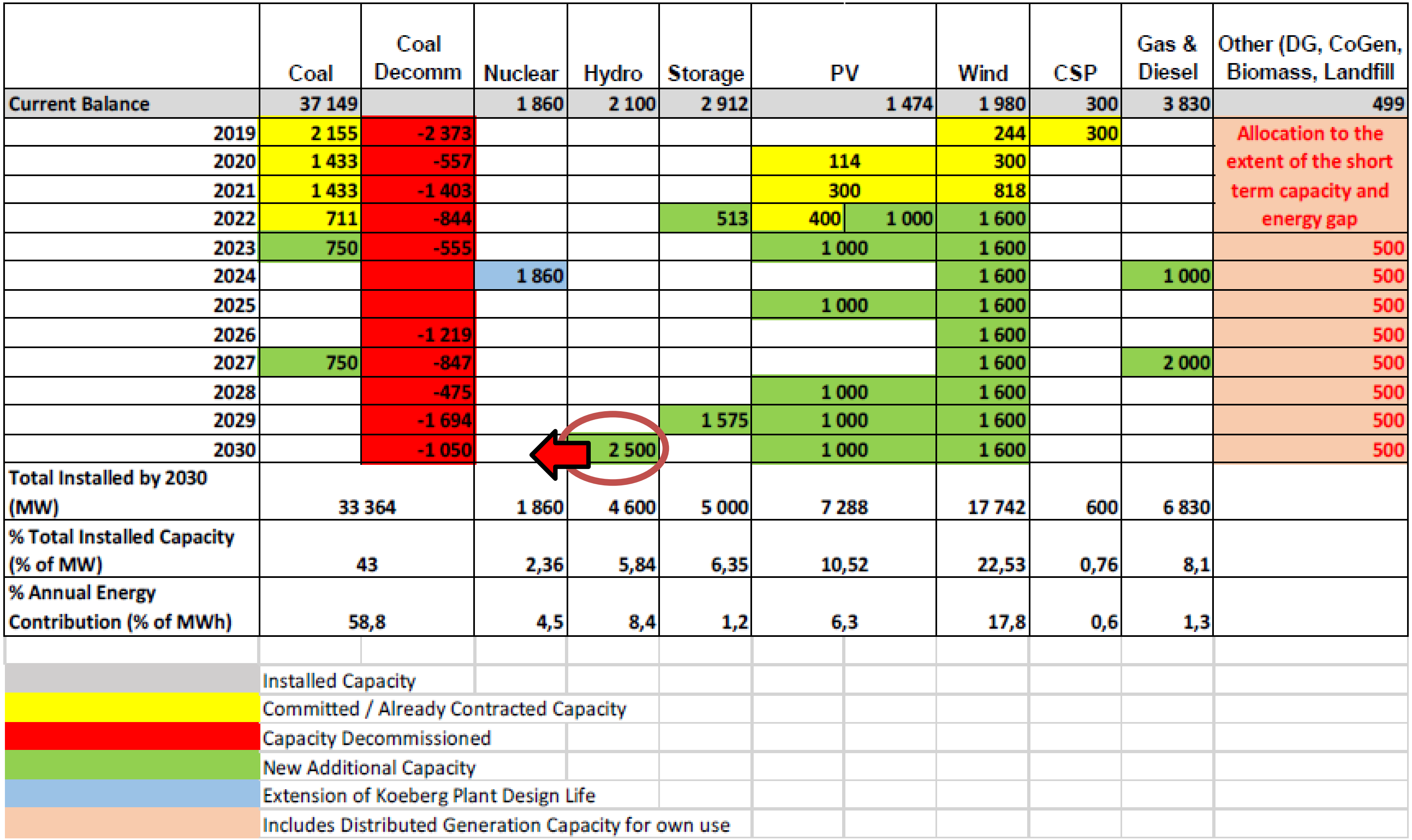
Commence preparations for a nuclear build programme to the extent of 2 500 MW at a pace and scale that the country can afford because it is a no-regret option in the long term.

Decision 9

In support of regional electricity interconnection including hydropower and gas, South Africa will participate in strategic power projects that enable the development of cross- border infrastructure needed for the regional energy trading.

NOTE: Decisions in grey lack evidence-base or are contradictory to the available evidence-base; Sources: IRP 2019; CSIR Energy Centre analysis

Although not stated in IRP 2019, the CSIR assumes the 2500 MW nuclear capacity was chosen by the DMRE to replace 2500 MW of hydro in the Gazetted IRP 2019



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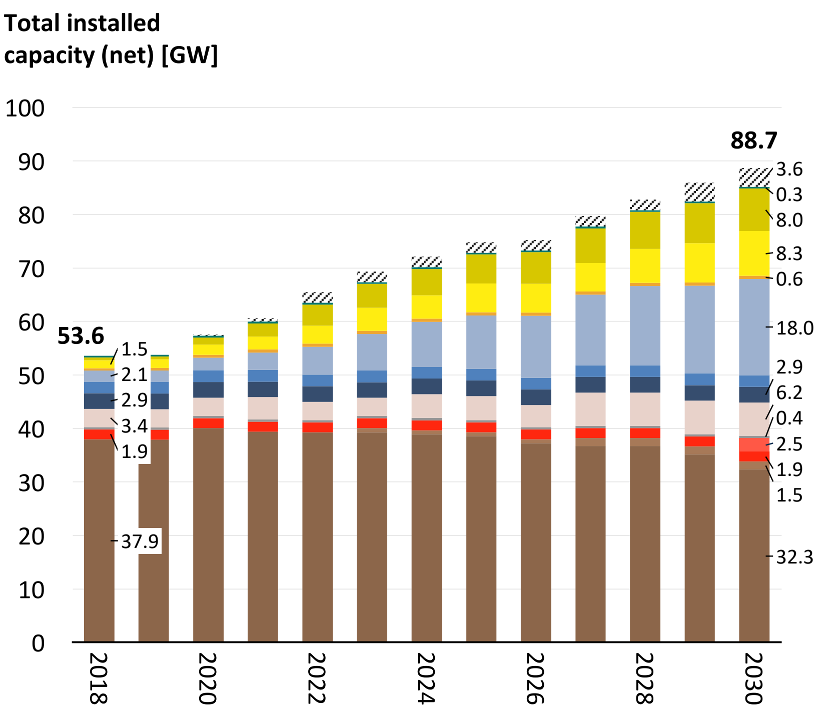
▨	Installed Capacity
🟨	Committed / Already Contracted Capacity
🟥	Capacity Decommissioned
🟩	New Additional Capacity
🟦	Extension of Koeberg Plant Design Life
🟧	Includes Distributed Generation Capacity for own use

Sources: DMRE IRP 2019

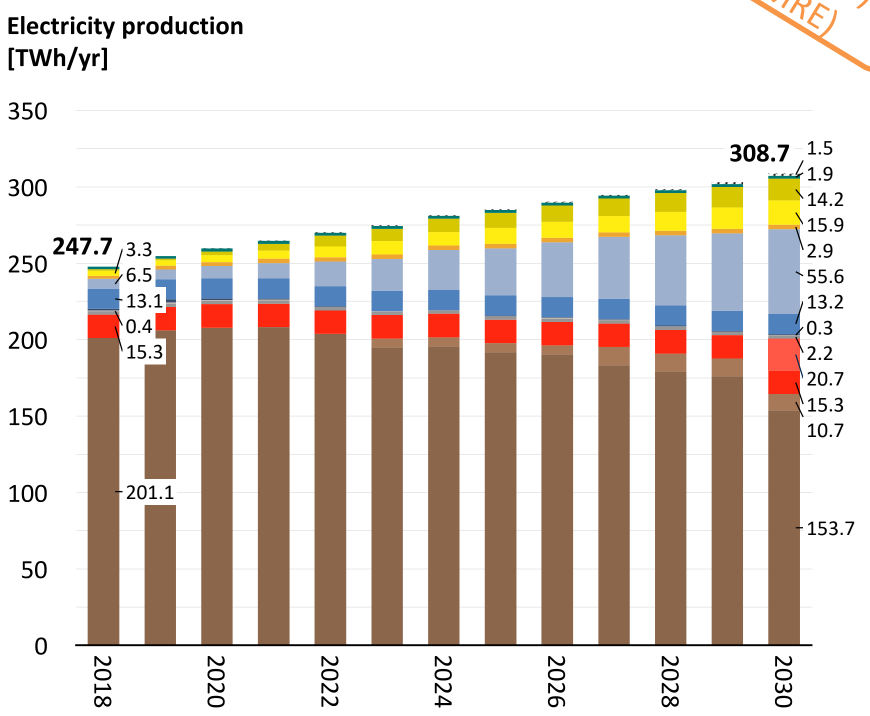
IRP 2019 Decision 8 displaces imported hydro with nuclear (2500 MW) – nuclear contribution doubles (~12% vs ~6% today)

IRP 2019 (nuc. adj.) (DMRE)

Installed capacity



Energy mix



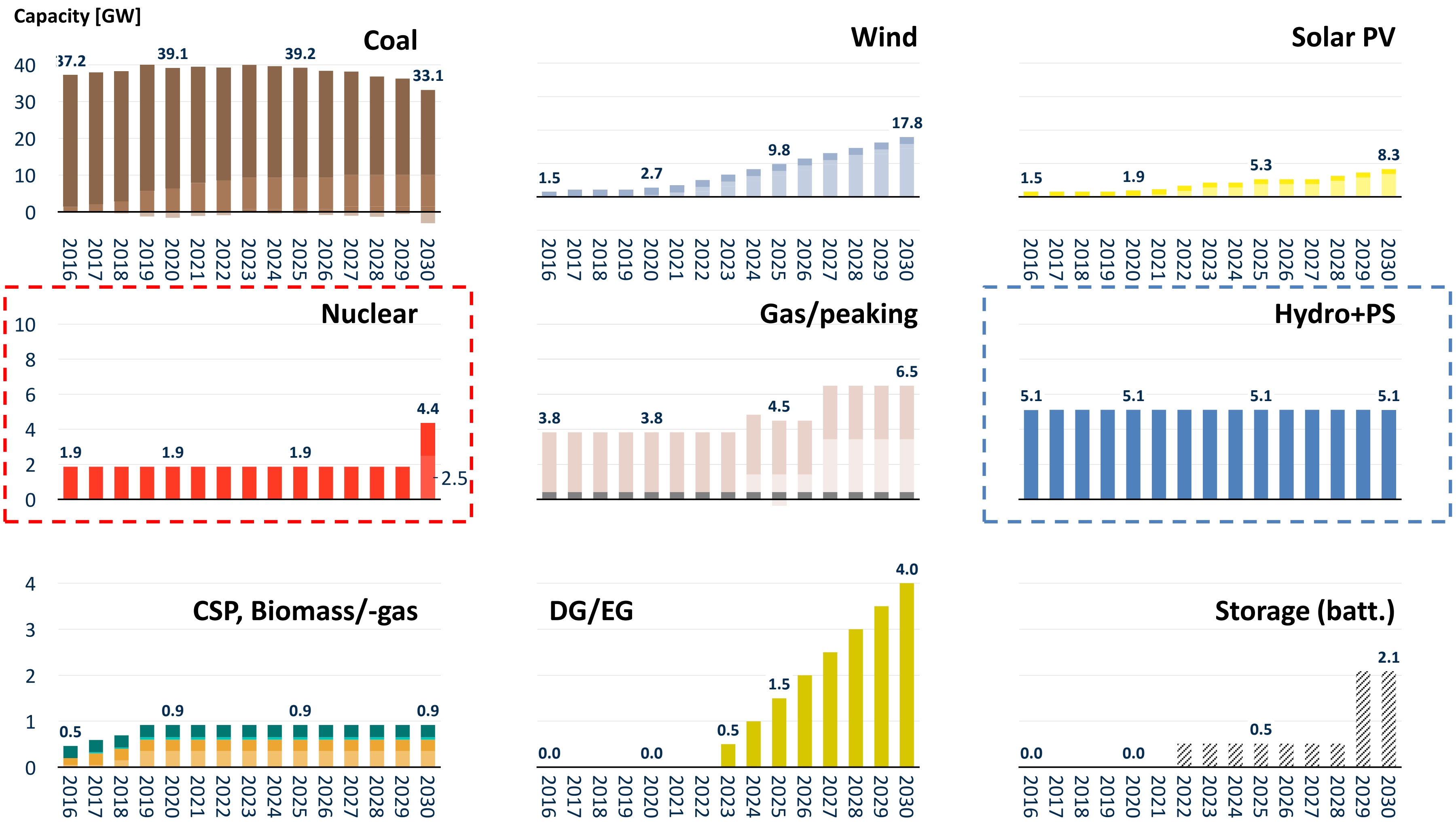
▨ Other Storage
🟨 DG
🟧 CSP
🟦 Hydro
⬜ Peaking
🟥 Nuclear (new)
🟫 Coal (New)
🟩 Biomass/-gas
🟨 Solar PV
🟦 Wind
⬛ PS
⬜ Gas
🟥 Nuclear
🟫 Coal

First new-builds:

Wind (2022)	*1.6 GW*
PV (2022)	*1.0 GW*
Storage (2022)	*0.5 GW*
Coal (2023)	*0.75 GW*
Gas (2024)	*1.0 GW*

DG = Distributed Generation; PS = Pumped Storage
NOTE: Energy share is a best estimate based on available data)
Sources: IRP 2019. CSIR Energy Centre analysis

Displacement of imported hydro (Inga) with 2 500 MW of nuclear capacity is what is proposed as ‘least-regret’



NOTE: Dark shade indicates existing capacity whilst light shade indicates under construction/committed and new-build capacity (negative values indicate decommissioning); DSR (Demand Side Response) not included

Sources: IRP 2019. CSIR Energy Centre analysis

Agenda

It is not consistent with energy planning best practices to assume base-demand must be met with base-supply

Reference to South Africa’s coal fleet decommissioning and therefore nuclear capacity being required as replacement base-supply capacity for energy security is inaccurate and sub-optimal

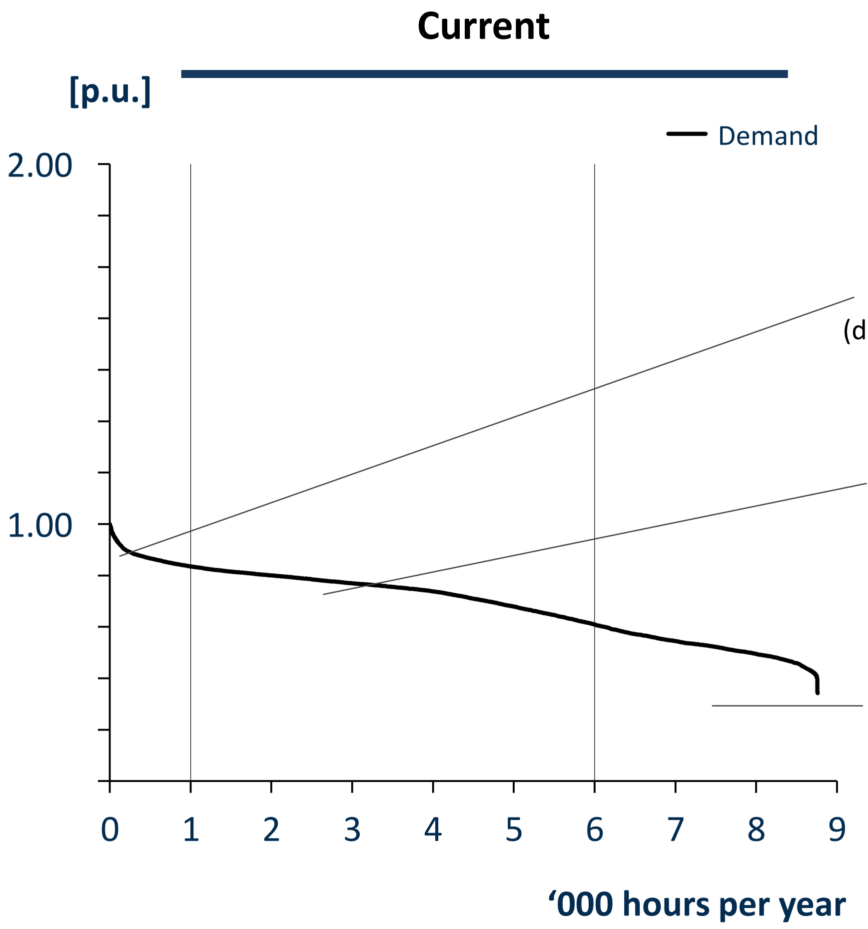
This has been demonstrated in various iterations of the IRP for South Africa (as published by DMRE) as well as by others (including CSIR) – nuclear is not part of least-cost and would require policy adjustment

The IRP for South Africa addresses these concerns consistently across all scenarios by ensuring minimum system adequacy criteria (via adequate reserves).

