Submitted to DoE on 25 October 2018

Formal comments on Integrated Resource Plan (IRP) 2018

CSIR Energy Centre
Pretoria. 25 October 2018

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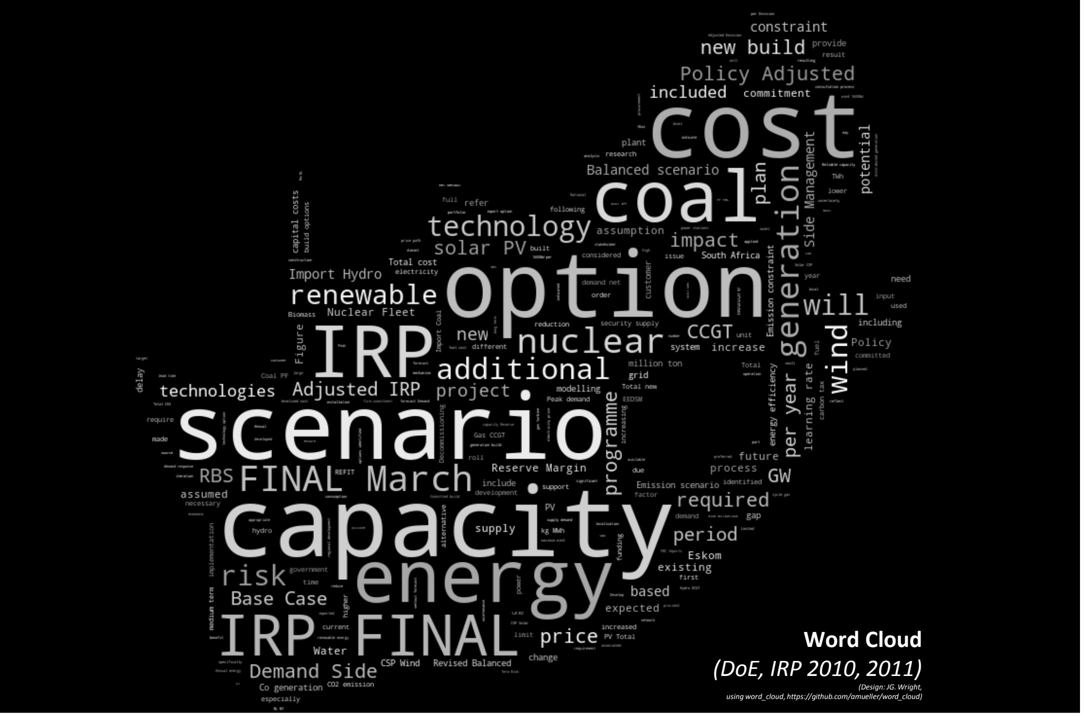
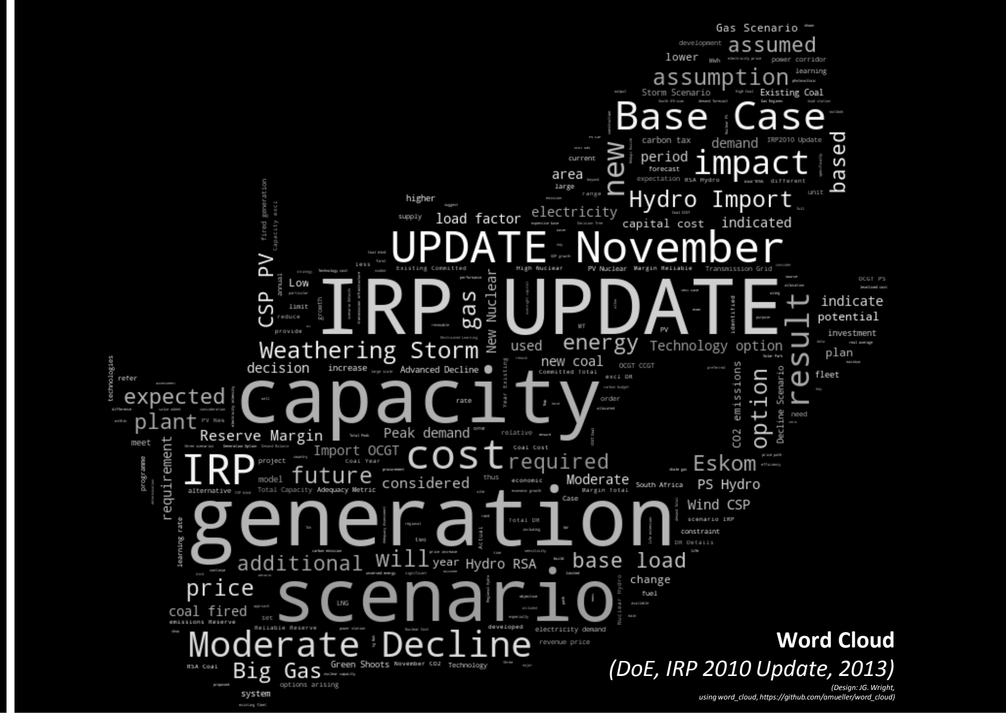


Word Cloud
(DoE, IRP 2010, 2011)
(Design: JG. Wright,
using word_cloud, https://github.com/amueller/word_cloud)



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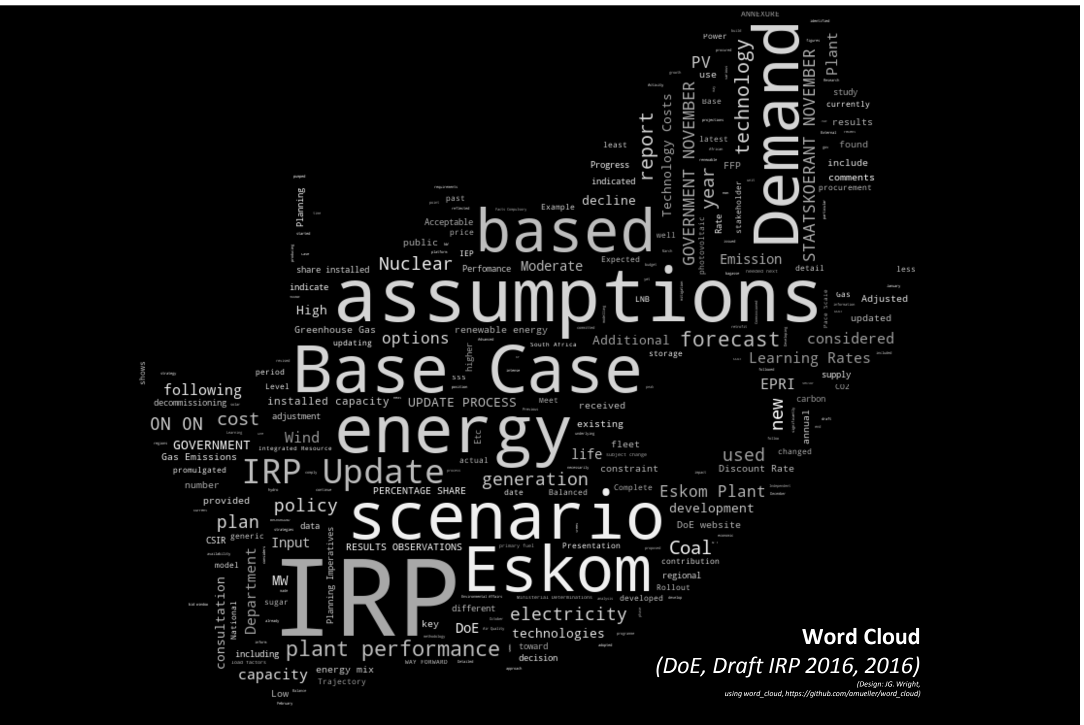

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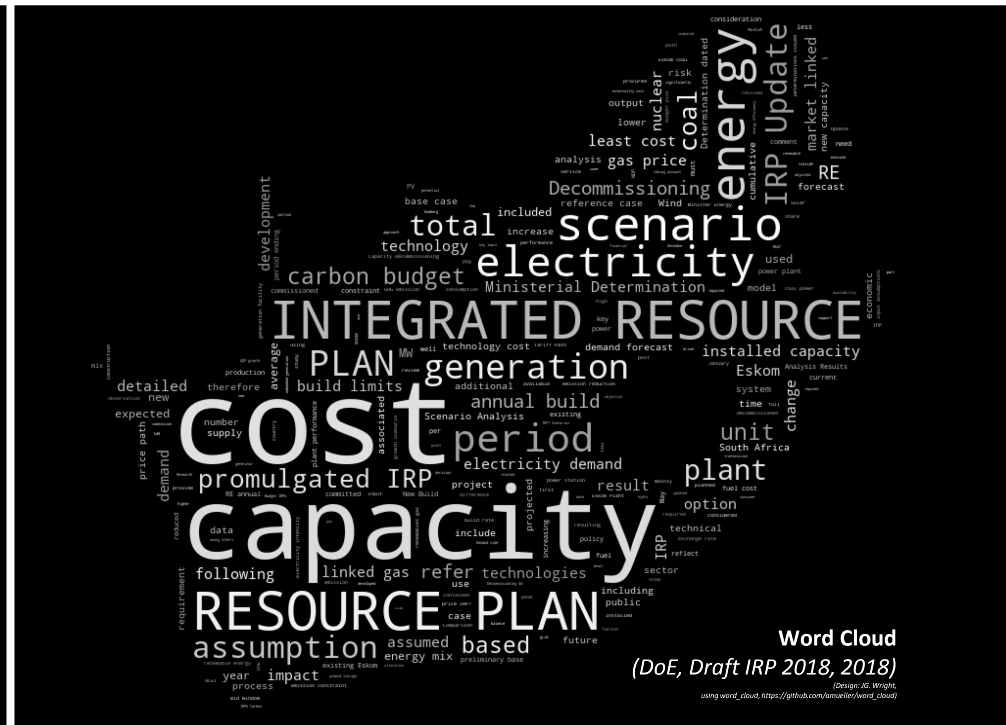

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Formal comments on Draft IRP 2018

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Formal comments on Draft IRP 2018

Key Messages

Key Messages

Draft IRP 2018 is a very different plan to the Draft IRP 2016 and establishes solid principles

VRE (PV and wind) with flexibility[1] confirmed as least-cost energy mix as existing coal fleet decommissions; This energy mix also exhibits the least CO_2 emissions and least water usage

Demand growth impacts the timing of new-build capacity but energy mix remains largely unchanged

New-build coal only post-2030 if CO_2 emissions are not too restrictive and new-build VRE is constrained

New-build nuclear only post-2030 if CO_2 emission are restrictive and new-build VRE is constrained

[1] Natural gas fired peaking and mid-merit capacity considered as a proxy for this.
NG - Natural gas; PV – Solar Photovoltaics; VRE – Variable renewable energy; EAF – Energy Availability Factor; RoCoF – Rate of Change of Frequency

Key Messages

Key Messages

To 2030 - outcomes similar across most scenarios but notable risks;
Eskom coal fleet EAF (and decommissioning schedule), completion of new-build coal, stationary storage and DSR

To 2030, in the Recommended Plan, expect net employment increase (as system grows) but net decrease in coal

Post 2030 - key drivers include VRE new build limits, decommissioning, demand growth, stationary storage

Natural gas risk relatively small and can be replaced by appropriate domestic flexibility sources or stationary storage

No system integration issues foreseen pre-2030 but an informed and co-ordinated work program is necessary to sufficiently prepare for post-2030 relatively high VRE penetration levels

[1] Natural gas fired peaking and mid-merit capacity considered as a proxy for this.
NG - Natural gas; PV – Solar Photovoltaics; VRE – Variable renewable energy; EAF – Energy Availability Factor; RoCoF – Rate of Change of Frequency

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At a glance

Previous CSIR contributions have notably impacted and are mentioned throughout the Draft IRP 2018

- Demand forecast: CSIR (Built Environment) provide this as an input to DoE
- Principles raised by CSIR comments on Draft IRP 2016 have been explicitly considered
- These were: New-build limits removed (IRP1), RE costs aligned with REIPPPP, least-cost Base Case established

CSIR have engaged with key stakeholders in the 60 day public consultation period

- Bilateral engagements: DoE, SALGA, EIUG, Nersa, Eskom
- Attendance at IRP workshops: EE Publishers, FFF, NIASA (requested feedback)
- Tentative: Parliament Portfolio Committee (Energy)

At a glance

Draft IRP 2018 scenario summaries – this is a very different plan to the Draft IRP 2016 and establishes solid principles

- Least-cost confirmed as combination of PV, wind and flexible capacity[1] as coal decommissions – also exhibits lowest CO_2 emissions and water usage by 2050
- Technology new-build limits (PV, wind) mean post-2030 deployment is constrained with new-build coal and gas replacing it (assuming less restrictive CO2 constraints)
- Higher NG price means less NG usage (notable capacity for system adequacy) and increased new-build coal
- More strict CO2 emissions (Carbon Budget) with RE new-build limits means less new-build coal and deployment of nuclear instead
- Higher NG price and more strict CO2 emissions (Carbon Budget) with RE new-build limits means less NG and coal, increased nuclear instead
- Higher/Lower demand forecast means same mix of new-build of PV, wind and flexibility1 just earlier/later

[1] Natural gas fired peaking and mid-merit capacity considered as a proxy for this; NG - Natural gas; PV – Solar Photovoltaics

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Energy mix by 2030 similar across scenarios as coal dominates, IRP1 is ≈R10bn/yr cheaper than next best IRP3, IRP7 lowest CO_2 emissions

Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

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Least-cost mix confirmed as new-build solar PV, wind and flexible capacity (NG) - ≈R15-55 bn/yr cheaper than alternative scenarios

2040

Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

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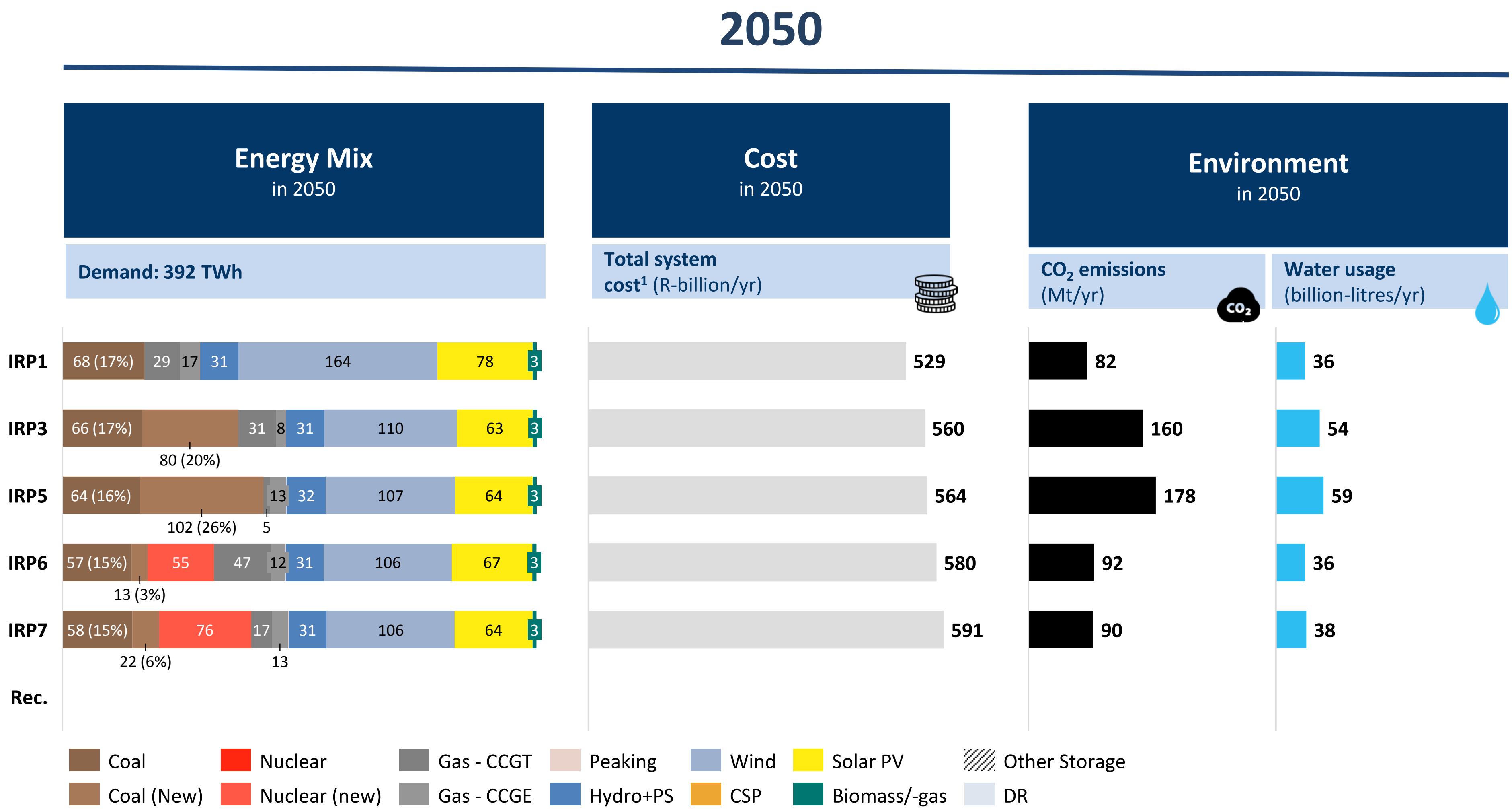
By 2050 - Least-cost mix is 70% solar PV and wind, ≈R30-60 bn/yr cheaper than alternatives, least CO_2 emissions and least water usage

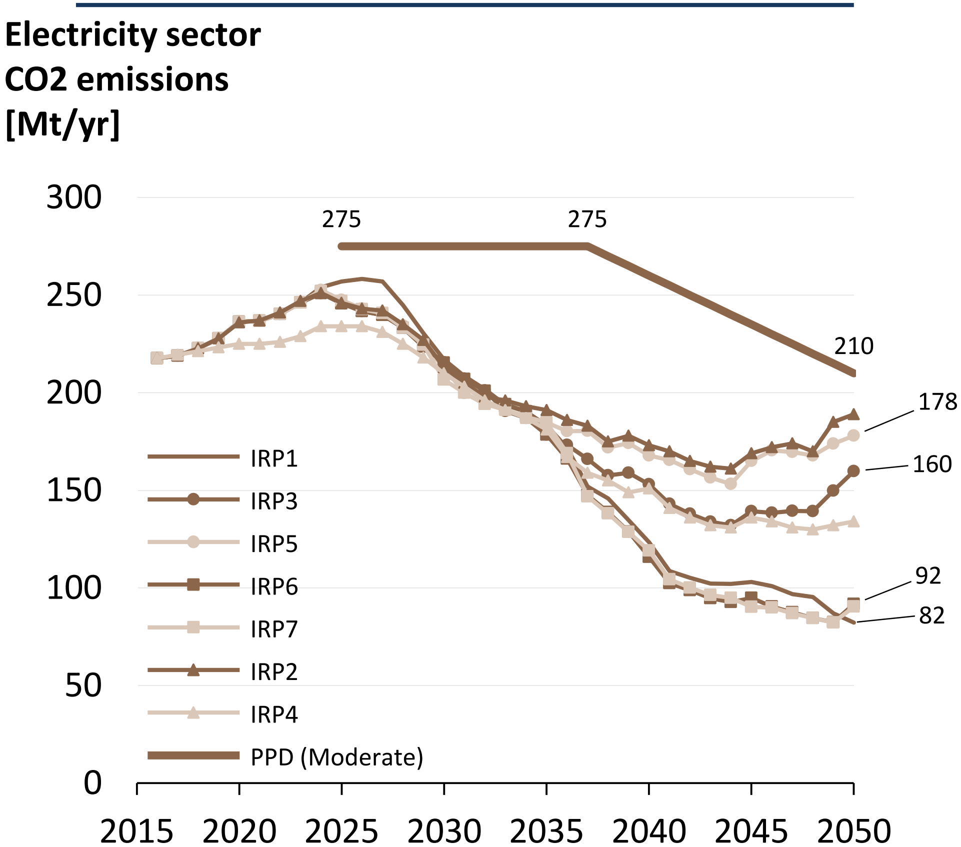


Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

CO2 emissions trajectories for PPD Moderate never binding (only CB) while water use declines as expected as coal fleet decommissions

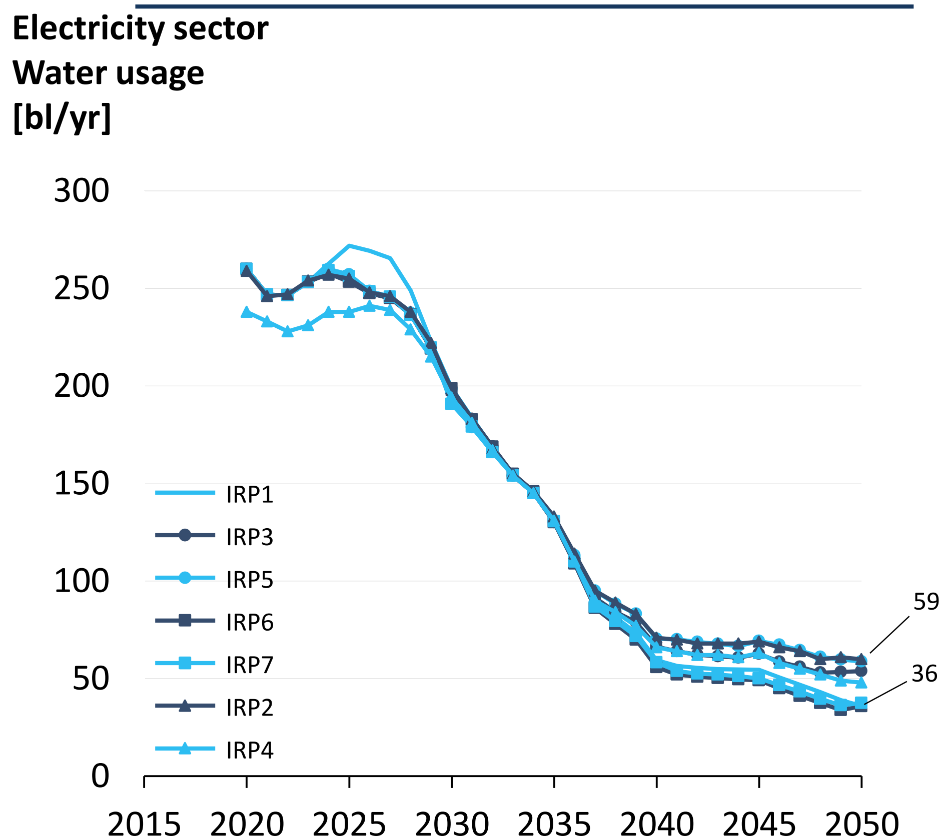
Scenarios from Draft IRP 2018

CO2 emissions



Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

Water usage



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At a glance

Jobs impact of Recommended Plan – reduced role of coal whilst growth in other sectors is expected

- If the Recommended Plan is implemented, there is an employment reduction expected in coal pre-2030
- Overall jobs grow as the power system grows – in solar PV, wind and gas sectors
- This transition needs sufficient preparation – our comments attempt to assist to quantify effects

EAF – Energy Availability Factor
Sources: Eskom; CER

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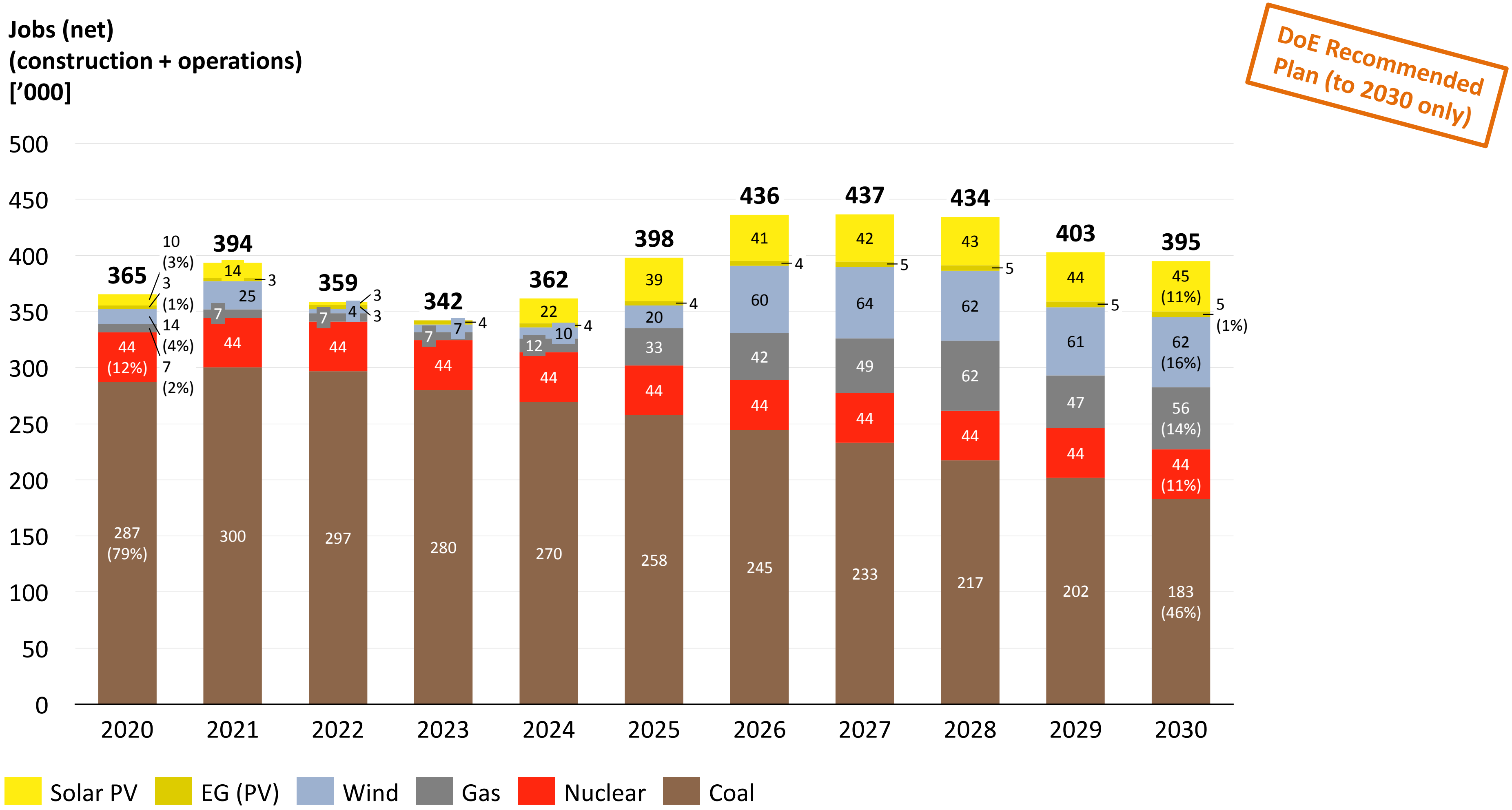
Net reduction of jobs in coal of ≈100k but net gain overall as gas grows to ≈55k jobs towards 2030, RE contributes up to ≈110k by 2030



Sources: Draft IRP 2018; CSIR Energy Centre analysis
Note: Job potential includes direct, indirect and induced jobs; Nuclear is estimated based on existing experience at Koeberg (KPMG, 2017)

At a glance

Key energy planning risks – Existing fleet low EAF, stationary storage, DSR, further RE learning

- Existing fleet Low EAF: Earlier new-build (2023), outcomes return to IRP1 if low demand and low coal fleet performance
- Storage: Decreasing stationary storage costs (batteries) results in deployment pre-2030, less NG usage and increased solar PV
- DSR: A more responsive demand-side test via electric water heating and EVs delays some capacity investment and deploys slightly more solar PV
- Further RE learning: Increased solar PV and wind post-2030 with timing pre-2030 unchanged, no import hydro
- A risk adjusted scenario: Combining storage, DSR and further RE learning results in increased new-build wind, PV, storage and further lower NG use
-





EAF – Energy Availability Factor; DSR – Demand Side Response; Evs – Electric Vehicles
Sources: Eskom; Tesla; BNEF; CSIR

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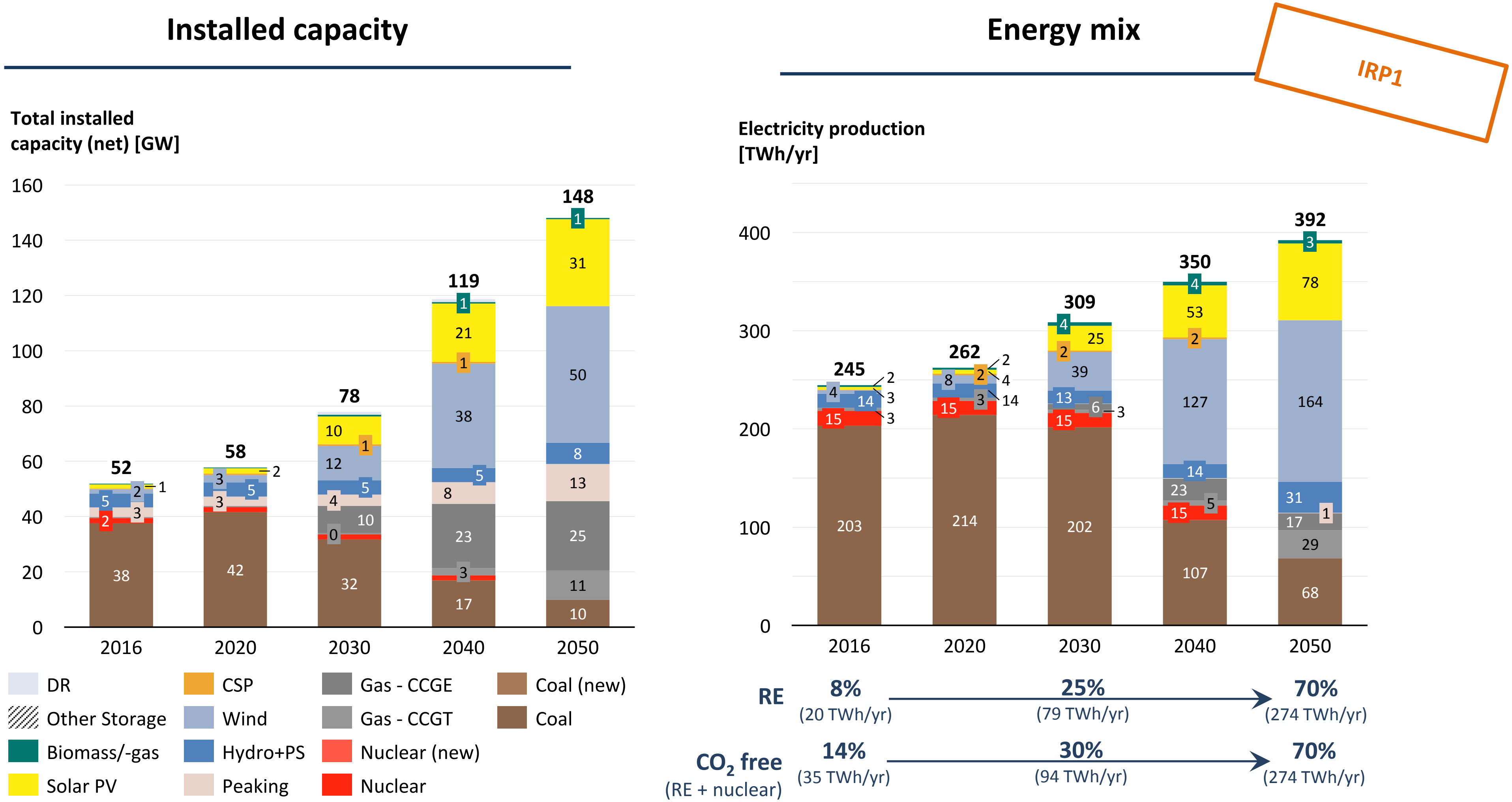
Draft IRP 2018 (IRP1) - Least-cost deploys considerable wind, solar PV and NG capacity to 2030 and beyond as the coal fleet decommissions

Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018



Sources: Draft IRP 2018. CSIR Energy Centre analysis

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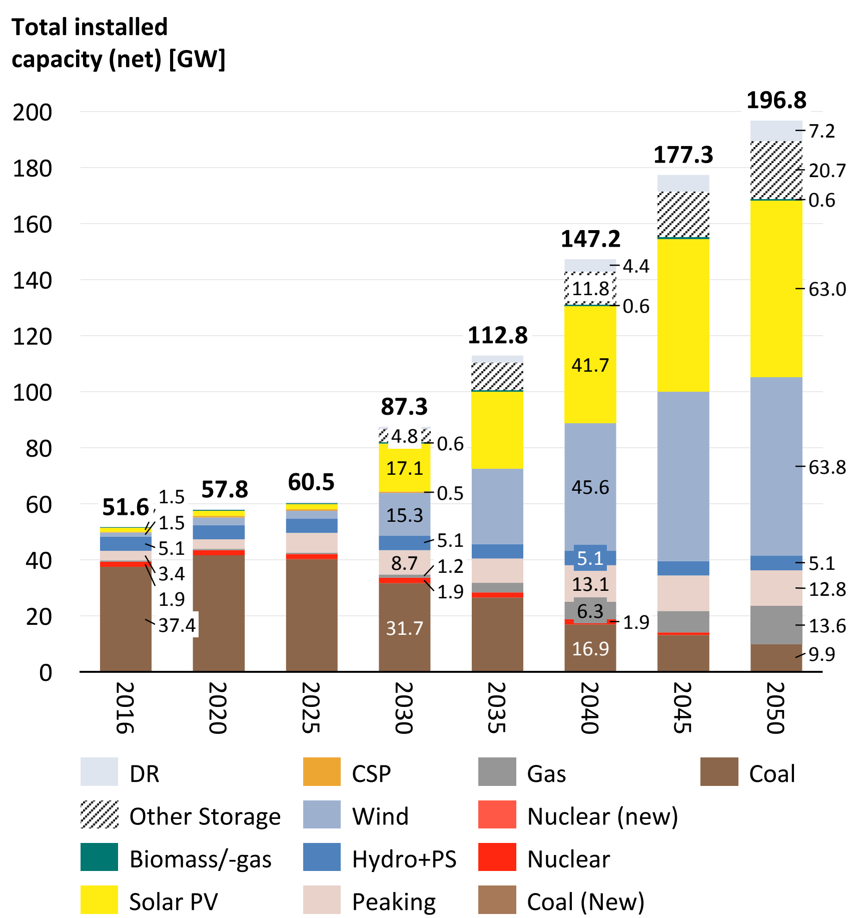
Draft IRP 2018 IRP1 with storage, DSR and lower RE costs results in increased new-build wind, solar PV, storage and less NG

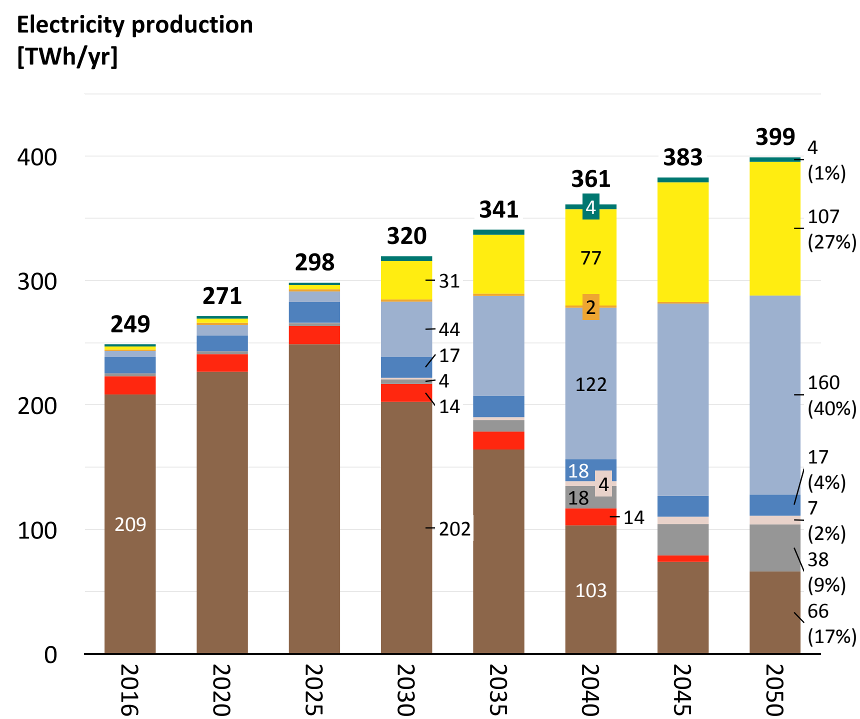
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with storage, DSR and higher RE cost reductions