The IRP considers all supply options (existing, under construction, decommissioning, new-build) relative to demand expectations over time and optimises via least-cost suite of supply options

Demonstration of these principles outlined here to assist with this consistent understanding

Classical energy planning approaches consider a LDC (descending ordered demand profile)



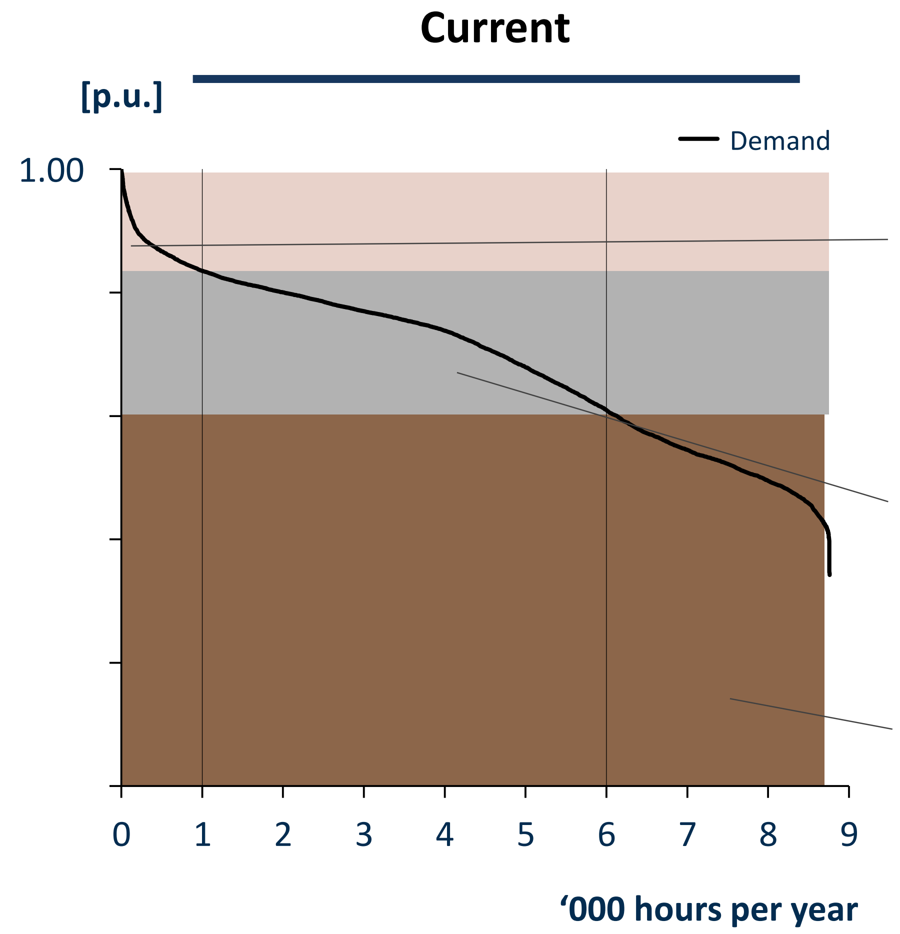
These are "peak" demand requirements (demand that only exists for very few hours of the year, typically <1000 hrs/yr)

These are "mid-merit" demand requirements (varying demand levels for most hours of the year, typical range of 1000-6000 hrs/yr)

These are "base" demand requirements (consistent demand levels required to be met for almost all hours of the year, typically >6000 hrs/yr)

LDC – Load Duration Curve

Typically deploy 1:1 classical supply technologies to meet base, mid-merit and peak demand requirements - VRE changes this…

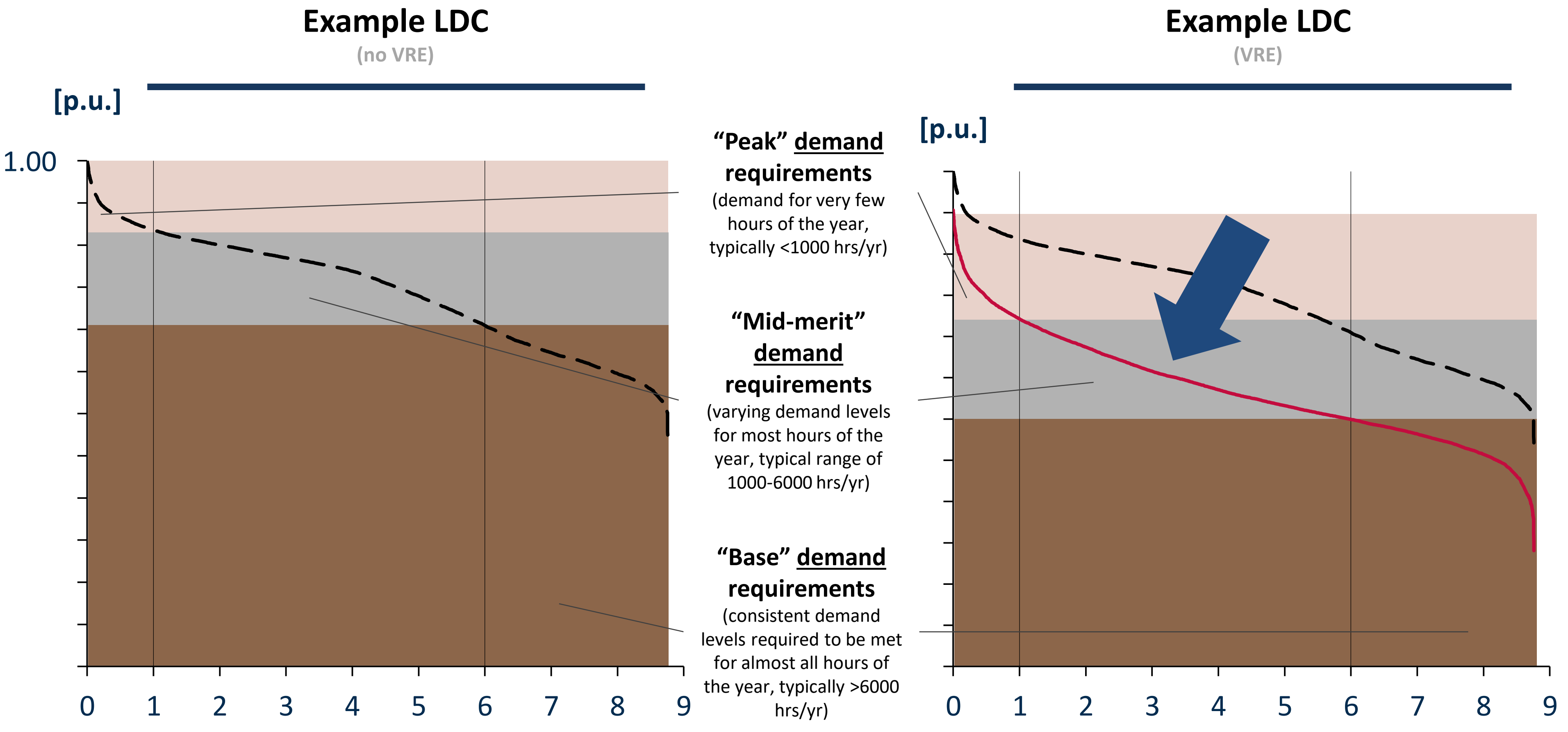


"Peak" demand requirements
(demand for very few hours of the year, typically <1000 hrs/yr)

"Mid-merit" demand requirements
(varying demand levels for most hours of the year, typical range of 1000-6000 hrs/yr)

"Base" demand requirements
(consistent demand levels required to be met for almost all hours of the year, typically >6000 hrs/yr)

Classical energy planning approaches consider a LDC (descending ordered demand profile)



"Peak" demand requirements (demand for very few hours of the year, typically <1000 hrs/yr)

"Mid-merit" demand requirements (varying demand levels for most hours of the year, typical range of 1000-6000 hrs/yr)

"Base" demand requirements (consistent demand levels required to be met for almost all hours of the year, typically >6000 hrs/yr)

'000 hours per year

'000 hours per year

Solar PV	= 0.43 p.u. (capacity);
Wind	= 0.43 p.u. (capacity)
VRE (energy)	= 0.30 p.u.

▬ ▬ Demand

▬ Residual Demand = Demand – VRE[1]

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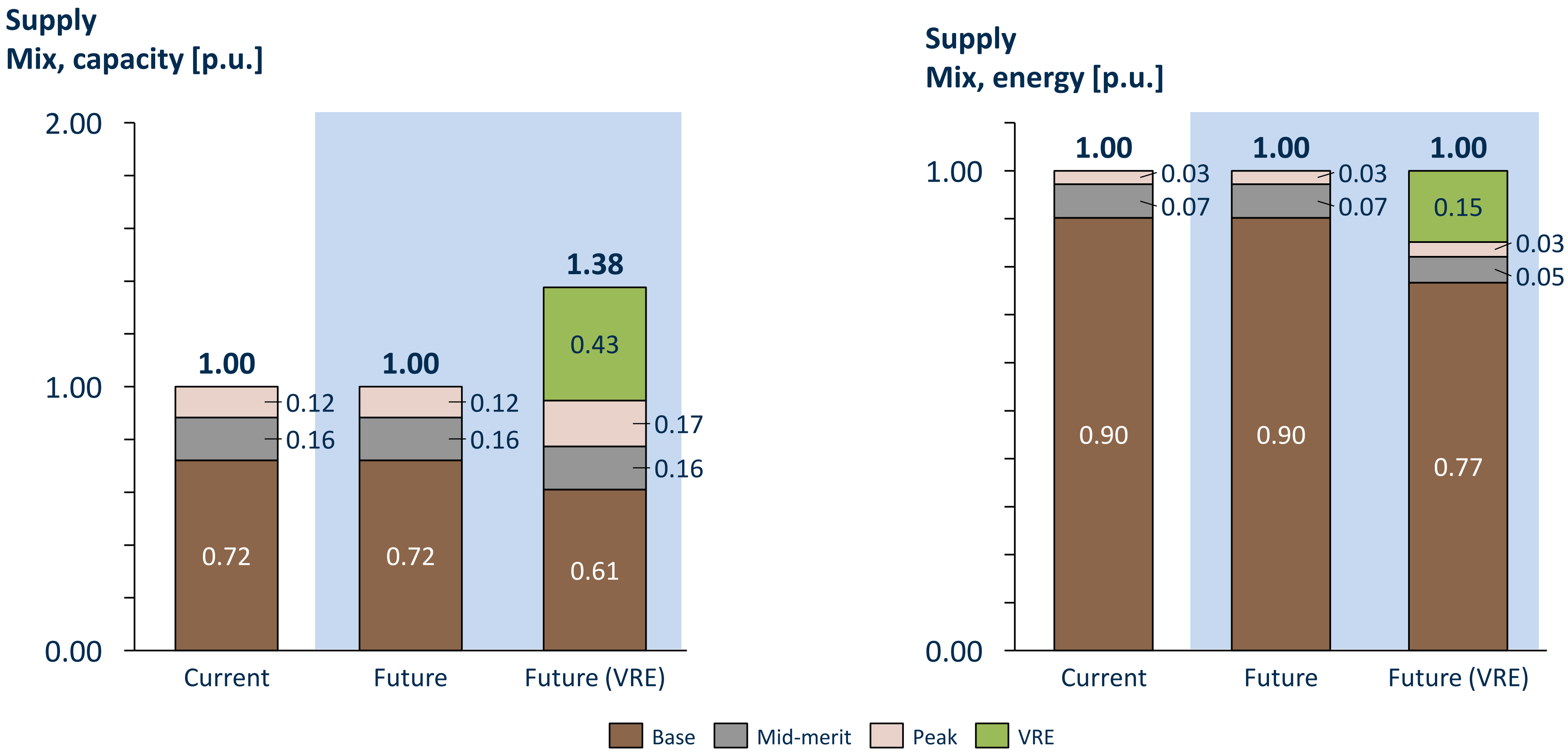
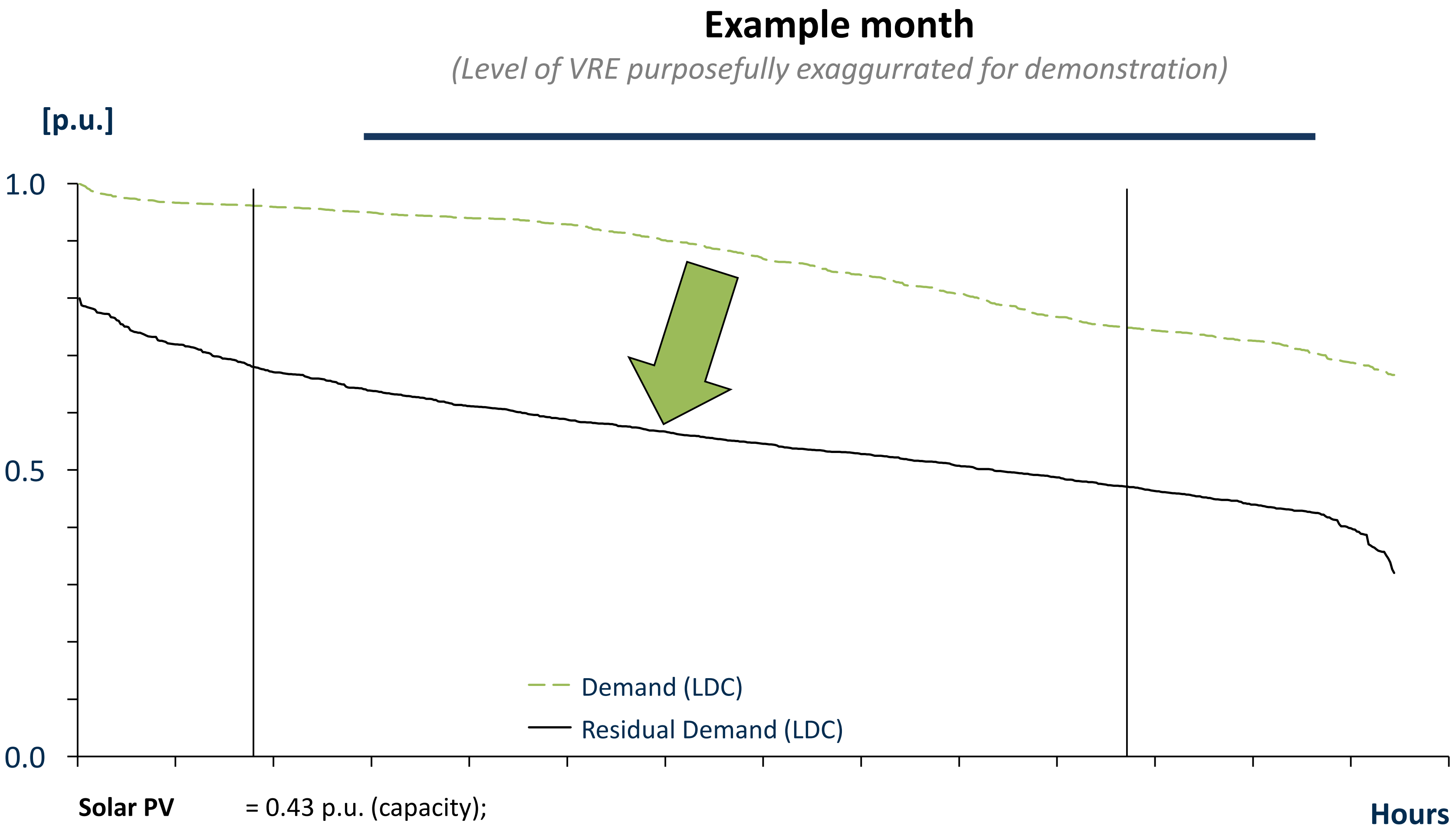
[1] VRE – Variable Renewable Energy

A very different supply mix if VRE is least-cost – less base-supply, more mid-merit and much more peaking



Peaking/mid-merit volumes likely underestimated as LDC model does not account for temporal variability of VRE – increased flexibility requirements imposed by VRE (addressed next)

When VRE becomes part of least-cost - high VRE penetration requires different demand model.. the when, not just how much

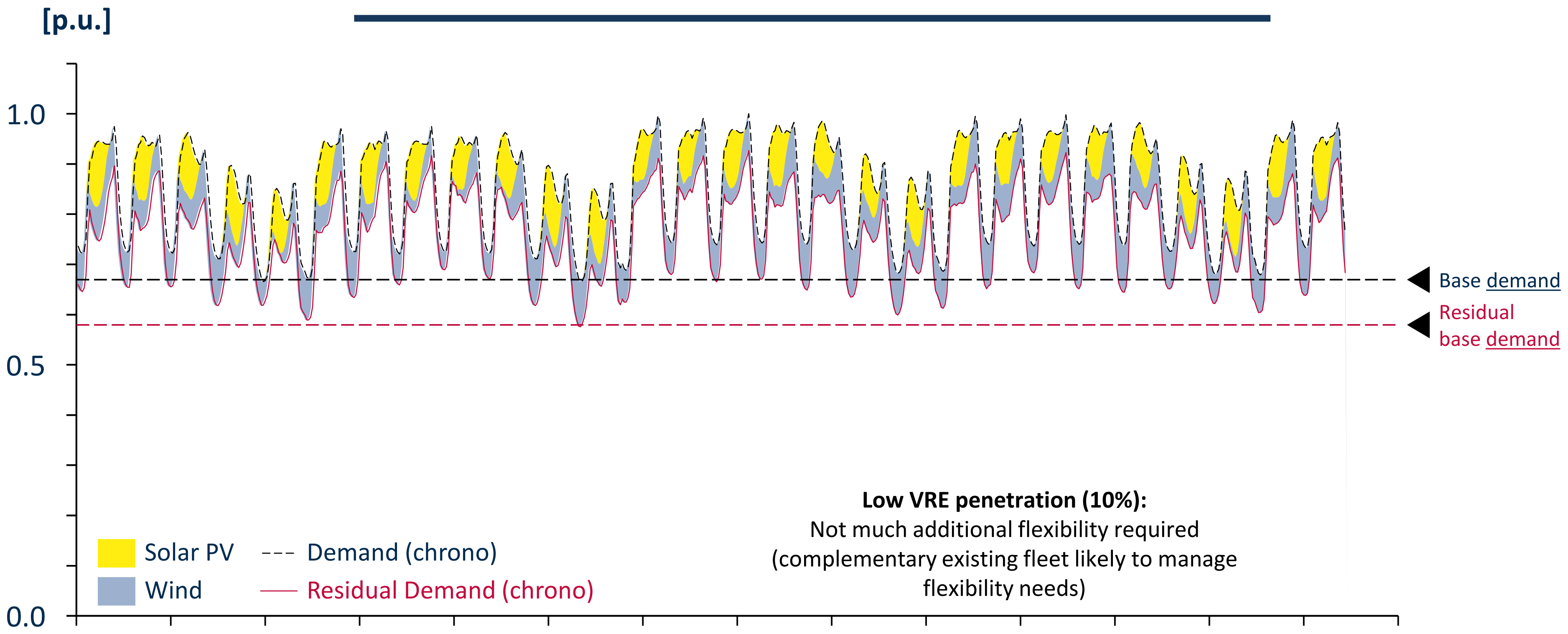


Solar PV = 0.43 p.u. (capacity);
Wind = 0.43 p.u. (capacity)
VRE (energy) = 0.30 p.u.

Model fidelity improved via chronological models – energy mix impacted & energy security more accurately represented

Example month

(likely by early 2020s in RSA)



Low VRE penetration (10%):
Not much additional flexibility required (complementary existing fleet likely to manage flexibility needs)

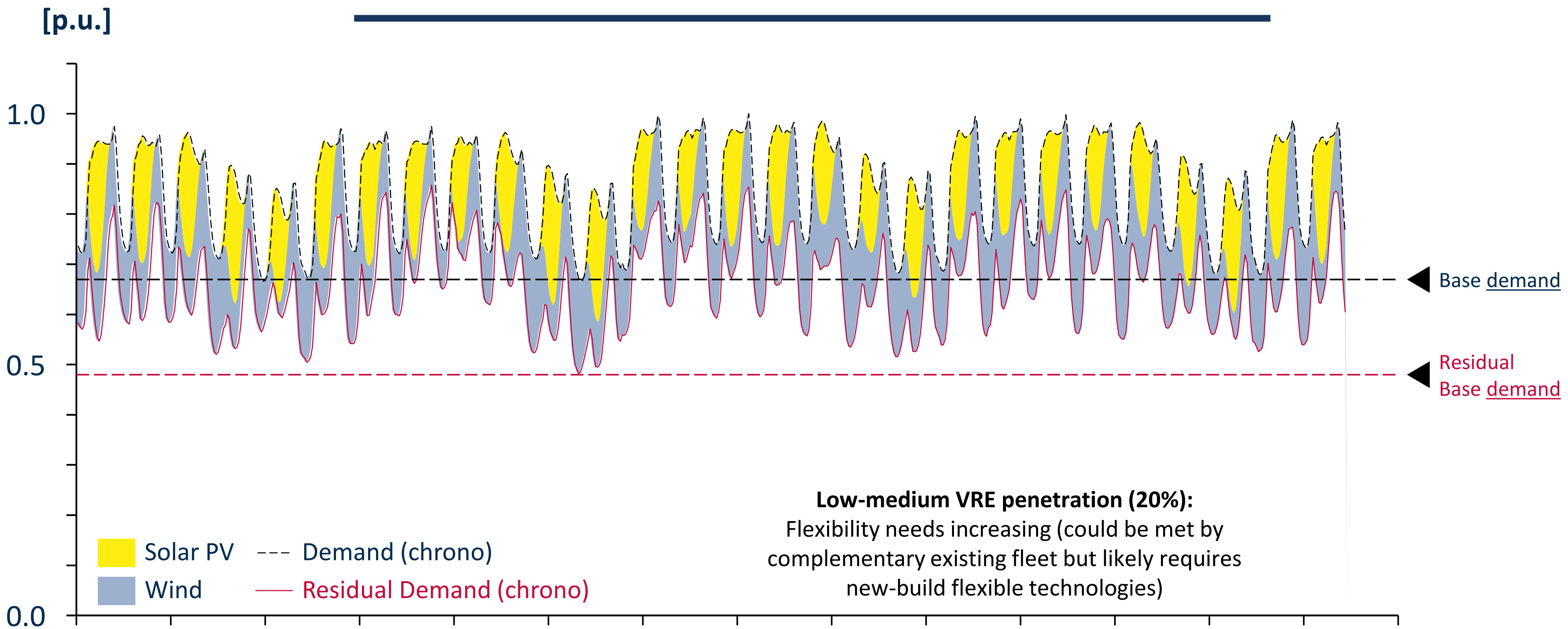
Solar PV = 0.14 p.u. (capacity);
Wind = 0.14 p.u. (capacity)
VRE (energy) = 0.10 p.u.

	System	***Residual***
"Base" demand	◕	◕
"Mid-merit" demand	◑	◑
"Peaking" demand	◔	◔

Demonstrating an increasing need for more flexible capacity and less base-supply capacity

Example month

(Likely by mid-2020s to late 2020s in RSA)



Low-medium VRE penetration (20%):
Flexibility needs increasing (could be met by complementary existing fleet but likely requires new-build flexible technologies)

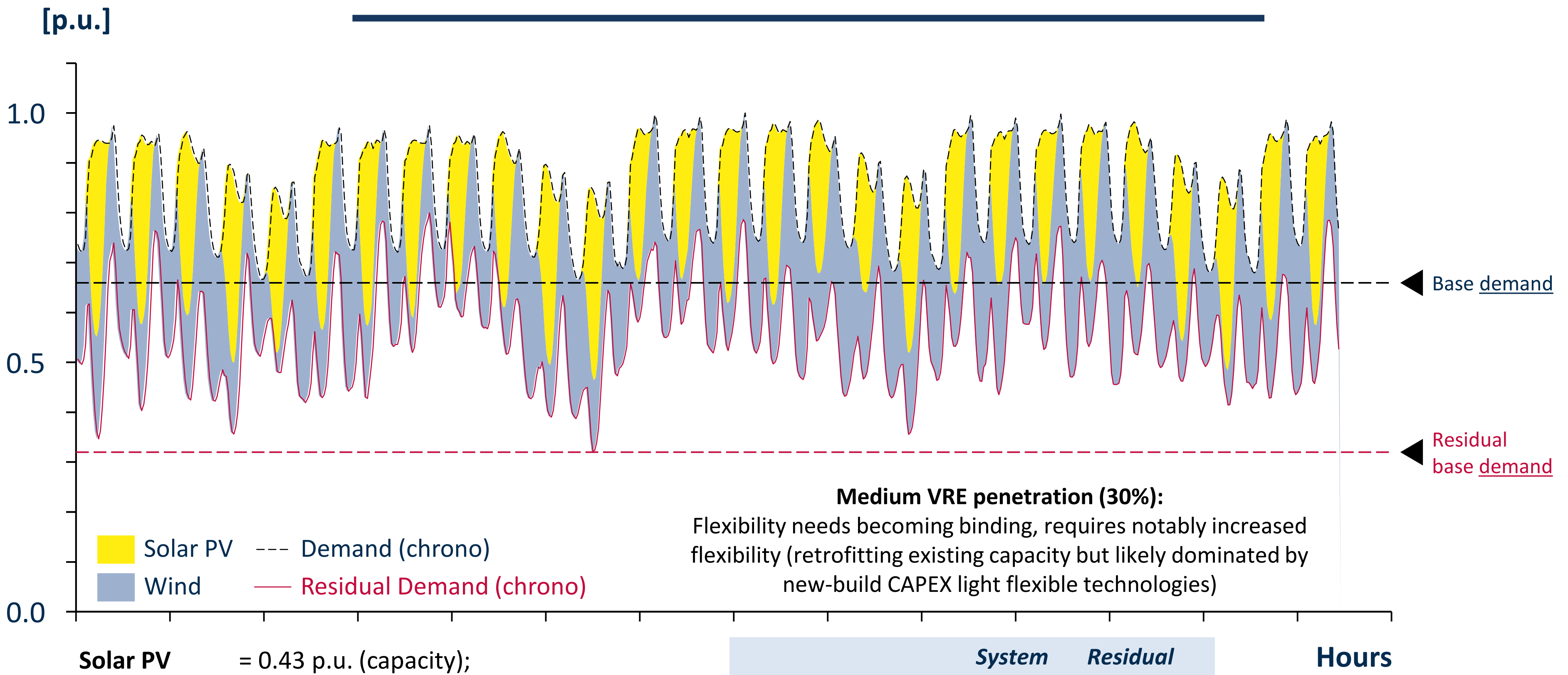
Solar PV = 0.29 p.u. (capacity);
Wind = 0.29 p.u. (capacity)
VRE (energy) = 0.20 p.u.

	System	***Residual***
"Base" demand	◕	◑
"Mid-merit" demand	◑	◑
"Peaking" demand	◔	◑

Increasing deployment of VRE (as in IRP) incompatible with further base-supply (regardless of technology choice)

Example month

(Likely by 2030 in RSA)



Medium VRE penetration (30%):
Flexibility needs becoming binding, requires notably increased flexibility (retrofitting existing capacity but likely dominated by new-build CAPEX light flexible technologies)

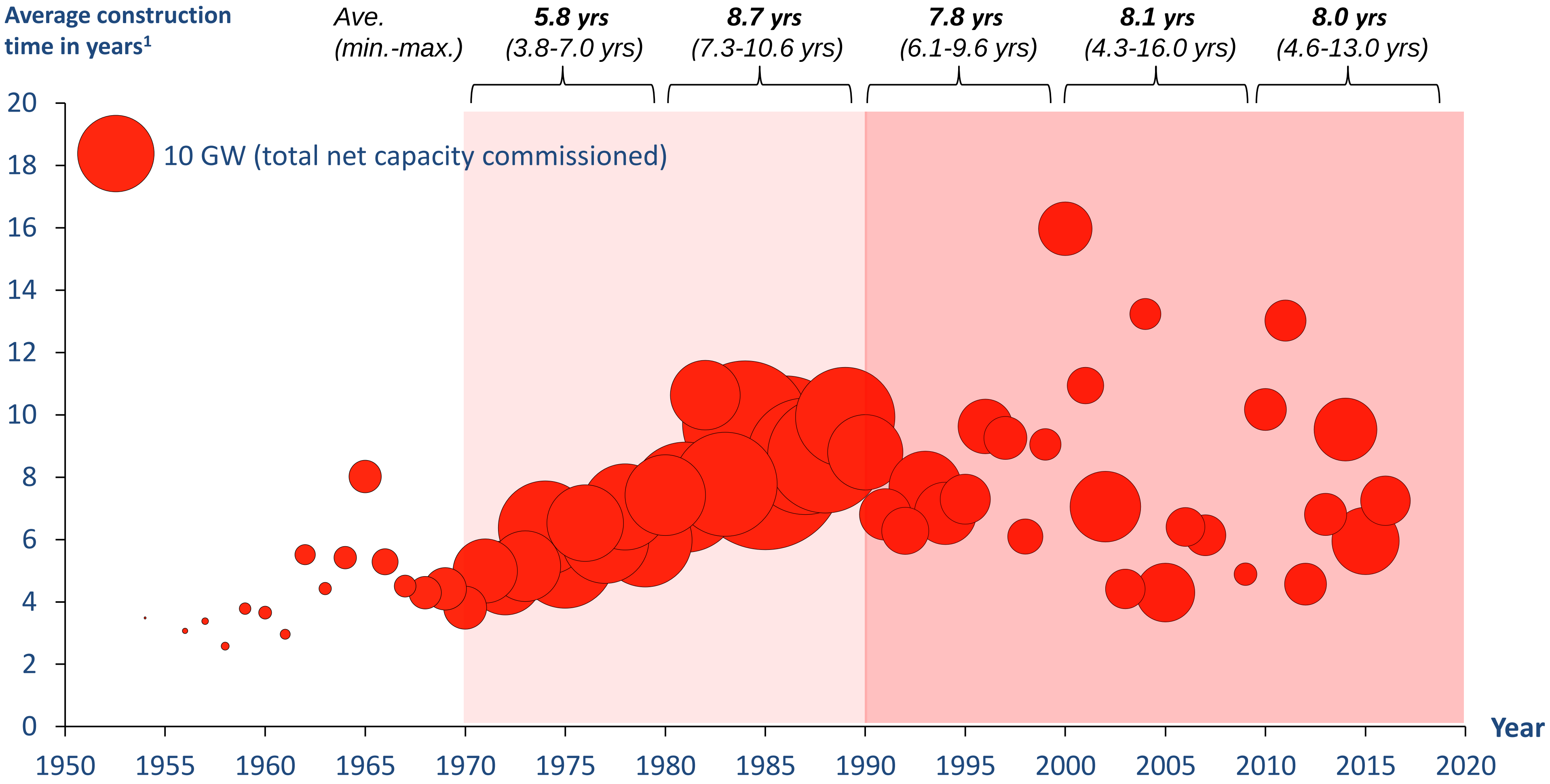
Solar PV = 0.43 p.u. (capacity);
Wind = 0.43 p.u. (capacity)
VRE (energy) = 0.30 p.u.

	System	*Residual*
"Base" demand	◕	◔
"Mid-merit" demand	◑	◕
"Peaking" demand	◔	◕

Agenda

In the "heydays" of nuclear construction, average construction times were increasing while recently more variation is seen

Evolution of capacity weighted average nuclear reactor construction time in years (1954-2016)



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[1] Construction time is calculated as the date from start of construction to date of first power

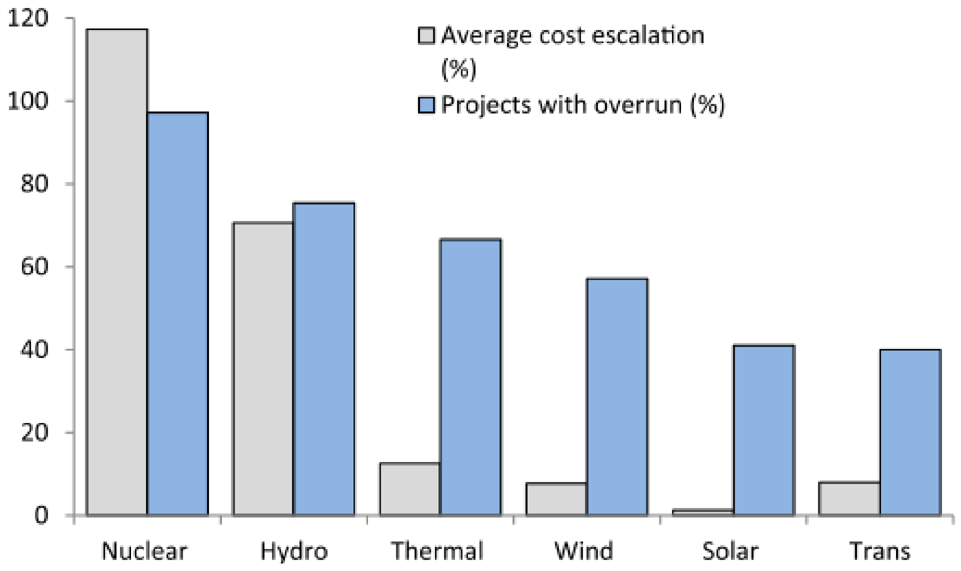
Sources: World Nuclear Association - Reactor database, CSIR energy centre analysis

Agenda

Globally – generation projects almost always exhibit cost escalation whilst nuclear construction cost escalation is notably higher than other technologies

Historical cost escalations for major electrical infrastructure projects (401 projects, 325 GW, 1936-2014) revealed a clear trend across all classes – there is almost always inevitable cost escalation (across all technologies)

Nuclear construction cost escalation is by some margin notably higher than others (~2.2 times original budgets) whilst almost all new-build nuclear projects exhibit cost escalation

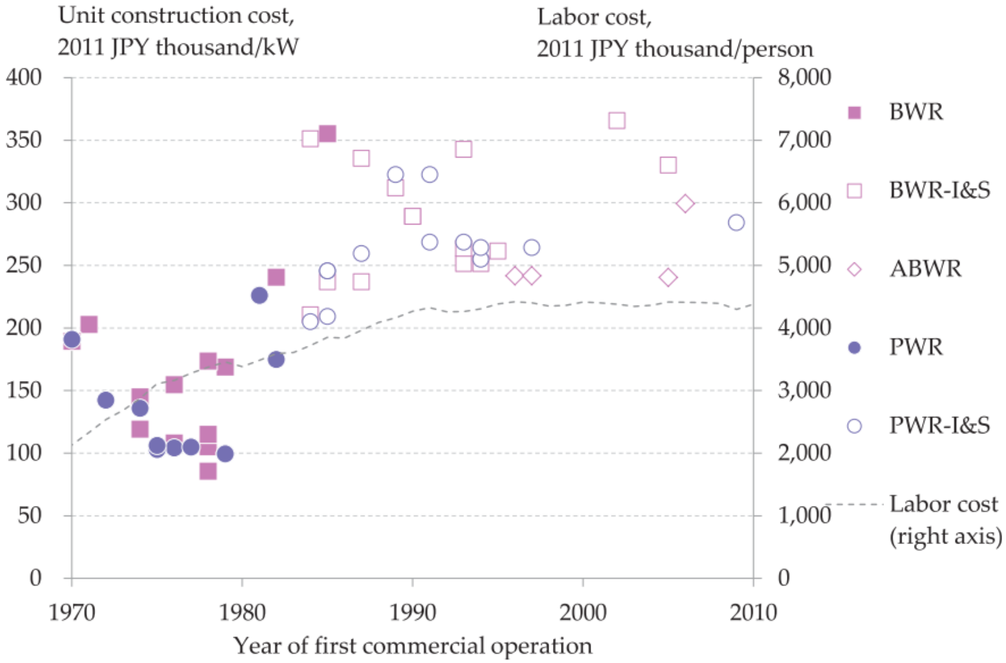


Sources: Sovacool et. al.

The Japanese experience reveals an extended period of construction costs escalation only paused by standardisation

The Japanese experience revealed an initial inverted learning rate (construction costs for FOAK vs NOAK and beyond did not reduce) which cannot only be explained by increased labour costs

Only once Improvement and Standardisation (I&S) programs from 1980 onwards were implemented did relative construction costs stabilise (but never decrease)

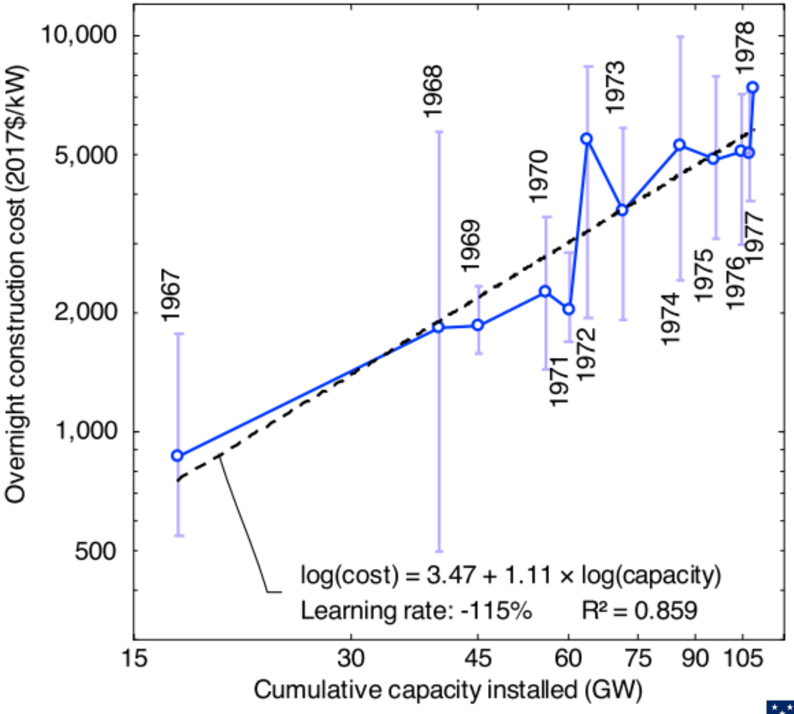


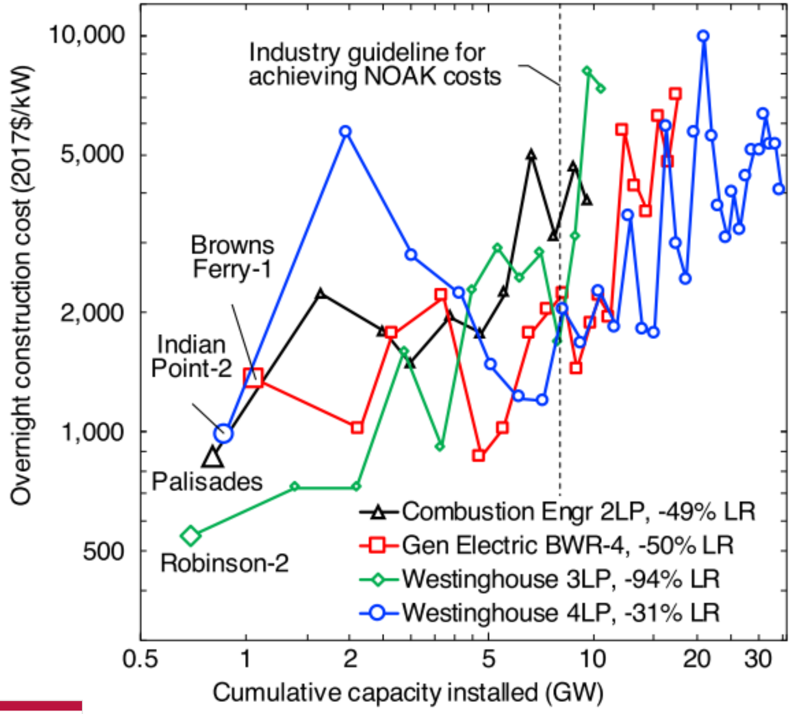
NOTES: FOAK – First of a Kind; NOAK – n-th of a kind
Sources: Matuo and Nei