Risk-adjusted scenario

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2027)	*6.5 GW*
Wind (2027)	*2.1 GW*
OCGT (2024)	*1.9 GW*
Storage (2027)	*1.1 GW*

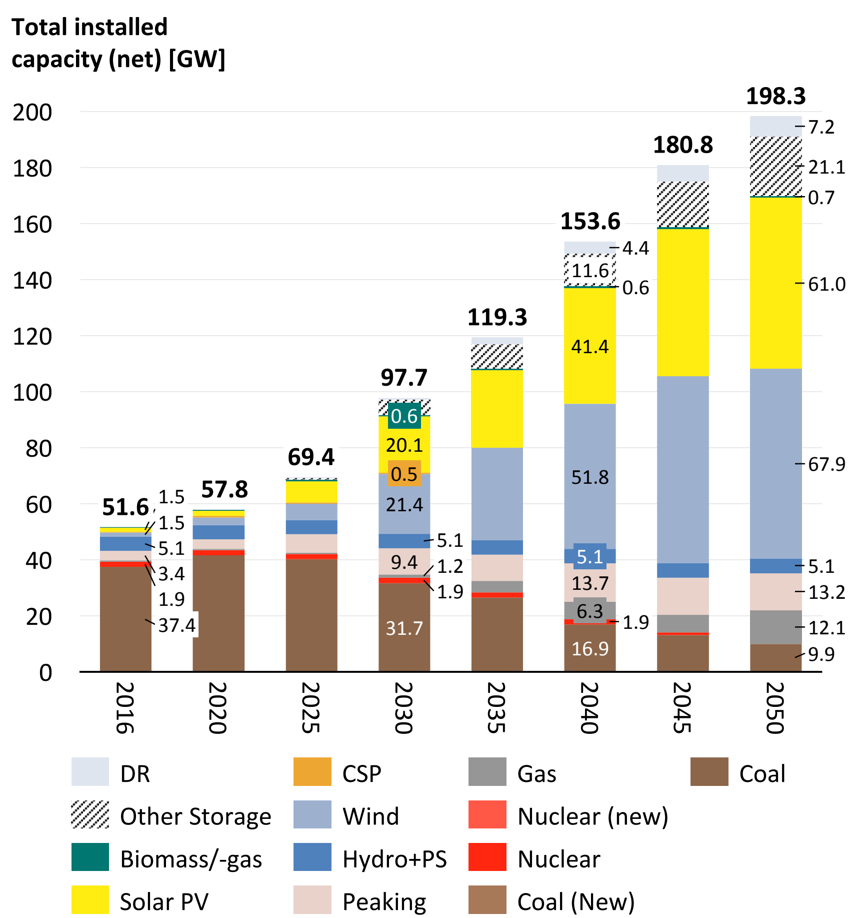
Notes: NG = Natural gas
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Risk-adjusted scenario with Low EAF requires earlier new-build around 2023 too and increased absolute levels of new-build by 2030

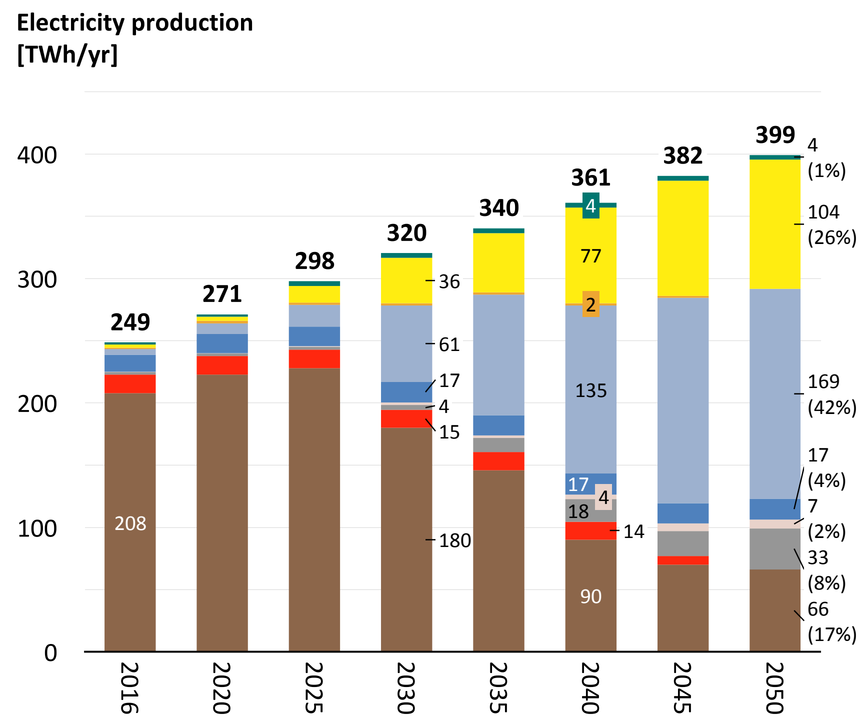
Installed capacity and electricity supplied from 2016 to 2050 for Risk-adjusted scenario with low coal fleet EAF

Risk-adjusted scenario - Low EAF

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2023)	*0.4 GW*
Wind (2023)	*0.2 GW*
OCGT (2023)	*1.9 GW*

Sources: Draft IRP 2018. CSIR Energy Centre analysis

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At a glance

Descriptive inputs/comments – new-build limits, NG import risk and embedded generation

- Technology new-build limits: Still unjustified, constant as power system grows, misaligned with international experience today
- Coal capacity: Investigations reveal that older existing coal capacity could be decommissioned earlier, parts of under construction capacity could be replaced by alternatives and it is not economically optimal to build new coal
- Natural gas import risk: Small role in energy mix (up to 5% pre-2030, 15% by 2050) - can be mitigated by range of domestic options (as well as stationary storage if costs decline)
- Embedded generation: Planning for this is not yet explicit and will need to change (implicit as negative demand)
- Demand profile will change further as different sectors grow, use energy differently and deploy EG for self-use

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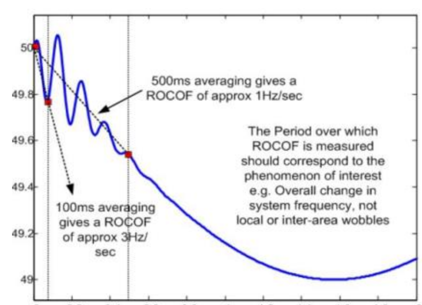
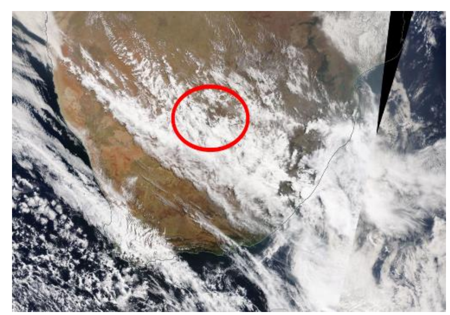
At a glance

System services and technical considerations

- System adequacy consistent across all scenarios i.e. reserve requirements included
- System non-synchronous penetration: No barriers pre-2030. Only above 25% from 2028 and 37% by 2030 for 10% of the time but at above 80% by 2050 i.e. system integration focus becomes important post-2030
- A critical indicator (inertia): No barriers pre-2030. Post-2030 worst case mitigating solution cost is ≈1% of total system cost
- Evolution of other system services need to be investigated for post-2030 transition expected (reactive power and voltage control, system strength)
- Variable resource forecasting will become more important - SO should be equipped will relevant tools and skills





Going forward – Recommendations

Improvements for future IRPs

- Need to have transparency in input assumptions, model and outcomes comprehensively and consistently published
- Investigate and establish the need for annual technology new-build limits;
  Remove annual new-build limits until further investigations establish the need for them
- Optimise the existing coal fleet while remaining cognisant of opportunity cost of capital expenditure on older assets (retrofitting for improved reliability, efficiency and flexibility)
- Inclusion of economic impacts of scenarios. At the very least – employment impacts
- Improved approaches to better understanding demand (sector shifts, load profile shape, price elasticity of demand)
- Better understanding the cost trajectory of all technologies for domestic application on a periodic basis
- Develop and implement an integrated program of work on long-term system integration topics i.e. stability, system strength, reactive power/voltage control (CSIR already initiated CIGRE WG including Eskom and international SOs)
- Focussed consideration and investigation into domestic flexibility options

Going forward – Recommendations

Long-term – structural and strategic

Formally establishing a set of links/triggers between IRP and MTSAO processes (or equivalent)
Periodic updating of the IRP should be prioritised to address dynamic planning environment

Further understanding just transition to address labour and socio-economic impacts in the energy sector

Integrating national and local level energy planning for improved co-ordination and leveraging of opportunities

Sector-coupling opportunities across the full energy sector (not just electricity)

Investigate approaches to include geospatial component of IRP – supply/network/demand (co-optimisation)

Further investigations into impacts/opportunities of new/emerging technologies e.g. stationary storage, EVs, DSR

Formal comments on Draft IRP 2018

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Integrated Resource Plan (IRP): Process for power generation capacity expansion in South Africa

Planning / simulation world

Inputs
1) Demand Forecast
2) Existing Supply Forecast:
- Plants under construction
- Preferred bidders
- Decommissioning
- Plant performance

3) New Supply Options:
- Technology costs **assumptions**
- Technology technical characteristics

4) Constraints:
- CO_2 limits
- Security/adequacy of supply level

IRP modelling framework (PLEXOS®)
LT[1] techno-economic least-cost optimisation

MT/ST[2] production cost testing system adequacy (security of supply)

Output
Per scenario:
- Total system costs
- Capacity expansion (GW)
- Energy share (TWh)
- CO_2 emissions
- Water usage
- Jobs in the electricity sector

After policy adjustment:
- Final "IRP" for promulgation
- Key questions answered:
  - What to build (MW)?
  - When to build it (timing)?

Actuals / real world

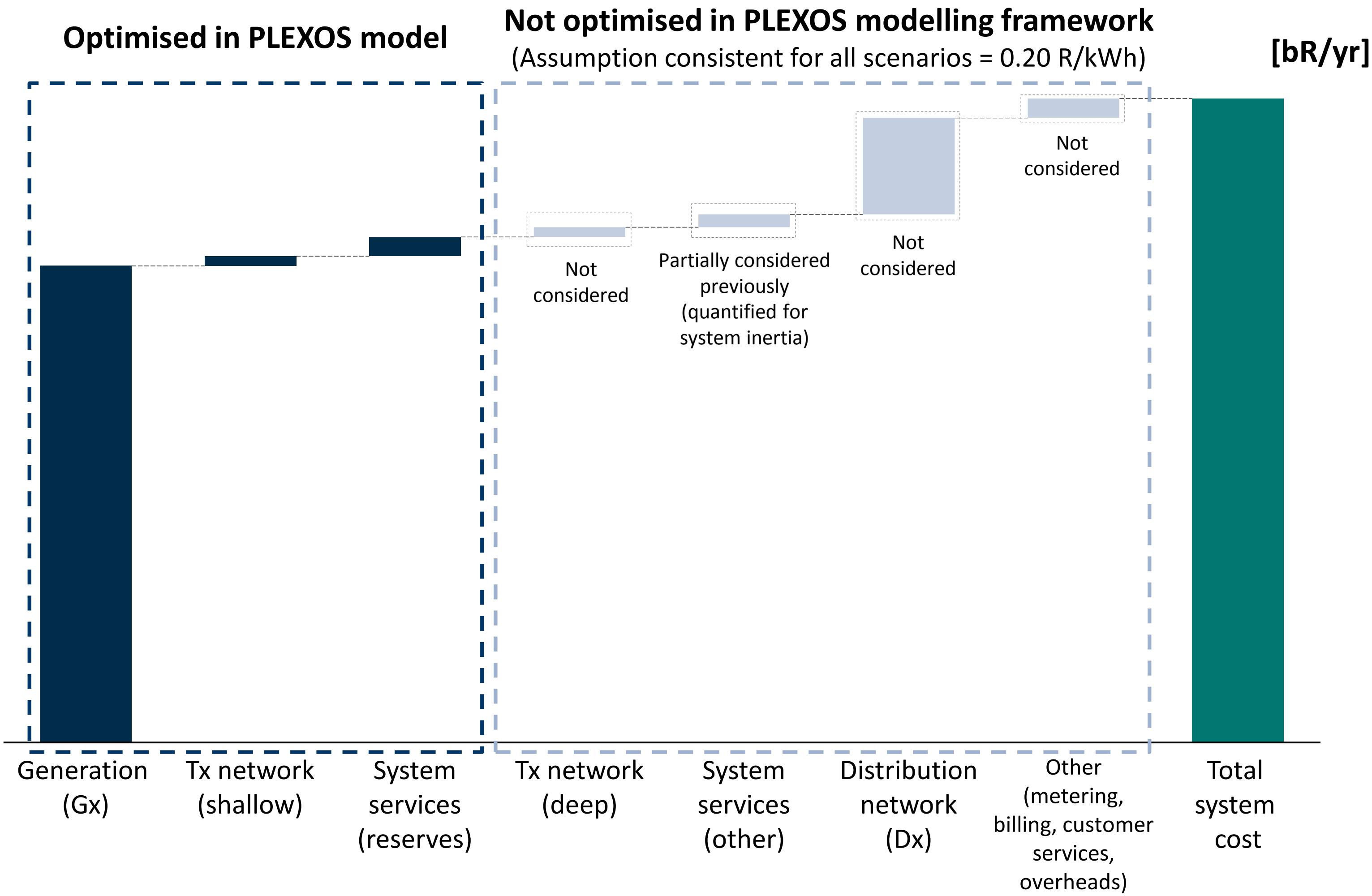
Inputs
- Ministerial Determinations for new technology specific generation capacity

Procurement
(competitive tender e.g. REIPPPP, coal IPPPP)

Outcomes
- Preferred bidders
- MW allocation
- Technology costs **actuals (Ø IPP tariffs)**

[1] LT = Long-term
[2] MT/ST = Medium-term/Short-term

The IRP currently optimises for the dominant generation costs, system reserves (adequacy) and shallow grid cost components of total system cost



Costs included in optimisation model:

- CAPEX (plant level)
- FOM[1]
- VOM[2]
- Fuel
- Shallow grid connection costs

Costs excluded in optimisation model:

- Gx: Externalities e.g. CO_2 emissions costs
- Gx: Decommissioning costs
- Gx: Waste management and/or rehabilitation
- Gx: Major mid-life overhaul
- Tx: Deep costs
- Other system services
- Dx: Distribution network costs
- Other costs

[1] FOM = Fixed Operations and Maintenence costs; [2] VOM = Variable Operations and Maintenence costs; [3] Typically referred to as Ancillary Services includes services to ensure frequency stability, transient stability, provide reactive power/voltage control, ensure black start capability and system operator costs.

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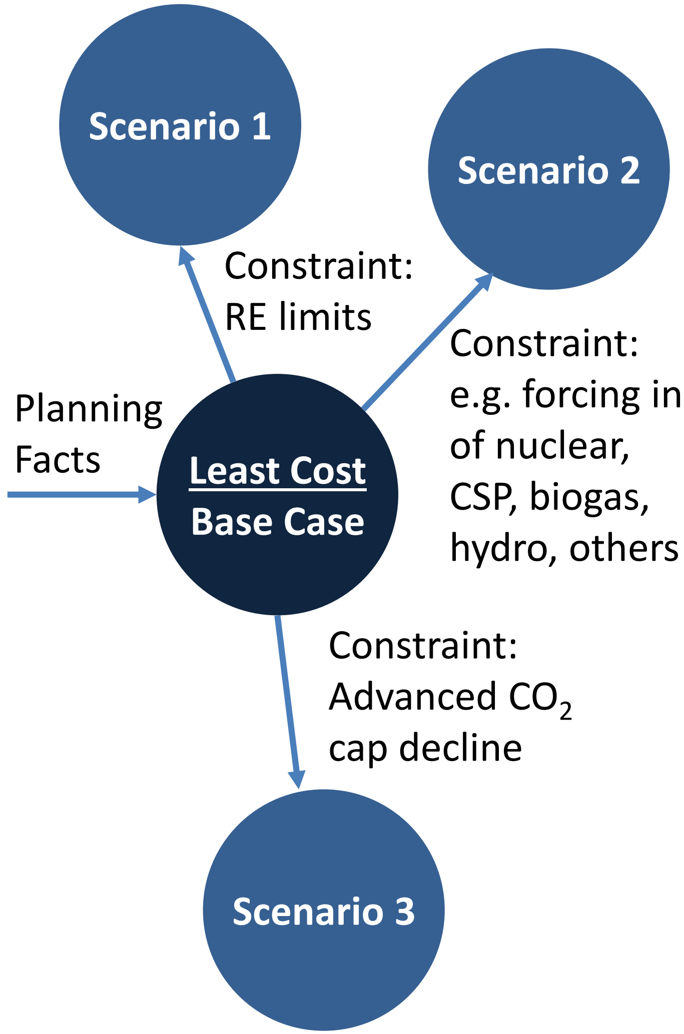
IRP process as described in the Department of Energy's Draft IRP 2016 document: least-cost Base Case is derived from technical planning facts



Case	**Cost**
Base Case	Base
Scenario 1	Base + Rxx bn/yr
Scenario 2	Base + Ryy bn/yr
Scenario 3	Base + Rzz bn/yr
…	…

1. Public consultation on costed scenarios
2. Policy adjustment of Base Case
3. Final IRP for approval and gazetting

Sources: Based on Draft IRP 2018

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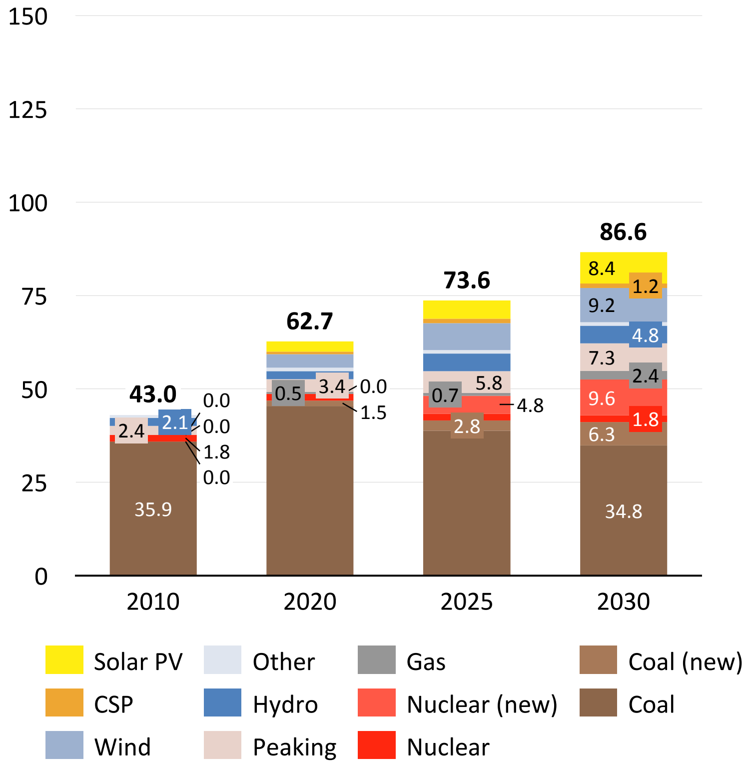
Reminder: IRP 2010 planned the electricity mix until 2030

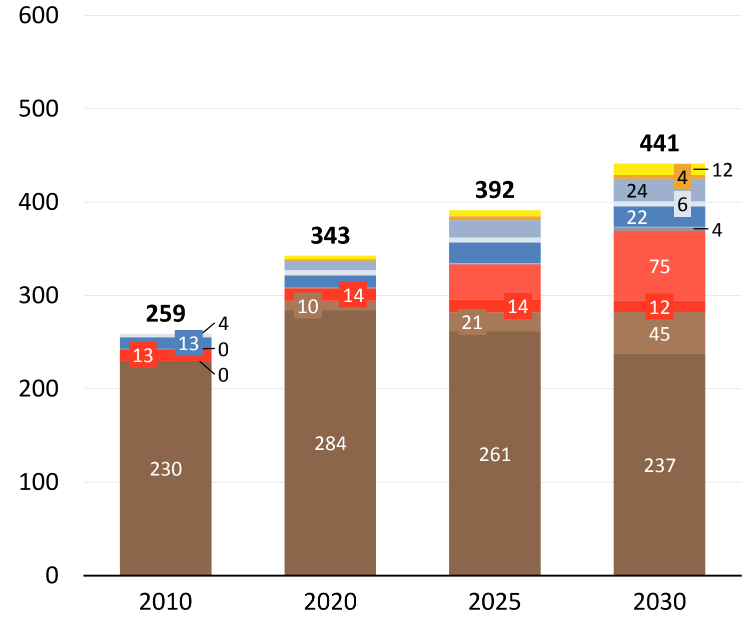
Installed capacity and electricity supplied from 2010 to 2030 as planned in the IRP 2010

Promulgated IRP 2010

Installed capacity



Energy mix



RE 5% (12 TWh/yr) → 14% (62 TWh/yr)

CO_2 free 10% (25 TWh/yr) → 34% (149 TWh/yr)

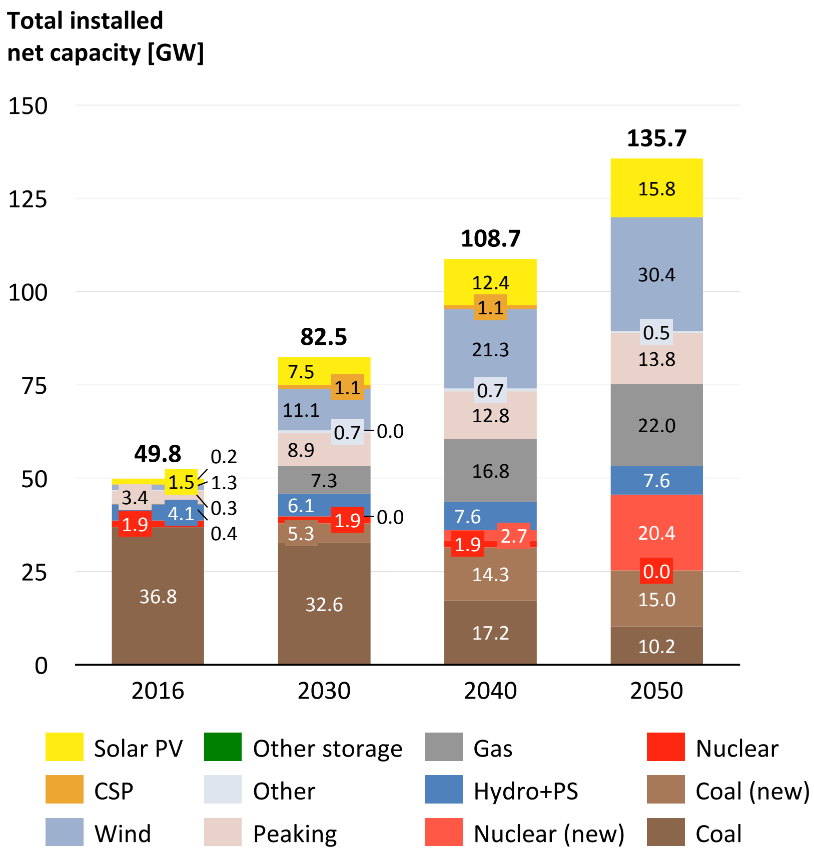
Note: Installed capacity and electricity supplied <u>excludes</u> pumped storage; Renewables include solar PV, CSP, wind, biomass, biogas, landfill and hydro (includes imports).

Sources: DoE IRP 2010-2030; CSIR Energy Centre analysis

Draft IRP 2016 Base Case planned until 2050

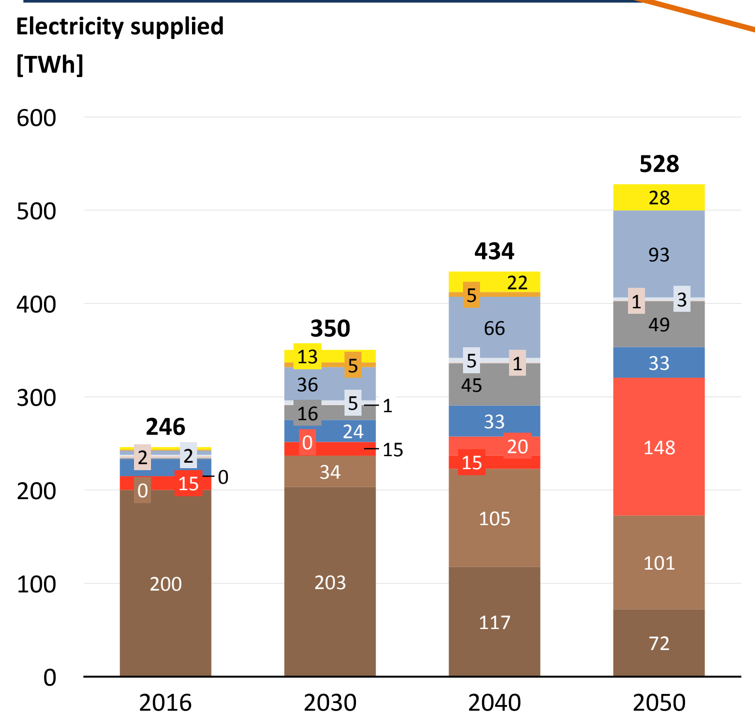
Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2016 Base Case

Installed capacity



Energy mix

Draft IRP 2016 Base Case



RE 10% (25 TWh/yr) → 29% (152 TWh/yr)

CO_2 free 10% (40 TWh/yr) → 57% (300 TWh/yr)

Note: Installed capacity and electricity supplied includes pumped storage; Renewables include solar PV, CSP, wind, biomass, biogas, landfill and hydro (includes imports).
Sources: DoE Draft IRP 2016; CSIR Energy Centre analysis

Formal comments on Draft IRP 2018

A range of scenarios have been assessed as part of the Draft IRP 2018 with key parameter changes

Parameter	IRP1	IRP2	IRP3	IRP4	IRP5	IRP6	IRP7
Demand forecast	Median	Hi	Median	Lower	Median	Median	Median
CO_2 *mitigation*	PPD	PPD	PPD	PPD	PPD	CB	CB
Annual new-build limit (RE)	-	Yes	Yes	Yes	Yes	Yes	Yes
Fuel prices	Const.	Const.	Const.	Const.	Market	Const.	Market.
Tx collector station costs	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Const. - Constant, Market - Natural gas linked to IEA expected market price
PPD - Peak Plateau Decline, CB - Carbon Budget

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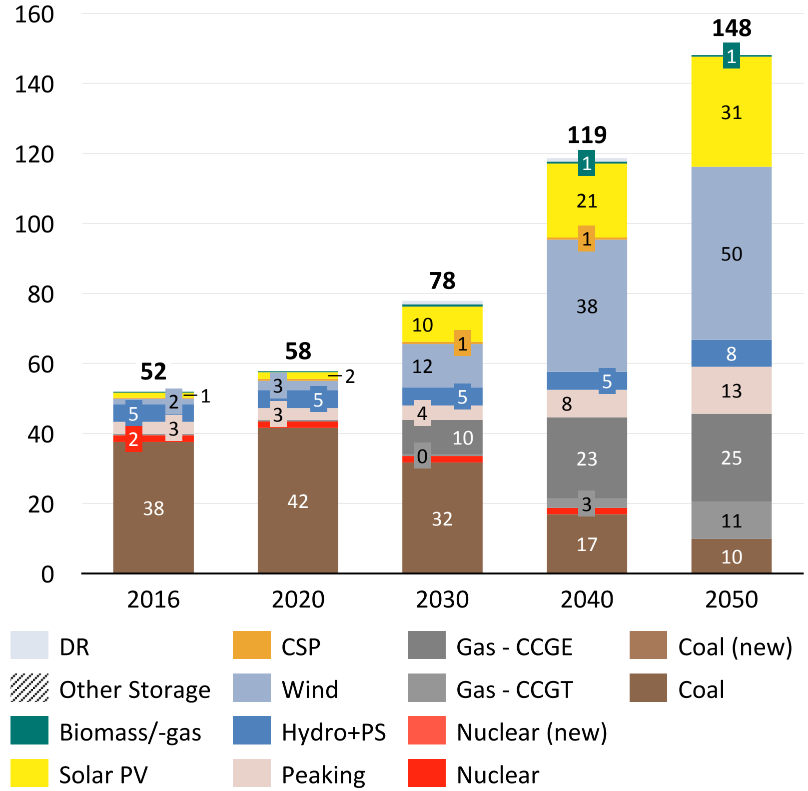
Draft IRP 2018 (IRP1) - Least-cost deploys considerable wind, solar PV and NG capacity to 2030 and beyond as the coal fleet decommissions

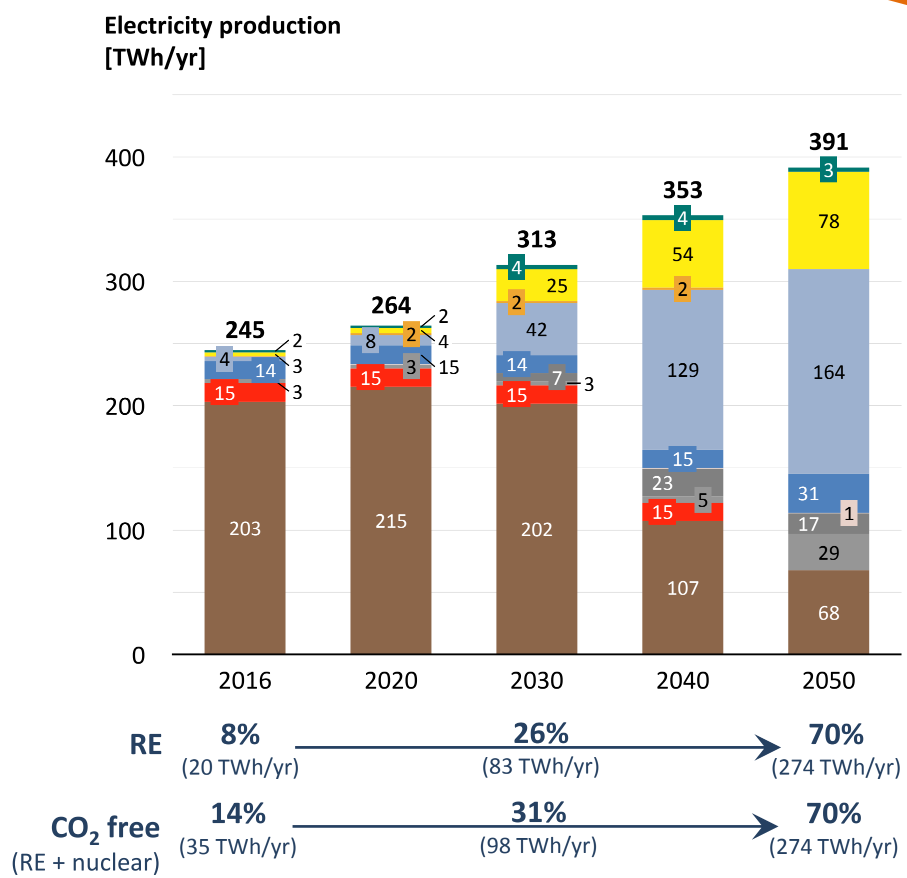
Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix

IRP1

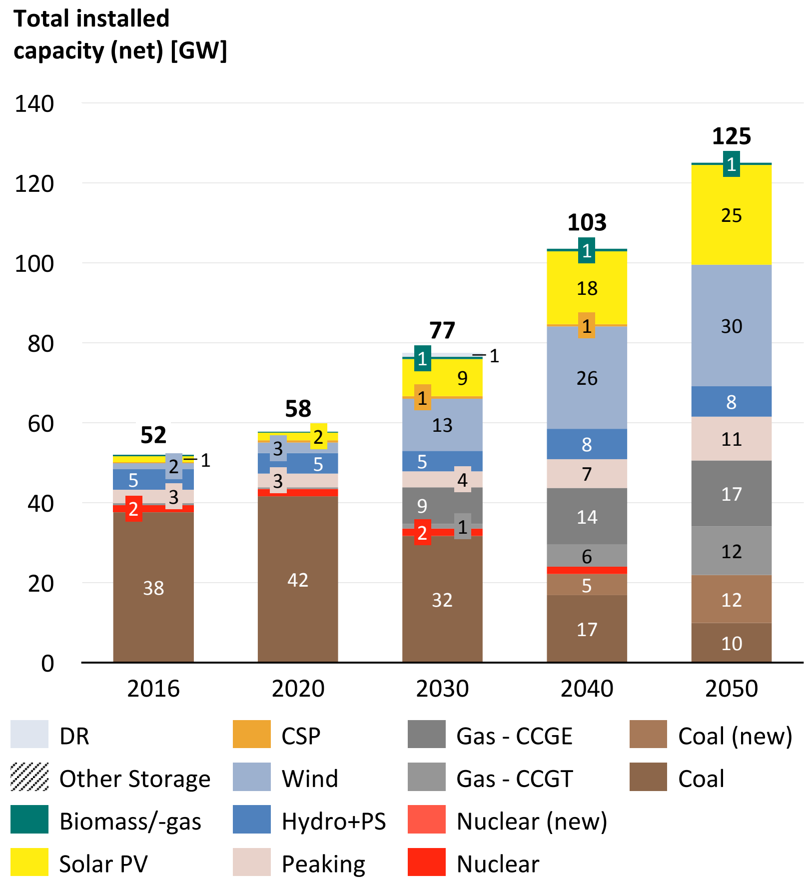


Sources: Draft IRP 2018. CSIR Energy Centre analysis

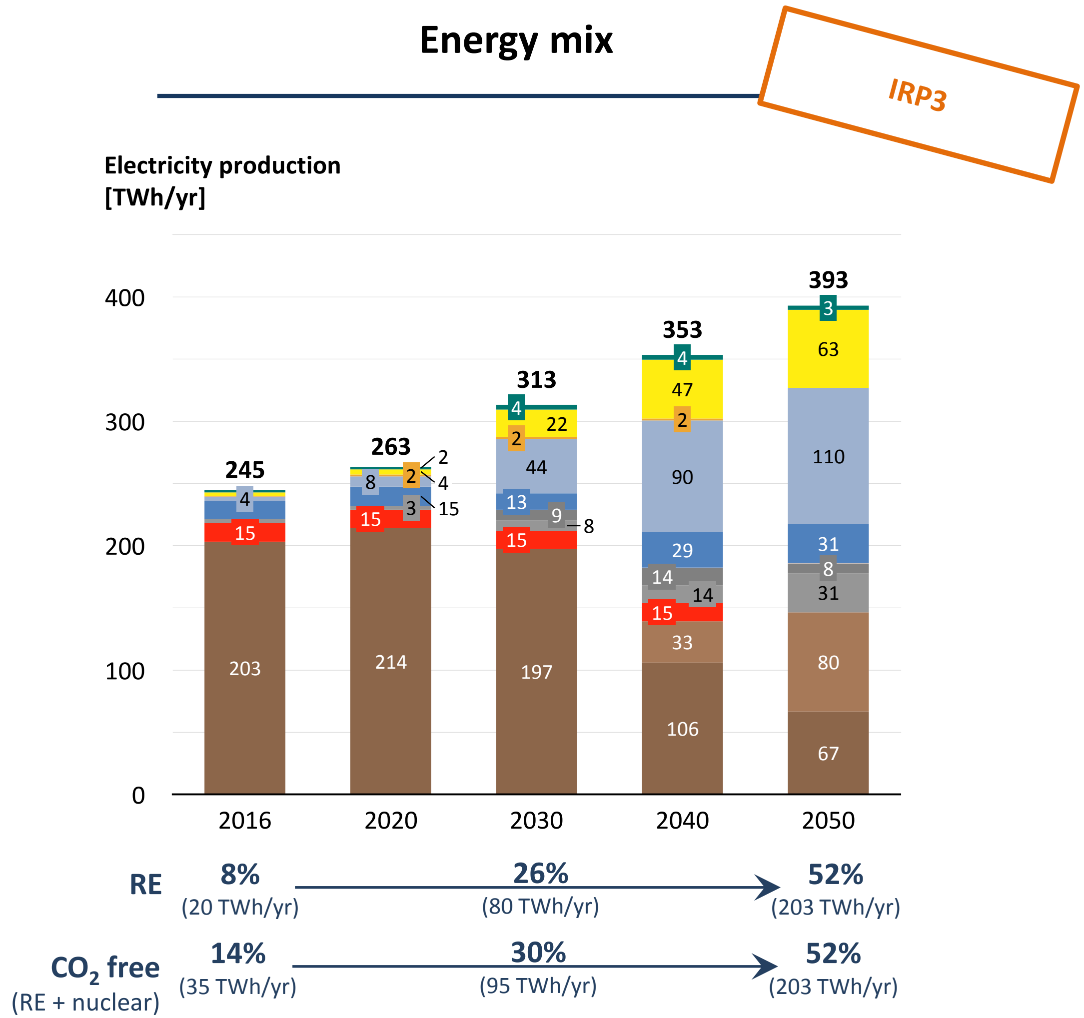
Draft IRP 2018 (IRP3) – RE new-build limits mean post-2030 deployment of solar PV and wind is constrained with new-build coal and gas replacing it

Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix



Sources: Draft IRP 2018. CSIR Energy Centre analysis

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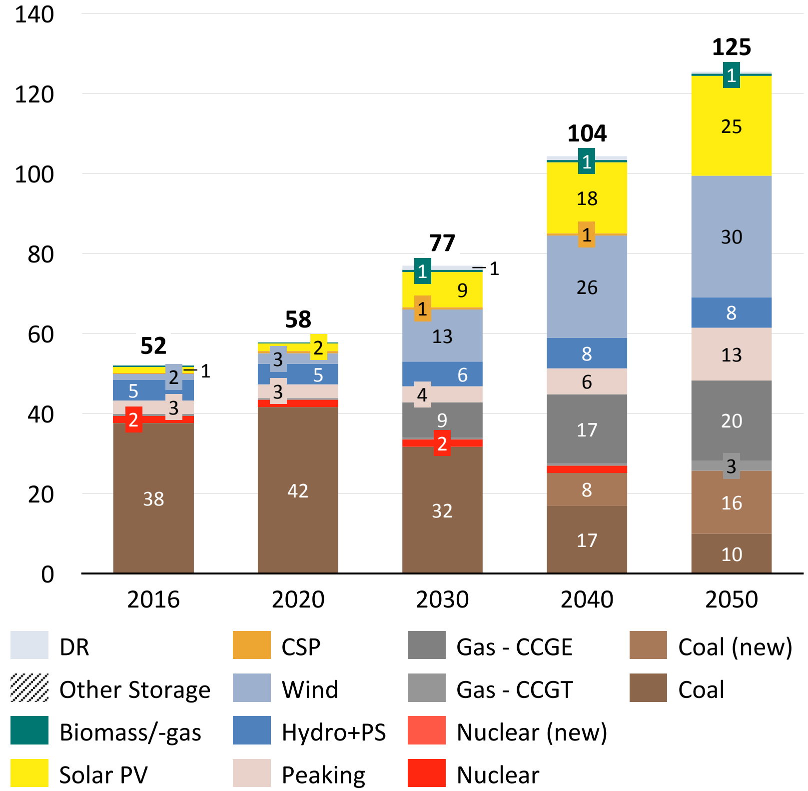
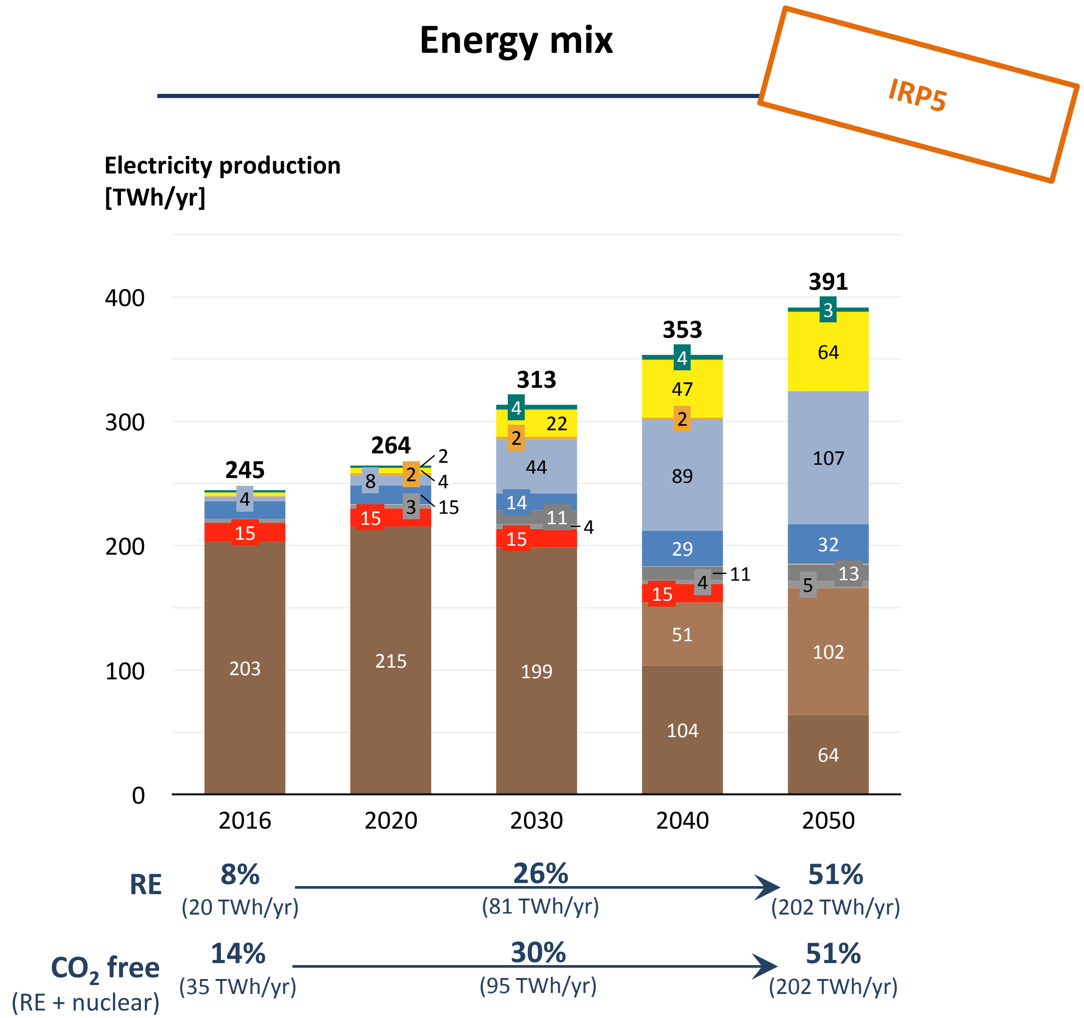
Draft IRP 2018 (IRP5) – Market linked NG price means in less NG usage, notable capacity for system adequacy and increased new-build coal

Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix



Sources: Draft IRP 2018. CSIR Energy Centre analysis

Draft IRP 2018 (IRP6) – Carbon Budget limits new-build coal capacity and deploys new-build nuclear capacity instead

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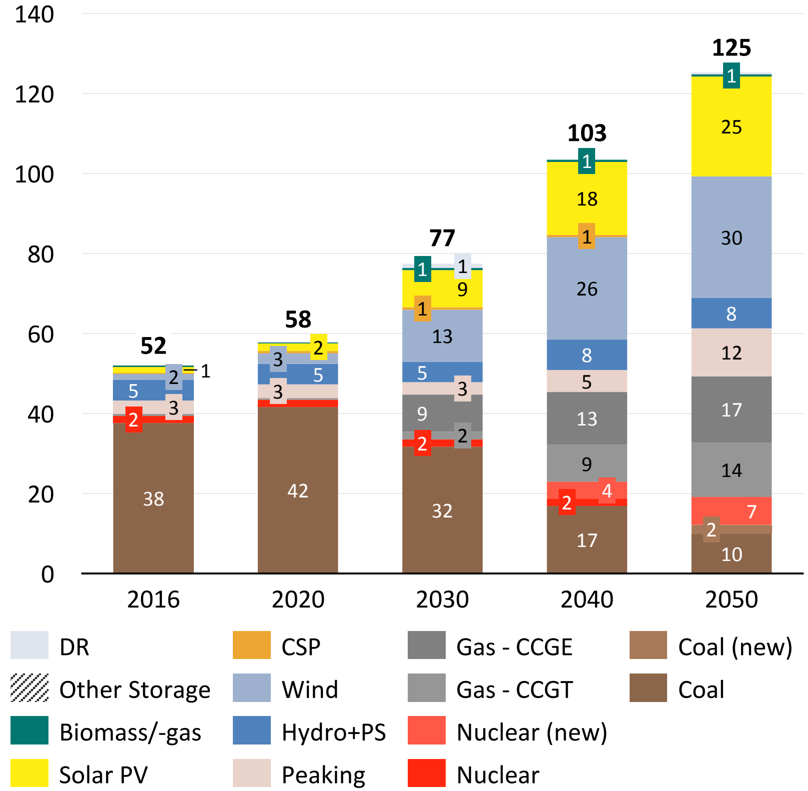
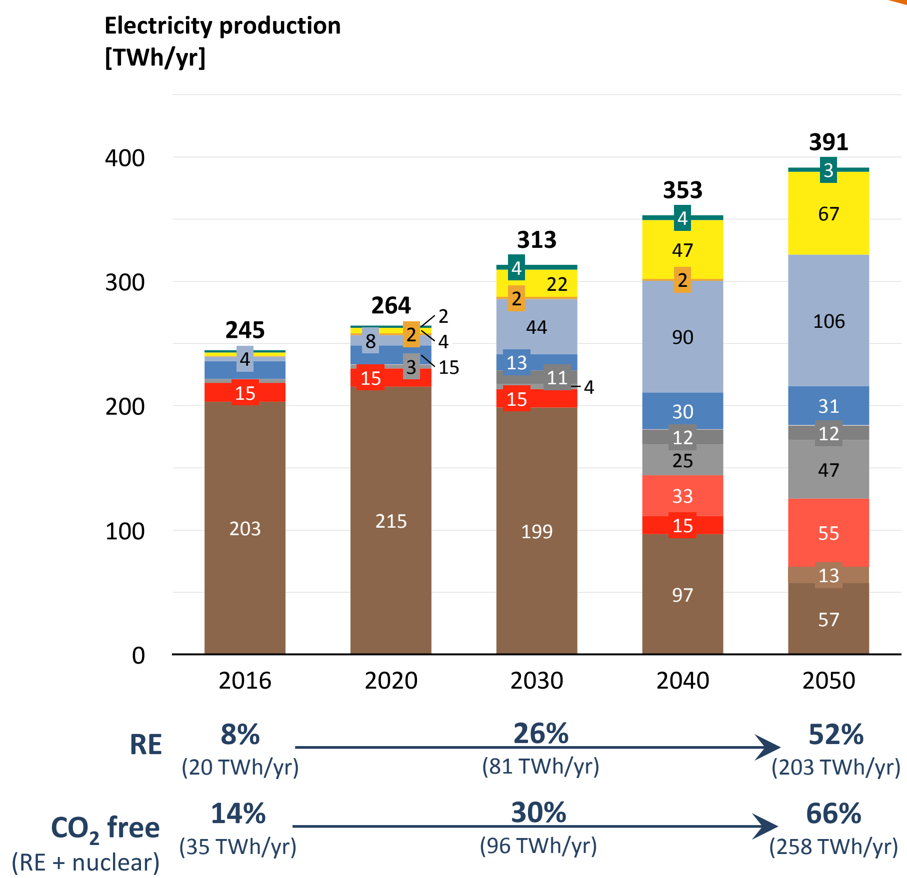
Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix

IRP6



Sources: Draft IRP 2018. CSIR Energy Centre analysis

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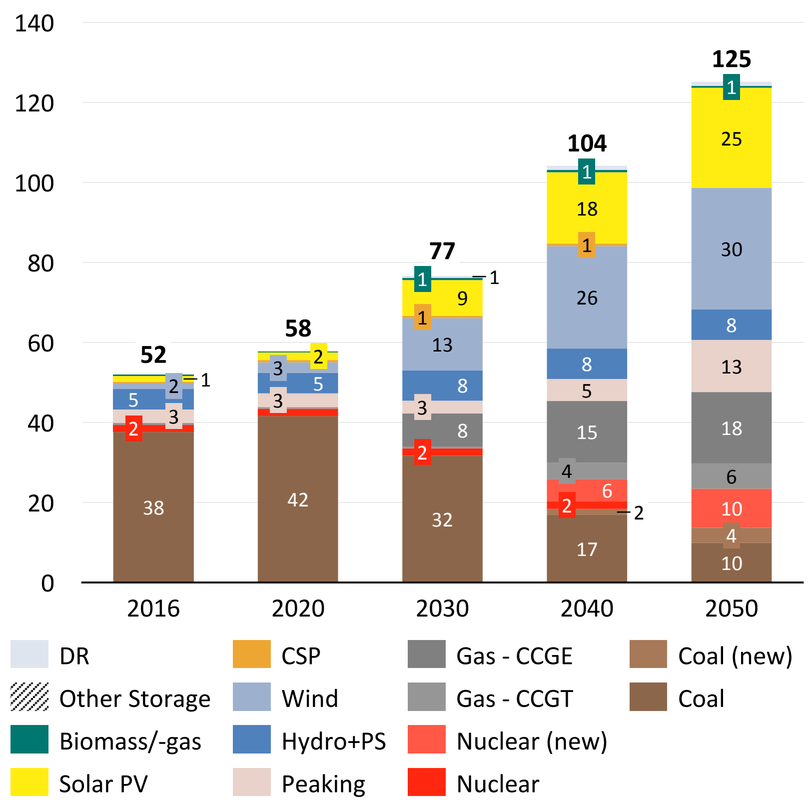
Draft IRP 2018 (IRP7) – Market linked NG price & Carbon Budget combines IRP 5&6 meaning less NG and coal capacity, increased nuclear new-build

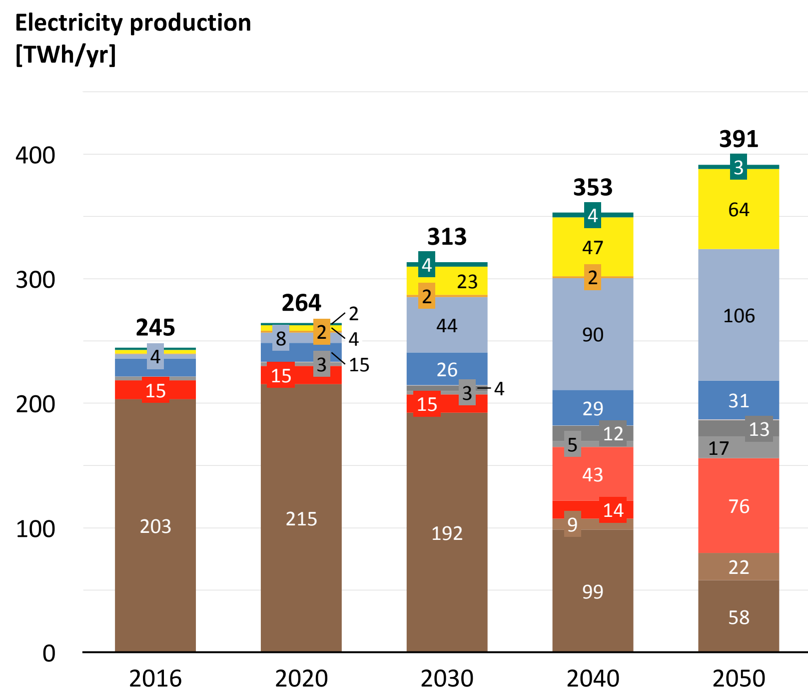
Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix

IRP7

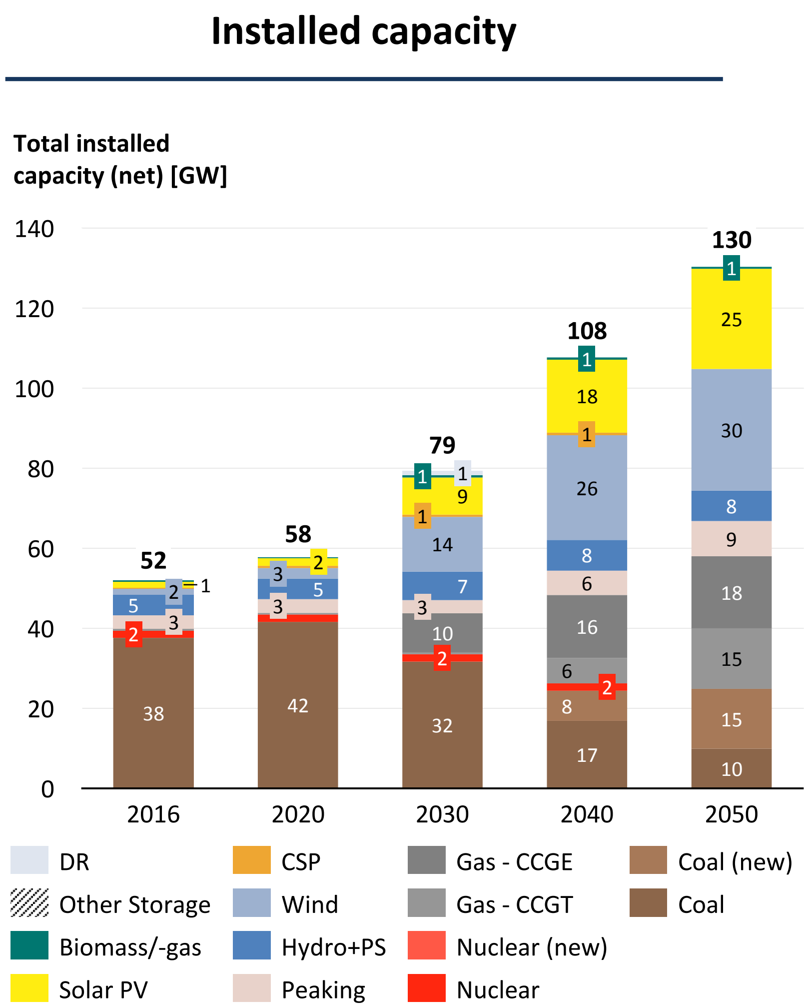


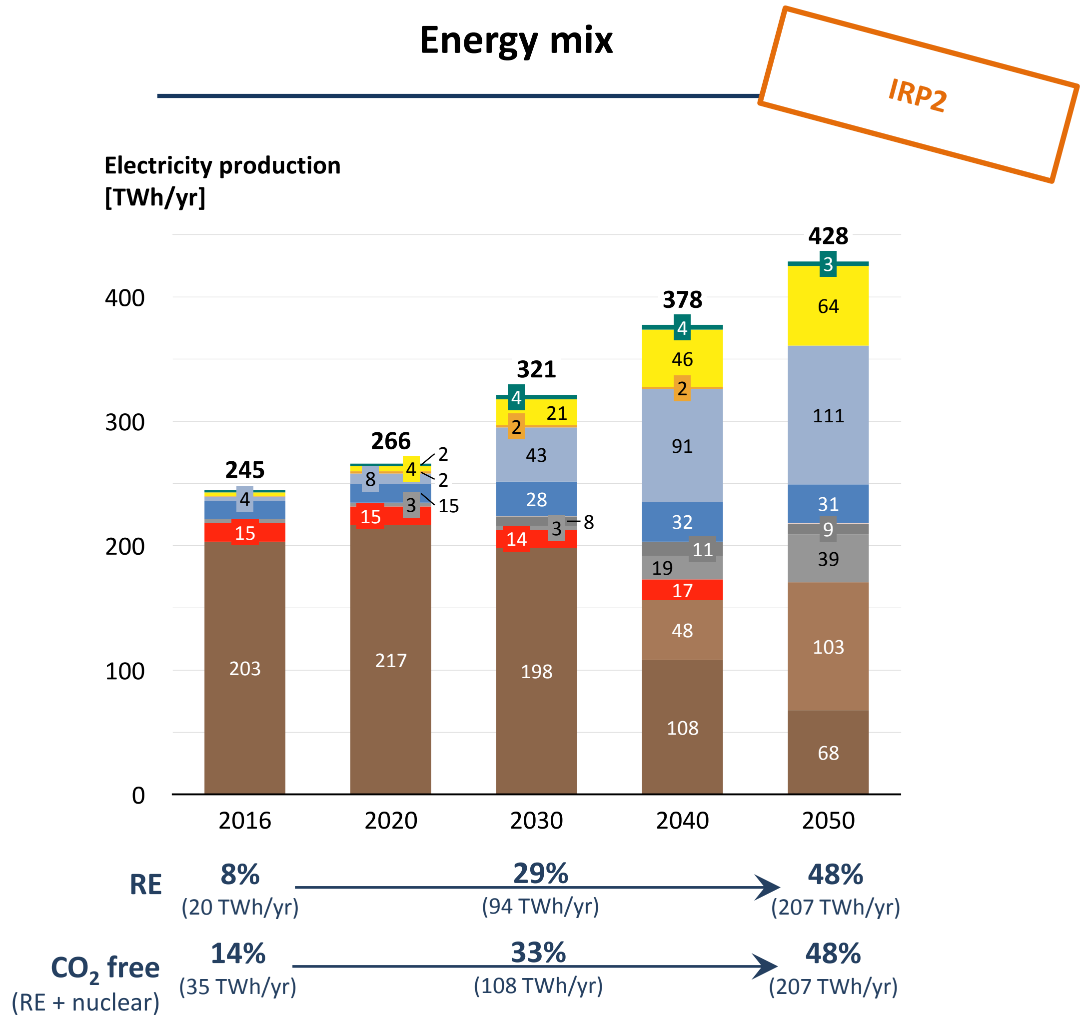
	2016	2030	2050
RE	8% (20 TWh/yr)	30% (95 TWh/yr)	51% (201 TWh/yr)
CO_2 free (RE + nuclear)	14% (35 TWh/yr)	35% (110 TWh/yr)	70% (277 TWh/yr)

Sources: Draft IRP 2018. CSIR Energy Centre analysis

Draft IRP 2018 (IRP2) – Upper Demand forecast with similar outcomes to IRP3 just with earlier first new-build and more new-build overall

Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018





Sources: Draft IRP 2018. CSIR Energy Centre analysis

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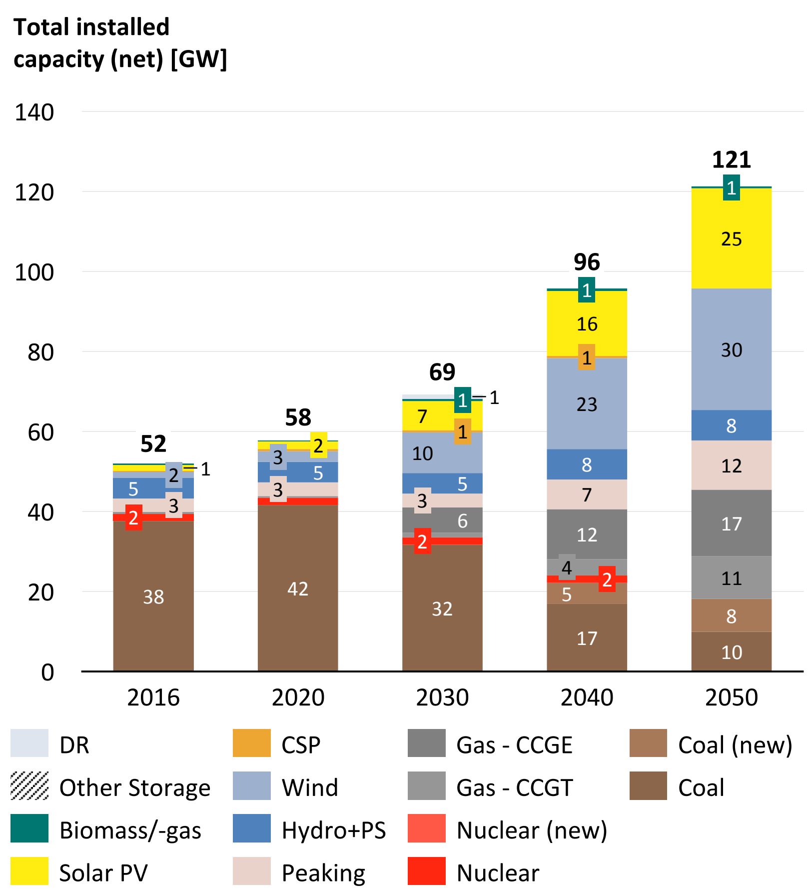
Draft IRP 2018 (IRP4) – Lower Demand forecast with similar outcomes to IRP3 just with later first new-build and less new-build overall

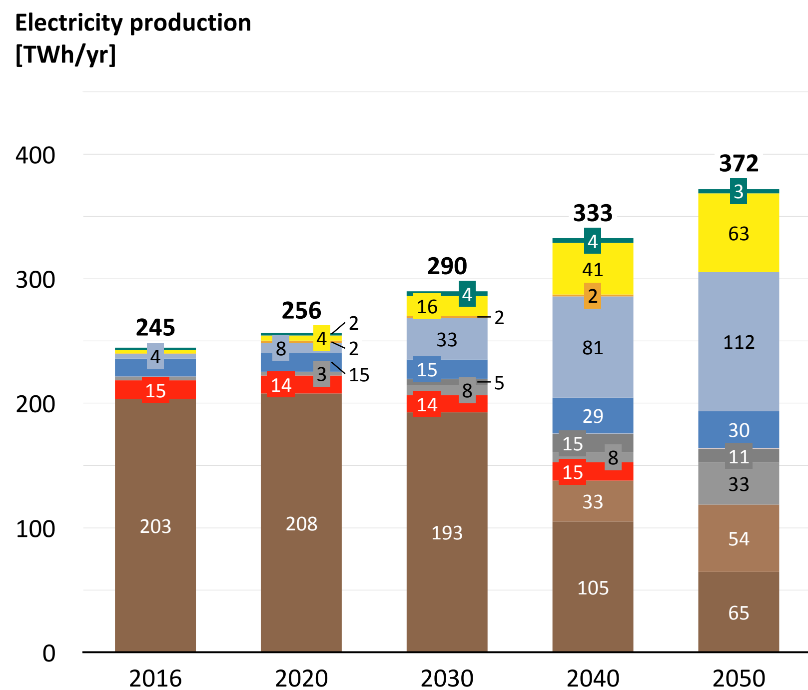
Installed capacity and electricity supplied from 2016 to 2050 as planned in the Draft IRP 2018

Installed capacity



Energy mix

IRP4



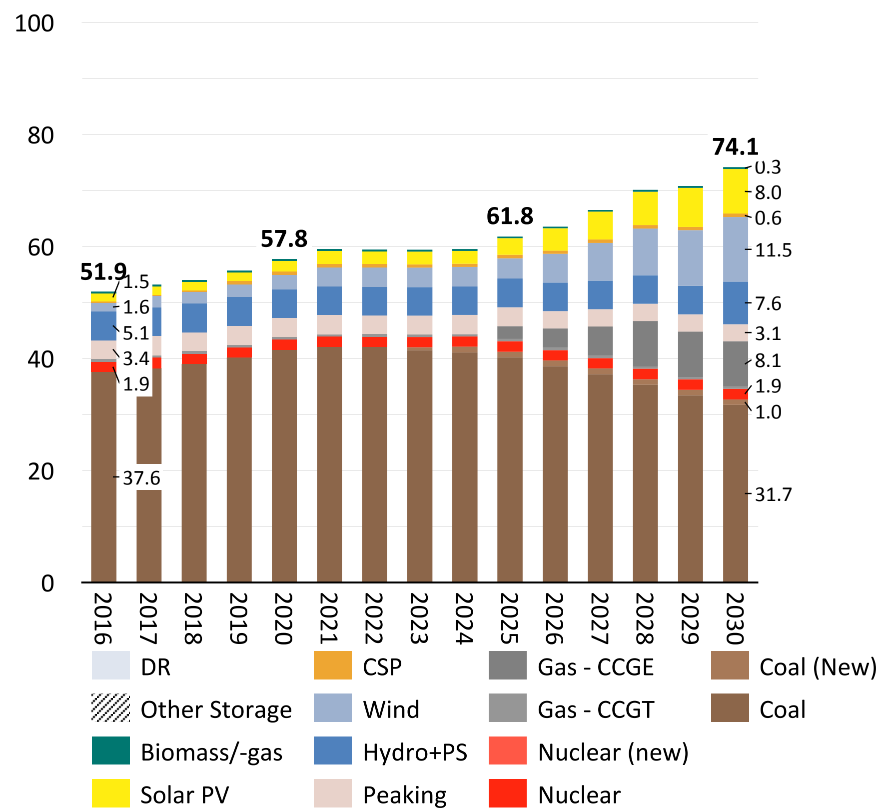
	2016	2030	2050
RE	8% (20 TWh/yr)	23% (66 TWh/yr)	55% (204 TWh/yr)
CO_2 free (RE + nuclear)	14% (35 TWh/yr)	28% (80 TWh/yr)	55% (204 TWh/yr)

Sources: Draft IRP 2018. CSIR Energy Centre analysis

Draft IRP 2018 (Recommended Plan) includes RE new-build limits and policy adjustment for new-build coal and imported hydro

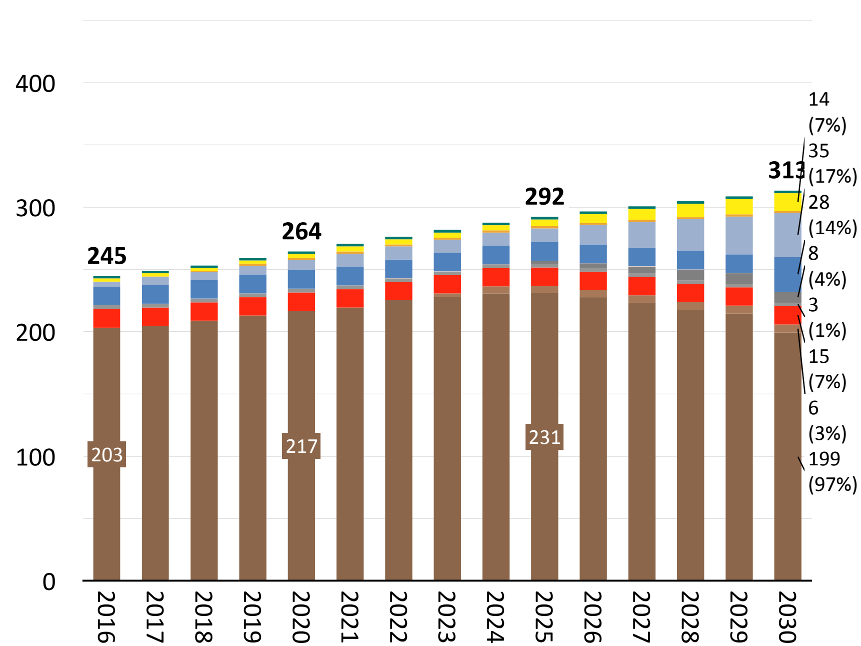
Installed capacity and electricity supplied from 2016 to 2030 as planned in the Draft IRP 2018

Installed capacity



Energy mix

Recommended Plan (to 2030 only)



First new-builds:

Coal (2023)	*1.0 GW*
PV (2025)	*0.7 GW*
Wind (2025)	*0.2 GW*
CC-GE (2026)	*2.3 GW*

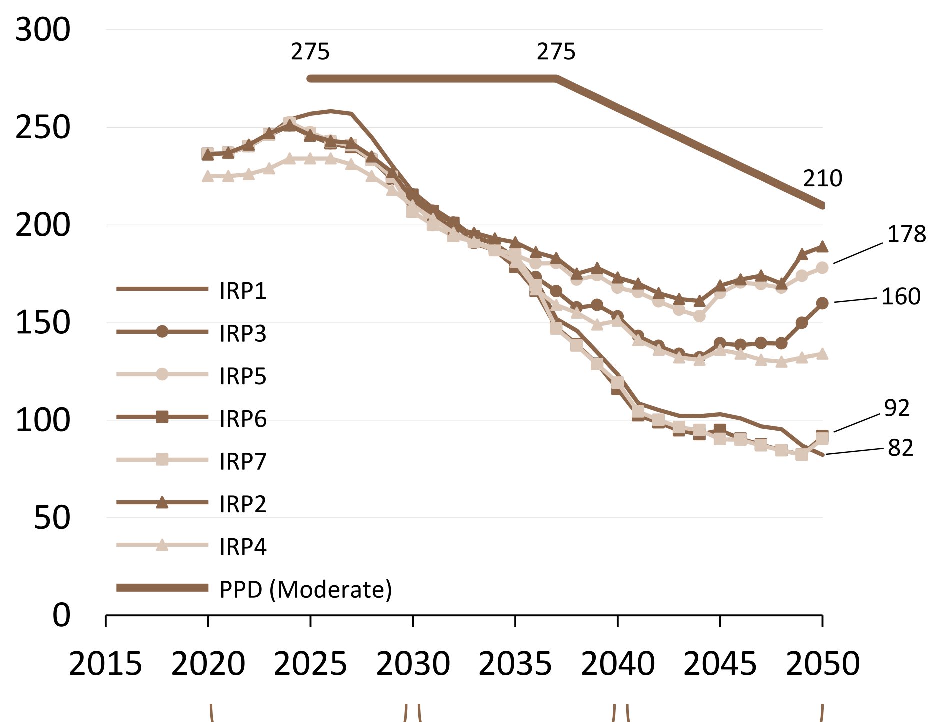
Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO2 emissions trajectories for PPD Moderate never binding (only CB) while water use declines as expected as coal fleet decommissions

Scenarios from Draft IRP 2018

CO2 emissions

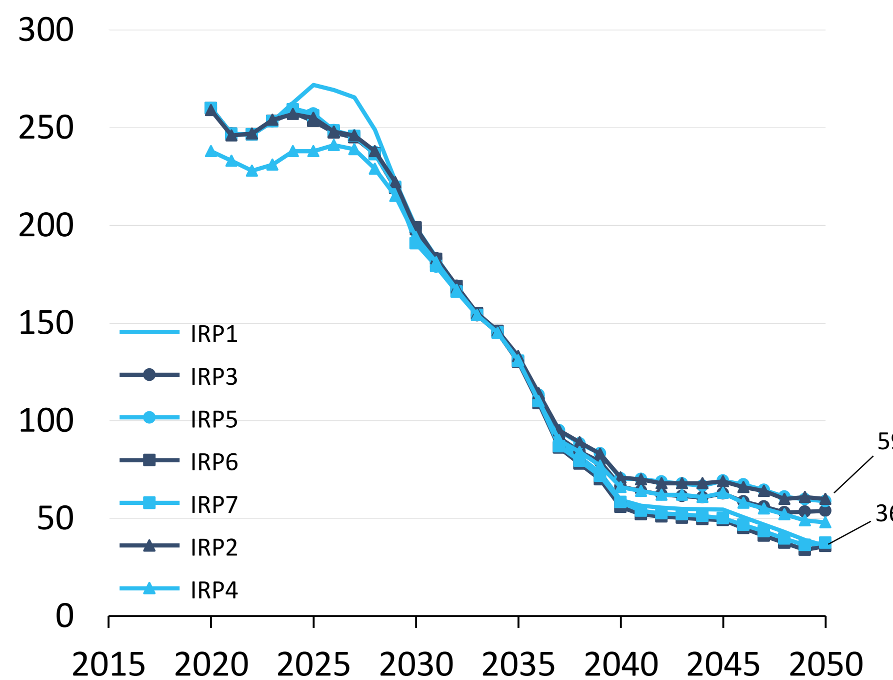
Electricity sector
CO2 emissions
[Mt/yr]



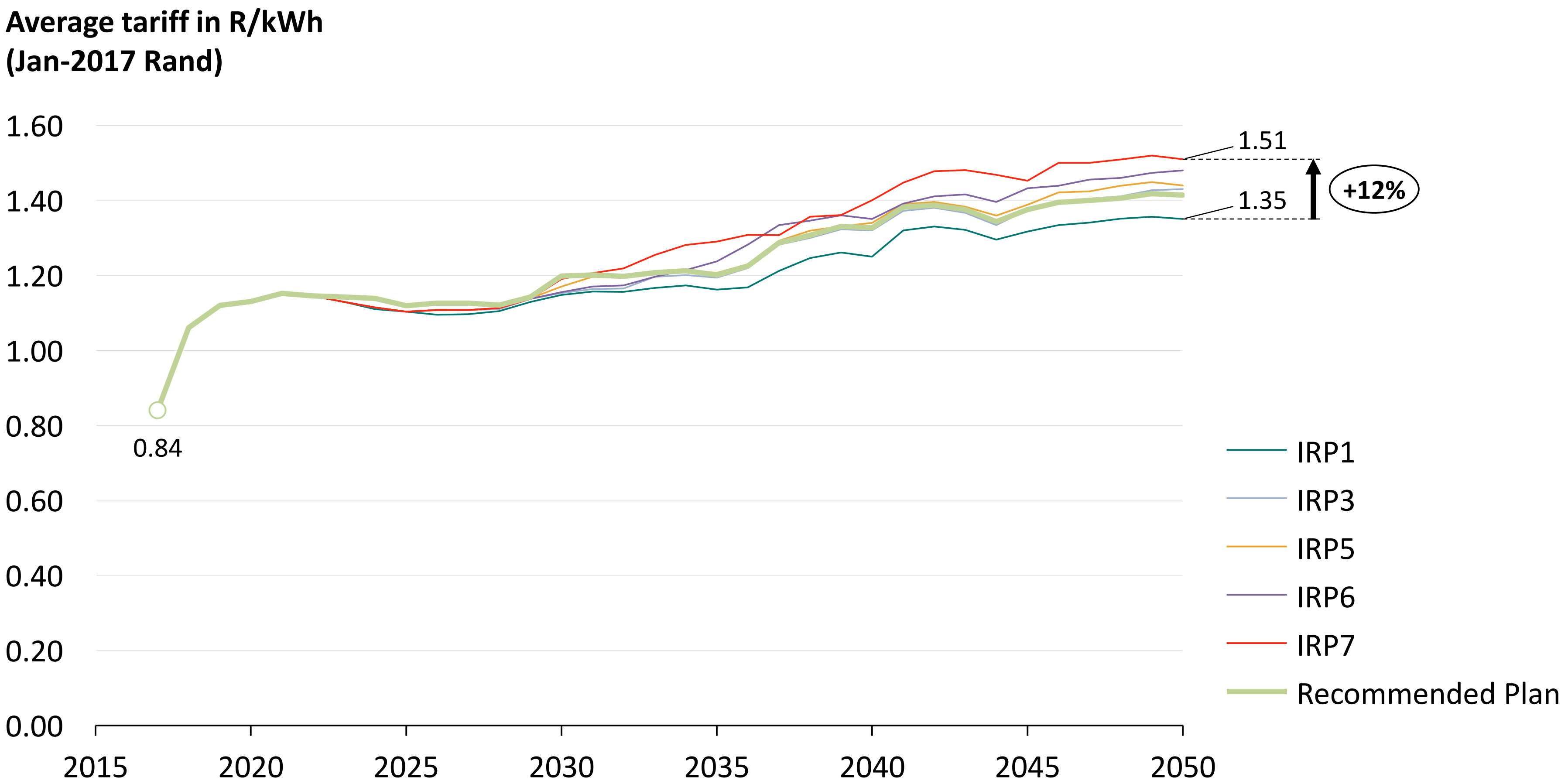
Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

Water usage

Electricity sector
Water usage
[bl/yr]



Average tariff (without CO_2 costs) across scenarios revealing how IRP1 (Least-cost) is 12% cheaper than the most expensive scenario (IRP7)



Note: Shift from 2017 to 2018 based on immediate move to cost reflectivity
Sources: Draft IRP 2018. CSIR Energy Centre analysis

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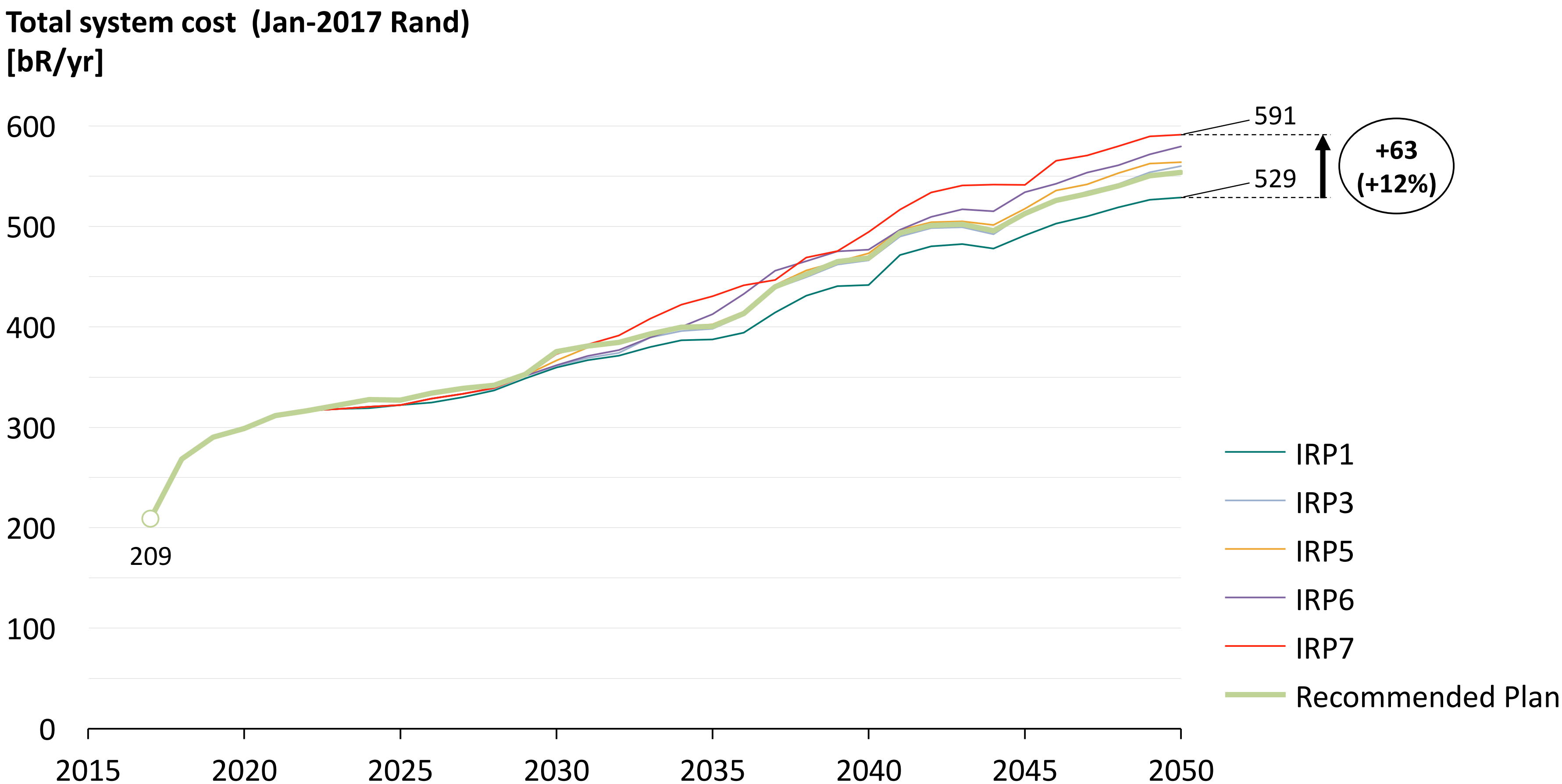
Total system cost increase as the power system grows (as expected) IRP1 is least-cost and ≈R60-bn/yr cheaper than IRP7 by 2050



Note: Shift from 2017 to 2018 based on immediate move to cost reflectivity
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Energy mix by 2030 similar across scenarios as coal still dominates while IRP1 is ≈R10bn/yr cheaper than IRP7, IRP7 lowest CO_2 emissions

2030

Energy Mix
in 2030

Demand: 313 TWh

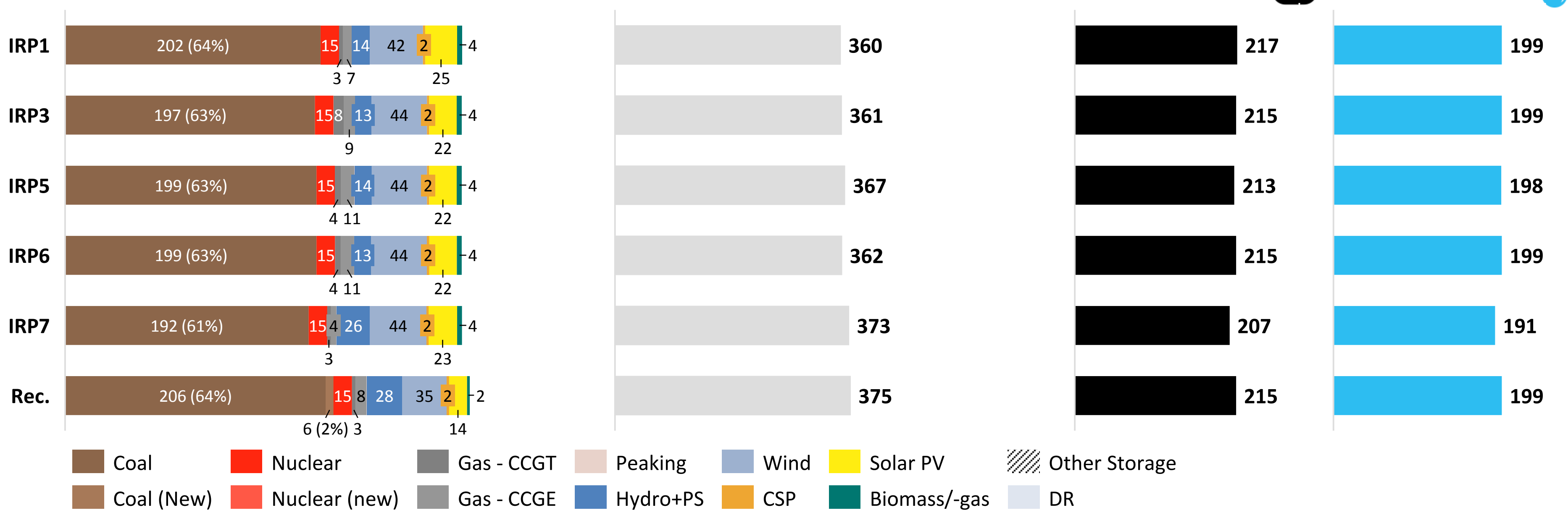
Cost
in 2030

Total system cost[1] (R-billion/yr)

Environment
in 2030

CO_2 emissions (Mt/yr)

Water usage (billion-litres/yr)



Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

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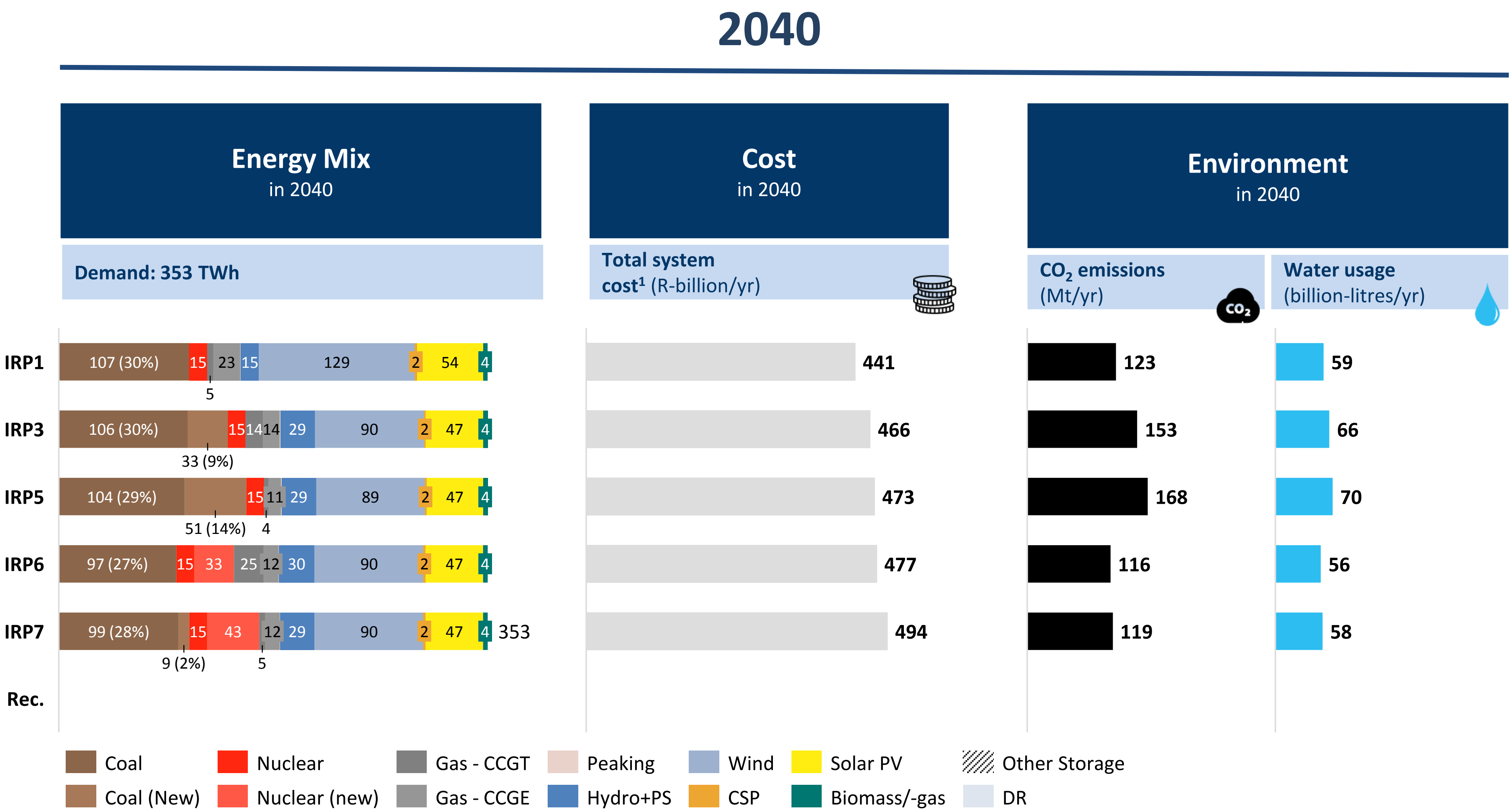
Least-cost mix confirmed as new-build solar PV, wind and flexible capacity (NG) - ≈R15-55 bn/yr cheaper than alternative scenarios



Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

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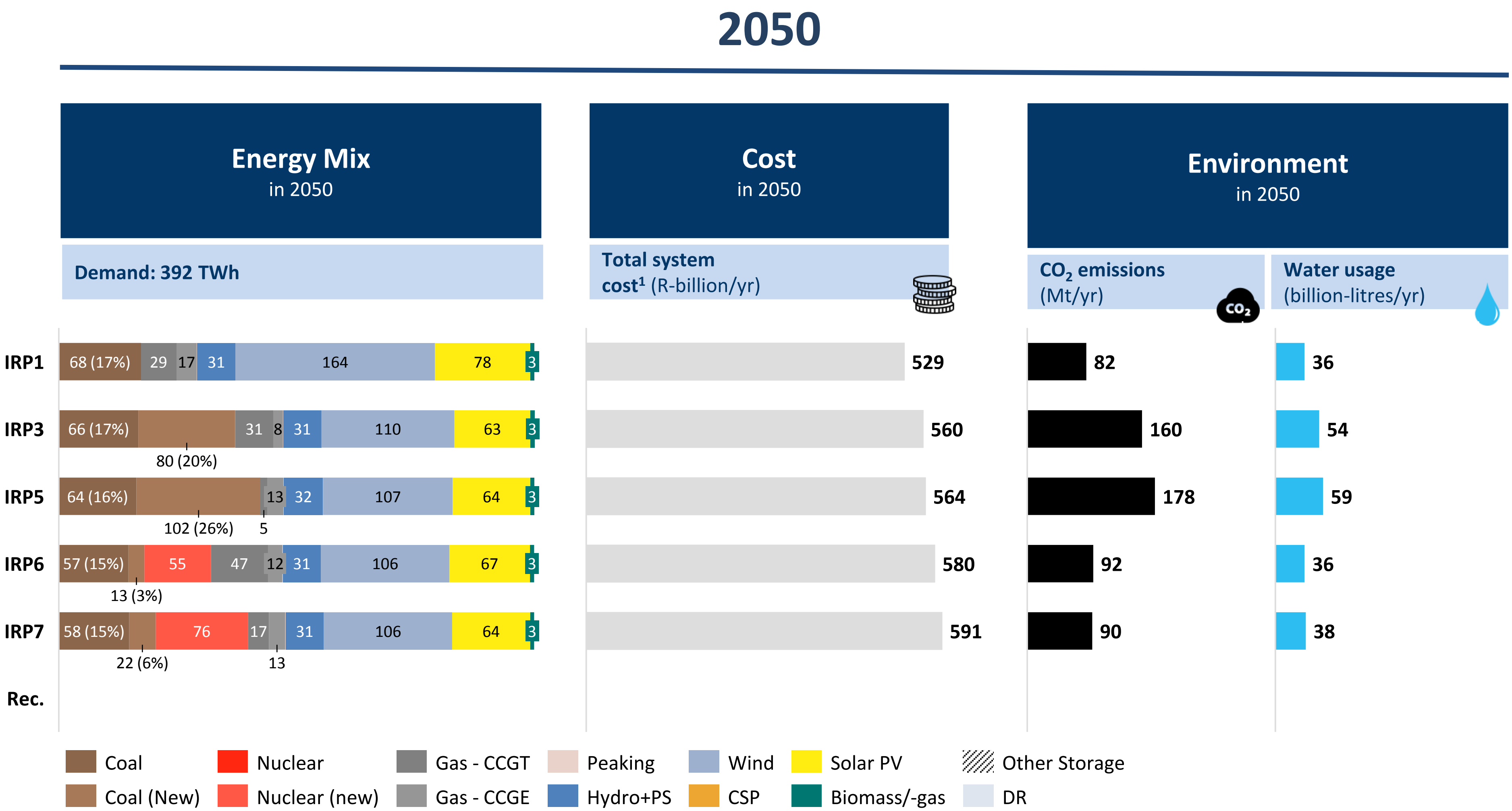
By 2050 - Least-cost mix is 70% solar PV and wind, ≈R30-60 bn/yr cheaper than alternatives, least CO_2 emissions and least water usage



Sources: DoE Draft IRP 2018; Eskom on Tx, Dx costs; CSIR analysis; flaticon.com

Formal comments on Draft IRP 2018

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CSIR have analysed selected scenarios from Draft IRP 2018 using a transparent, well established and understood tool - iJEDI

The International Jobs and Economic Development Impacts (I-JEDI) model is a freely available economic tool to understand economic changes (jobs focus at this stage) for energy technology choices

I-JEDI has been customised for application to the South African environment by the CSIR team

CSIR utilised the developed I-JEDI tool for South Africa to assess the Recommended Plan in the Draft IRP 2018 for a range of technologies including wind, solar, coal and natural gas (for now)… more in future

High-level approach

- I-JEDI estimates economic impacts by characterising construction and operation of energy projects in terms of expenditures and portion of these made within the country (localised)
- These are then used in a country-specific input-output (I-O) model to estimate employment (amongst a range of other metrics)

An indicative analysis of jobs in nuclear is also provided (but not based on I-JEDI for now)

Analysis of other Draft IRP 2018 scenarios as well as those presented by CSIR to come[1]

[1] Time available was not not sufficient to do this in the 60 day public consultation period.
Sources: https://www.nrel.gov/analysis/jedi/about.html

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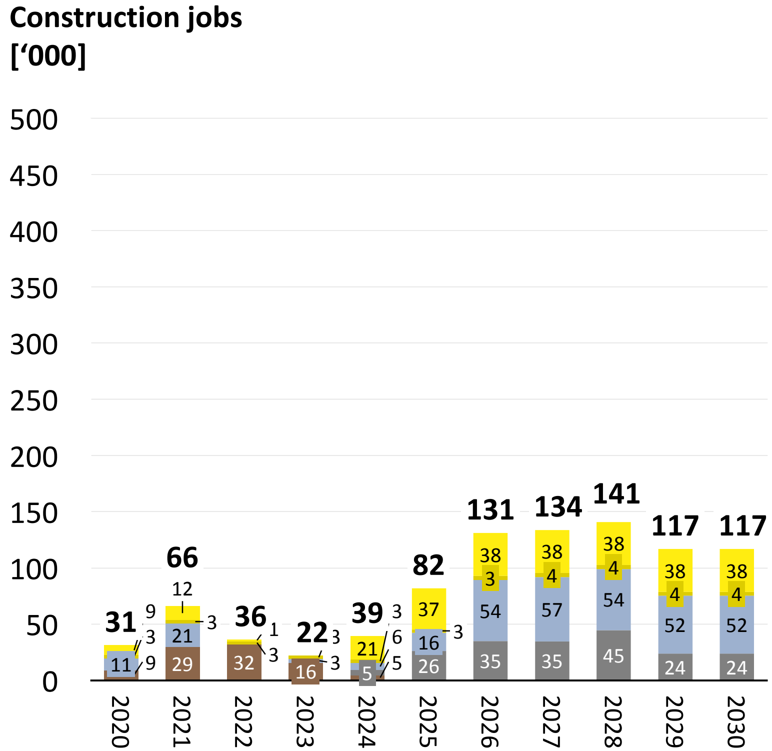
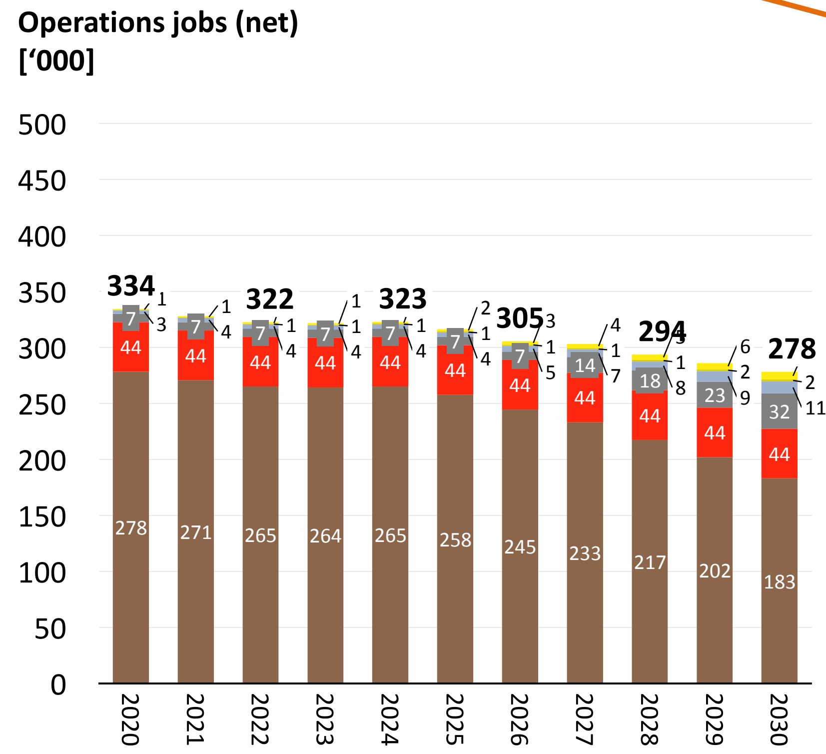
Coal dominant in jobs (as expected) but declines to 2030 in Recommended Plan as gas grows, notable gap for wind and PV

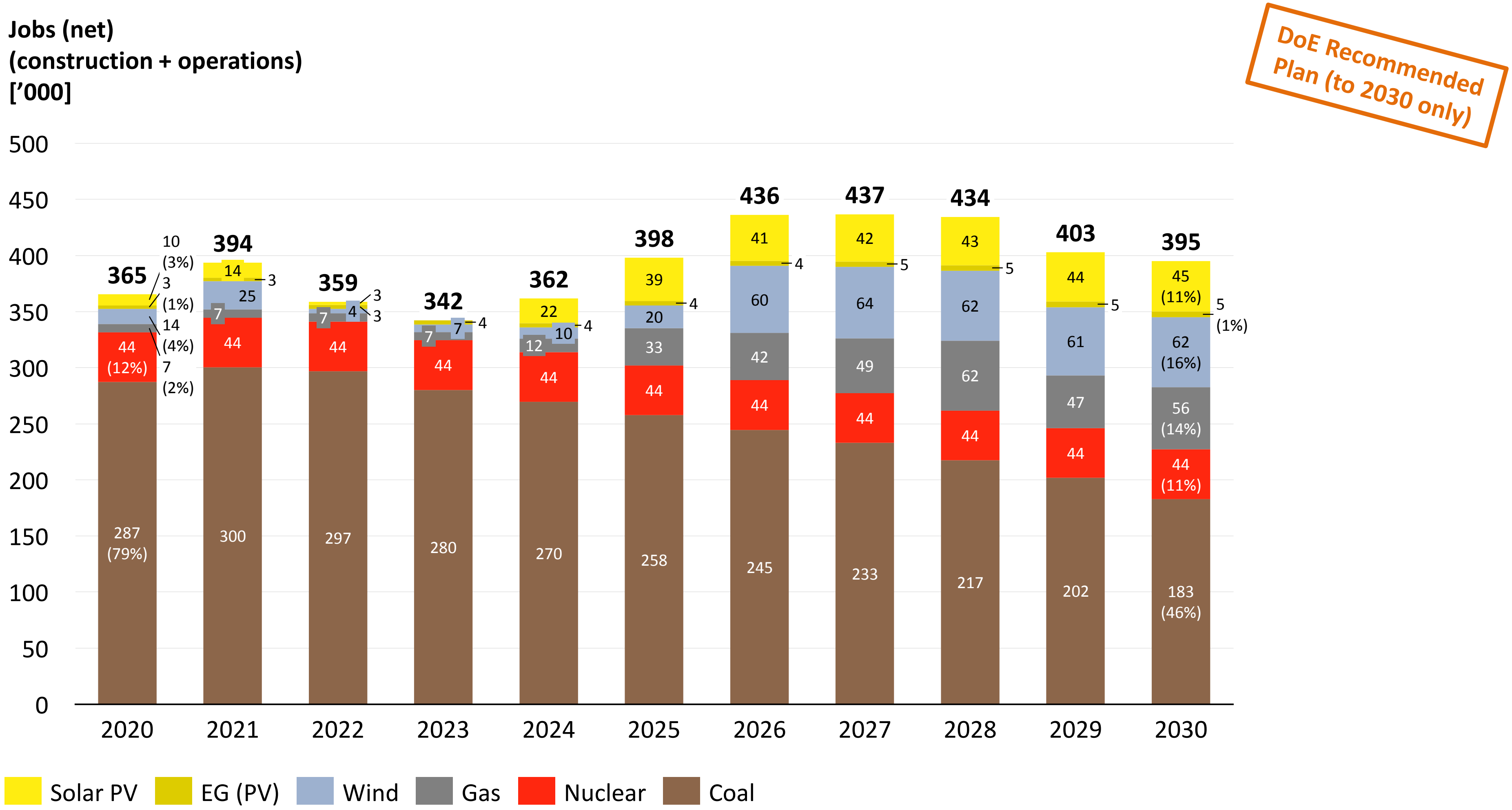
DoE Recommended Plan (to 2030 only)





Sources: Draft IRP 2018; CSIR Energy Centre analysis
Note: Job potential includes direct, indirect and induced jobs; Nuclear is estimated based on existing experience at Koeberg (KPMG, 2017)

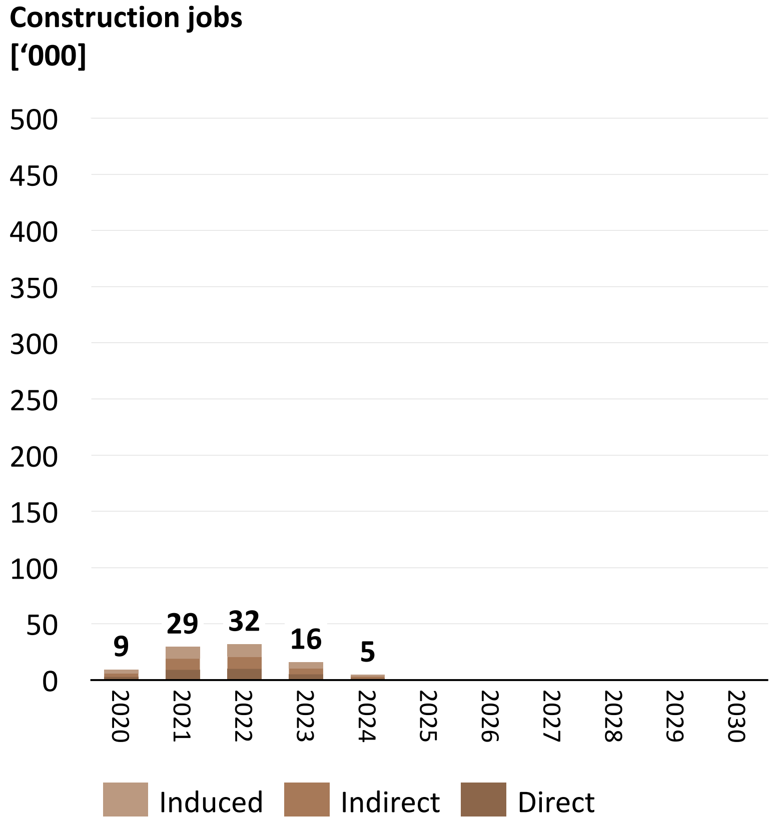
Net job decrease in coal of ≈100k but net gain overall as gas grows to ≈55k jobs towards 2030, RE contributes up to ≈110k by 2030

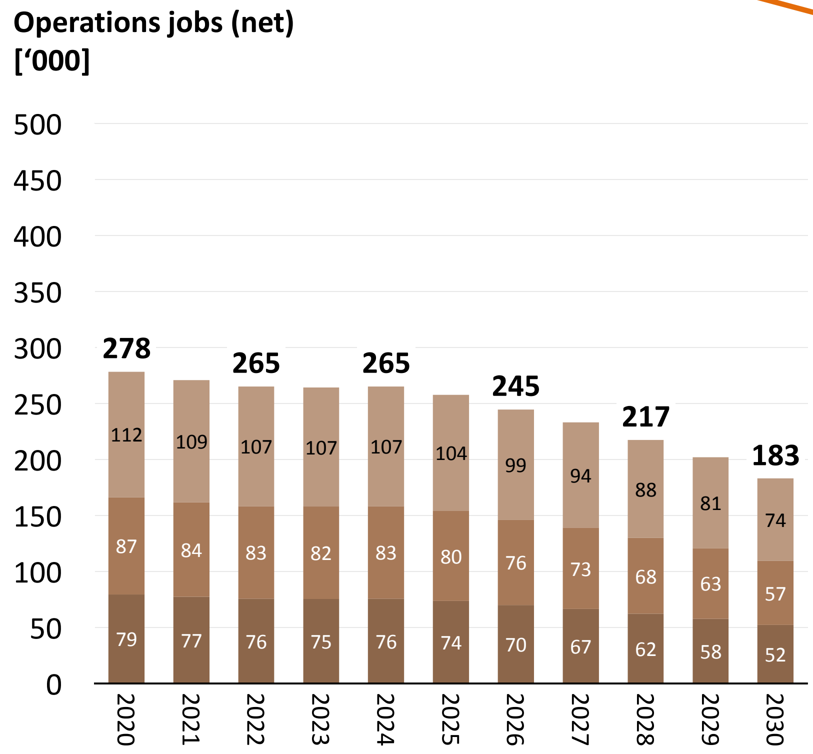


Sources: Draft IRP 2018; CSIR Energy Centre analysis
Note: Job potential includes direct, indirect and induced jobs; Nuclear is estimated based on existing experience at Koeberg (KPMG, 2017)

Focus on coal: Emphasising impact of construction jobs via new-build (excl. Medupi/Kusile) and net decline in operations jobs to 2030

DoE Recommended Plan (to 2030 only)





Sources: Draft IRP 2018; CSIR Energy Centre analysis
Note: Job potential includes direct, indirect and induced jobs

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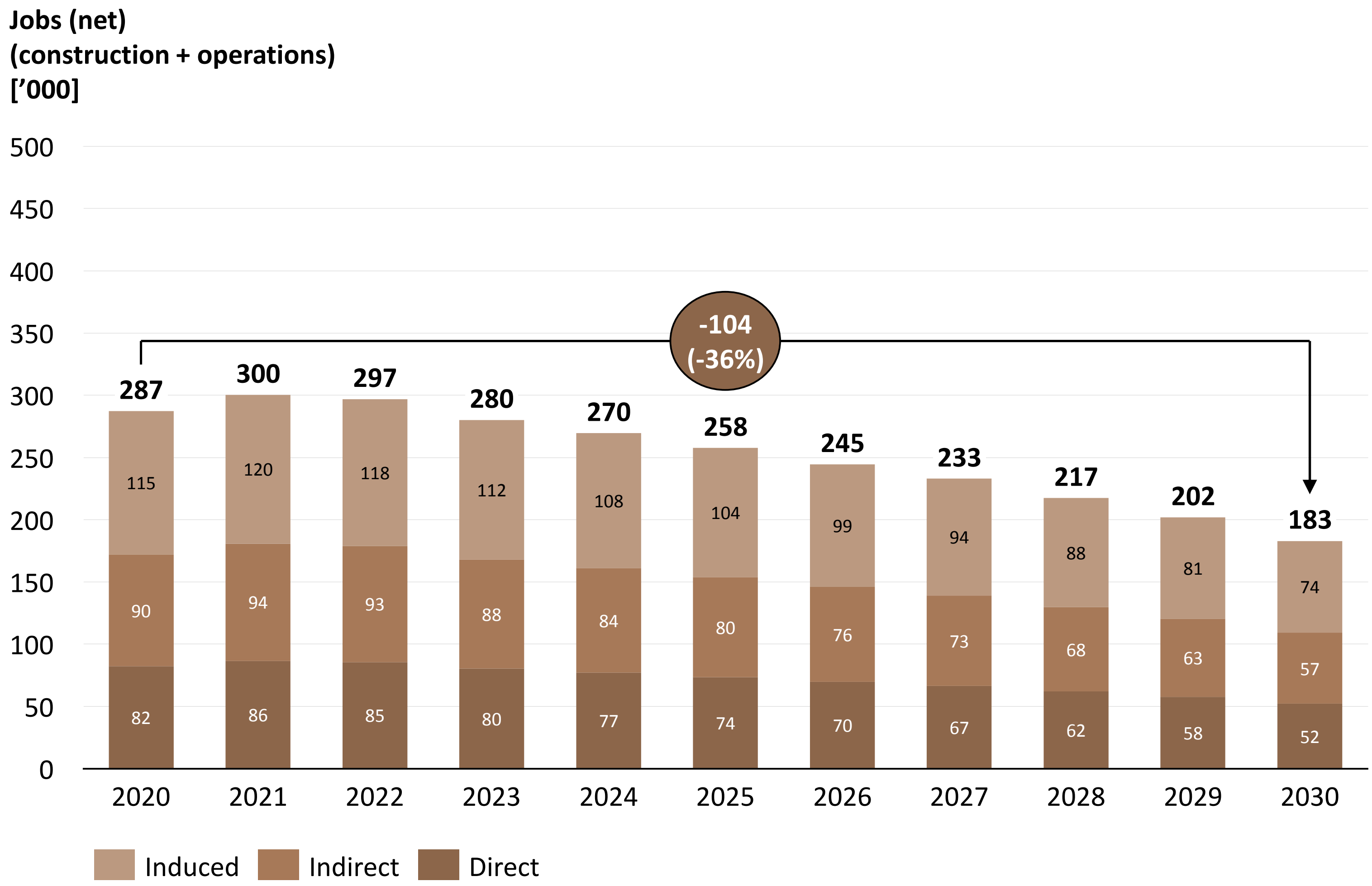
Net job losses in coal overall of ≈100k, direct jobs in coal shifting from ≈80k in 2016 to ≈50k by 2030

DoE Recommended Plan (to 2030 only)



Sources: Draft IRP 2018; CSIR Energy Centre analysis
Note: Job potential includes direct, indirect and induced jobs

Formal comments on Draft IRP 2018

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Formal comments on Draft IRP 2018

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Impact of stationary storage (scenario)

In the Draft IRP 2018 – no cost reductions are considered for stationary storage

What if stationary storage costs start to decline?