In the US, nuclear plant construction costs have not exhibited learning by doing (as is typically the case and as is expected)

A 50 year analysis in the US identifies particular reasons for this (site specific conditions and lack of standardisation) - negative learning rates are exhibited as nuclear capacity ramped up

(It should be noted that the ramp-up of capacity was during 1970s and 1980s only)



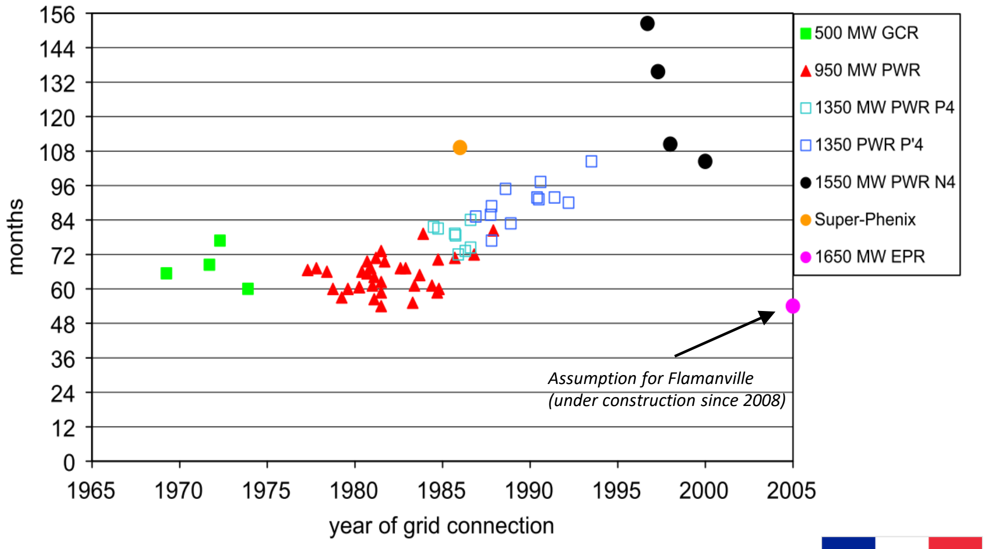


Sources: Eash-Gates

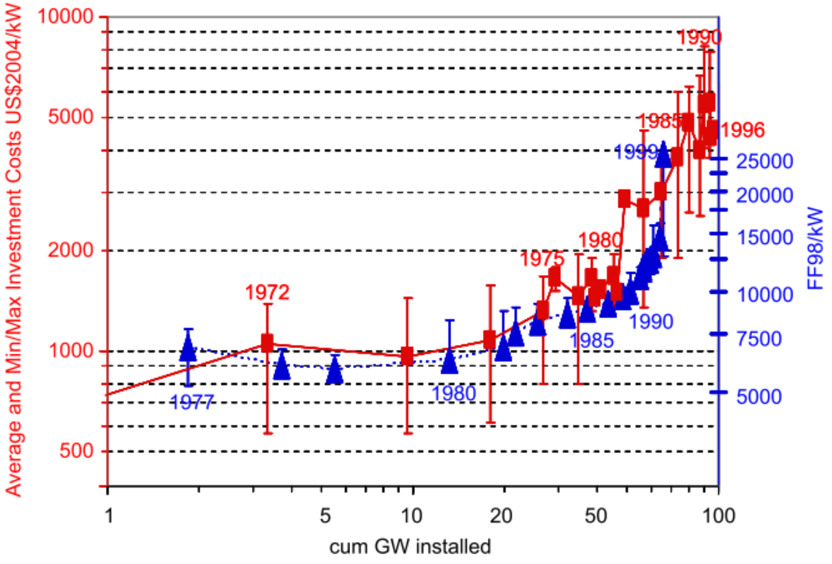
The French nuclear fleet is one of the largest in the world and has been highlighted as a case of negative learning by doing

Although generally characterised as a successful scale-up of new complex technology deployment to improve energy security (since the 1970s), the French example of new-build nuclear capacity cost and lead-time escalations (negative learning rates) needs to be carefully considered

(It should be noted that the ramp-up of capacity was during 1970s and 1980s only)



Assumption for Flamanville (under construction since 2008)

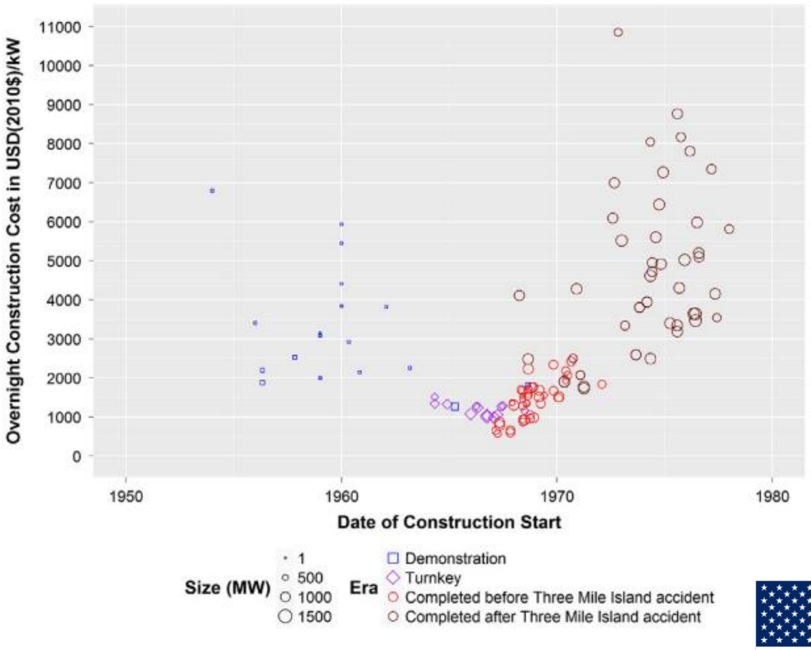


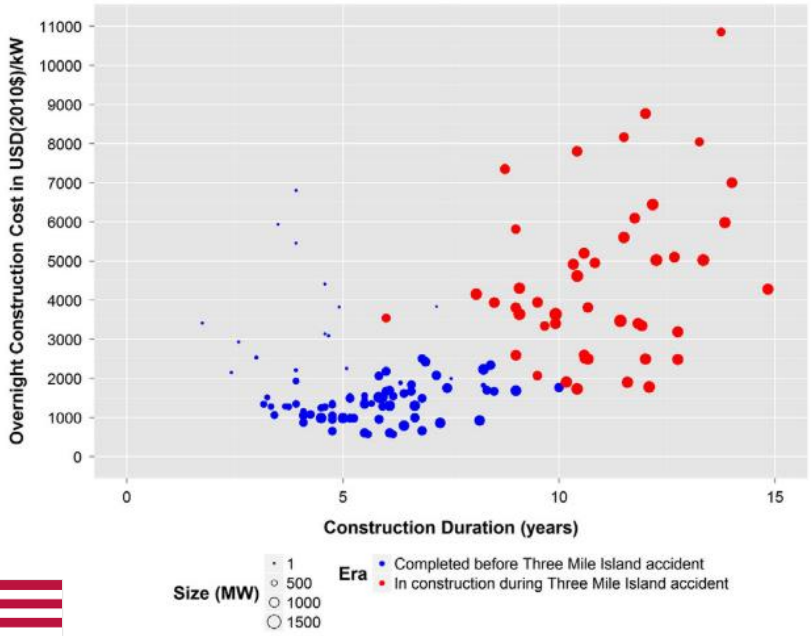
NOTES: FF – French Francs; EPR – European Pressurised Reactor; GCR – Graphite Gaz Reactor; PWR – Pressurised Water Reactor
Sources: Grubler; CSIR analysis

Globally, an updated view on nuclear new-build construction costs reveals variations in costs across vintage and country – all on increasing trends unfortunately

A more updated investigation into costs of new-build nuclear capacity globally from 1954-2015 and includes USA, France, Japan, South Korea, Germany, Canada and India

Distinct phases of nuclear capacity construction are noted in the US – increased safety and regulatory compliance resulted in significantly increased costs



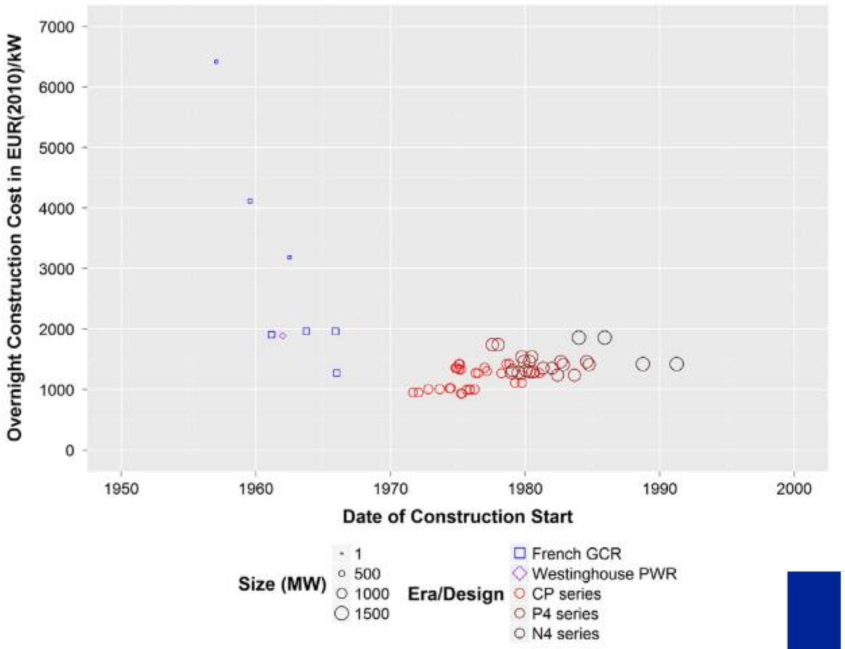


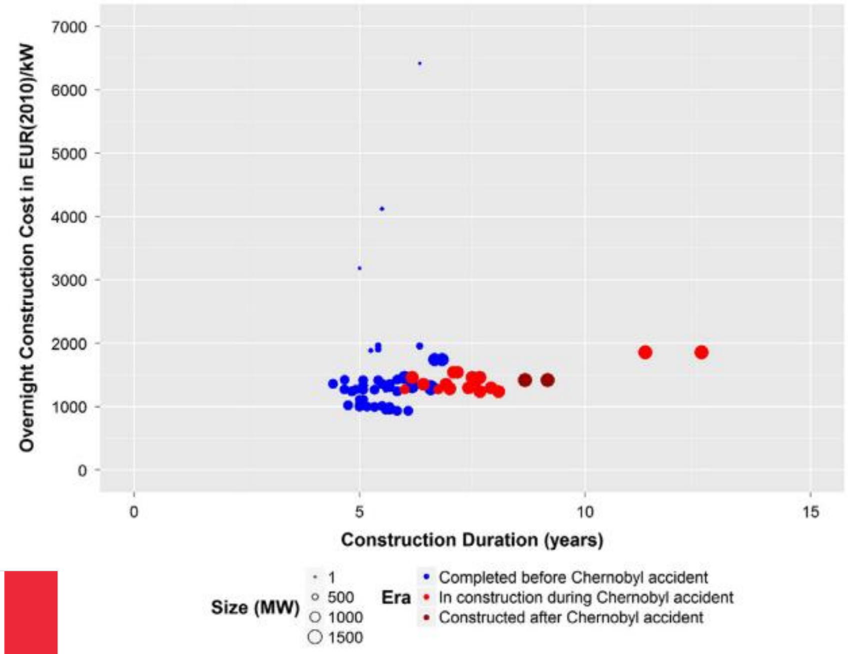
Sources: Lovering et. al.; CSIR analysis

French experience shows more controlled cost escalations focused on particular events and impacts on resulting impacts on costs

Increase in costs as a result of Chernbobyl accident in 1986 is noted but significantly less affected that the USA construction costs (after Three Mile Island accident in 1979)

Vertical integration of the national utility in France standardization of reactor designs assisted in controlling cost escalations relative to other experiences globally

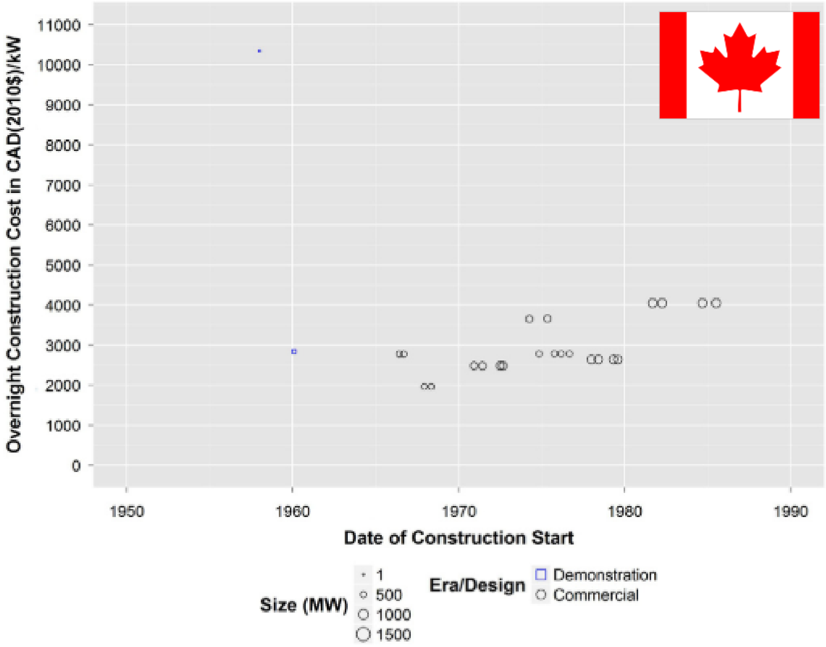




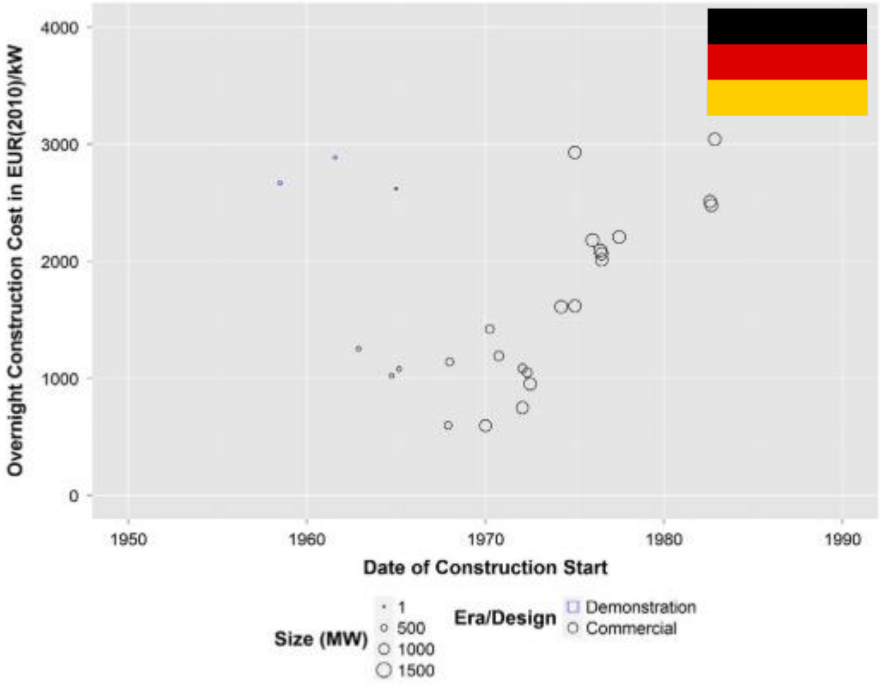
Sources: Lovering et. al.; CSIR analysis

Differing experience from other countries with relatively large nuclear fleets – controlled and uncrontrolled cost escalation

Canada nuclear capacity always kept small but stopped in the 1980s – slight cost escalations



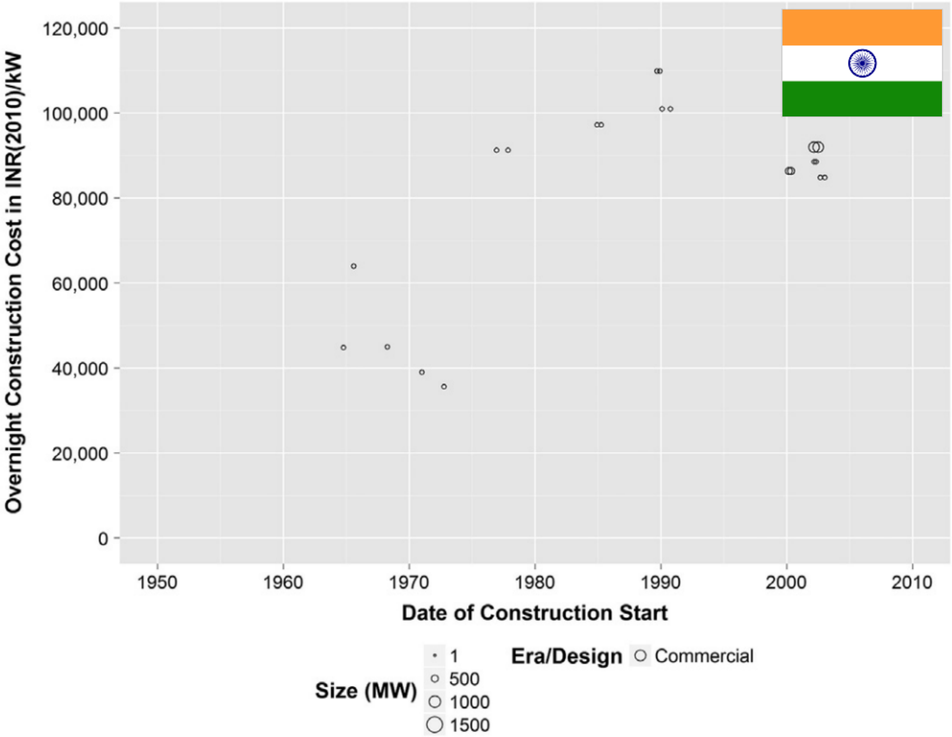
Germany nuclear capacity scaled significantly with larger unit sizes and significant cost escalations (no stabilisation)