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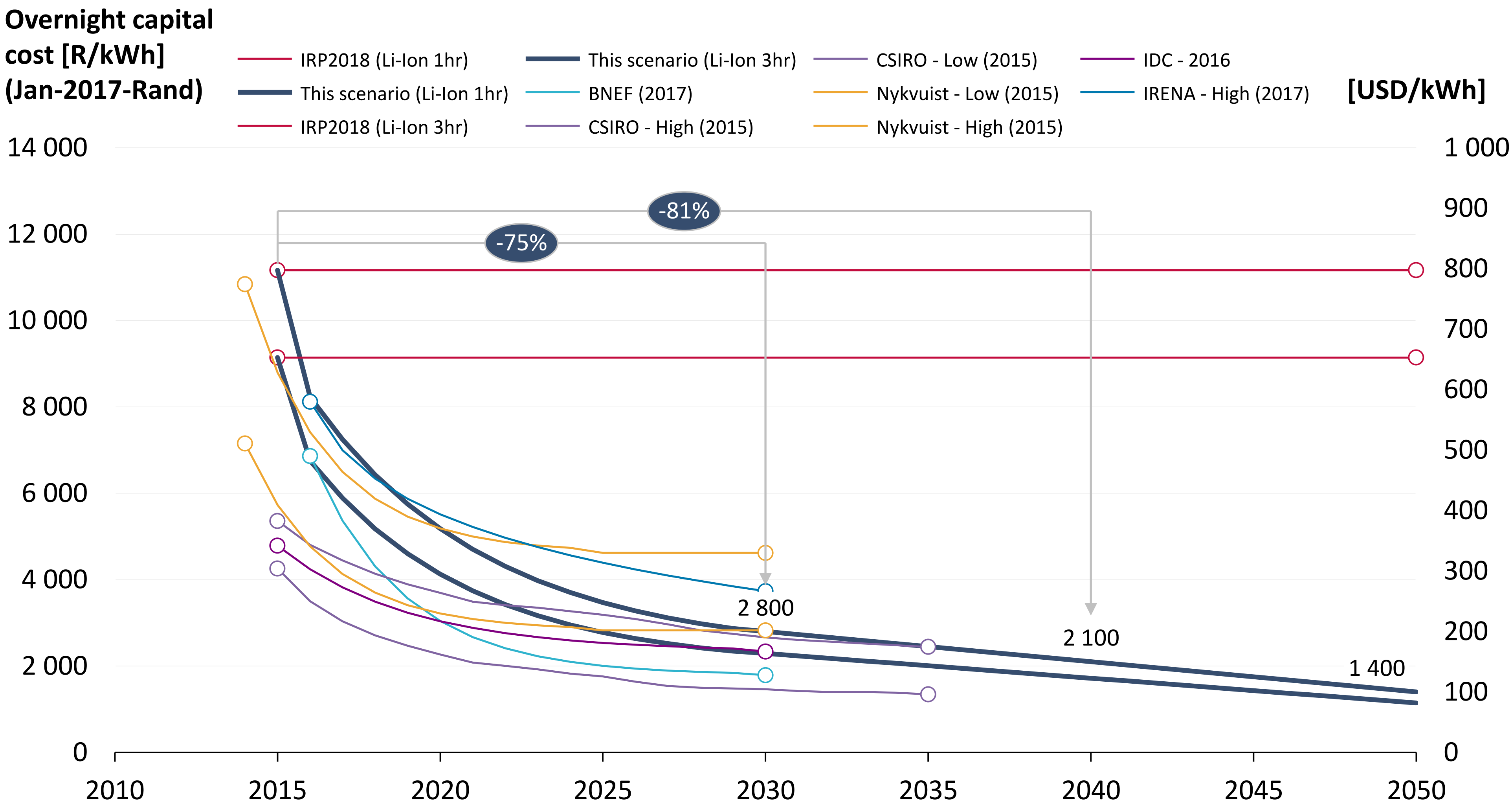
Stationary storage (excl. pumped storage): 200 $/kWh (2030), 150 $/kWh (2040), 100 $/kWh (2050)



USD:ZAR = 14.00; NOTE: Battery packs are assumed to make up 60% of total utility-scale stationary storage costs (from BNEF).
Sources: StatsSA for CPI; Draft IRP 2018; CSIR; BNEF; CSIRO (2015); Nykvist (2015); IDC; IRENA (2017)

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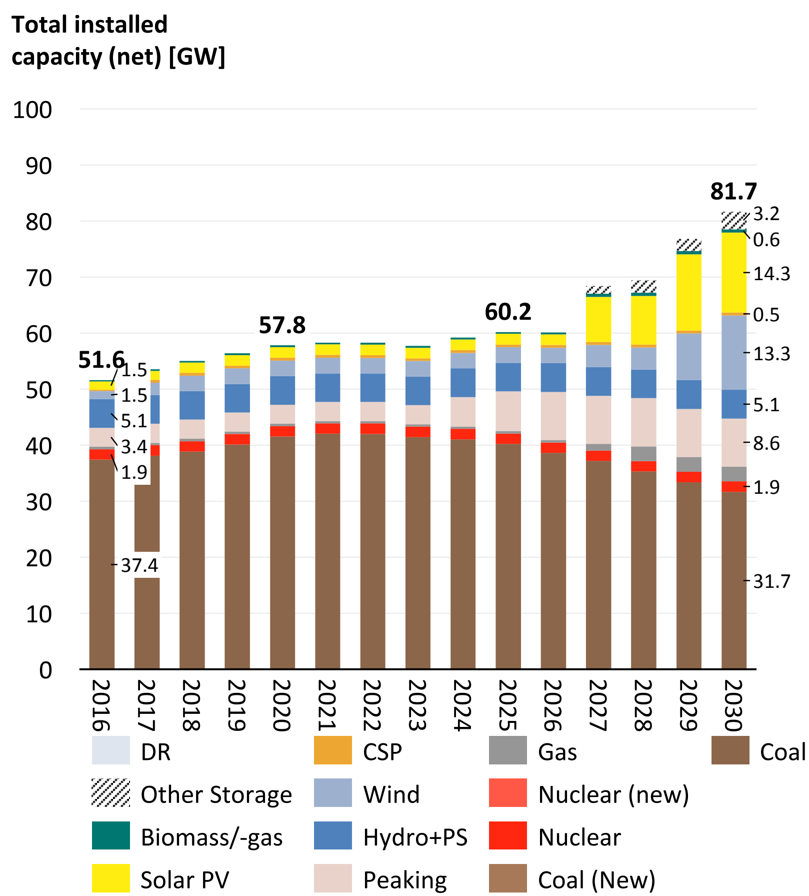
Draft IRP 2018 IRP1 with storage cost declines means notably less NG, with storage deployed from 2027, increased solar PV and wind

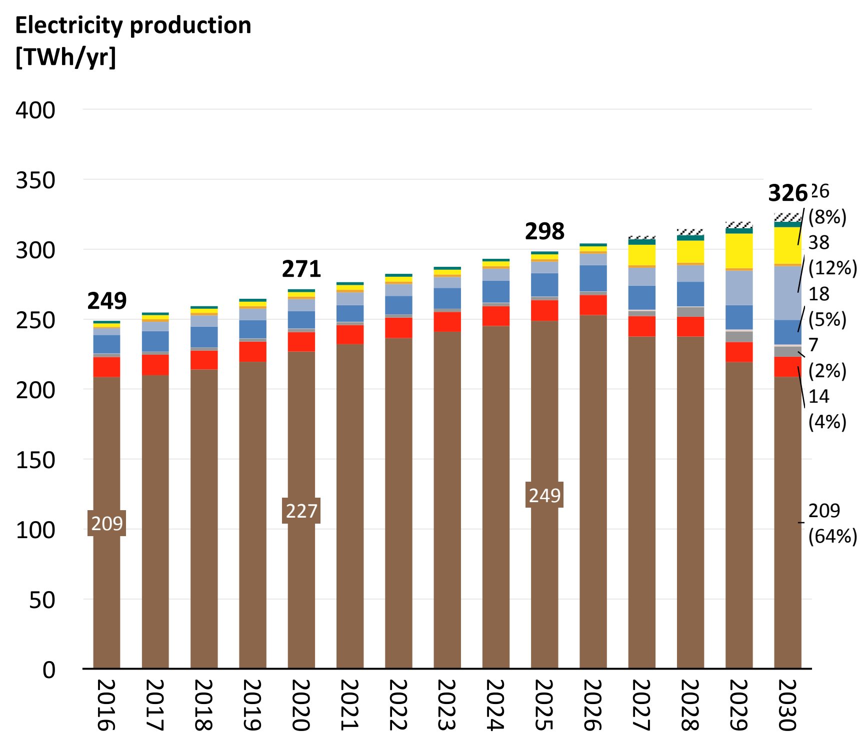
Installed capacity and electricity supplied from 2016 to 2030 as planned in the Draft IRP 2018

Storage technology cost declines

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2027)	*6.2 GW*
Wind (2027)	*1.2 GW*
OCGT (2024)	*1.9 GW*
Storage (2027)	*1.3 GW*

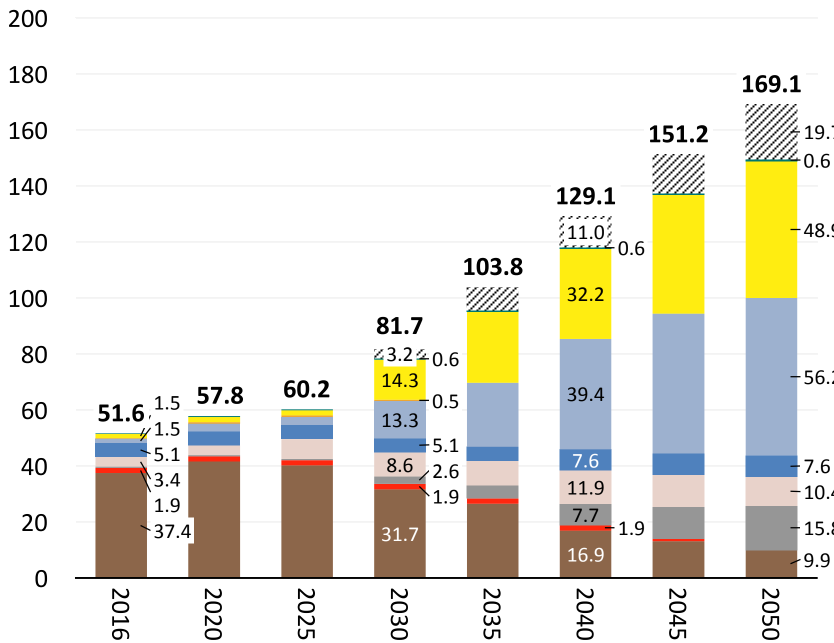
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Draft IRP 2018 IRP1 with storage cost declines means less NG, increased solar PV and wind with considerable deployment post-2030

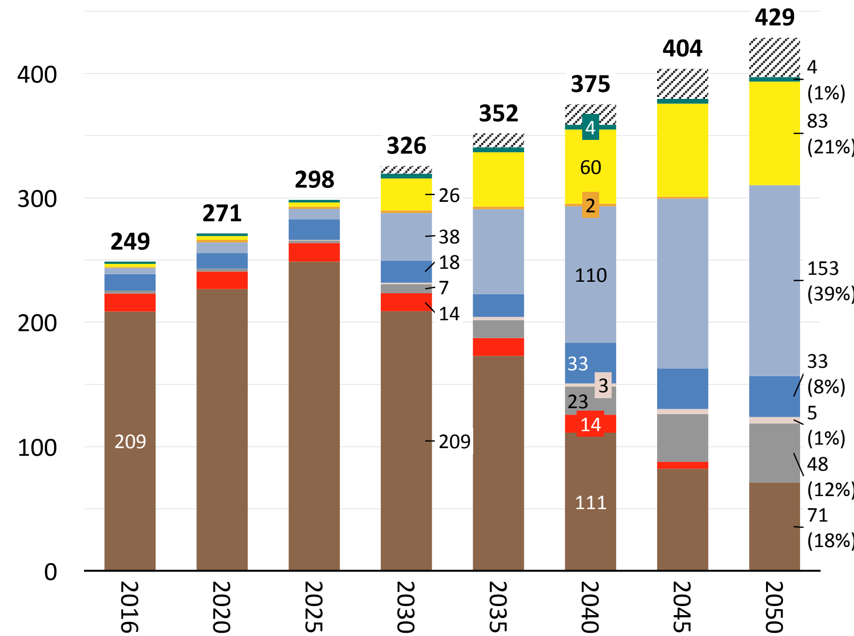
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with Demand Side Response

Storage technology cost declines

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2027)	*6.2 GW*
Wind (2027)	*1.2 GW*
OCGT (2024)	*1.9 GW*
Storage (2027)	*1.3 GW*

Notes: Assumed capacity factors for wind and solar PV differ slightly to IRP1

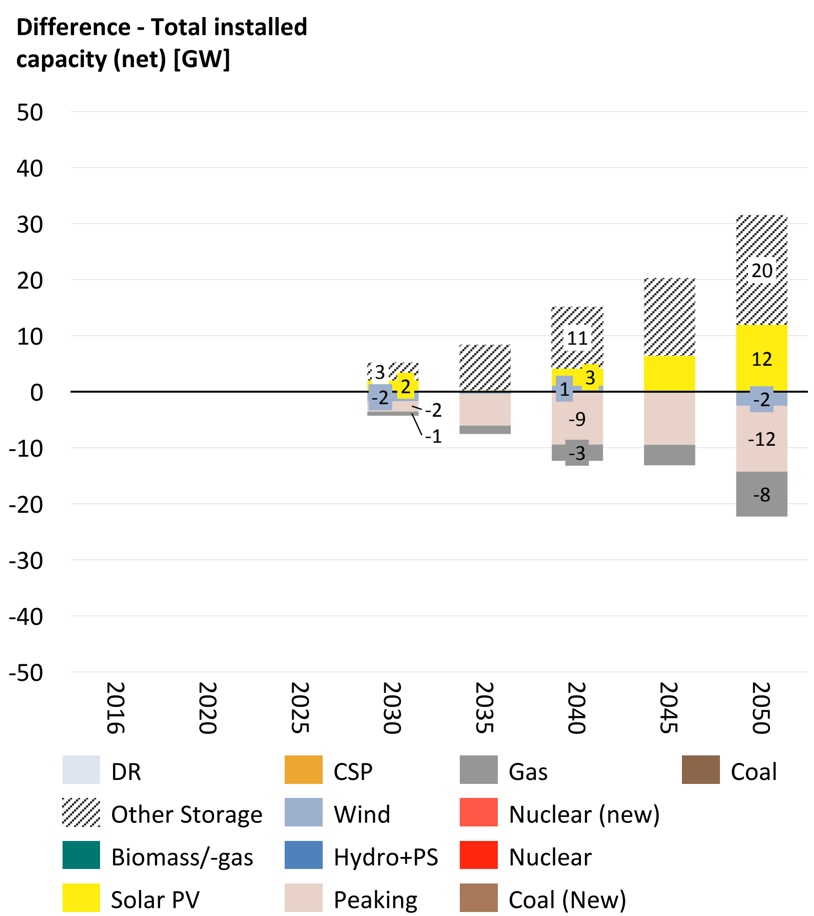
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Difference in installed capacity and energy mix with storage cost declines relative to IRP1, less NG with increased solar PV

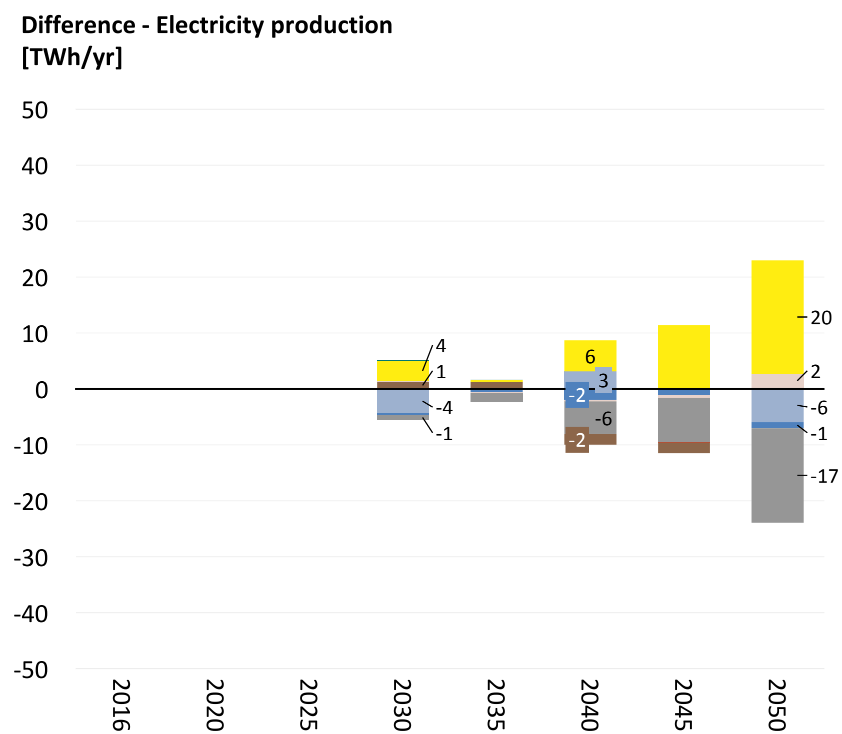
Installed capacity and electricity supplied from 2016 to 2050 for IRP 1 with storage cost declines

Storage technology cost declines

Installed capacity



Energy mix



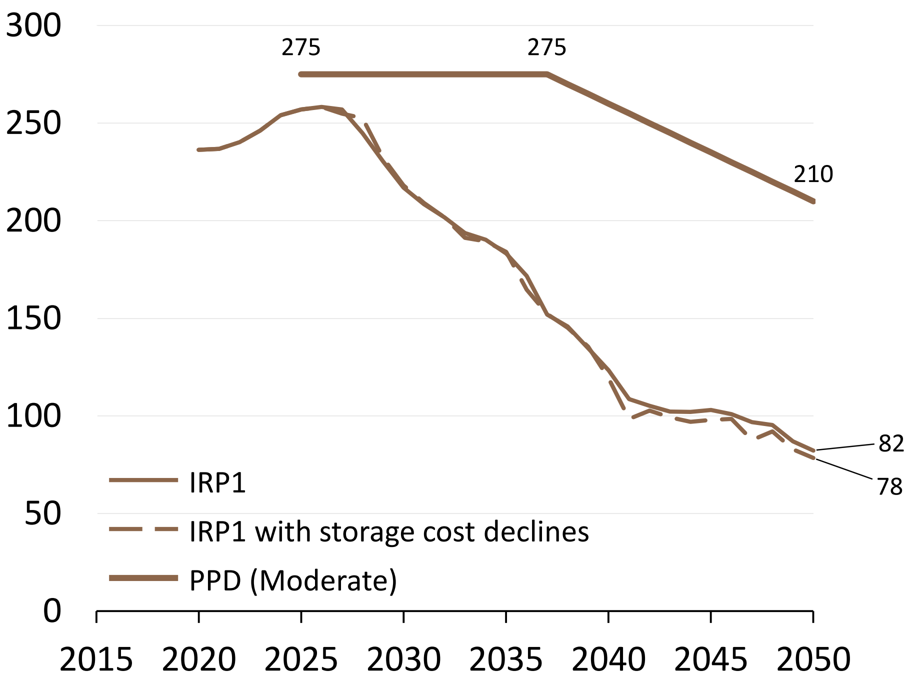
Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

IRP 1 with storage cost declines

CO_2 emissions

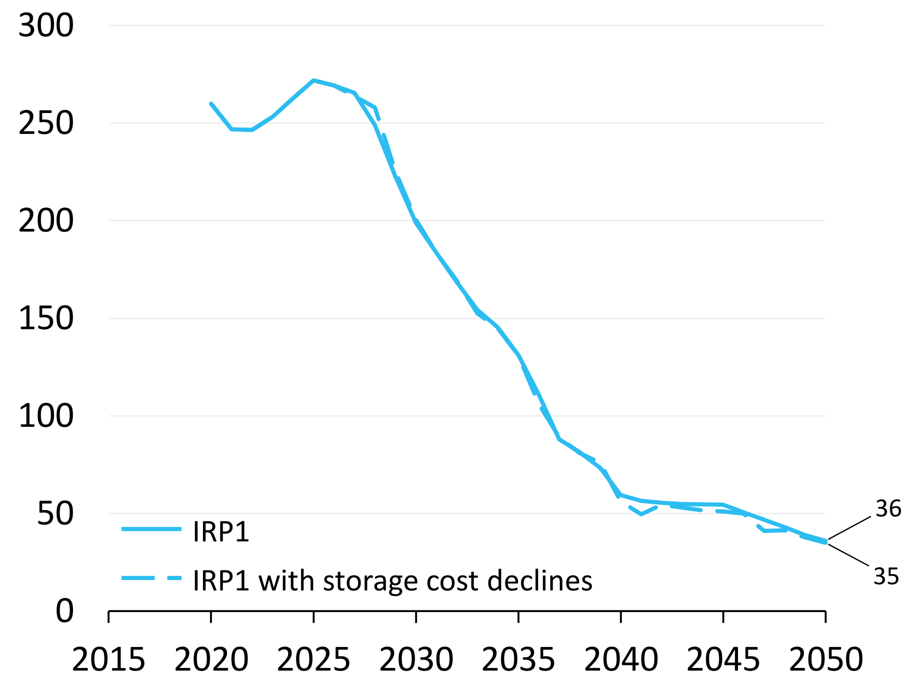
Electricity sector
CO_2 emissions
[Mt/yr]



	2020–2030	2030–2040	2040–2050
Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

Water usage

Electricity sector
Water usage
[bl/yr]



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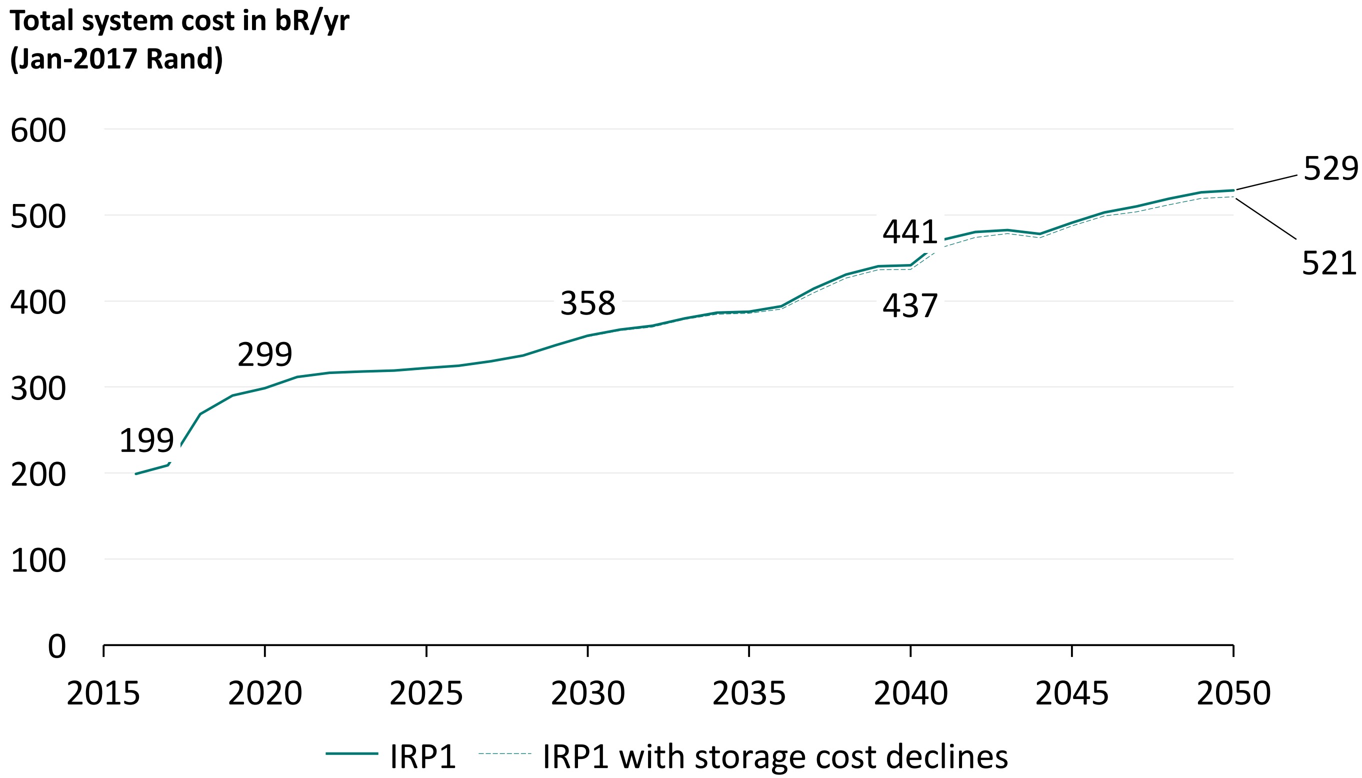
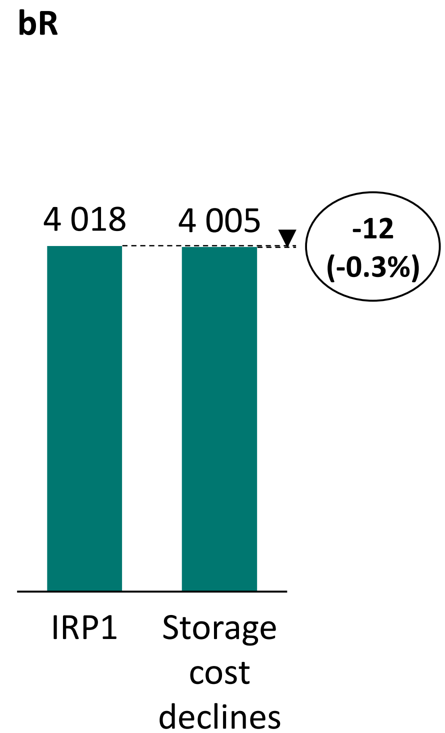
Total system cost: IRP1 with storage cost declines ≈R8 bn/year less expensive by 2050 than IRP1, marginal difference before 2030

Total System Cost



Net Present Value System Cost

(2016 - 2050)



Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

Sources: Draft IRP 2018. CSIR Energy Centre analysis.

Formal comments on Draft IRP 2018

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Impact of demand response - EVs, warm water heating (scenario)

What if the demand side became more flexible and responsive i.e. Demand Side Response (DSR)

Similar to previous comments in Draft IRP 2016 with some updated analysis on DSR options

- Warm-water heating (geysers)
- Electric vehicles

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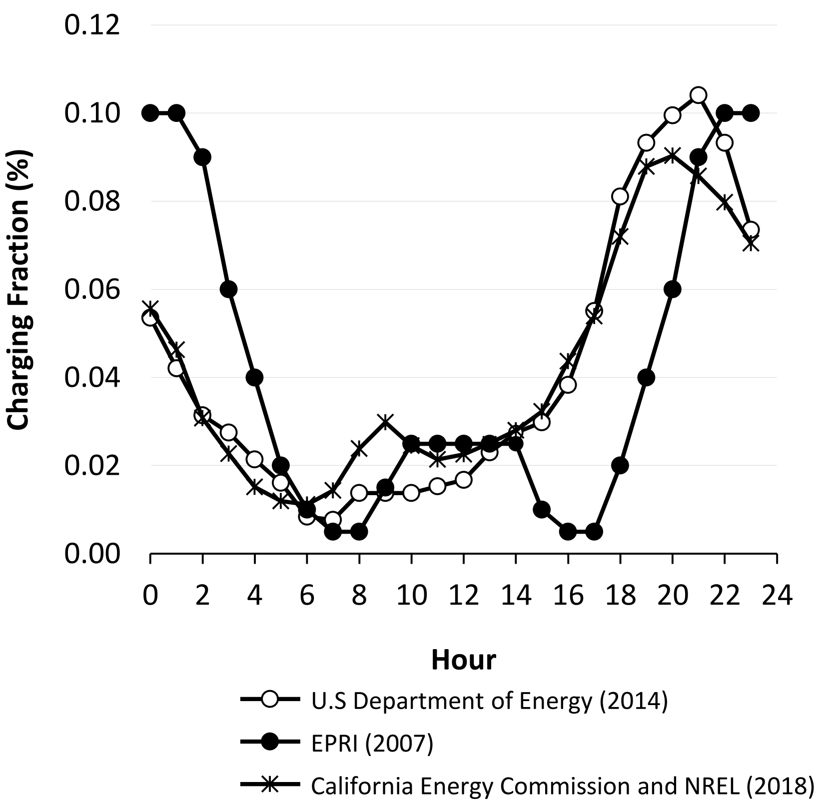
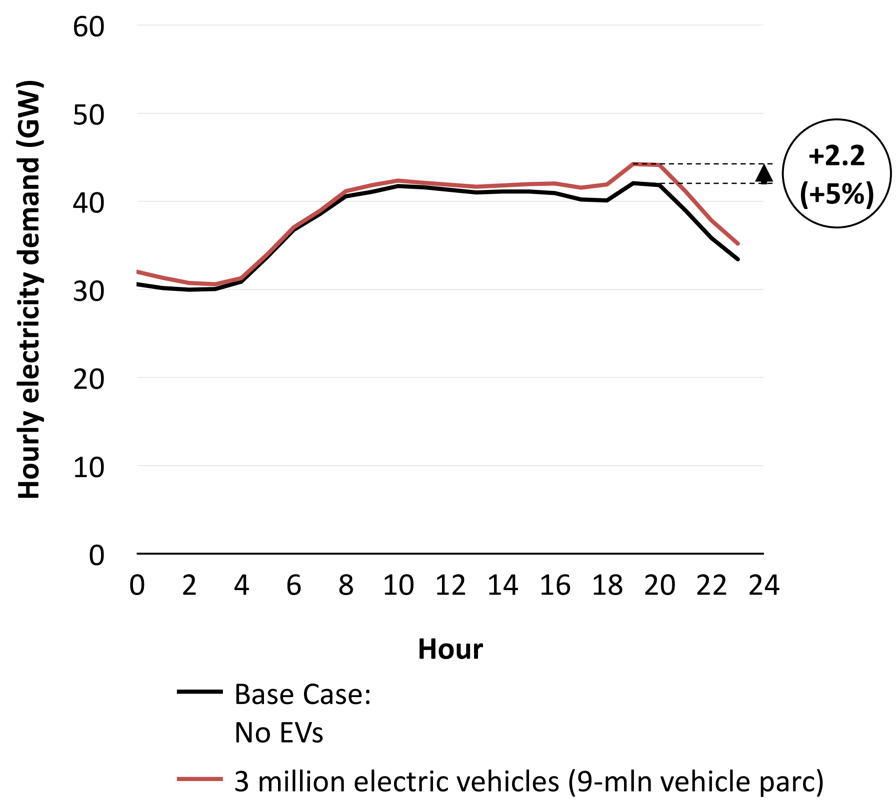
Majority of EV owners charge vehicles overnight in off-peak – this will have a relatively small impact on demand profile (beyond 2030)

Typical EV charging profiles



Impact of typical EV charging on RSA demand profile



NOTE: EVs assumed only light passenger vehicles for now.
Sources: Calitz (2018); Bedir, N. et. Al. (2018); U.S. Department of Energy (2014); EPRI (2007)

Electric vehicle usage for demand side flexibility i.e. Vehicle-to-Grid (V2G)

Inclusion of a demand side flexibility resource in the form of mobile storage (electric motor vehicles) demonstrates impact on the power system as adoption increases

Considered with similar functionality as that of Electric Water Heating (EWH) demand shaping - a resource with intra-day controllability (can be dispatched as needed on any given day) based on power system needs i.e. vehicle-to-grid (V2G)

Key input parameters to estimate potential demand shaping via electric motor vehicles:

- Current population
- Expected population growth to 2050
- Current number of motor vehicles
- Expected motor vehicles per capita
- Adoption rate of electric vehicles to 2050
- Electric vehicle fleet capacity (MW)
- Electric vehicle energy requirement (GWh/d)
- Proportion of electric vehicle fleet connected simultaneously

Electric vehicle demand shaping can provide ~96 GW/4.2 GW (demand increase/decrease) with ~40 GWh/d of dispatchable energy by 2050

Property	Unit	2016-2019	2020	2031	2040	2050
Population	[mln]	0 - 0	58.0	61.7	64.9	68.2
Number of motor vehicles	[mln]	7 - 8.2	8.5	12.3	16.2	20.5
EVs adoption	[%]	0 - 0	1.5	8.1	28.5	48.9
Number of EVs	[mln]	0 - 0	0.1	1.0	4.6	10.0
EVs energy requirement	[TWh/a]	-	0.5	3.7	17.1	37.0
EVs energy requirement	[GWh/d]	-	1.3	10.1	46.8	101.4
EVs (demand increase)	[MW]	-	-	4 600	44 300	95 800
EVs (demand decrease)	[MW]	-	-	400	2 000	4 200

Sources: CSIR estimates; StatsSA; eNaTis

Demand shaping as a demand side resource - domestic electric heaters (EWHs)

Many opportunities for demand shaping in a number of end-use sectors (domestic, commercial, industrial)

In the scenarios assessed by CSIR - the intention of including one particular demand shaping opportunity (domestic electric water heating) is to demonstrate the significant impact this can have on the power system.

Modelled as a resource with intra-day controllability (can be dispatched as needed on any given day) based on power system needs

Key input parameters to estimate potential demand shaping via EWH:

- South African population (to 2050)
- Number of households (current)
- Number of persons per household (future)
- EWHs (current)
- EWHs per household (future)
- Adoption rate of demand shaping via EWHs (future)
- Calibration for power (MW) and energy (TWh) used for electric water heating (existing)
- Movement to EWH technologies i.e. heat pumps vs electric geysers (future)

Demand shaping can provide ~24 GW/3 GW (demand increase/decrease) with ~70 GWh/d of dispatchable energy by 2050

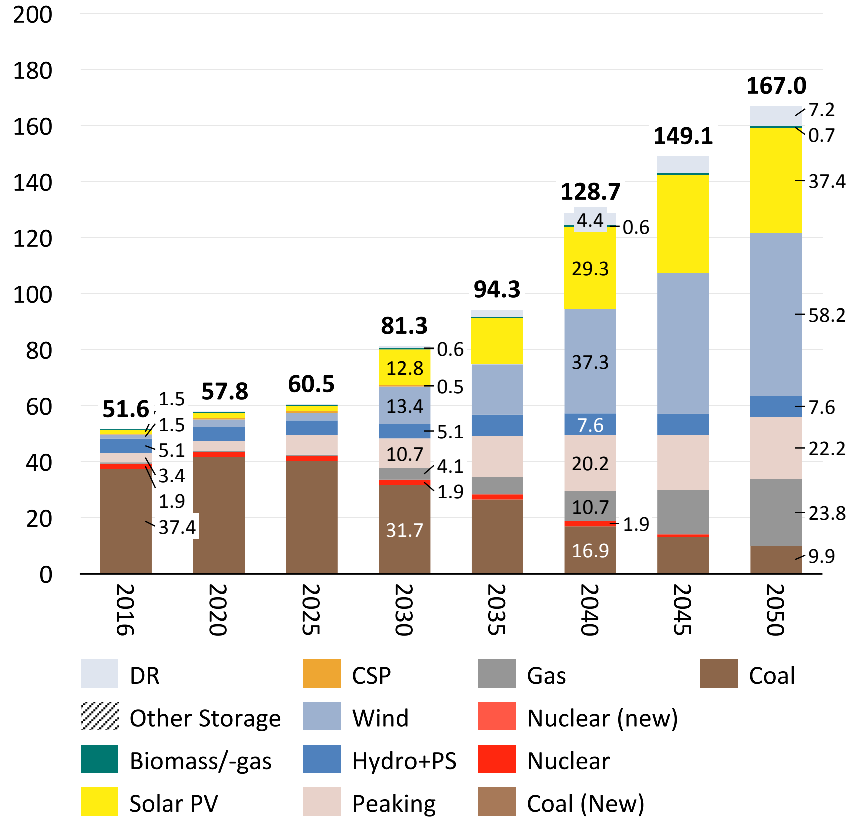
Property	Unit	2016-2019	2020	2030	2040	2050
Population	[mln]	55.7 - 57.5	58.0	61.7	64.9	68.2
Number of HHs	[mln]	16.9 - 18.1	18.5	22.4	26.0	27.3
Residents per HH	[ppl/HH]	3.29 - 3.17	3.13	2.75	2.50	2.50
HHs with EWH	[%]	28 - 33	34	50	75	100
HHs with EWH	[mln]	4.7 - 5.9	6.3	11.2	19.5	27.3
Demand shaping adoption	[%]	-	2	25	100	100
Demand shaping	[TWh/a]	-	0.4	5.4	28.3	26.4
Demand shaping	[GWh/d]	-	1.1	14.9	77.4	72.3
Demand shaping (demand increase)	[MW]	-	371	4 991	25 970	24 265
Demand shaping (demand decrease)	[MW]	-	46	620	3 226	3 015

Sources: CSIR estimates; StatsSA; AMPS survey; Stastista; Eskom; Draft IRP 2016

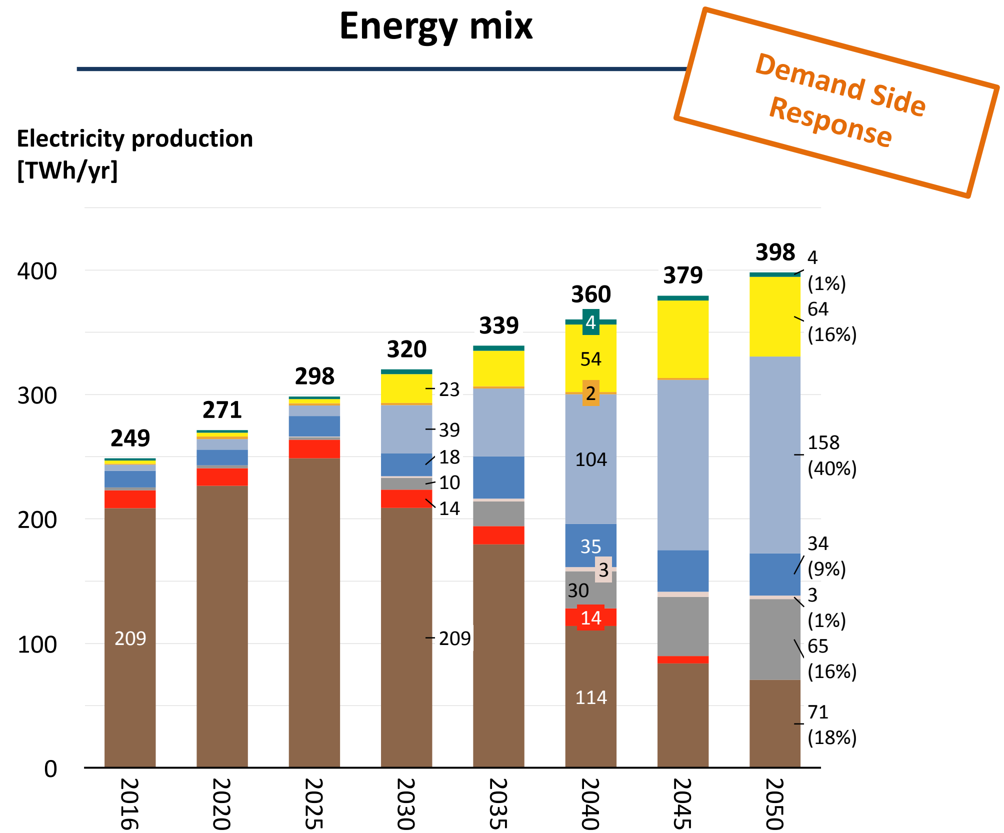
Draft IRP 2018 IRP1 with DSR impact marginal, shift in timing of import hydro, wind & PV (2030-2040)

Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with Demand Side Response

Installed capacity



Energy mix



Demand: Median

First new-builds:

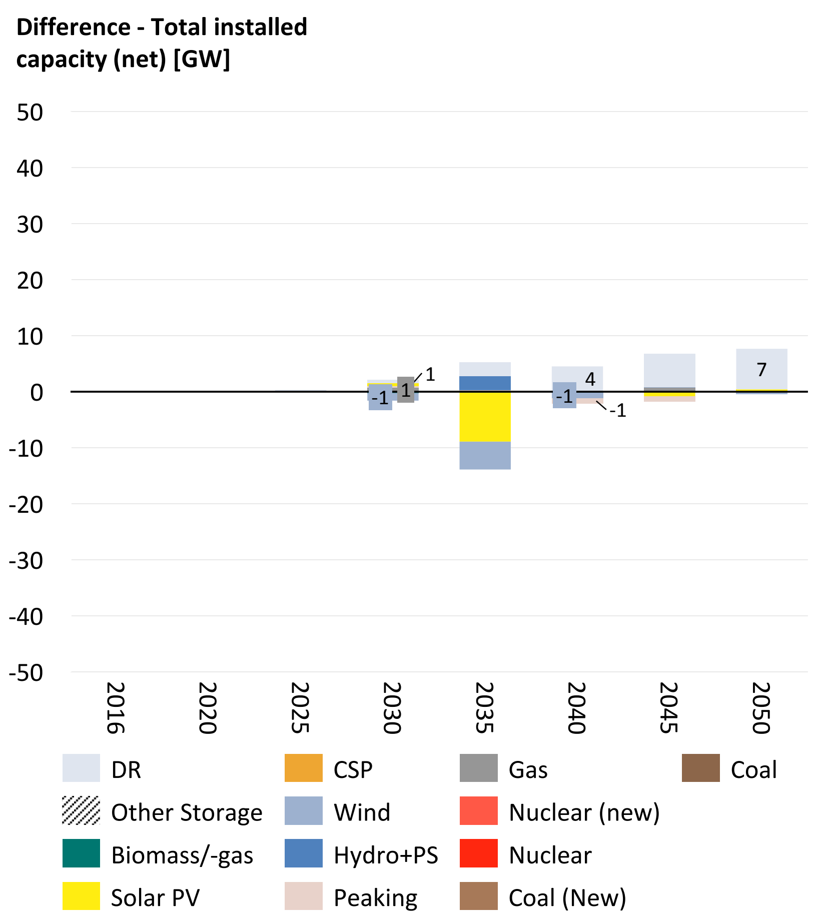
PV (2027)	*5.2 GW*
Wind (2027)	*1.1 GW*
OCGT (2024)	*1.9 GW*

Notes: NG = Natural gas
Sources: Draft IRP 2018. CSIR Energy Centre analysis

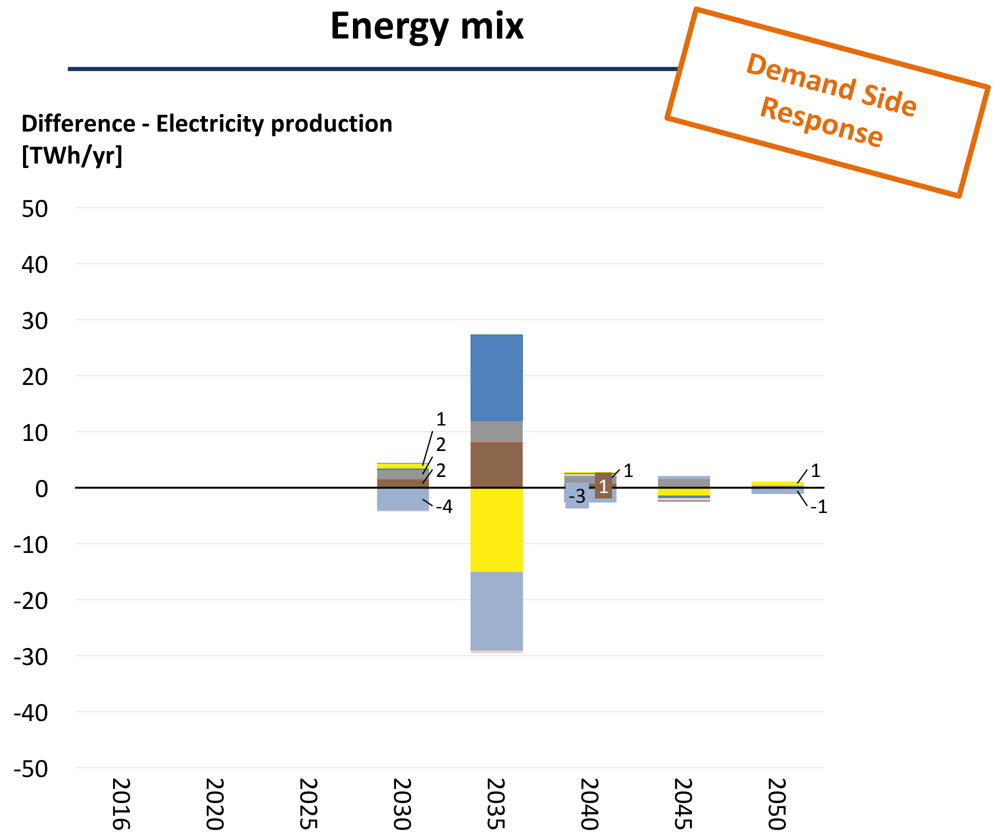
Difference in installed capacity and energy mix with DSR relative to IRP1 marginal, shift in timing of import hydro, wind & PV (2030-2040)

Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with Demand Side Response

Installed capacity



Energy mix

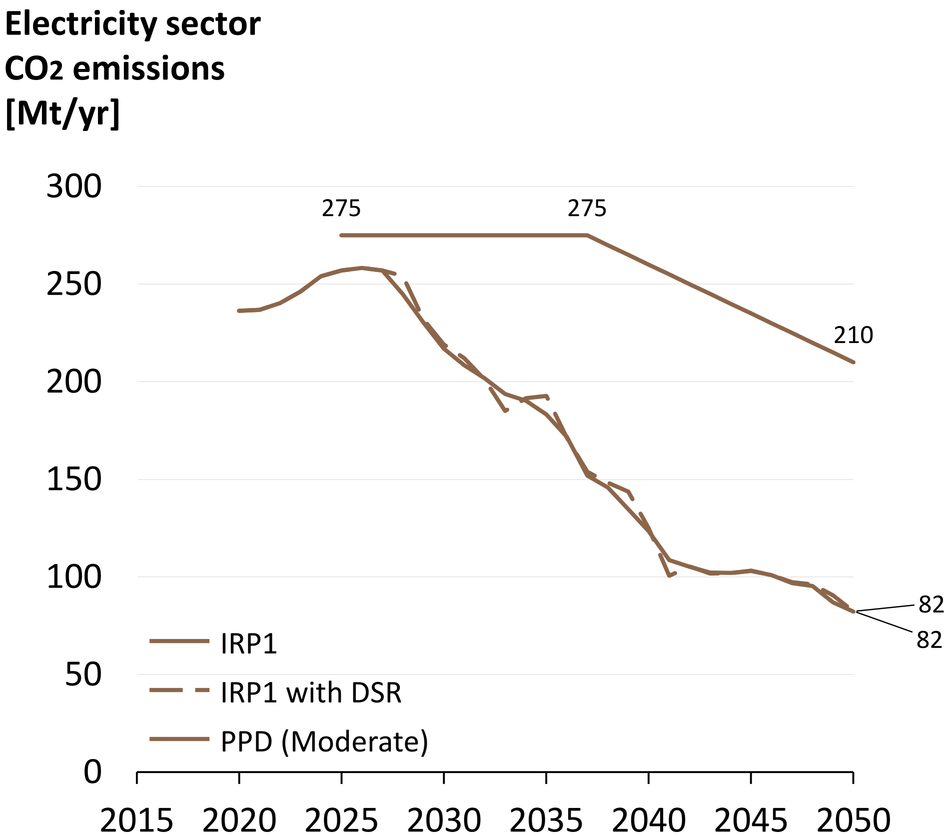


Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

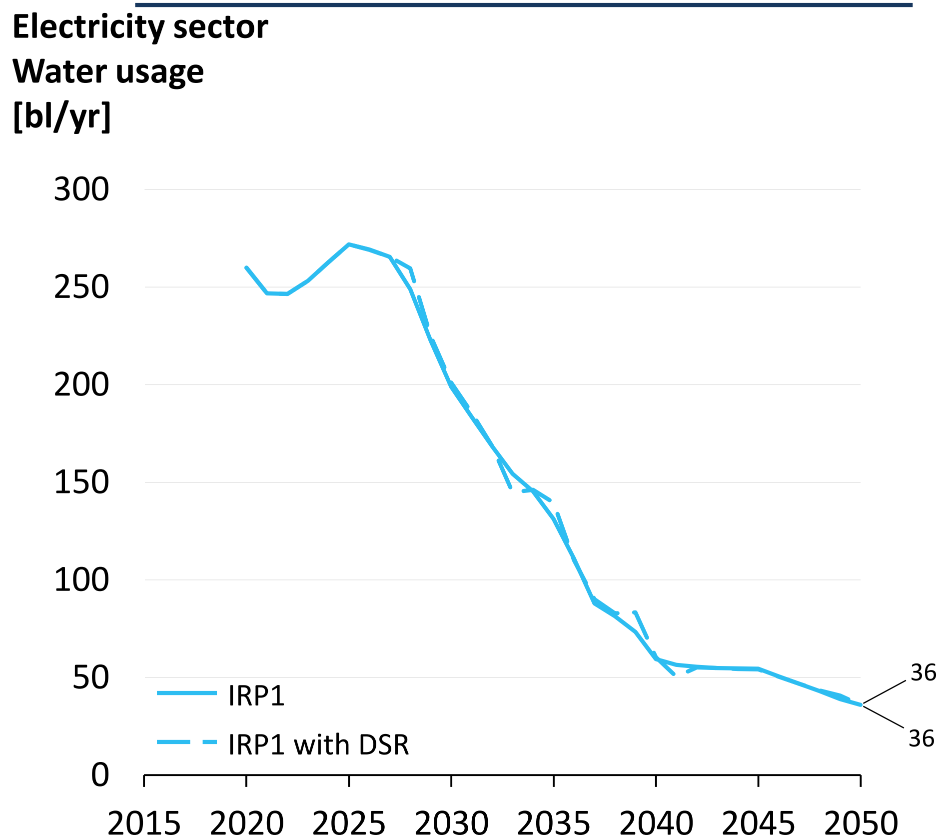
IRP 1 with Demand Side Response

CO_2 emissions



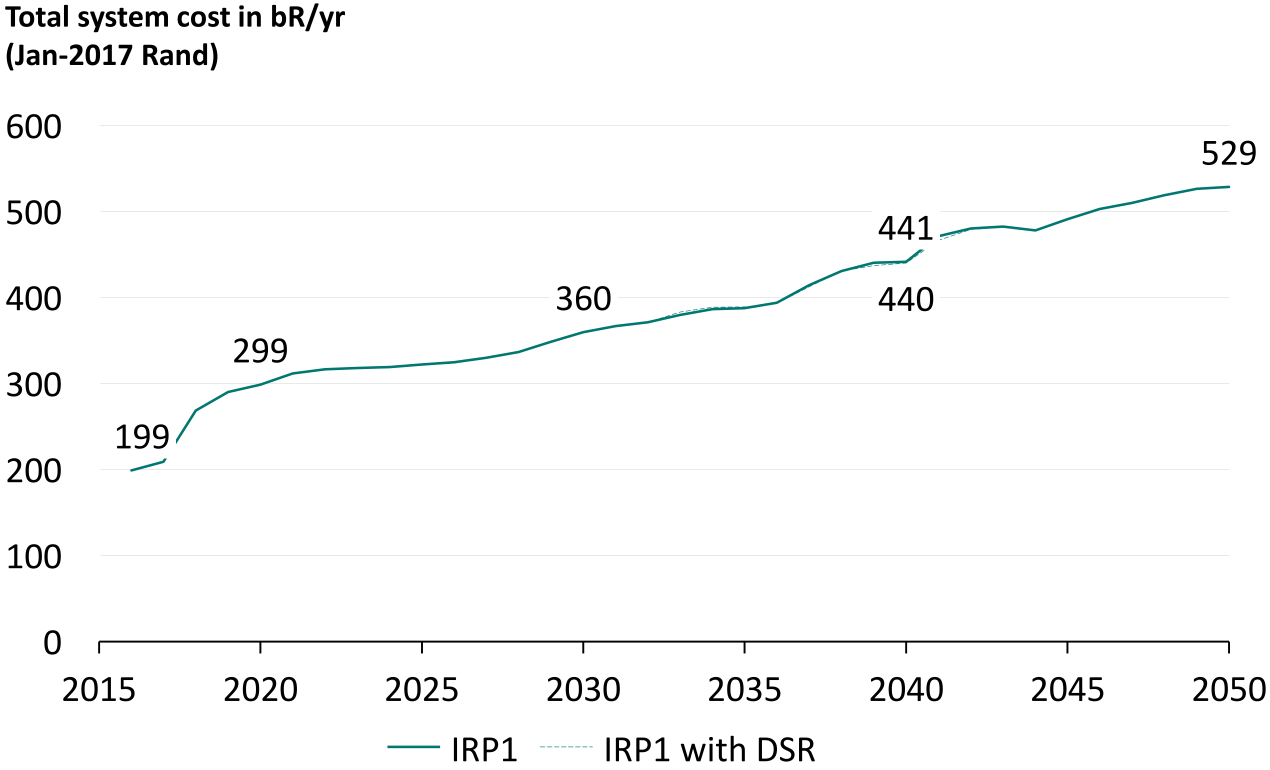
Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

Water usage



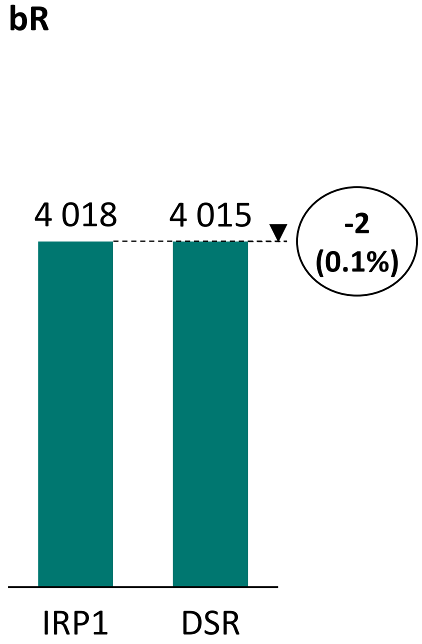
Total system cost: IRP1 with DSR marginal difference in total system cost relative to IRP1

Total System Cost



Net Present Value System Cost

(2016 - 2050)



Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

Sources: Draft IRP 2018. CSIR Energy Centre analysis. Eskom on Tx, Dx costs

Generally – additional EV demand met by least-cost mix of wind, solar PV and gas whilst V2G shifts this mix more towards solar PV and less gas

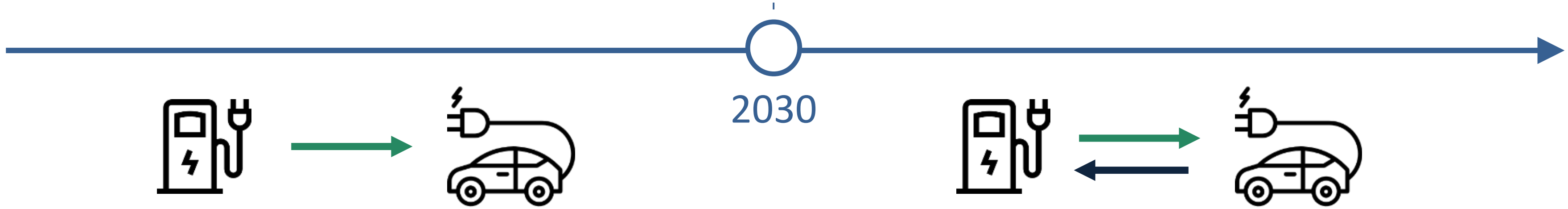
Impact on least-cost capacity mix

EVs typical configuration (G2V i.e. additional demand)

- For 1-mln EVs, increase of ≈3 TWh/yr
- For 1-mln EVs, increase ≈1 GW peak demand
- New build capacity to meet charging demand is mostly wind, solar PV and gas
- Most charging demand met by wind and gas

EVs as a demand shaping resource (V2G i.e. implicit in demand)

- Increase in proportion of new solar PV vs. wind
- Less gas capacity i.e. lower gas energy share
- Relative reduction in total system cost



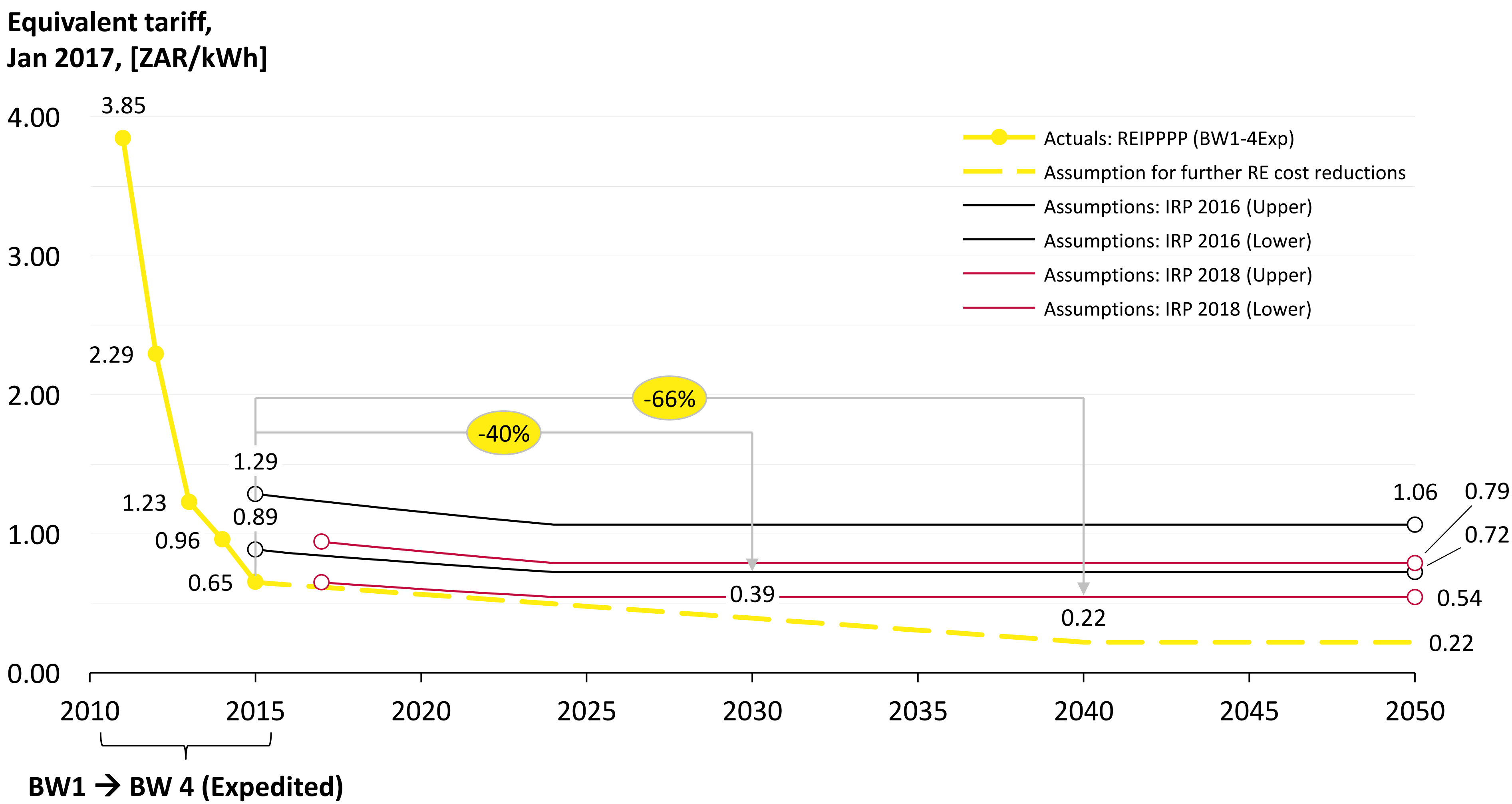
G2V - Grid to vehicle

V2G - Vehicle to grid

Formal comments on Draft IRP 2018

Solar PV learning assumptions in Draft IRP 2018

Actual solar PV tariffs and forecasted tariff trajectory



Notes: REIPPPP = Renewable Energy Independant Power Producer Programme; BW = Bid Window; bid submissions for the different BWs: BW1 = Nov 2011; BW2 = Mar 2012; BW 3 = Aug 2013; BW 4 = Aug 2014; BW 4 (Expedited) = Nov 2015

Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis . Learning rate - Bloomberg New Energy Outlook 2017

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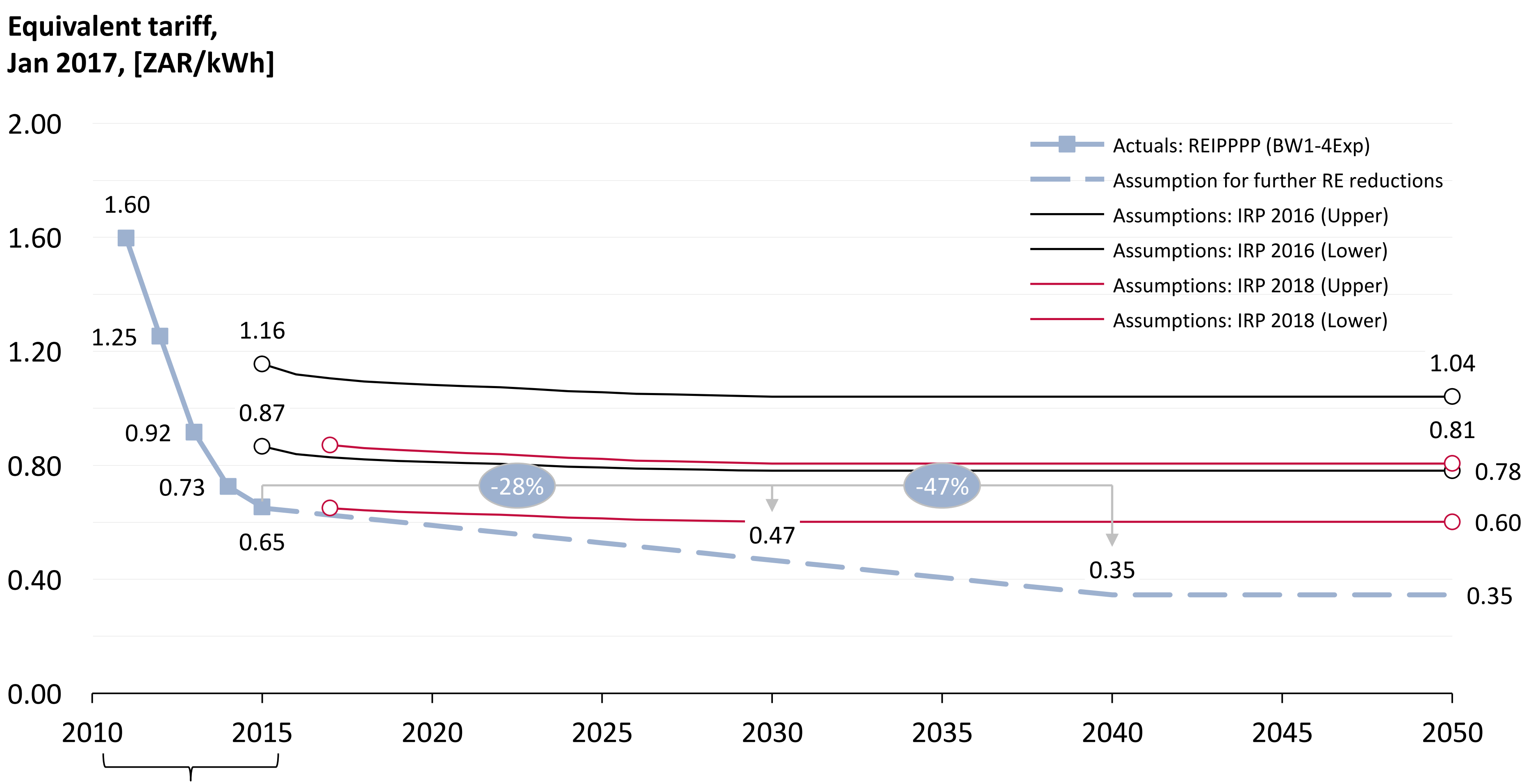
Wind cost learning assumptions in Draft IRP 2018

Actual wind tariffs and forecasted tariff trajectory



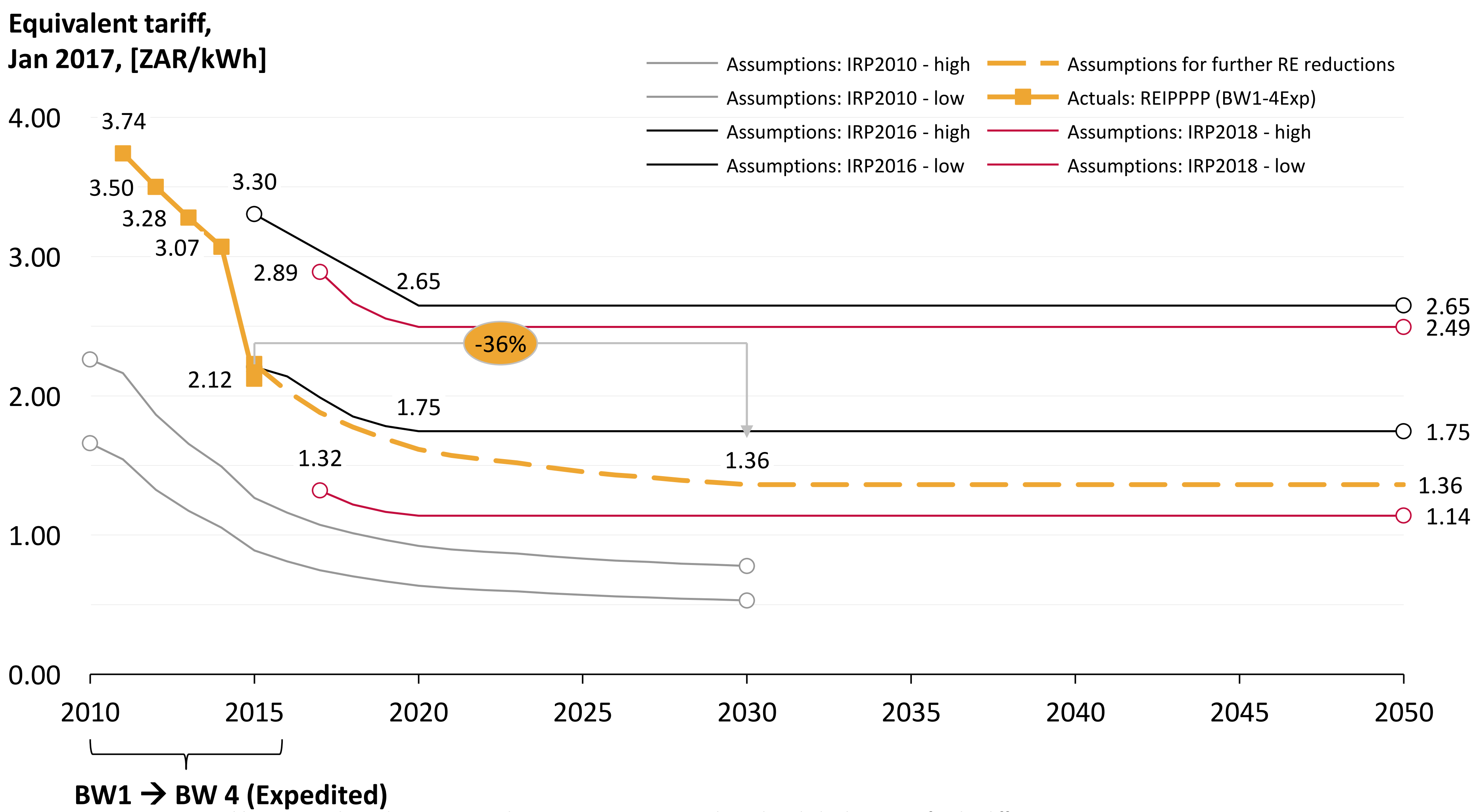
BW1 → BW 4 (Expedited)

Notes: REIPPPP = Renewable Energy Independant Power Producer Programme; BW = Bid Window; bid submissions for the different BWs: BW1 = Nov 2011; BW2 = Mar 2012; BW 3 = Aug 2013; BW 4 = Aug 2014; BW 4 (Expedited) = Nov 2015

Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis . Learning rate - Bloomberg New Energy Outlook 2017

Input assumptions for CSP from Draft IRP 2018 and further cost declines

Today's latest tariff as starting point, same cost decline as per IRP 2010



Notes: REIPPPP = Renewable Energy Independant Power Producer Programme; BW = Bid Window; bid submissions for the different BWs: BW1 = Nov 2011; BW2 = Mar 2012; BW 3 = Aug 2013; BW 4 = Aug 2014; BW 4 (Expedited) = Nov 2015; For CSP bid window 3, 3.5 and 4 Exp, weighted average tariff of base and peak tariff calculated on the assumption of 64%/36% base/peak tariff utilisation ratio; Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis

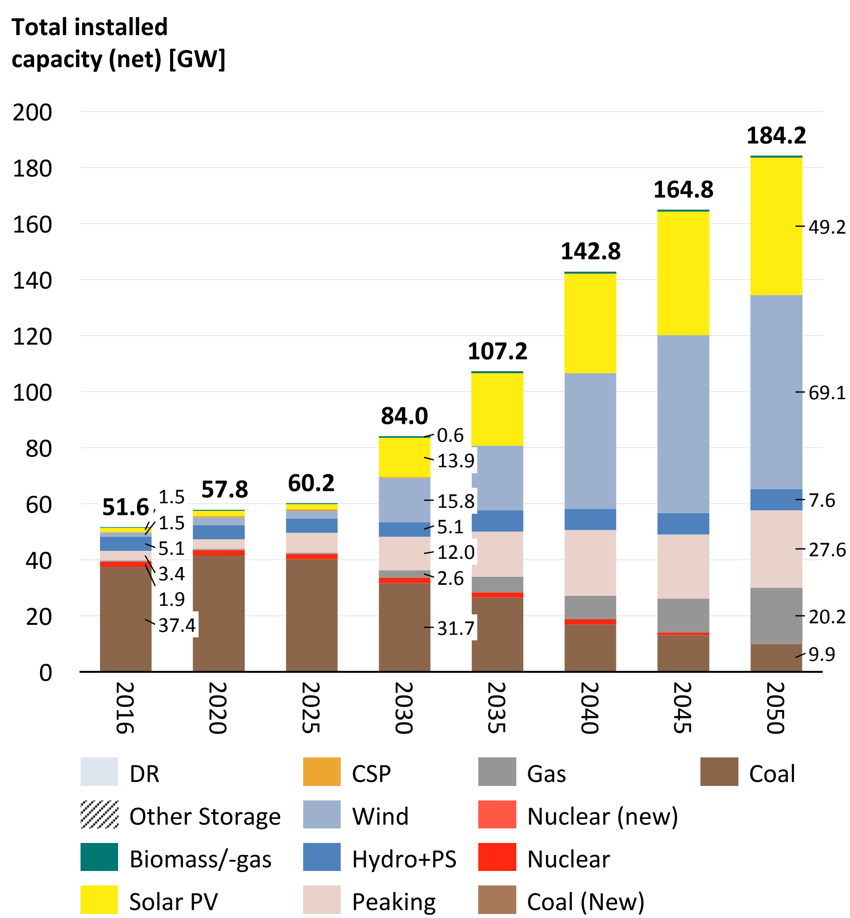
Draft IRP 2018 IRP1 with further RE cost reductions, increased solar PV and wind from 2030 onwards, timing unchanged, no import hydro