Sources: Lovering et. al.; CSIR analysis

India have also experience increased construction costs as they opted for increased localisation of designs

Indian experience is interesting with initial importing of reactors from other experienced countries followed by own indigenous PHWR – this resulting in notably higher construction costs and significant jump in the post-2000 era

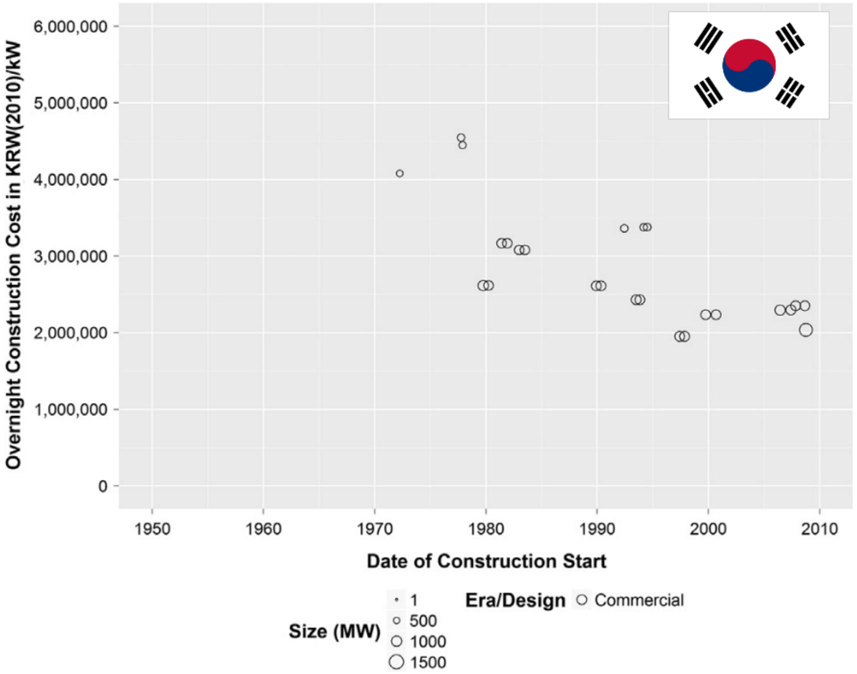


PHWR – Pressurised Heavy Water Reactor
Sources: Lovering et. al.; CSIR analysis

The exception - South Korea – the only country to demonstrate a positive cost learning rate when deploying nuclear capacity

There is always an exception to the rule and this seems to be South Korea where a positive learning rate has been experienced as more nuclear capacity has been deployed

Similar to India – South Korea began importing nuclear reactors from other experienced countries (later than other countries that did similar – avoiding demonstration reactors) followed by own designs thereafter and successfully driving down construction costs



PHWR – Pressurised Heavy Water Reactor
Sources: Lovering et. al.; CSIR analysis

Agenda

1 Background

2 CSIR comments

  2.1 Overarching policy guidance (NDP)

  2.2 IRP 2019 policy adjustment - transparency

  2.3 Energy planning fundamentals

  2.4 Delivery timeframe (lead times)

  2.5 New-build nuclear learning rates (global experience)

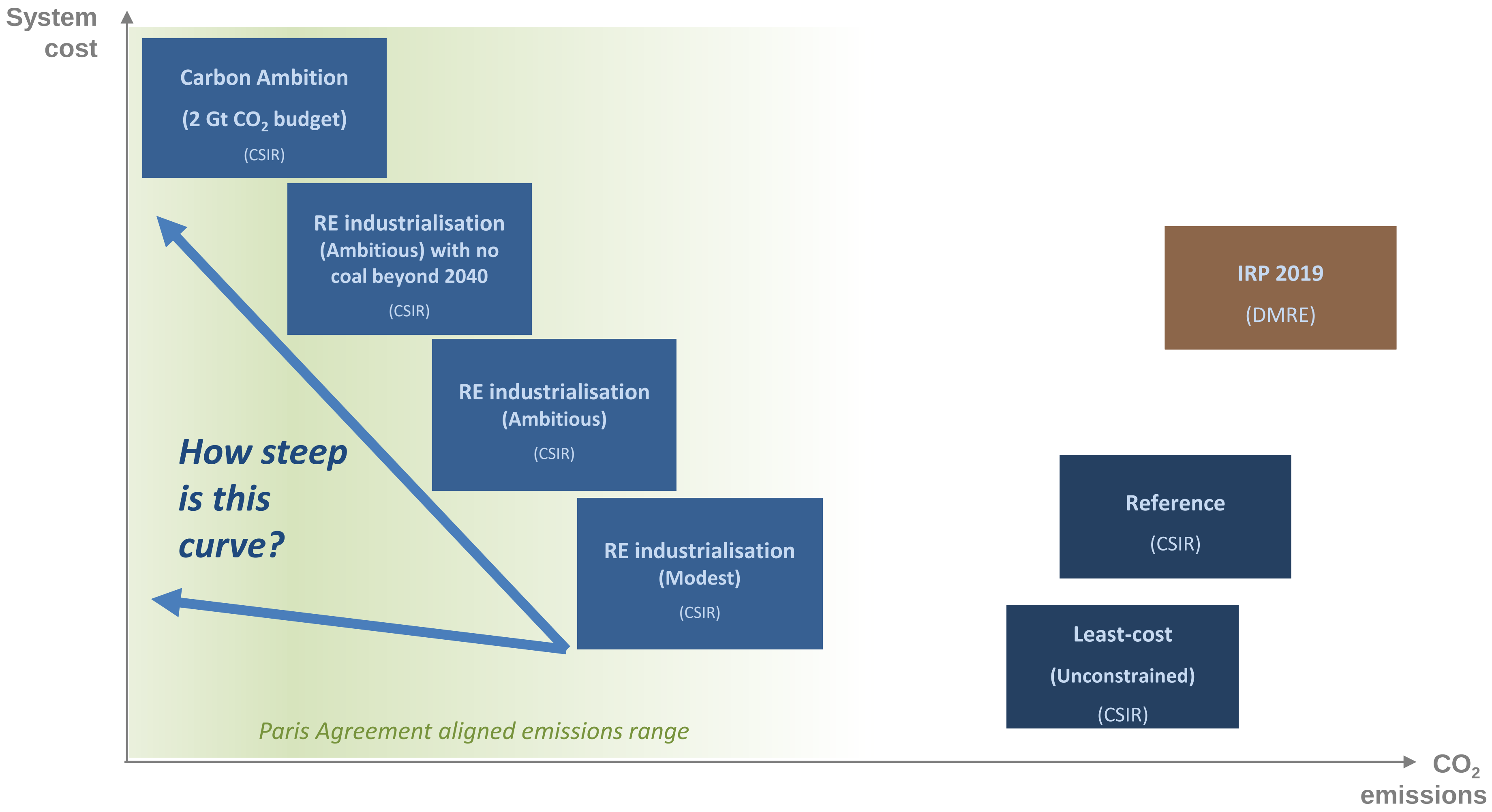
  2.6 Power sector decarbonisation

  2.7 Fill the gap

3 Summary

4 References

How much more than least-cost would it cost to decarbonise power in RSA and what technologies form part of the mix?



System cost

Carbon Ambition

(2 Gt CO_2 budget)

(CSIR)

RE industrialisation (Ambitious) with no coal beyond 2040

(CSIR)

RE industrialisation (Ambitious)

(CSIR)

RE industrialisation (Modest)

(CSIR)

How steep is this curve?

Paris Agreement aligned emissions range

IRP 2019

(DMRE)

Reference

(CSIR)

Least-cost

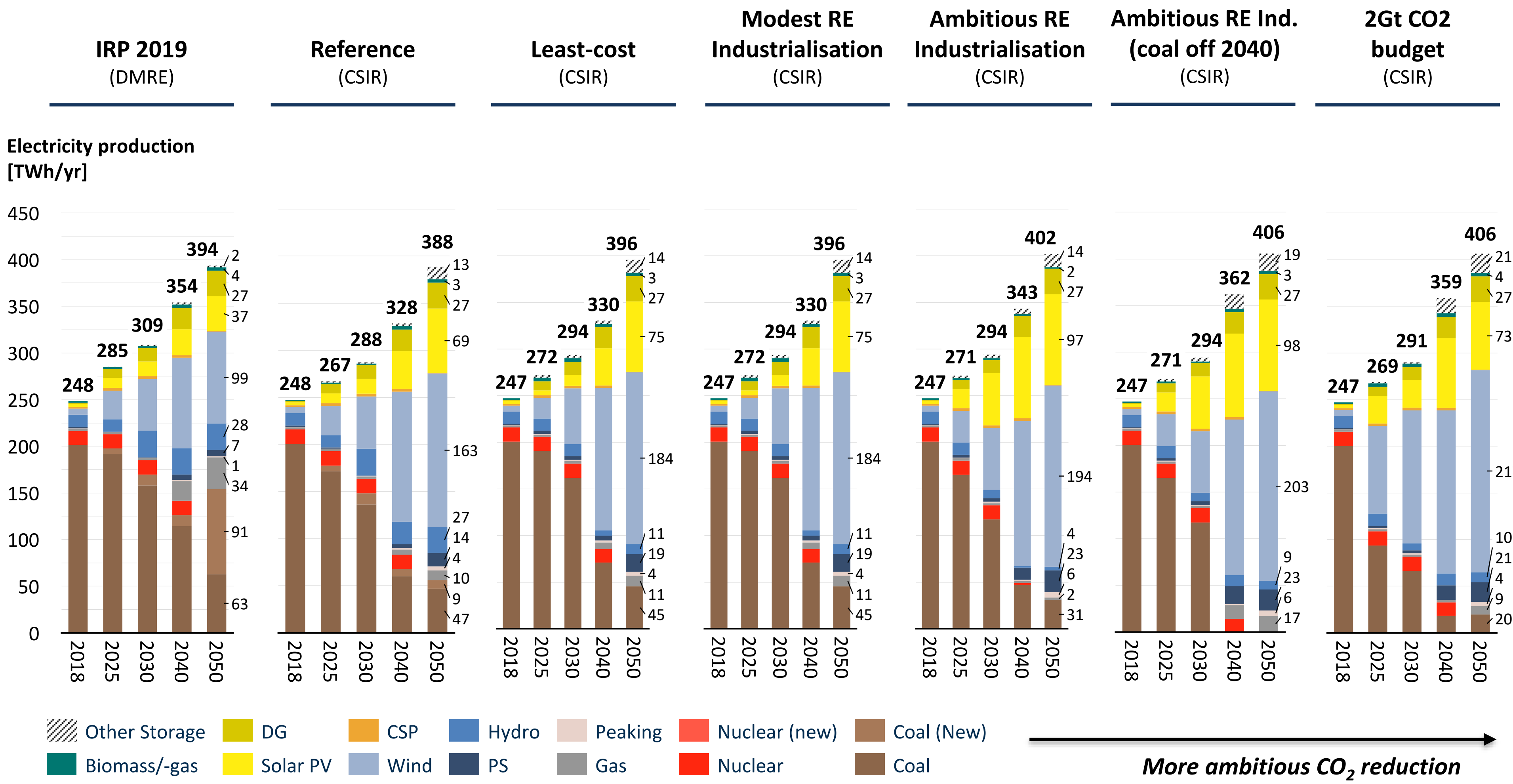
(Unconstrained)

(CSIR)

CO_2 emissions

Full study available: Wright, J.G. Calitz, J.C. Systems analysis to support increasingly ambitious CO_2 ambitions, 2020
Link: https://researchspace.csir.co.za/dspace/handle/10204/11483

Even under ambitious CO_2 trajectories, new-build nuclear capacity does not form part of the least-cost energy mix

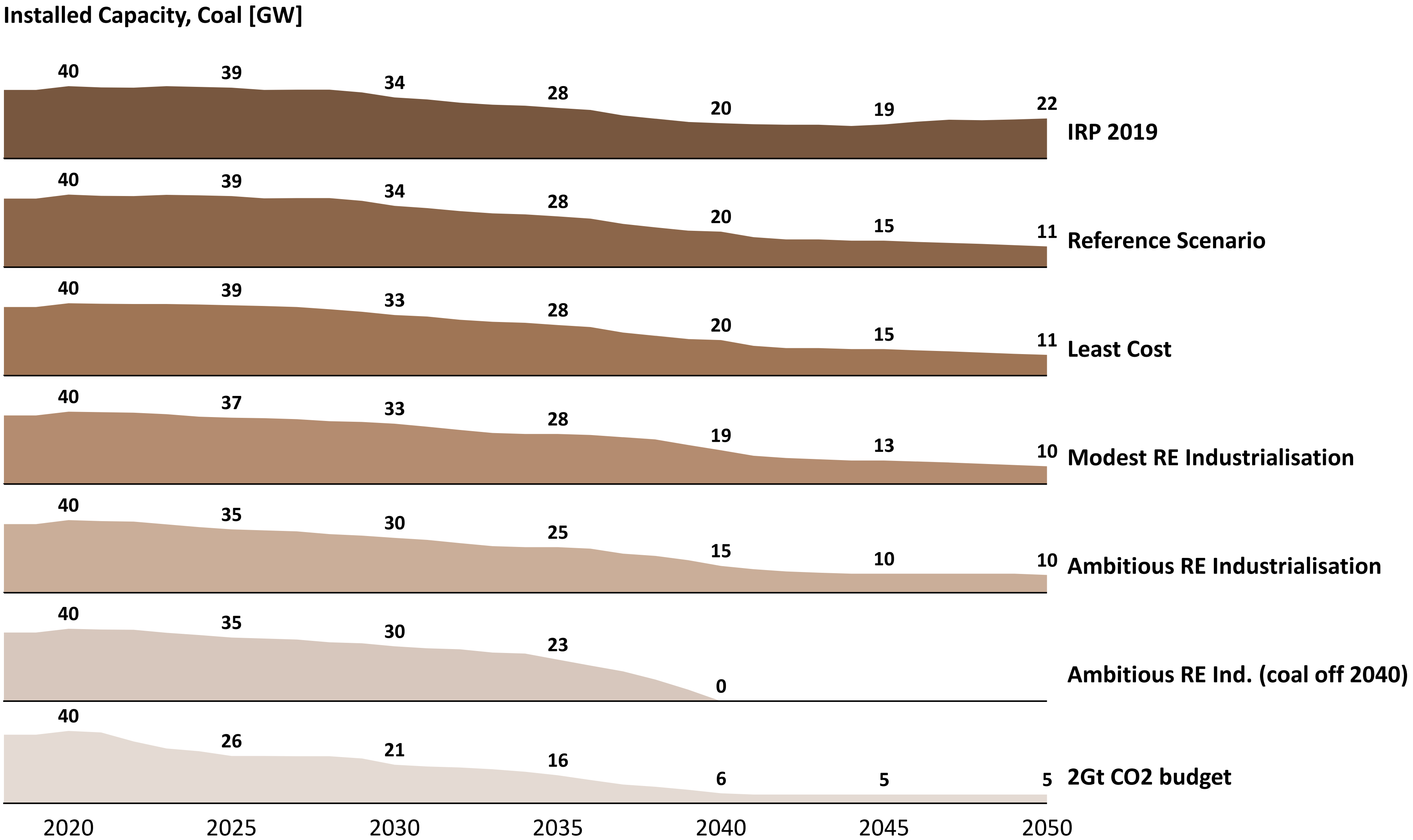


DG = Distributed Generation; PS = Pumped Storage

Sources: CSIR Energy Centre analysis

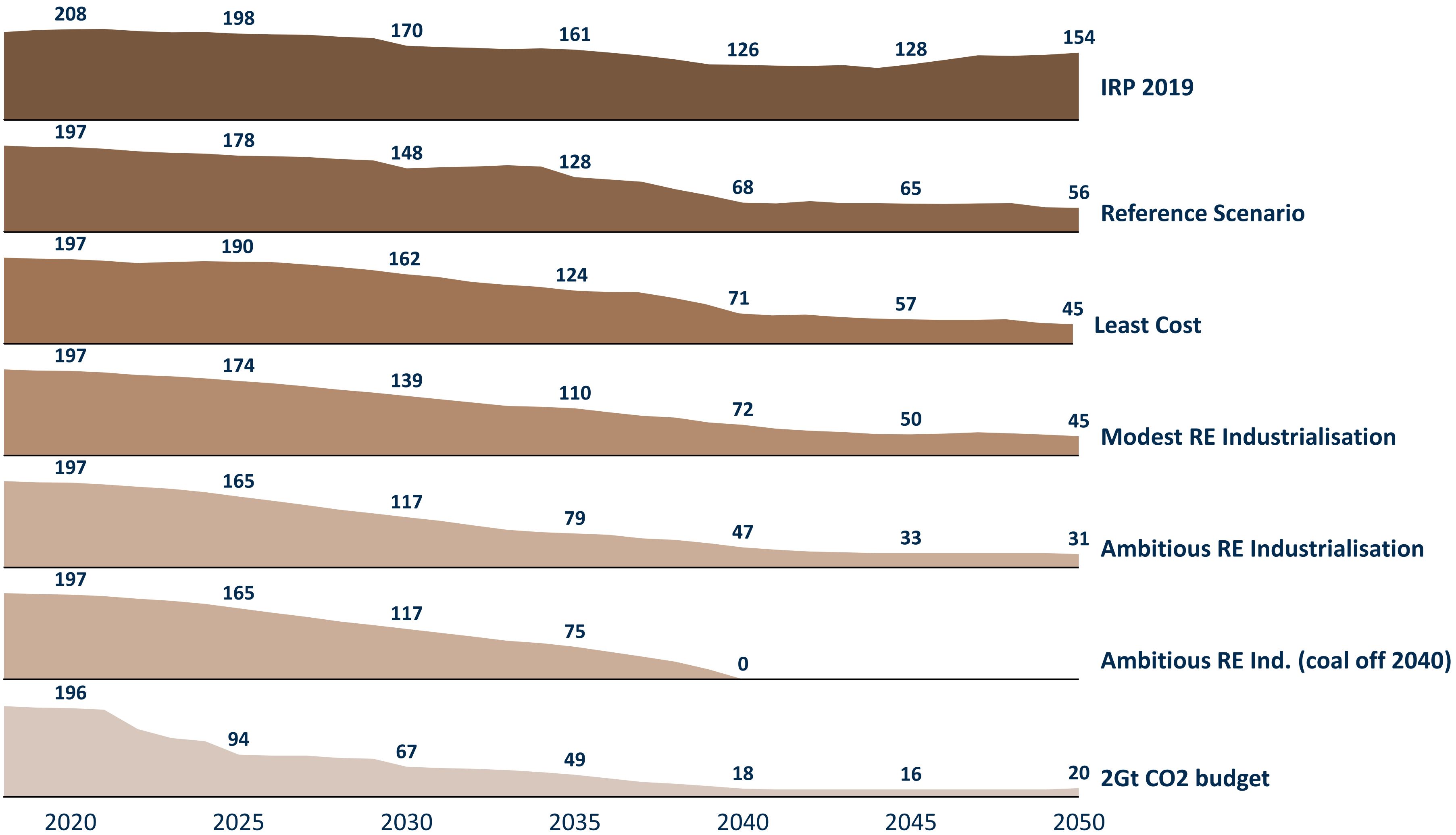
Full study available: Wright, J.G. Calitz, J.C. Systems analysis to support increasingly ambitious CO_2 ambitions, 2020
Link: https://researchspace.csir.co.za/dspace/handle/10204/11483