Submitted to DoE on 25 October 2018

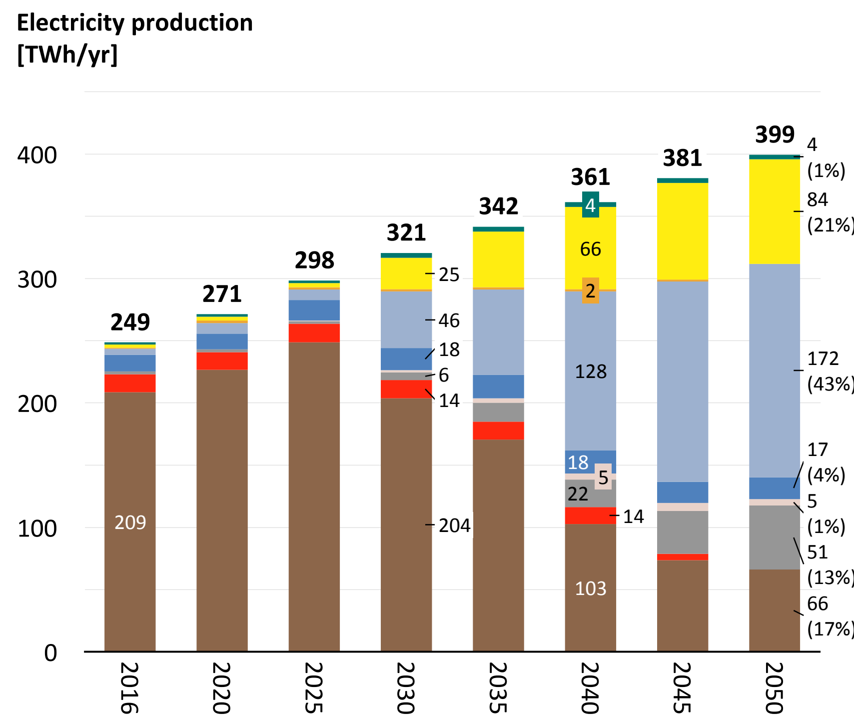
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with higher RE cost reductions

Further RE cost reductions

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2027)	*5.9 GW*
Wind (2027)	*2.8 GW*
OCGT (2024)	*1.9 GW*

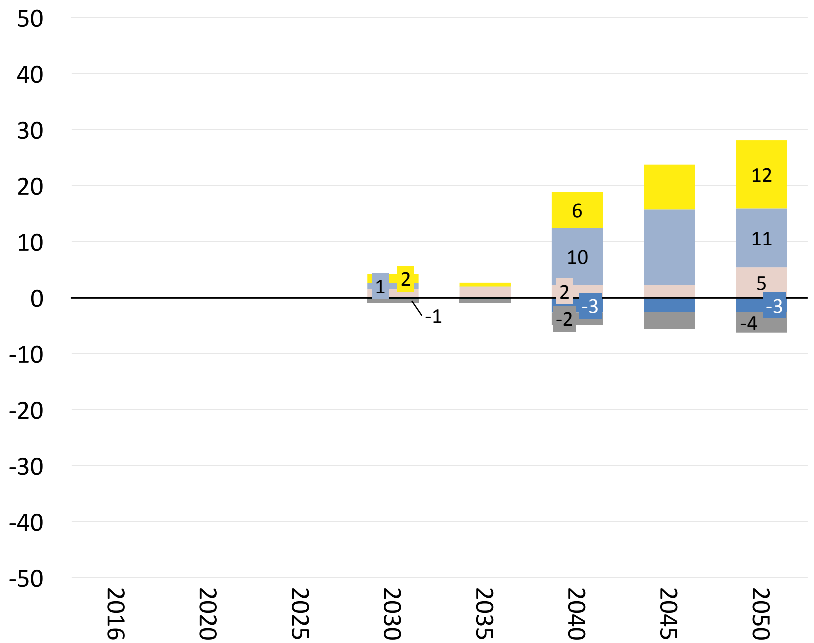
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Difference in installed capacity and energy mix with higher RE cost reductions relative to IRP1, higher RE & peaking gas, less mid-merit gas

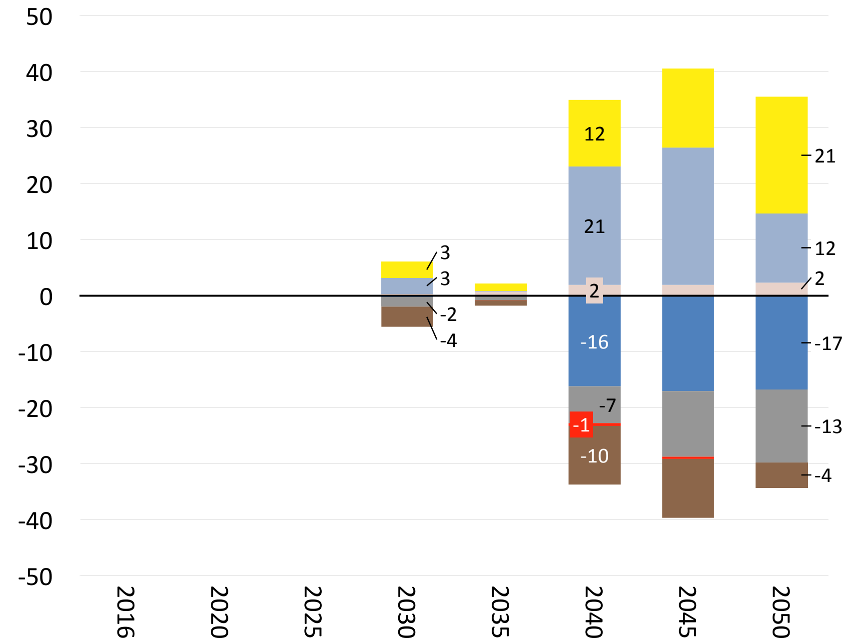
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with higher RE cost reductions

Further RE cost reductions

Installed capacity



Energy mix



DR | Solar PV | Hydro+PS | Nuclear (new) | Coal
Other Storage | CSP | Peaking | Nuclear
Biomass/-gas | Wind | Gas | Coal (New)

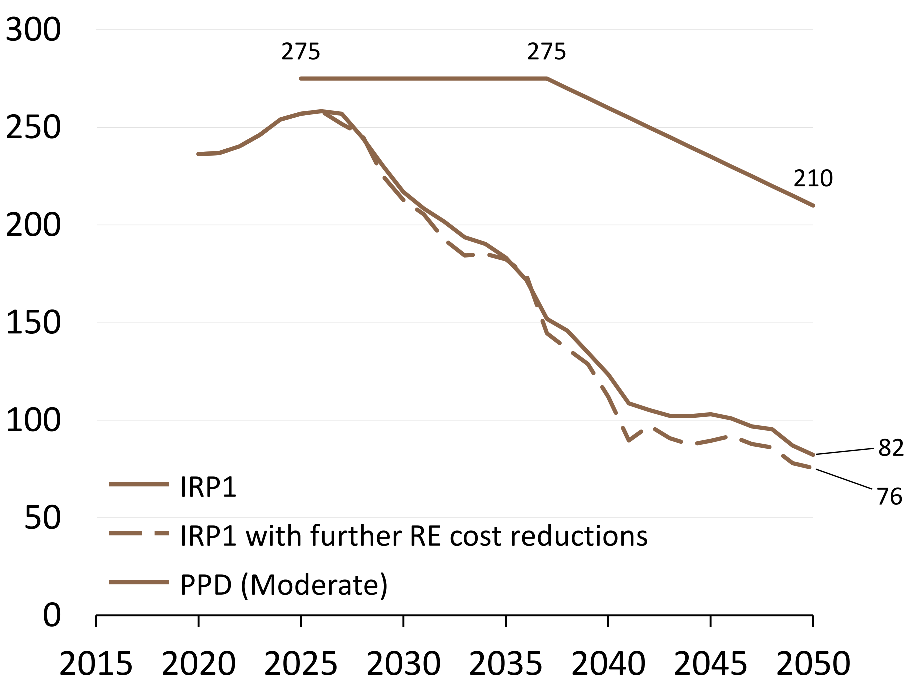
Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

IRP 1 with higher RE cost reductions

CO_2 emissions

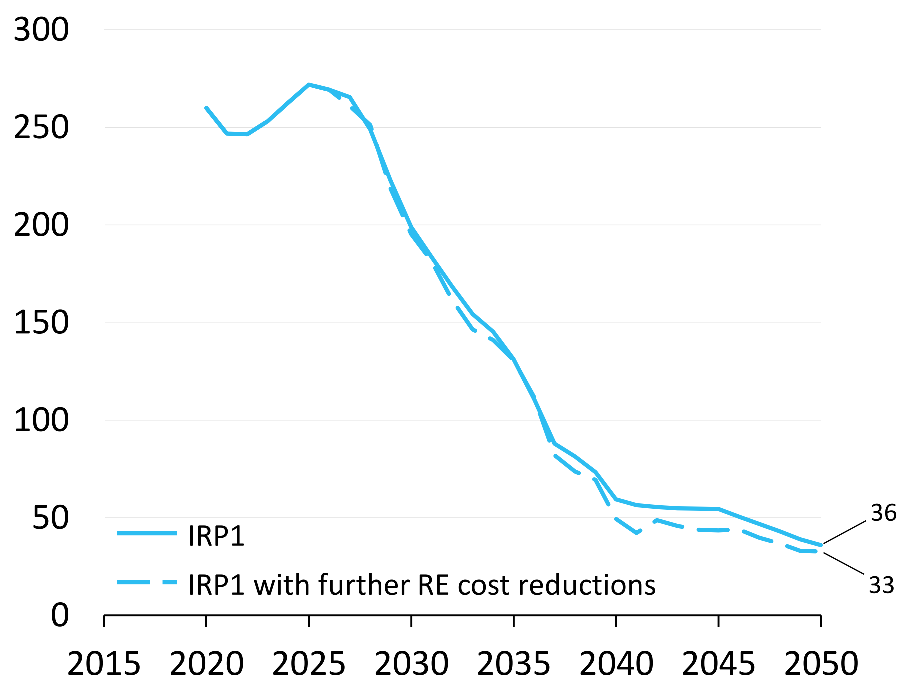
Electricity sector
CO_2 emissions
[Mt/yr]



Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

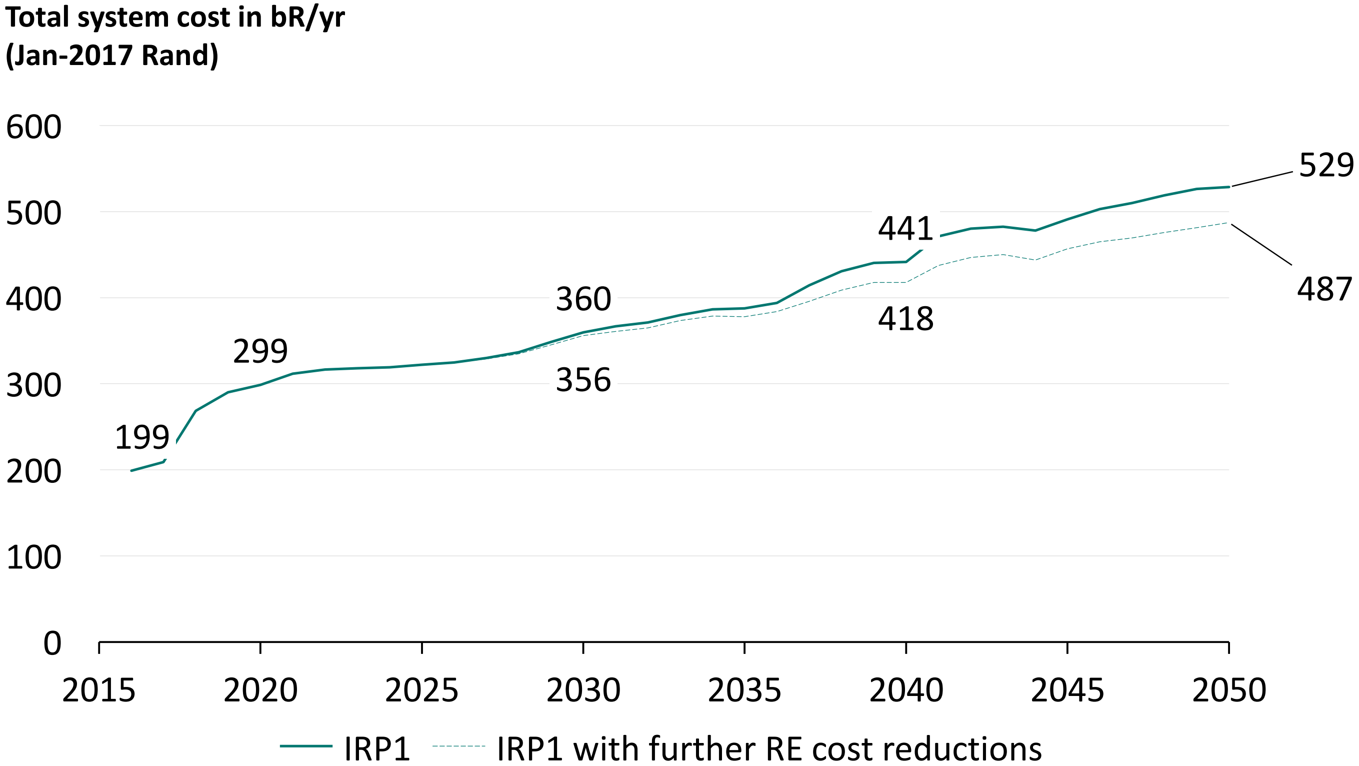
Water usage

Electricity sector
Water usage
[bl/yr]

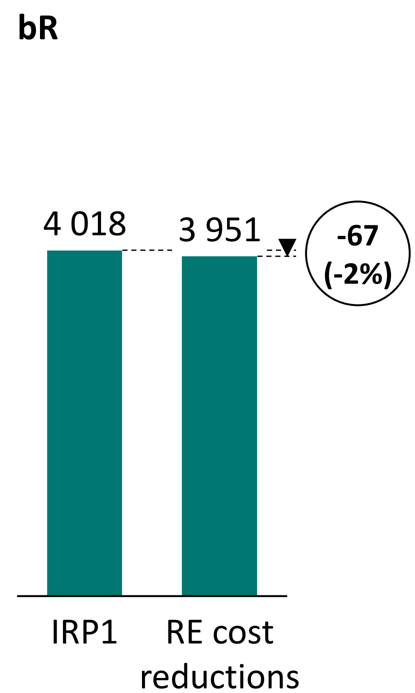


Total system cost: IRP1 with higher RE cost reductions would result in lower system cost

Total System Cost



Net Present Value System Cost
(2016 - 2050)



Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

Sources: Draft IRP 2018. CSIR Energy Centre analysis. Eskom on Tx, Dx costs

Submitted to DoE on 25 October 2018

Formal comments on Draft IRP 2018

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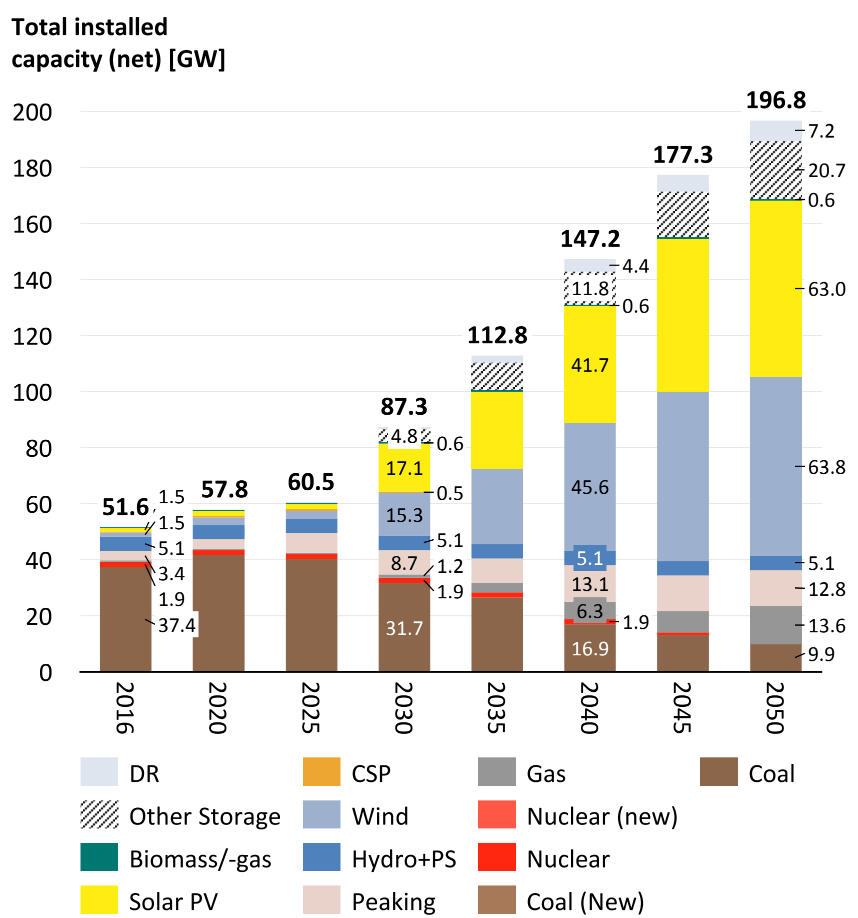
Draft IRP 2018 IRP1 with storage, DSR and lower RE costs results in increased new-build wind, solar PV, storage and less NG

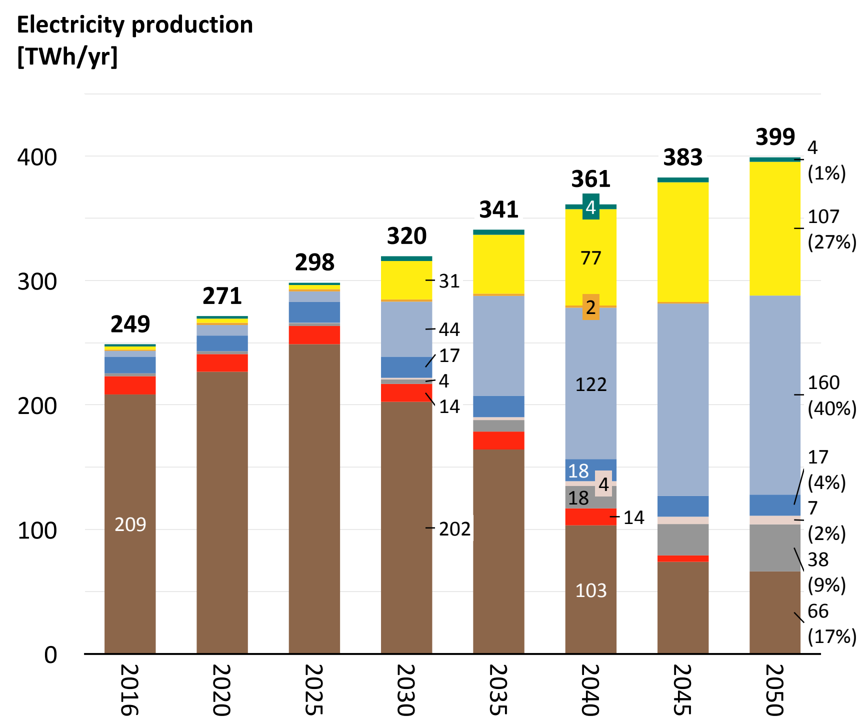
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with storage, DSR and higher RE cost reductions

Risk-adjusted scenario

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2027)	*6.5 GW*
Wind (2027)	*2.1 GW*
OCGT (2024)	*1.9 GW*
Storage (2027)	*1.1 GW*

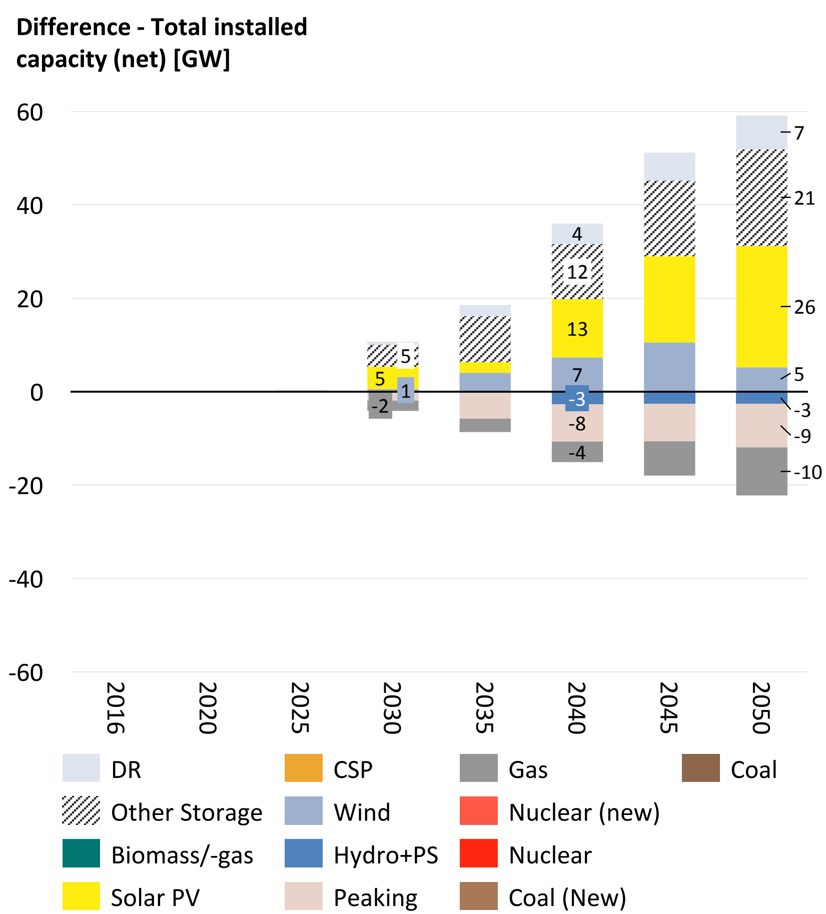
Notes: NG = Natural gas
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Difference in installed capacity and energy mix Risk-adjusted scenario relative to IRP1, higher wind, PV & storage, less NG

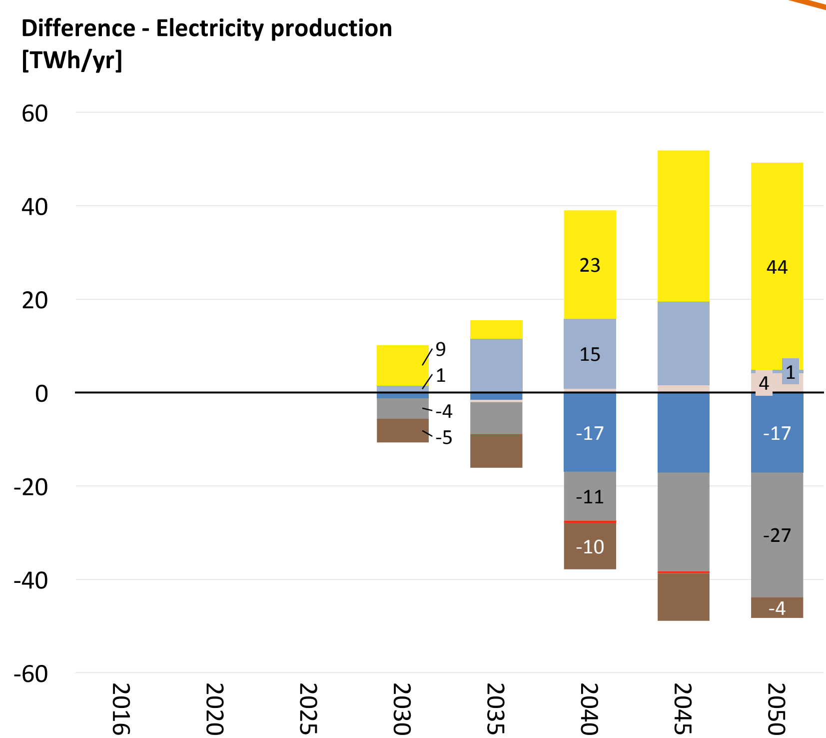
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with storage, DSR and higher RE cost reductions

Risk-adjusted scenario

Installed capacity



Energy mix



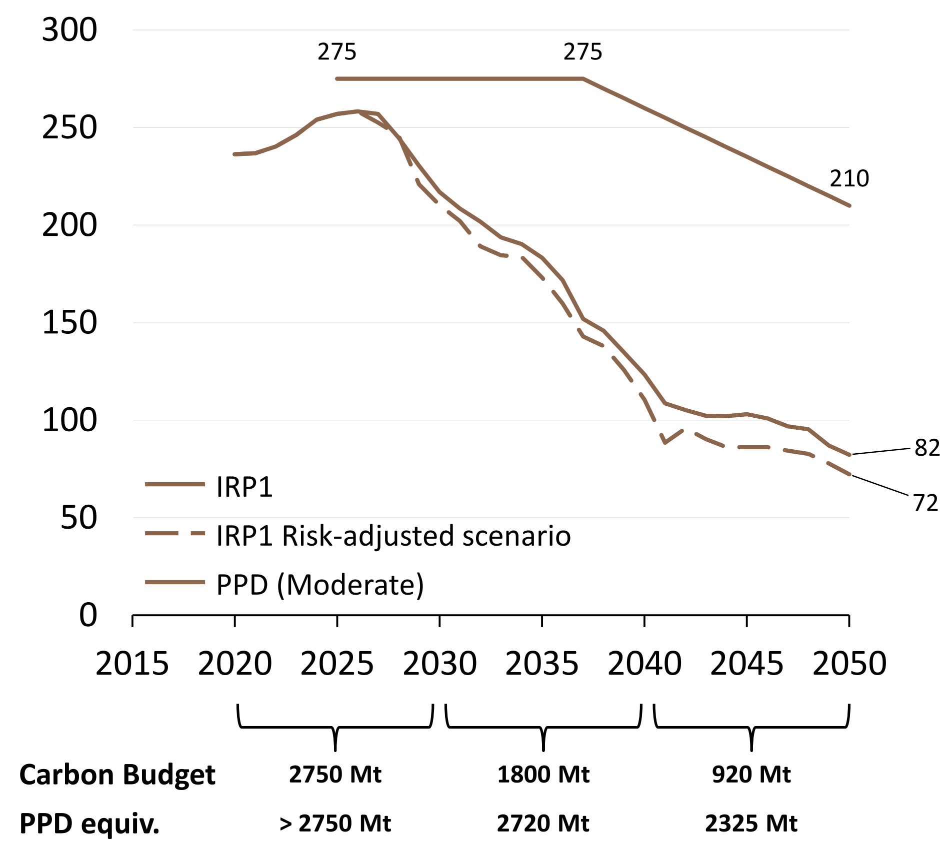
Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

IRP 1 with storage, DSR and higher RE cost reductions

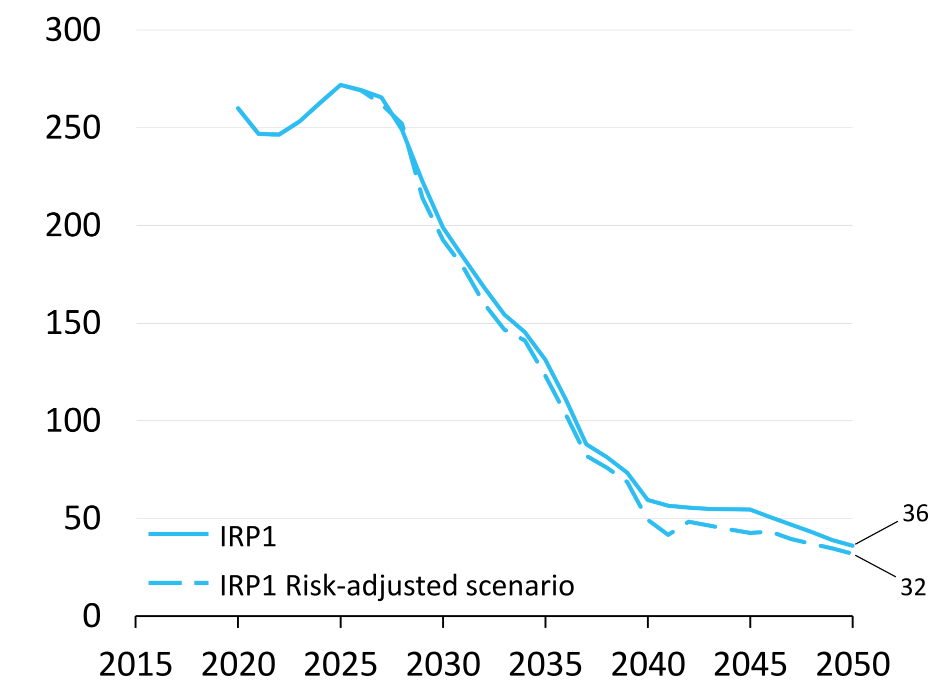
CO_2 emissions

Electricity sector
CO2 emissions
[Mt/yr]

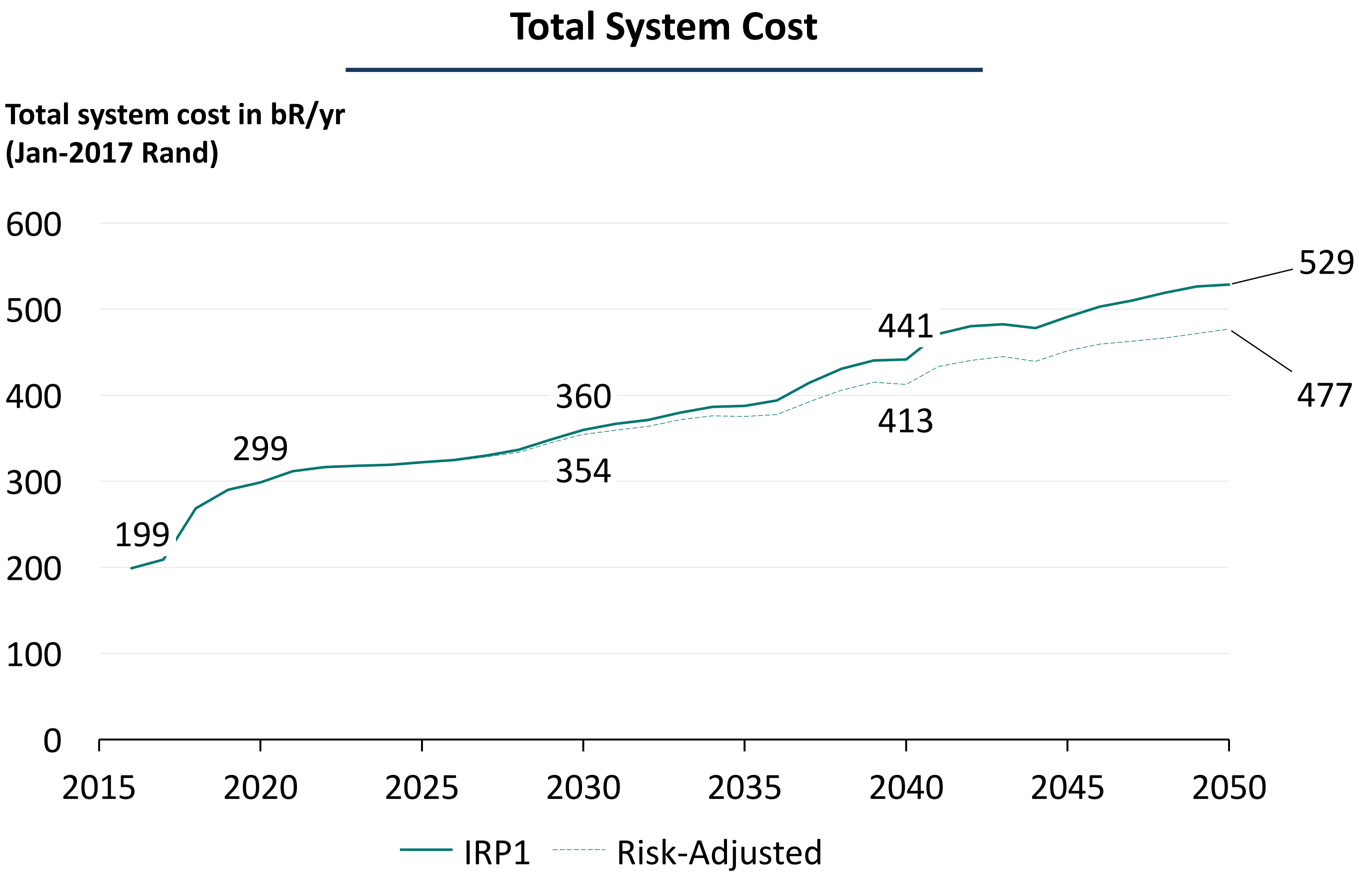


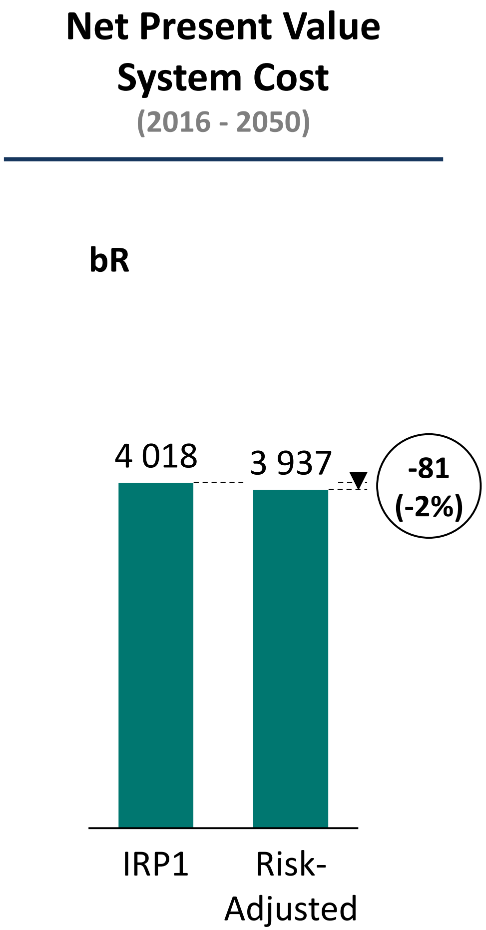
Water usage

Electricity sector
Water usage
[bl/yr]