Early coal decommissioning becomes more prevalent with lower CO_2 emission ambitions in the power sector



Full study available: Wright, J.G. Calitz, J.C. Systems analysis to support increasingly ambitious CO_2 ambitions, 2020
Link: https://researchspace.csir.co.za/dspace/handle/10204/11483

Lower utilisation of the existing coal fleet will require increased flexibility under increasingly ambitious CO2 pathways



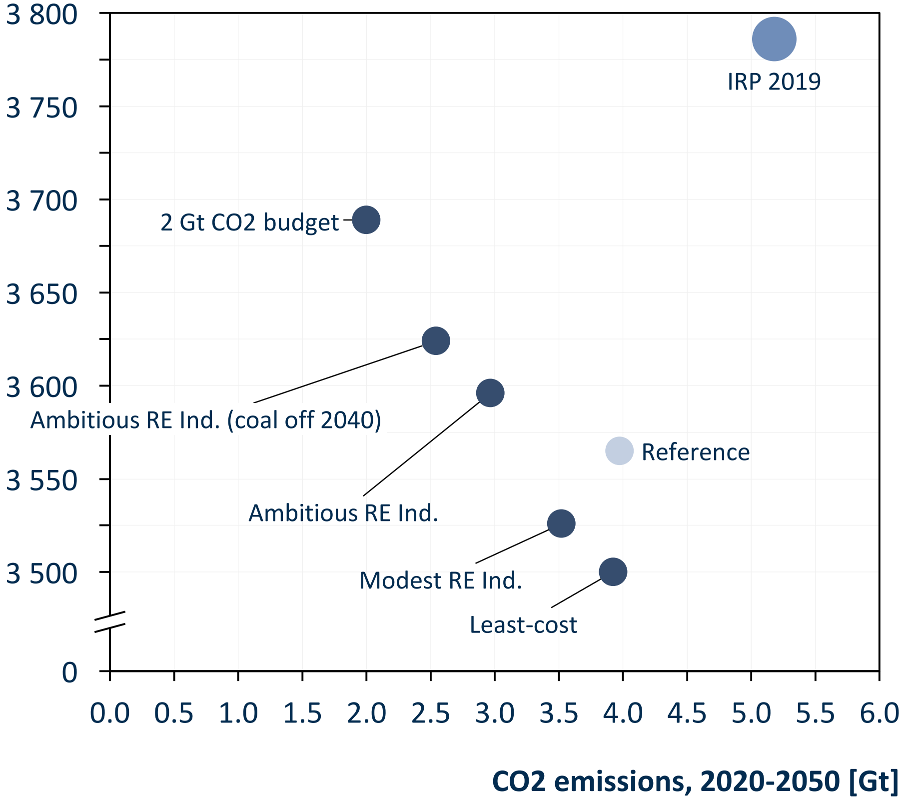
Electricity production, Coal [TWh/yr]

Full study available: Wright, J.G. Calitz, J.C. Systems analysis to support increasingly ambitious CO$_2$ ambitions, 2020
Link: https://researchspace.csir.co.za/dspace/handle/10204/11483

With increasing CO_2 ambition, costs increase but not as much as expected – clears a path for decarbonization driven by RE

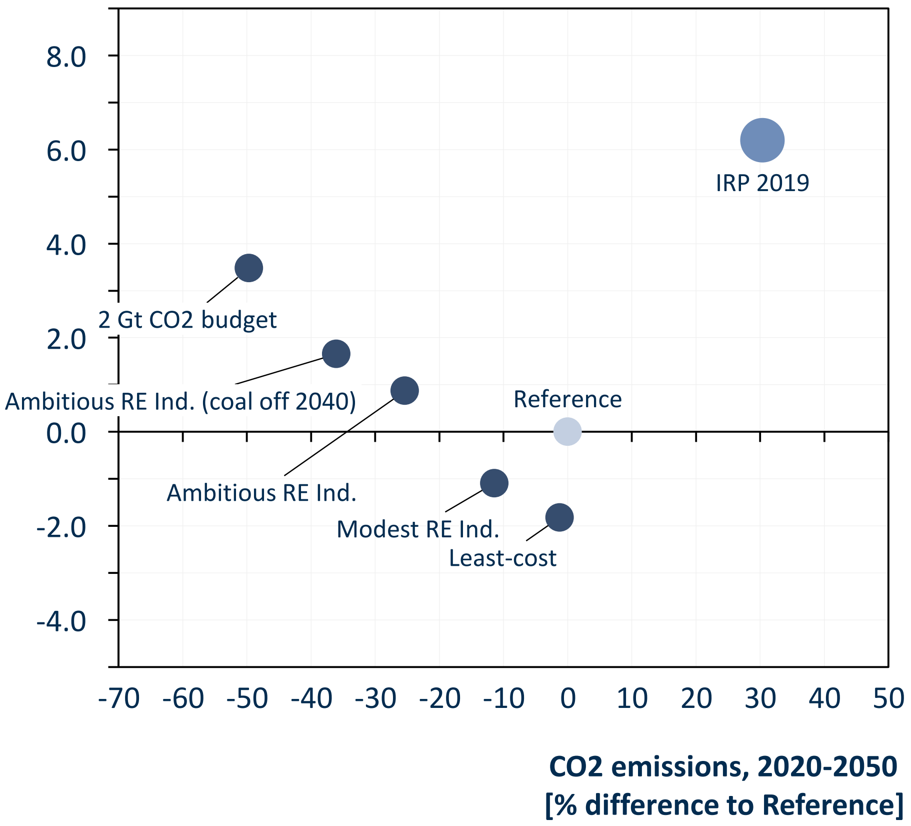
Absolute

Total system cost, discounted (2020-2050)
[R-billion] (Jan-2019 Rand)



Relative

Total system cost, discounted (2020-2050)
[% difference to Reference]



Sources: CSIR Energy Centre analysis

Full study available: Wright, J.G. Calitz, J.C. Systems analysis to support increasingly ambitious CO_2 ambitions, 2020
Link: https://researchspace.csir.co.za/dspace/handle/10204/11483

Agenda

IRP 2019 did not publish scientific evidence to support 2500 MW new nuclear as “no-regret” as IRP 2019 ends in 2030

IRP 2019 did not quantify the impact of deviating from least-cost – essential to decision makers

- No unconstrained least-cost scenario published for comparison to Policy Adjusted IRP 2019 outcomes (with specific emphasis on cost impacts of key decisions published)

IRP meant to be long-term visionary plan – not anymore and likely too prescriptive

- IRP 2019 does not provide insight beyond 2030 (only 9 years from now)
- Comprehensive impact of nuclear build (60 year life) not assessed in IRP as plan does not go beyond 2030
- Prescriptive & administrative nature of IRP removes ability to react to shocks and systemic changes

Transparent and comprehensive reporting would assist to establish policy adjustment trade-offs

- Comprehensive reporting of assumptions & scenario outcomes not in IRP 2019 or in NERSA Consultation Paper
- VRE (PV and wind) with flexibility[1] confirmed again as least-cost new-build energy mix[2]
- VRE (PV and wind) with flexibility[1] also previously shown to exhibit least CO_2 emissions & water usage

For policy adjustment to displace 2 500 MW - need to establish cost, CO_2 emissions, water-use (& other emissions) difference relative to unconstrained least-cost (in addition to potential localisation opportunities)

[1] Natural gas fired peaking and mid-merit capacity considered as a proxy for this; [2] While the existing coal fleet decommissions as expected.

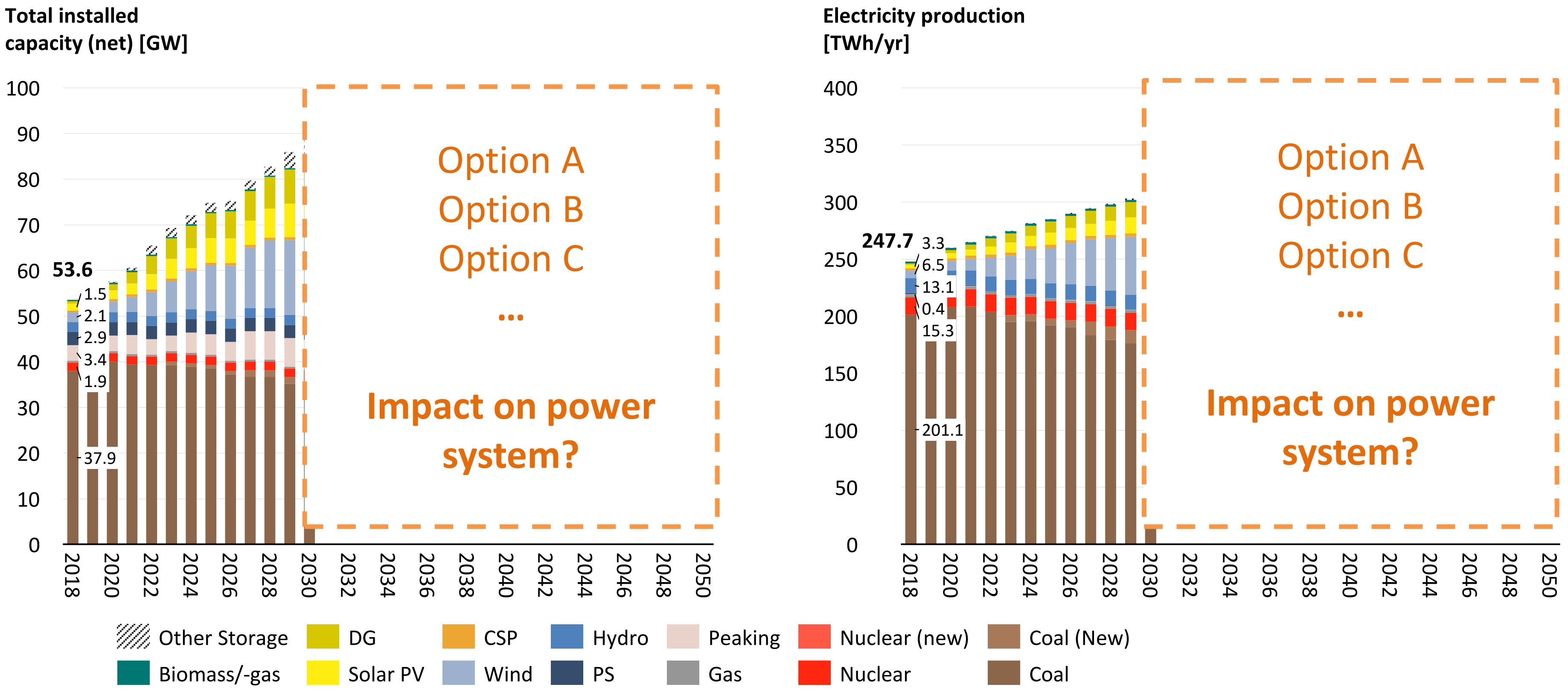
VRE – Variable Renewable Energy

Sources: CSIR Energy Centre analysis

Filling the 2 500 MW hydro “gap” requires analysis beyond 2030 that quantifies the impact of changing the technology mix on key parameters such as cost, emissions and jobs for informed decision making

Installed capacity

Energy mix



DG = Distributed Generation; PS = Pumped Storage
NOTE: Energy share is a best estimate based on available data)
Sources: IRP 2019. CSIR Energy Centre analysis

CSIR assessed the cost impact of nuclear vs. alternative supply options which can replace/provide same energy profile as import hydro

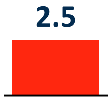
Illustrative example

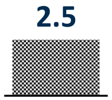
Import hydro (IRP 2019)

Nuclear? (NERSA Concurrence)

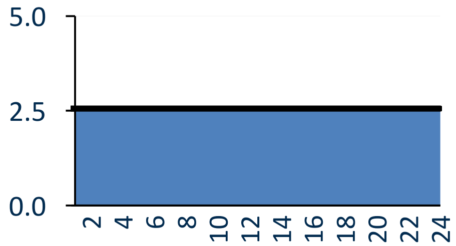
Least-cost? (Optimised)

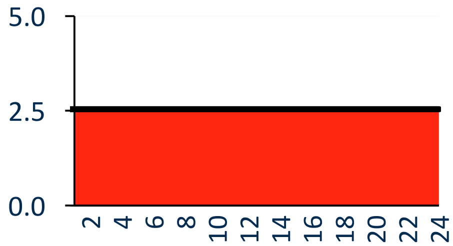
Scenario

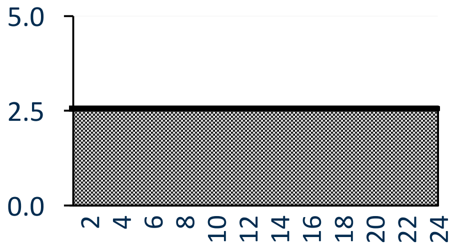




Meeting the energy gap?







	Import hydro (IRP 2019)	Nuclear? (NERSA Concurrence)	Least-cost? (Optimised)	
Total Cost?	Reference	(+)/(-)%	(+)/(-)%	*Focus of CSIR analysis*
CO_2 emissions?	Reference	(+)/(-)%	(+)/(-)%	*Suggested before concurrence for further analysis and publishing for stakeholder consideration*
Water?	Reference	(+)/(-)%	(+)/(-)%	
Employment & Economic impact	Reference	(+)/(-)%	(+)/(-)%	

Sources: CSIR Energy Centre analysis

Study assumptions for imported hydro from Inga based on IRP 2019

Imported hydro

(Inga)

CAPEX

(Overnight Cost + IDC)

IRP 2019 (2030)

74 340 R/kW

Utilisation / load factor

Inga energy profile

85%

● Study assumptions **(IRP 2019, CSIR)**

Sources: DMRE; CSIR Energy Centre analysis

Study assumptions consider conservative assumptions for nuclear construction costs, lead time and utilisation

Nuclear

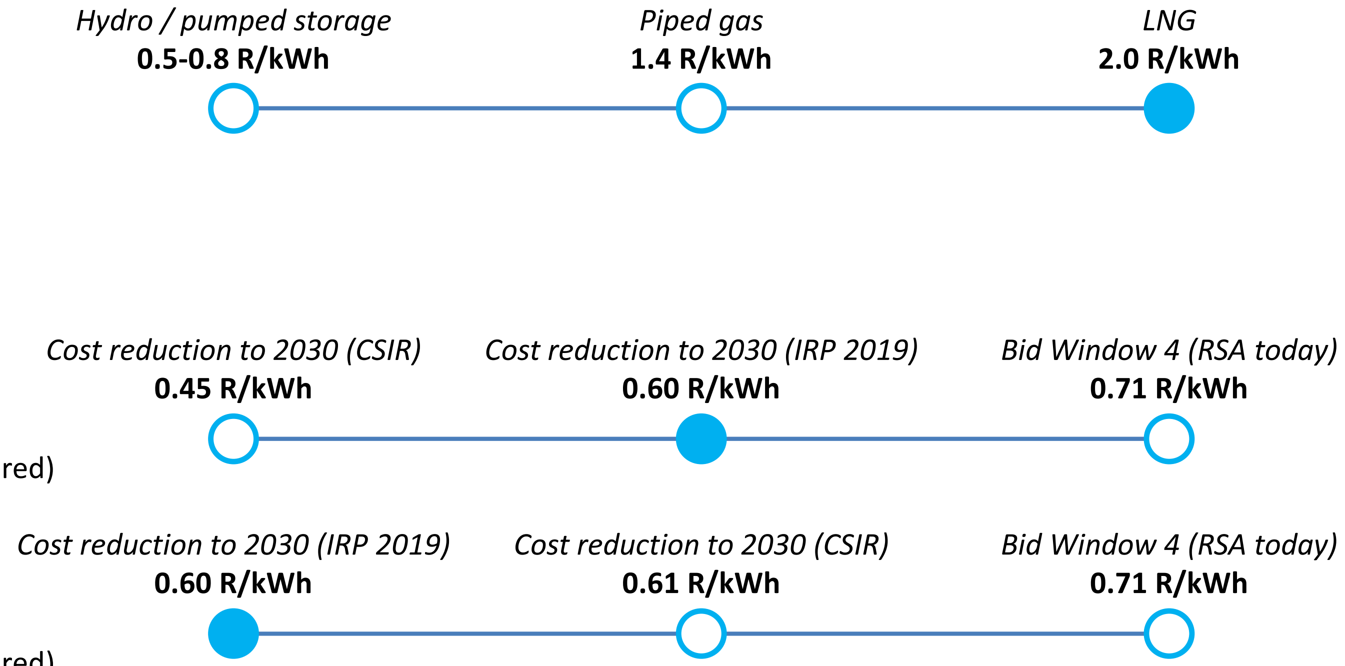
CAPEX (Overnight Cost + IDC)	*IRP 95% confidence (lower)* **5 685 $/kW** ○	*IRP 2019 (2030)* **6 360 $/kW** ●	*Hinkley Point C* **9 500 $/kW** ○
Construction time	*IRP 2019* **6 years** ●	*Flamanville (France)* **9 years** ○	*Olkiluoto (Finland) & Hinkley Point C* **13 years** ○
Utilisation / load factor	*IRP 2019* **92%** ○	Inga replacement energy profile **85%** ●	*Actuals Koeberg (2015-2020) (South Africa)* **80%** ○

●

Notes: USD:ZAR = 14.45 (2019 average); GBP:USD = 1.31 (2019 average)

Sources: DMRE; Ingerop; EDF; World Nuclear Association; Eskom; CSIR Energy Centre analysis

Study assumptions for other major technologies known to be part of least-cost from previous analysis



Flexible power generator

Unit cost
(capex+opex+fuel)
(at low load factor of 20%)

○ *Hydro / pumped storage*	○ *Piped gas*	● *LNG*
0.5-0.8 R/kWh	**1.4 R/kWh**	**2.0 R/kWh**

Renewables (RE)

Solar PV eq. tariff
(Fundamental capex/opex considered)

○ *Cost reduction to 2030 (CSIR)*	● *Cost reduction to 2030 (IRP 2019)*	○ *Bid Window 4 (RSA today)*
0.45 R/kWh	**0.60 R/kWh**	**0.71 R/kWh**

Wind tariff
(Fundamental capex/opex considered)

● *Cost reduction to 2030 (IRP 2019)*	○ *Cost reduction to 2030 (CSIR)*	○ *Bid Window 4 (RSA today)*
0.60 R/kWh	**0.61 R/kWh**	**0.71 R/kWh**

● Study assumptions **(IRP 2019)**

Sources: IRP 2019; CSIR Energy Centre analysis

Study assumptions for other major technologies known to be part of least-cost from previous analysis

Flexible power generator

Unit cost
(capex+opex+fuel)
(at low load factor of 20%)

- ○ *Hydro / pumped storage* **0.5-0.8 R/kWh**
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- ○ *Bid Window 4 (RSA today)* **0.71 R/kWh**

● Study assumptions **(CSIR)**

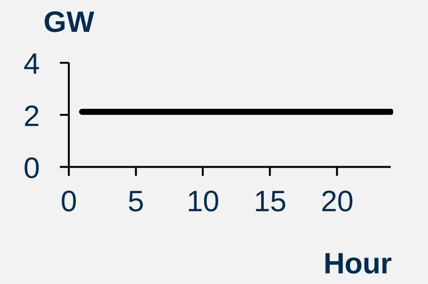
Sources: IRP 2019; CSIR Energy Centre analysis

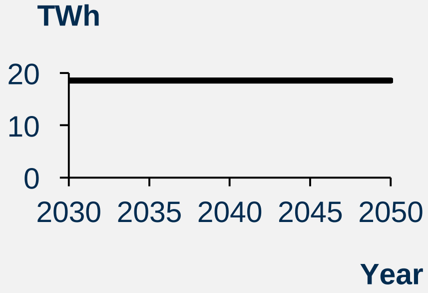
System analysis assumptions:

Alternatives to equivalent of import hydro that can supply this base-demand in same reliable manner as a single base-power generator assessed using systems analysis

Energy demand

Base-demand profile used to represent energy gap when removing 2.5 GW import hydro





New supply options

Scenario 1

2 500 MW nuclear

(NERSA Concurrence)

Scenario 2

Optimised portfolio

(least cost – IRP2019 costs)

?

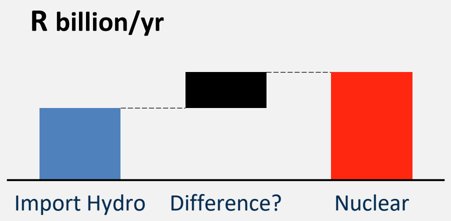
Scenario 3

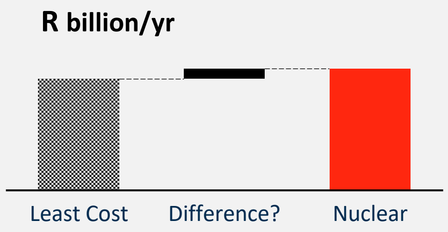
Optimised portfolio

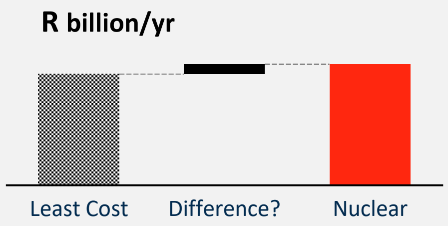
(least cost – CSIR costs)

?

Impact on total cost







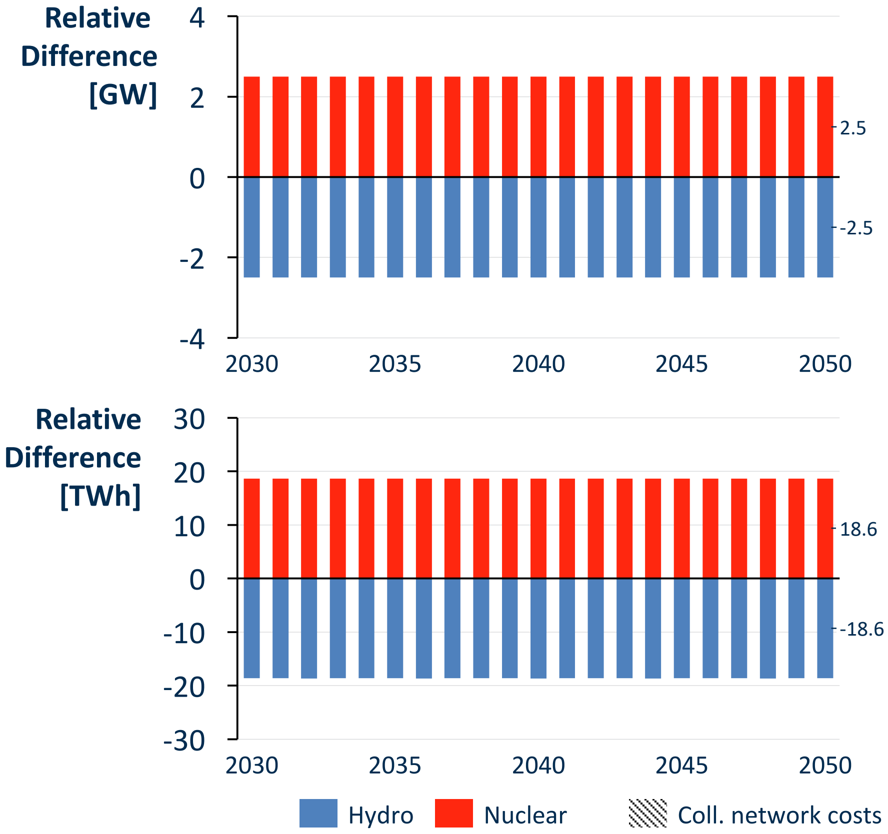
Notes: Capacity beyond 2030 based on optimisation of 2030-2050 energy mix utilising input assumptions from DMRE IRP 2019 (not least-cost) and CSIR, depending on scenario;
Sources: IRP 2019; CSIR Energy Centre analysis

Scenario 1: Replacing import hydro with Nuclear:

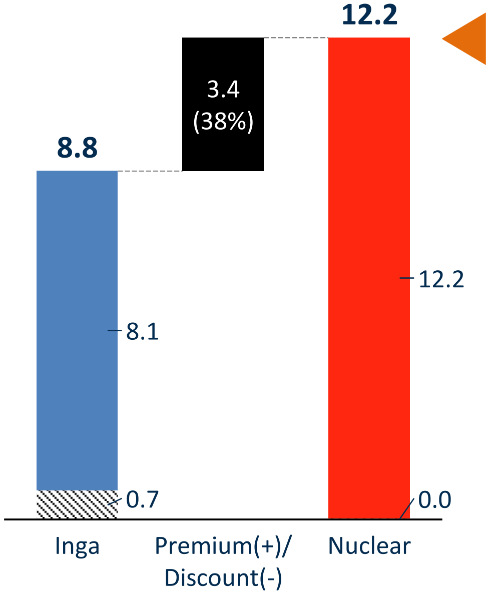
Replacing with nuclear could result in a cost premium of R3.4-billion per year (over 60 years) relative to the imported hydro (discounting from today)

Replace import hydro with nuclear

(New determination)



Annualised cost of power generation in R-bln/year over the next 60 years
(discounting from today, 2020)



Nuclear CAPEX
6 360 $/kW (IRP 2019)

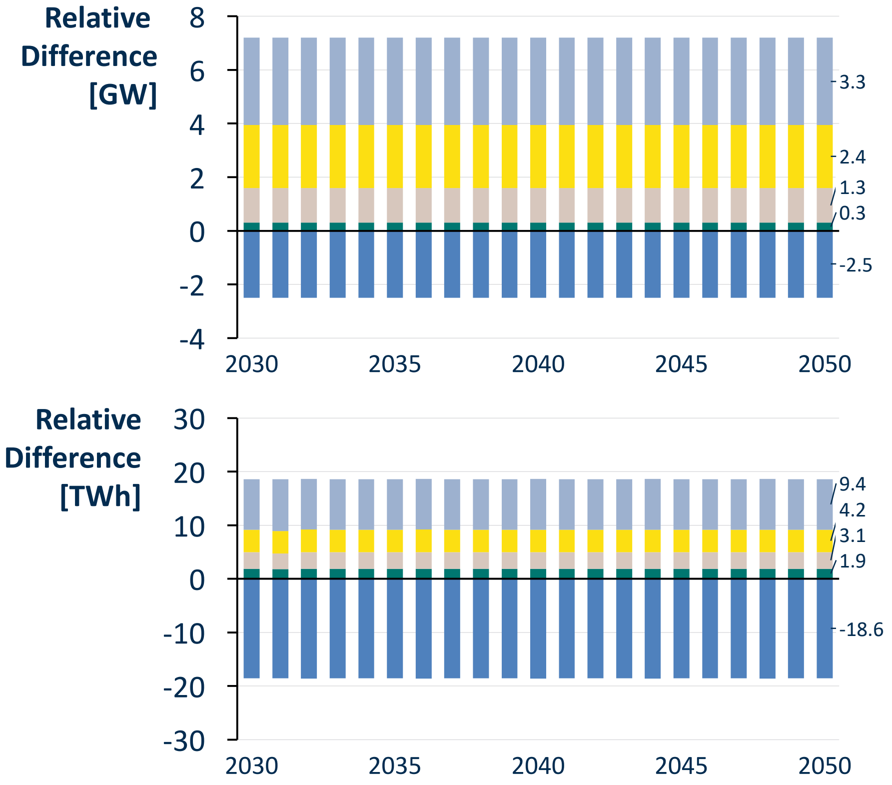
Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Capacity beyond 2030 based on optimisation of 2030-2090 energy mix utilising input assumptions from DMRE IRP 2019 and the CSIR;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

Scenario 2: Replacing with least-cost mix:

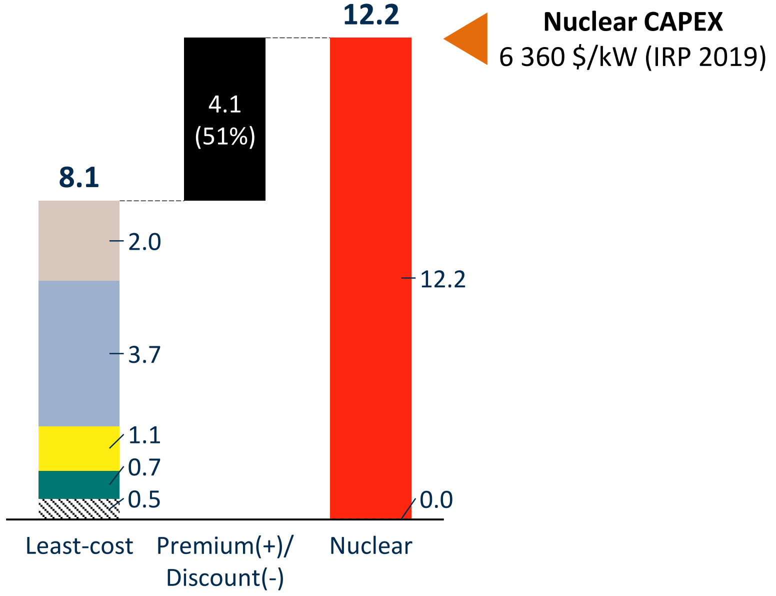
Annual new build capacity, energy and cost differences assuming IRP 2019 cost assumptions (discounting from today)

Least-cost?

(Optimised replacement of import hydro)



Annualised cost of power generation in R-bln/year over the next 60 years
(discounting from today, 2020)



Nuclear CAPEX
6 360 $/kW (IRP 2019)

▨ Storage 🟦 Wind 🟨 Solar PV 🟫 Peaking 🟩 Biomass/-gas 🟦 Hydro 🟥 Nuclear ▨ Coll. network costs

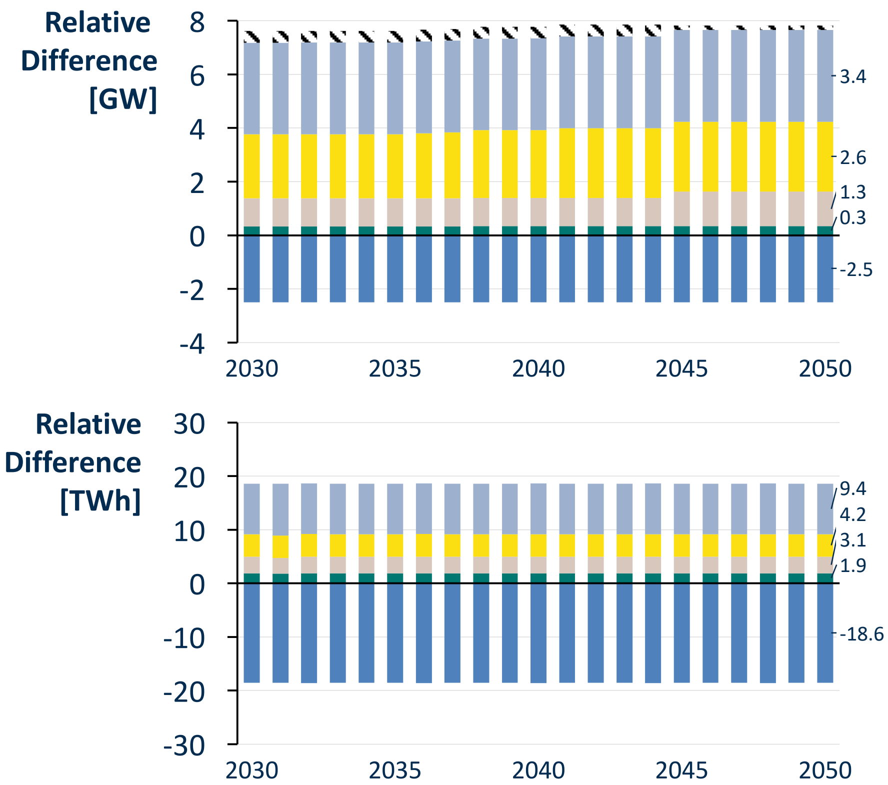
Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Capacity beyond 2030 based on optimisation of 2030-2090 energy mix utilising input assumptions from DMRE IRP 2019;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

Scenario 3: Replacing with least-cost mix using lower cost projections for wind, solar PV and battery storage

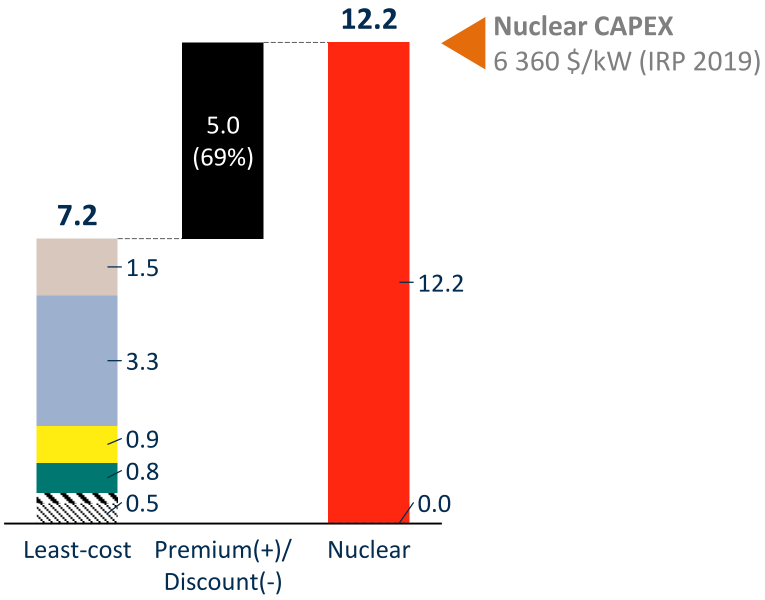
Replaced by a mix of renewable energy and flexible supply (discounting from today)

Least-cost?

(Optimised replacement of import hydro)



Annualised cost of power generation in R-bln/year over the next 60 years
(discounting from today, 2020)



▨ Storage ■ Wind ■ Solar PV ■ Peaking ■ Biomass/-gas ■ Hydro ■ Nuclear ▨ Coll. network costs

Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Capacity beyond 2030 based on optimisation of 2030-2090 energy mix utilising input assumptions from DMRE IRP 2019 and the CSIR;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

When discounting from today & 2030 deployment - anticipated cost premium for nuclear replacing Inga is just over R3 bln/yr and relative to least-cost is R4-5 bln/yr

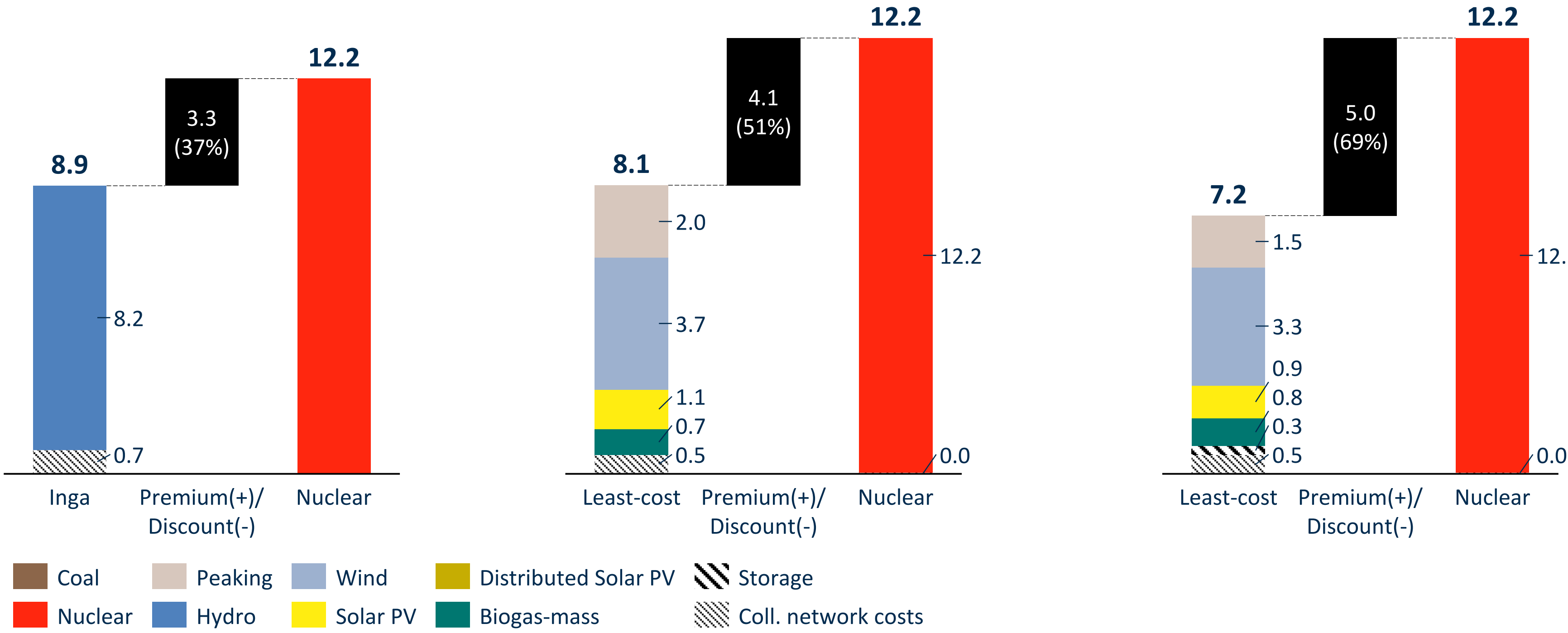
Discounting from 2020 onwards
(assuming 2030 deployment)

Scenario 1
2 500 MW Nuclear
(New determination)

Scenario 2
Least-cost mix
(IRP 2019 cost assumptions)

Scenario 3
Least-cost mix
(CSIR cost assumptions)

Annualised cost of power generation in R-bln/year over the next 60 years
(discounting from today, 2020)



Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Capacity beyond 2030 based on optimisation of 2030-2090 energy mix utilising input assumptions from DMRE IRP 2019 and the CSIR;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

When deployment is insensitive to calendar year - anticipated cost premium for nuclear replacing Inga is just over R7 bln/yr and relative to least-cost is R9-11 bln/yr

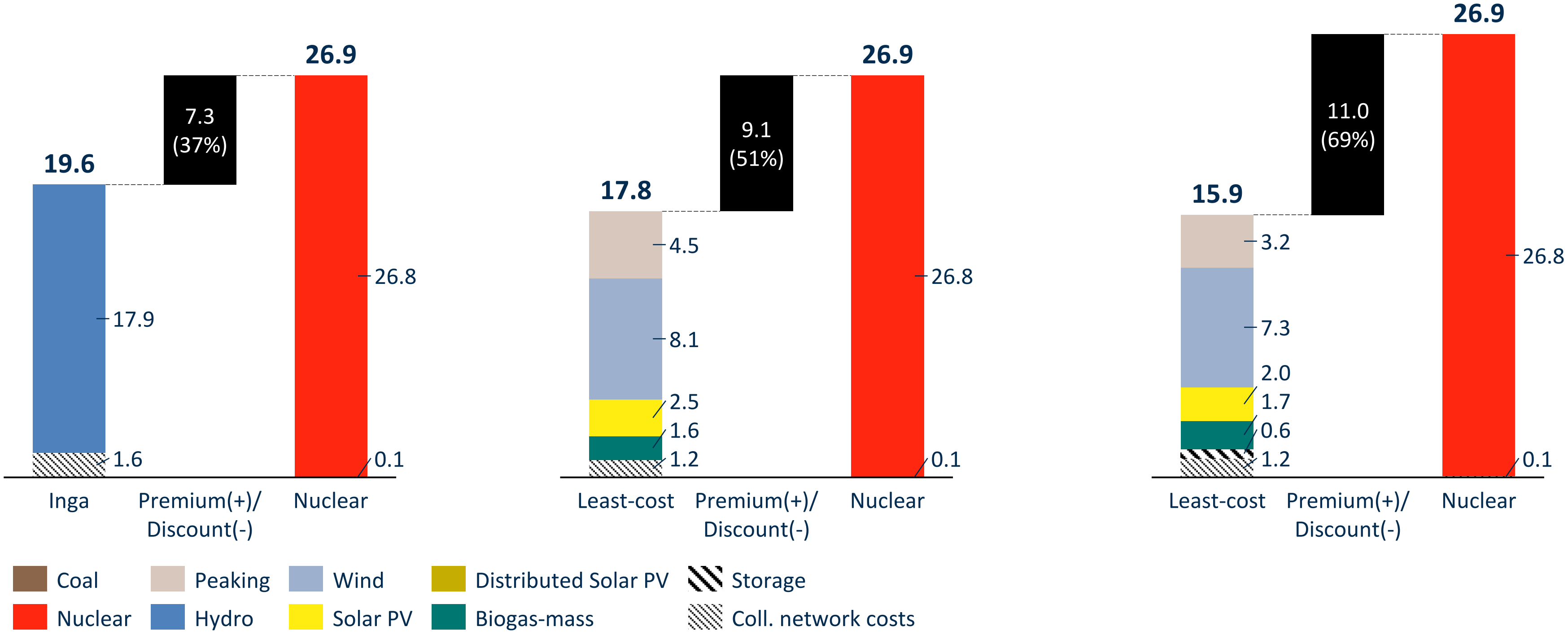
Discounting from year of operation
(insensitive to calendar year)

Scenario 1
2 500 MW Nuclear
(New determination)

Scenario 2
Least-cost mix
(IRP 2019 cost assumptions)

Scenario 3
Least-cost mix
(CSIR cost assumptions)

Annualised cost of power generation in R-bln/year over 60 years



Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Utilising input assumptions from DMRE IRP 2019 and the CSIR;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

What does the nuclear CAPEX need to be in order to be cost neutral with import hydro or the least-cost mix?

Nuclear Capex needs to be ~ 35–50% less than IRP 2019 cost assumption

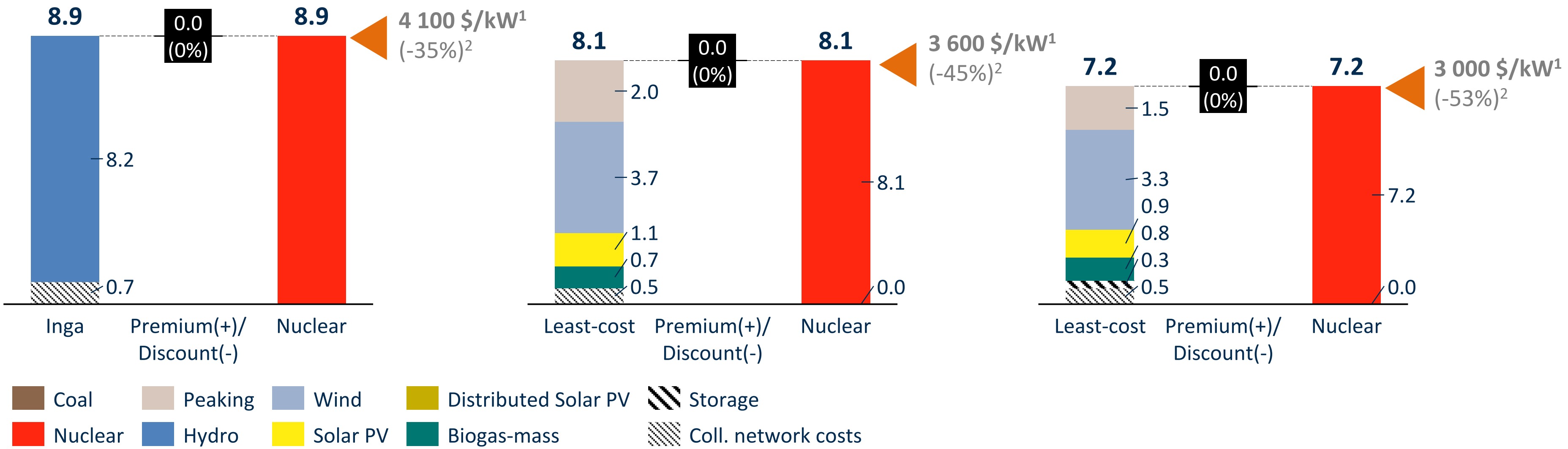
Nuclear CAPEX tipping point

Scenario 1
2 500 MW Nuclear
(New determination)

Scenario 2
Least-cost mix
(IRP 2019 cost assumptions)

Scenario 3
Least-cost mix
(CSIR cost assumptions)

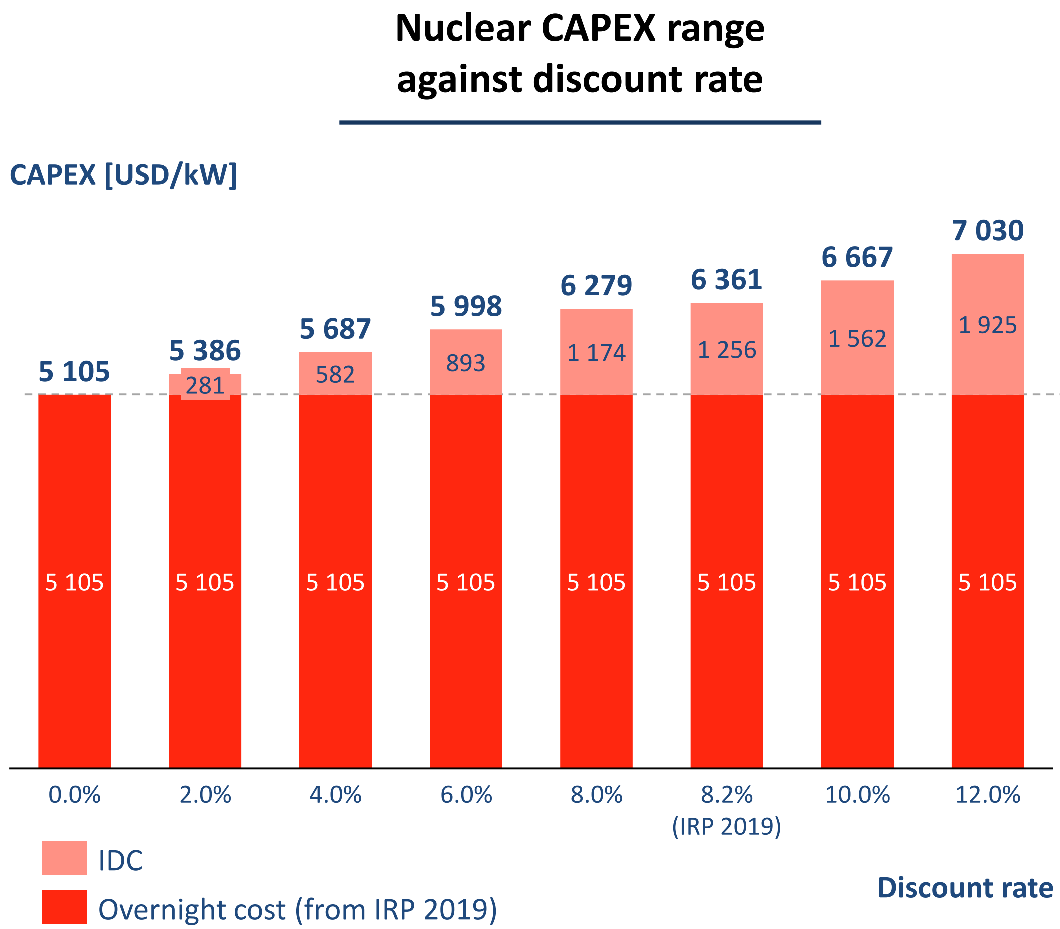
Annualised cost of power generation in R-bln/year over the next 60 years
(discounting from today, 2020)

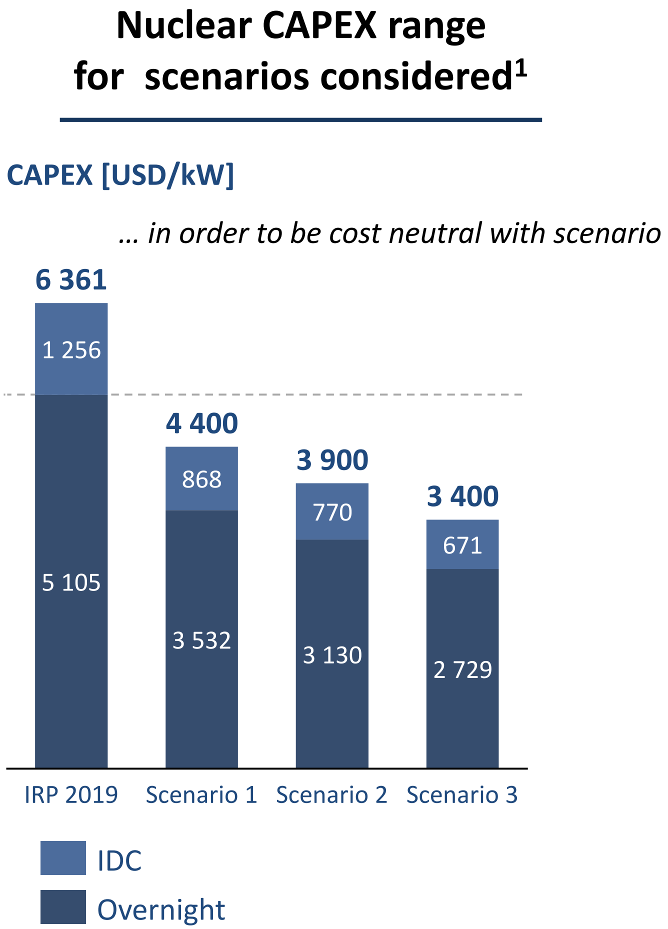


[1] Nuclear CAPEX (Overnight Cost plus IDC); [2] Relative to CAPEX assumed in IRP 2019

Notes: 2.5 GW of demand and 18.6 TWh/yr of energy.
Capacity beyond 2030 based on optimisation of 2030-2090 energy mix utilising input assumptions from DMRE IRP 2019 and the CSIR;
Transmission collector costs based on IRP 2019 Annex (Eskom);
Sources: IRP 2019; CSIR Energy Centre analysis

Even with low or no financing costs, it seems that 2 500 MW new-build nuclear capacity would cost more than all alternatives





[1] At identical discount rate as in IRP 2019 (8.2%). Lower discount rate would further drive down the CAPEX break-even for each scenario;
NOTE: Construction period = 6 years
Sources: IRP 2019; CSIR Energy Centre analysis

Agenda

Summary of comments

Gazetted IRP 2019* does not include 2500 MW of new nuclear in the planned energy mix but does include life extension of Koeberg to 2044 and a decision to include 2 500 MW of new-build nuclear capacity

Decision 8 in the IRP 2019 is a deviation from IRP 2019* not justified/supported by published scientific evidence in the NERSA Consultation Paper on concurrence with DMRE Ministerial Determination

Published evidence would aid NERSA & other stakeholders to make a sufficiently informed decision surrounding concurrence with the Ministerial Determination for policy adjustment of 2500 MW of new nuclear capacity

As VRE penetration increases as part of the IRP 2019 there is an increasing need for flexible capacity and a decreasing need for base-supply capacity

The CSIR has again confirmed least-cost future energy mix in South Africa (also confirmed by DMRE and others) is a mix of VRE (solar PV, wind) and flexible capacity including storage as existing coal capacity decommissions. The quantified cost impact of deviation from gazetted IRP 2019 is:

- The inclusion of imported hydro capacity (Inga) in the IRP 2019 is a deviation from least-cost & results in an additional ~R 1.6-3.3 bln/yr more than least-cost (+10% to +20%)
- The displacement of 2 500 MW of imported hydro (Inga) with 2 500 MW of nuclear results in an additional cost of ~R 6.7 bln/yr (+37%)
- The inclusion of 2 500 MW of nuclear capacity results in an additional cost of ~R 8-10 bln/yr relative to least-cost (+50% to +70%)

*As per Table 5 in the IRP 2019 report

Summary of comments

Should electricity demand be lower than expected by 2030 (-10%), the sensitivity of a nuclear investment with the associated construction times is significantly higher than for alternative supply options part of least-cost

New-build nuclear construction costs will need to be 30-50% lower than assumed in the IRP 2019 in order to break-even with the already planned imported hydro (Inga) or the least-cost portfolio of technologies

When considering low financing costs for prospective new-build nuclear, CAPEX costs still remain higher than the break-even analysis undertaken for imported hydro and the least-cost portfolio of technologies

Broader economic impacts associated with policy adjustment have not been published by DMRE or Nersa and should be made available to stakeholders for consideration (CSIR have quantified costs impact only)

- CSIR have quantified cost impact of prospective 2 500 MW imported hydro (Inga) or nuclear deployment relative to least-cost
- Impacts in other dimensions including CO_2 emissions, water usage, localised emissions (PM, SOx, NOx), employment and economic impact of these options and prospective localisation needs to be undertaken and published for all stakeholder consideration

Fundamental energy planning principles have demonstrated how base-demand does not need to be met with base-supply capacity but instead by a portfolio of options - which could be least-cost or a combination of other technologies that deviates from least-cost

Summary of comments

Global experience with new-build nuclear capacity (whether large-scale or SMR) indicates it is unlikely that 2500 MW of nuclear capacity will come online by 2030 as indicated in IRP 2019

- Initial construction time for new nuclear capacity of ~6 years on average in the 1970s (range of 4-7 years) escalated to 8-9 yrs in the three decades thereafter
- In the 2010s, average construction times of 8.0 yrs have been seen with ranges of 5-13 years being experienced (lower end dominated by China)

CSIR have demonstrated that even under very ambitious CO_2 emissions trajectories for the South African power sector, nuclear does not from part of the least-cost energy mix and is instead met by VRE technologies and flexible capacity (including storage)

Agenda

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Thank you

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