Total system cost: Risk-adjusted scenario results in lower system cost than IRP1





Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

Sources: Draft IRP 2018. CSIR Energy Centre analysis. Eskom on Tx, Dx costs

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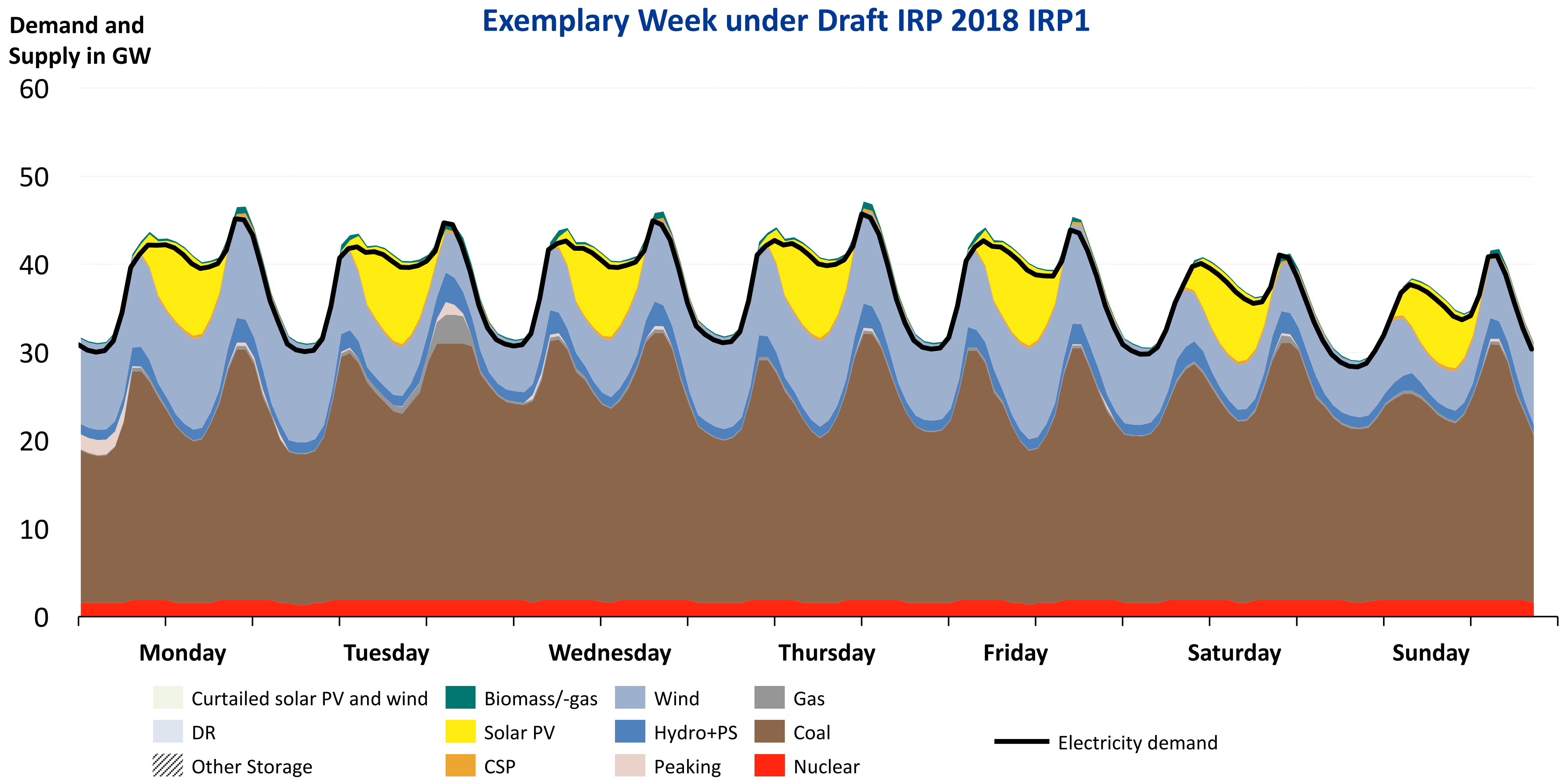
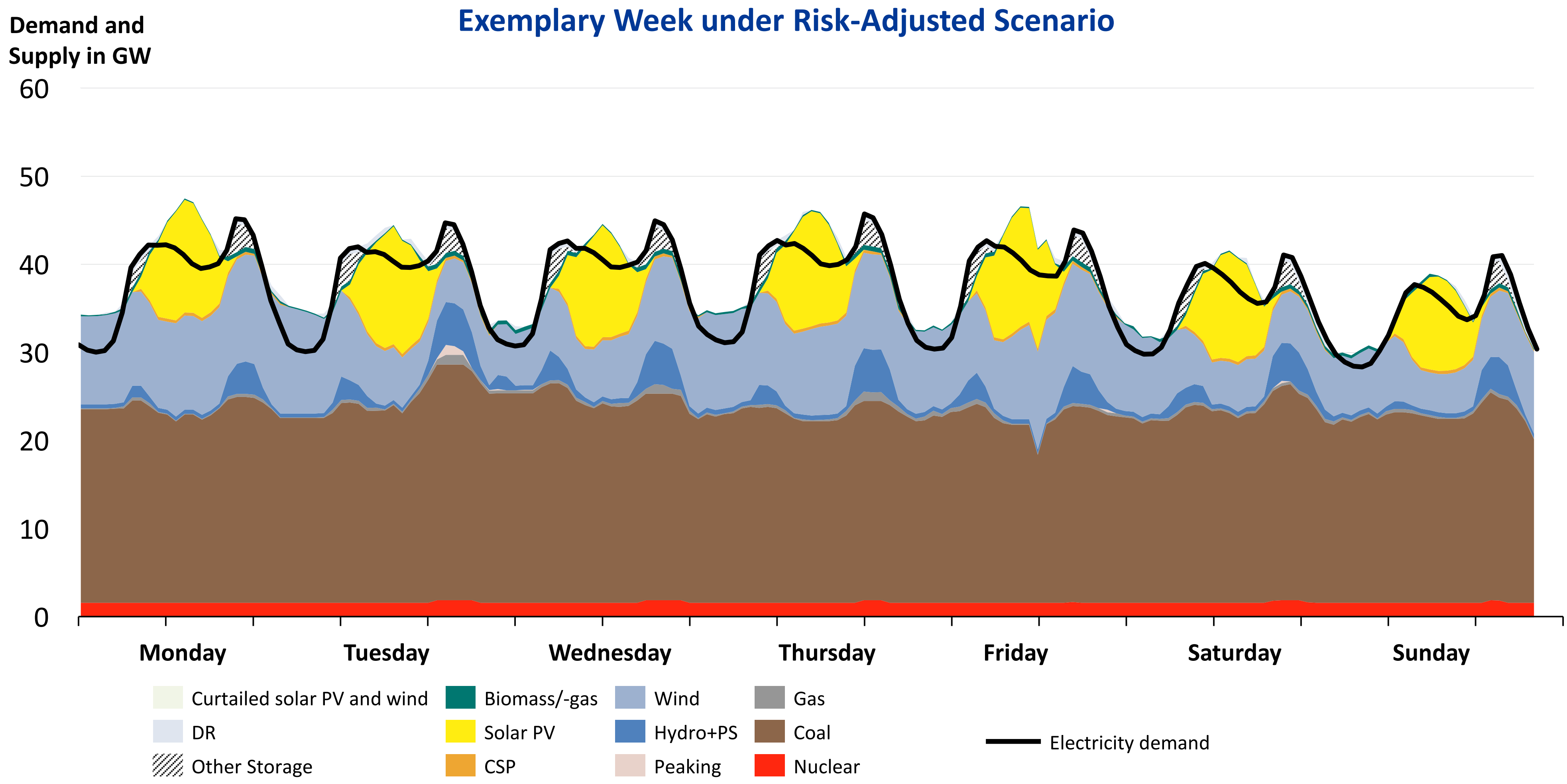
Draft IRP 2018 IRP1: 2030



Sources: CSIR analysis

Risk-Adjusted Scenario: 2030



Sources: CSIR analysis

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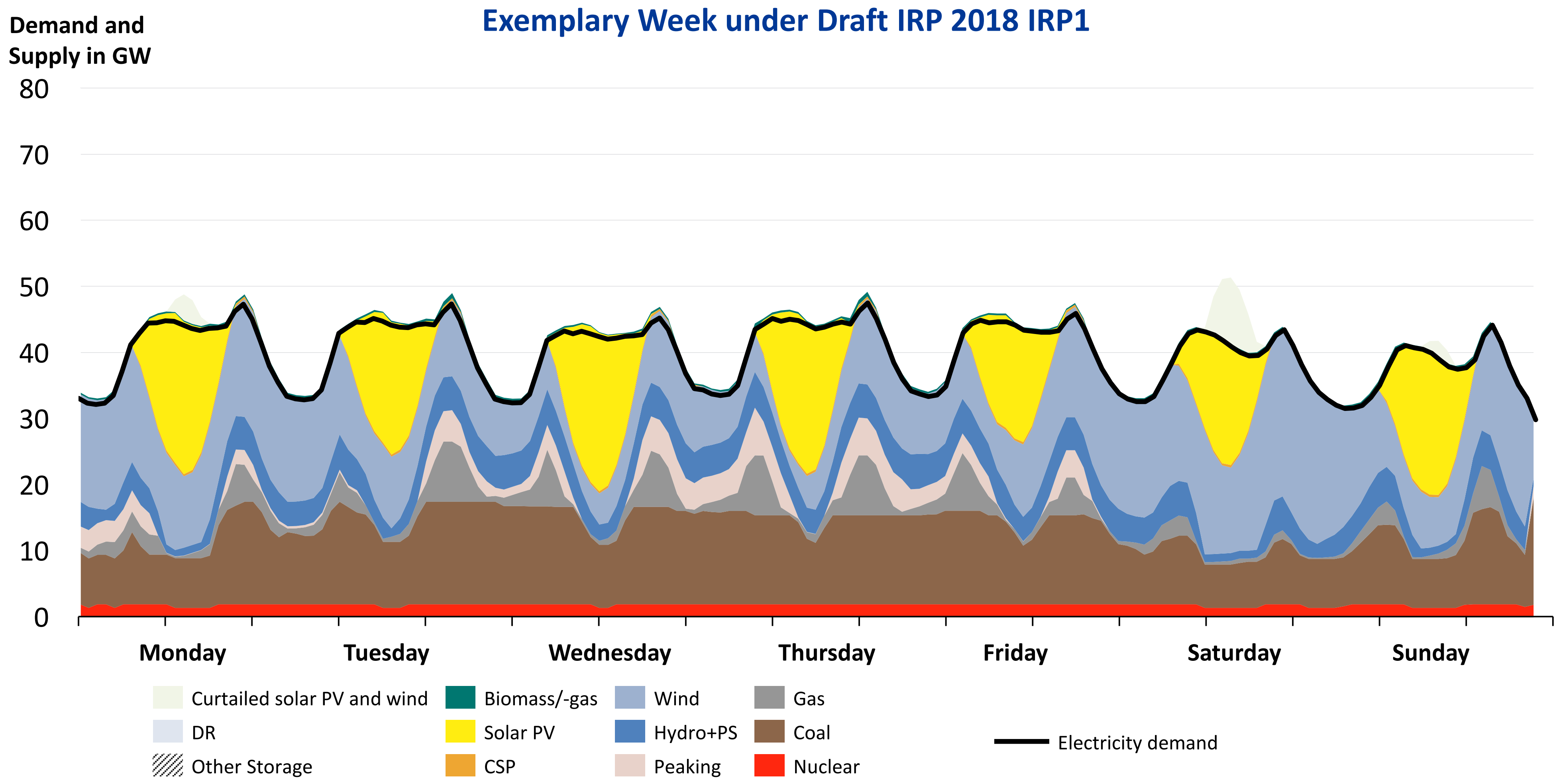
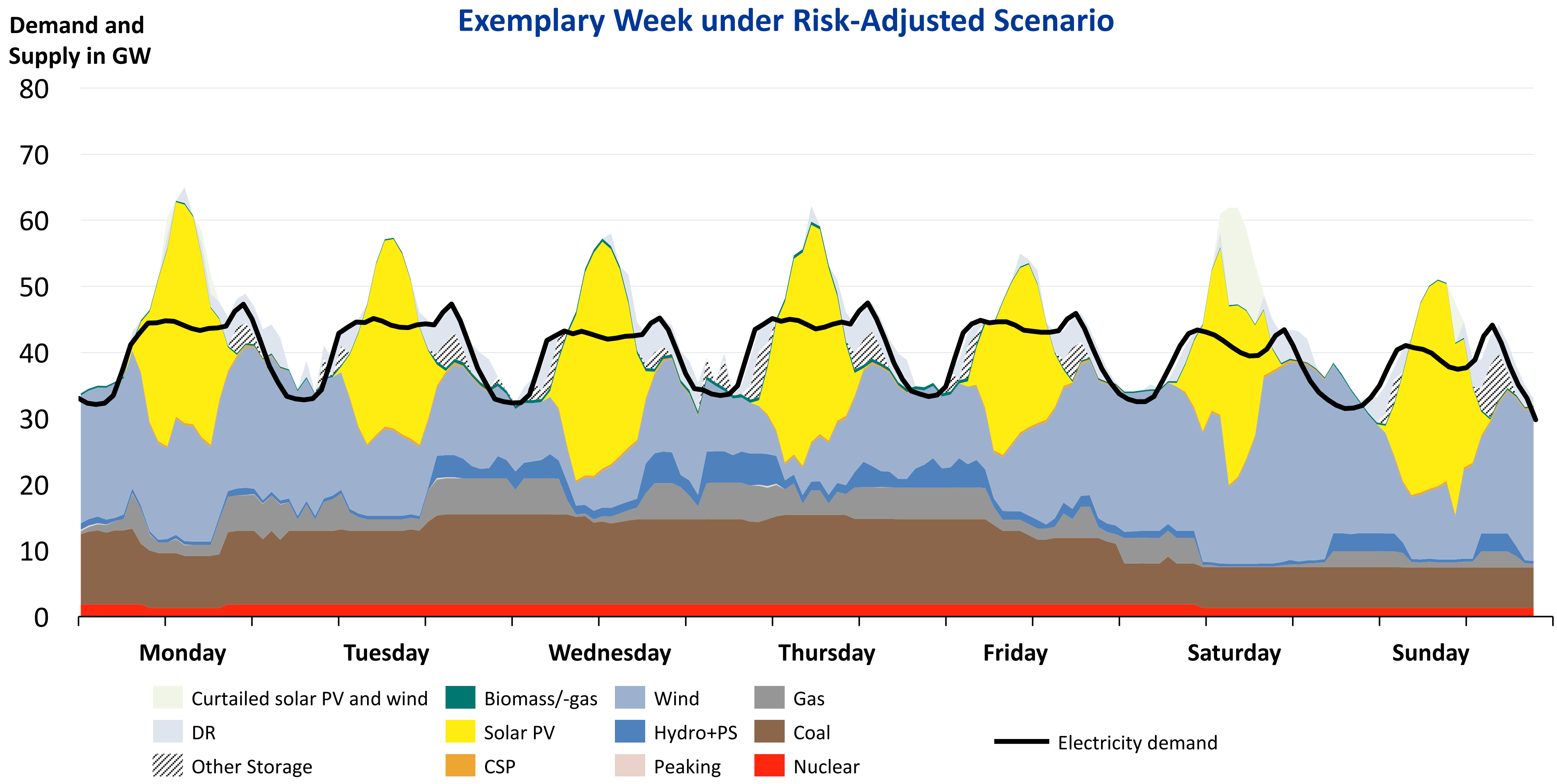
Draft IRP 2018 IRP1: 2040



Sources: CSIR analysis

Risk-Adjusted: 2040



Sources: CSIR analysis

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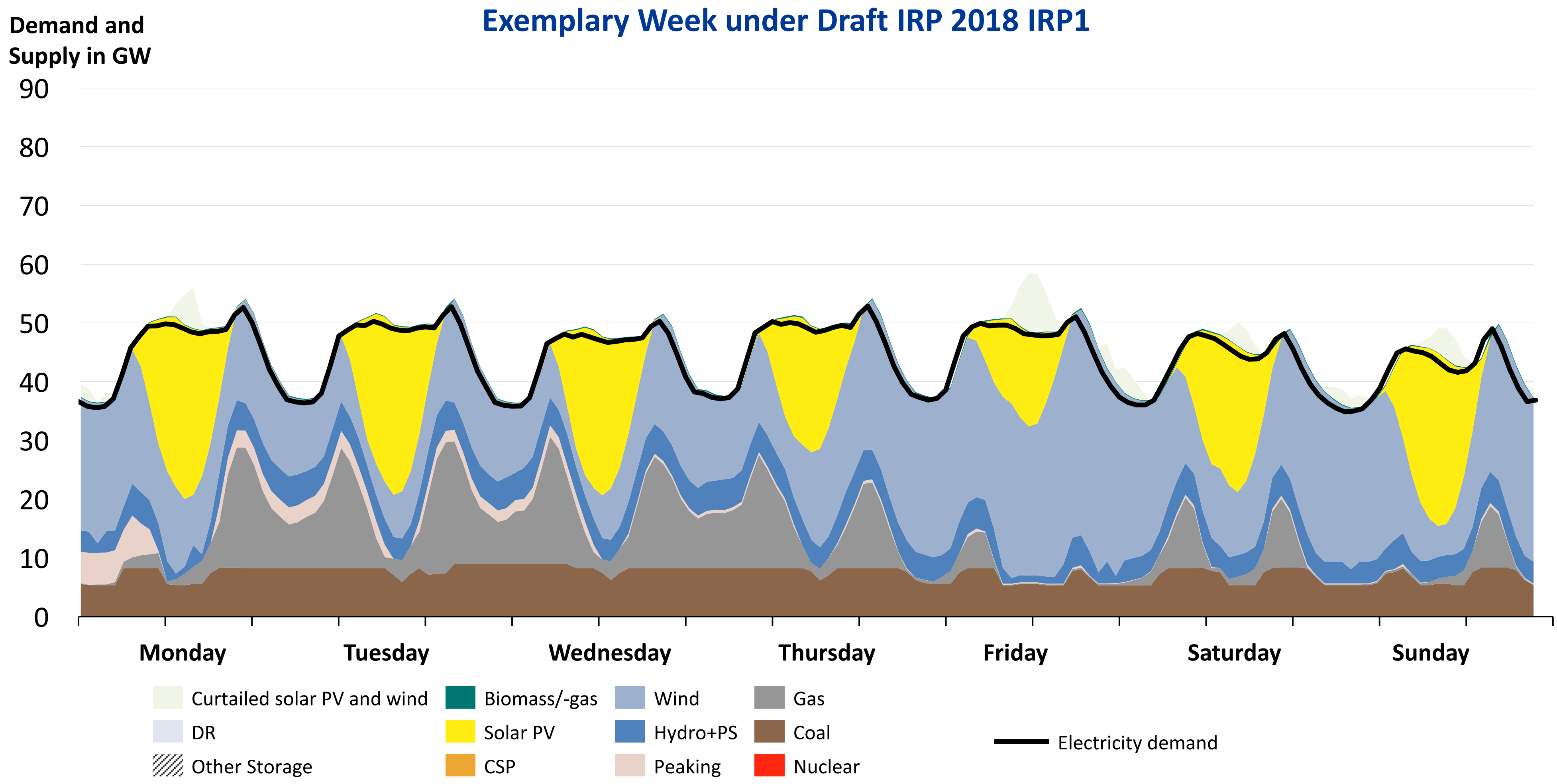
Draft IRP 2018 IRP1: 2050



Sources: CSIR analysis

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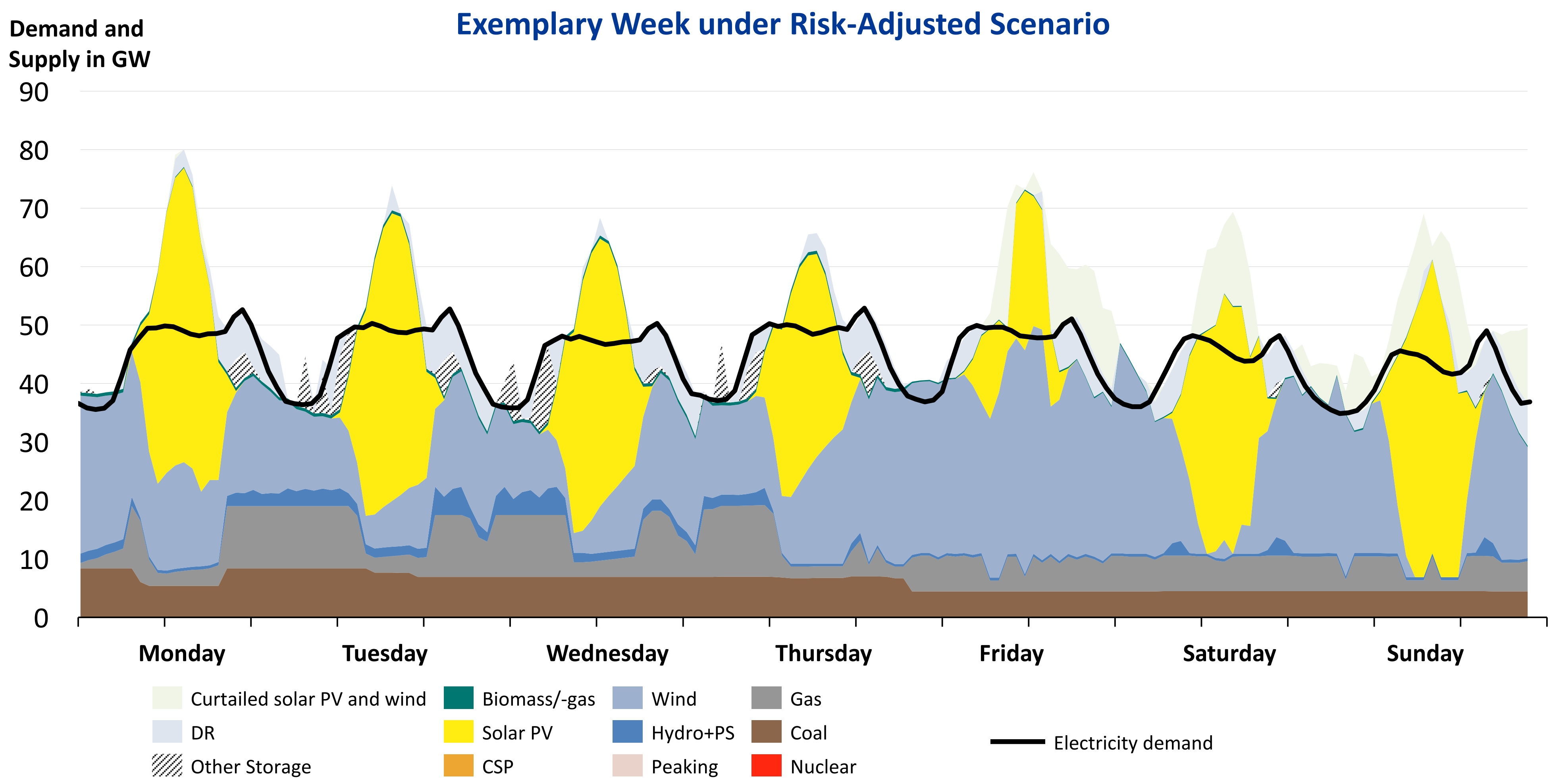
Risk-Adjusted: 2050



Sources: CSIR analysis

Formal comments on Draft IRP 2018

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Formal comments on Draft IRP 2018

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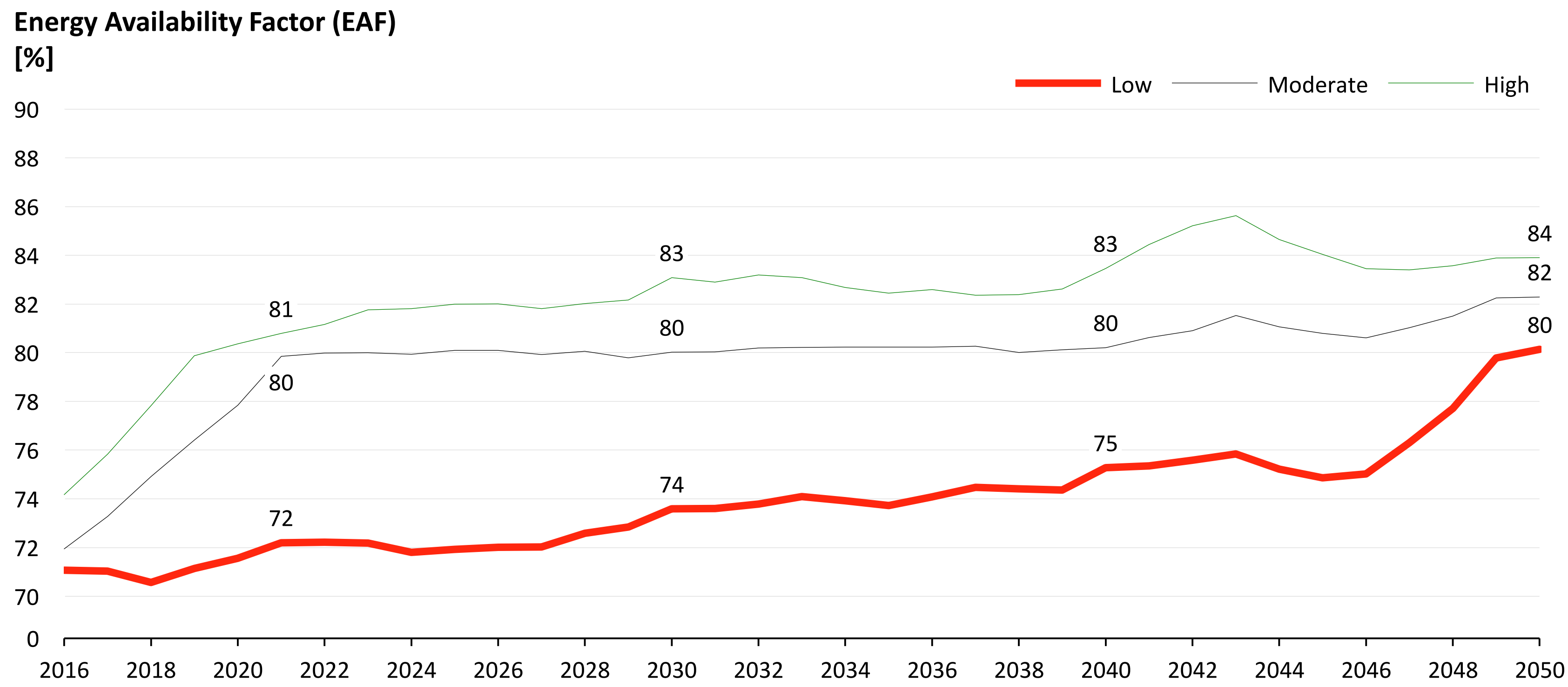
Eskom existing fleet performance – EAF (scenario)

If the existing coal fleet does not recover to the expected “Moderate“ EAF used in the Draft IRP 2018

“Low“ EAF of existing coal fleet is considered to test

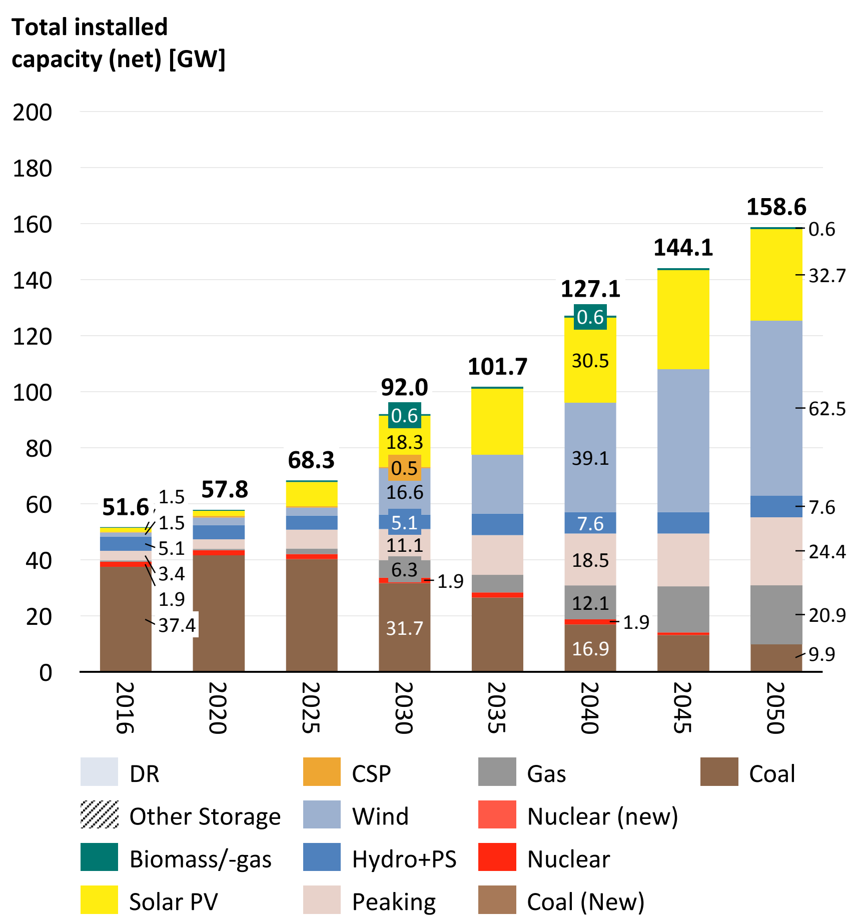


Submitted to DoE on 25 October 2018

Draft IRP 2018 IRP1 with Low EAF requires earlier new-build around 2023 and increased absolute levels of new-build by 2030

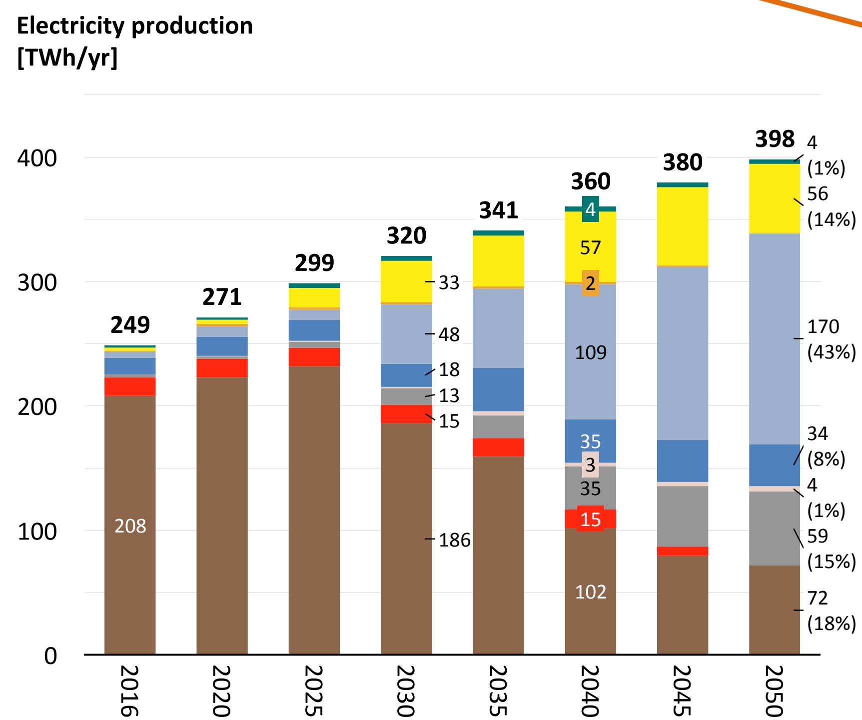
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with low coal fleet EAF

Installed capacity



Energy mix

Coal fleet Low EAF



Demand: Median

First new-builds:

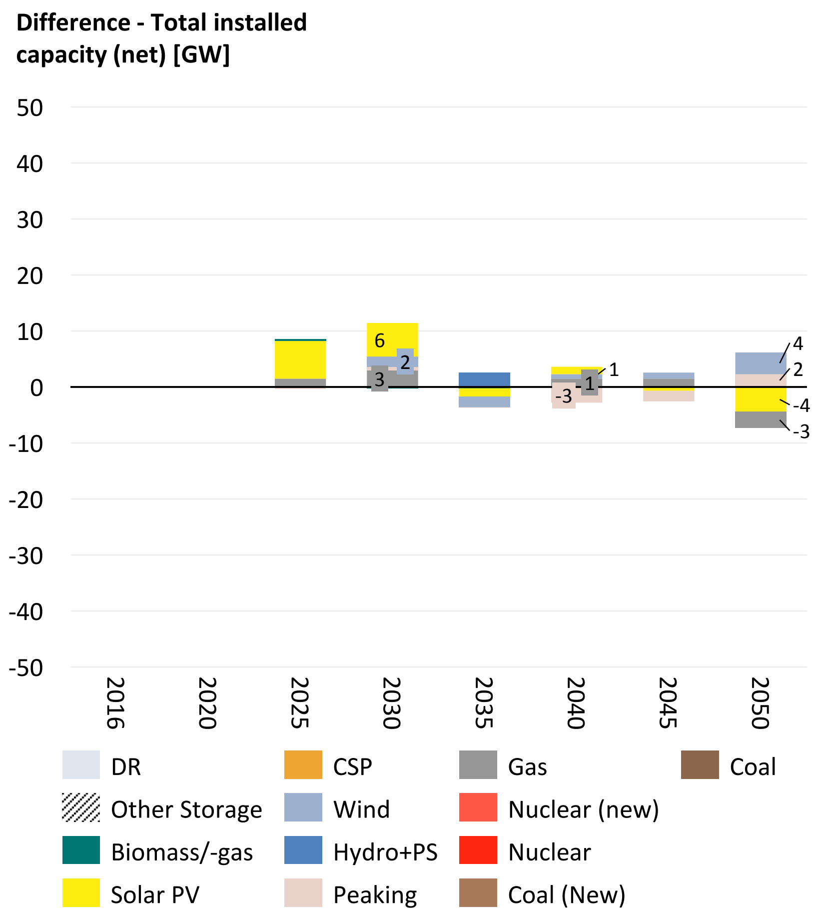
PV (2023)	*0.2 GW*
Wind (2026)	*3.6 GW*
OCGT (2023)	*2.0 GW*

Sources: Draft IRP 2018. CSIR Energy Centre analysis

Difference in capacity and energy mix with low EAF relative to IRP1, increased level of new-build, built earlier to cater for lower coal supply

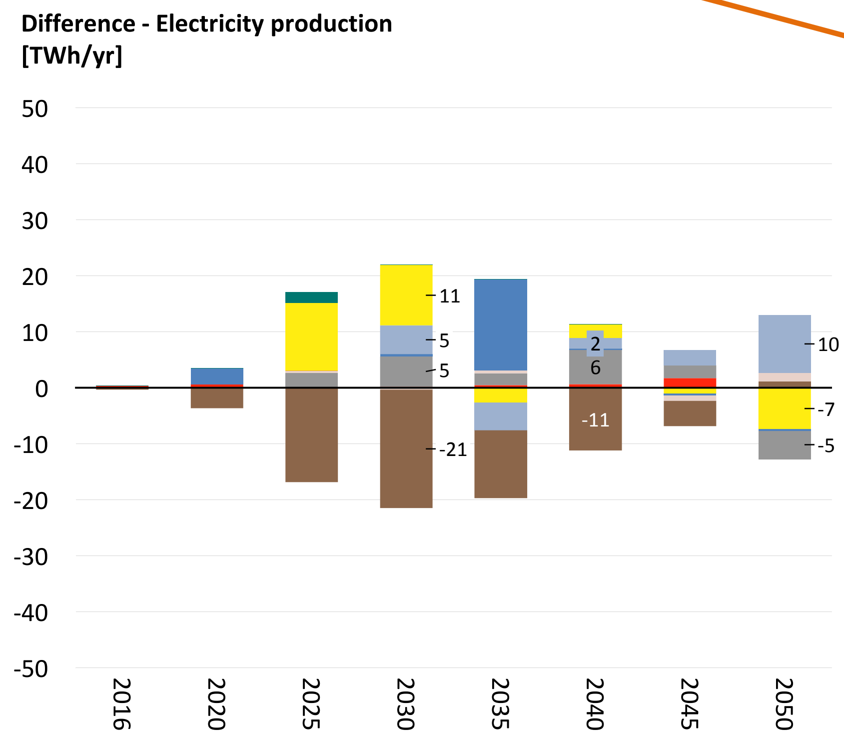
Installed capacity and electricity supplied from 2016 to 2050 for IRP1 with low coal fleet EAF

Installed capacity



Energy mix

Coal fleet Low EAF



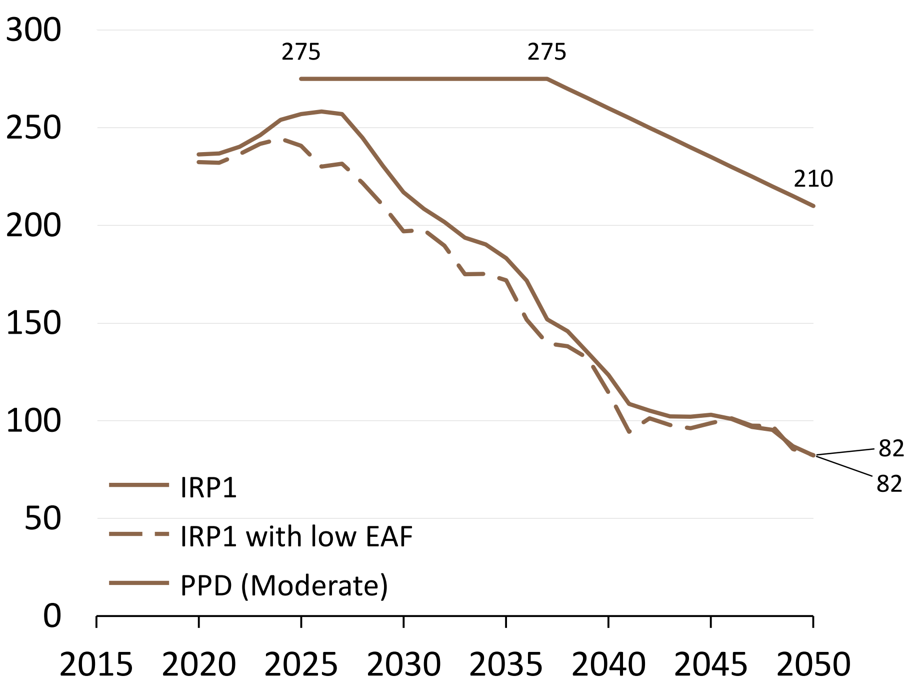
Sources: Draft IRP 2018. CSIR Energy Centre analysis

CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

IRP 1 with low coal fleet EAF

CO_2 emissions

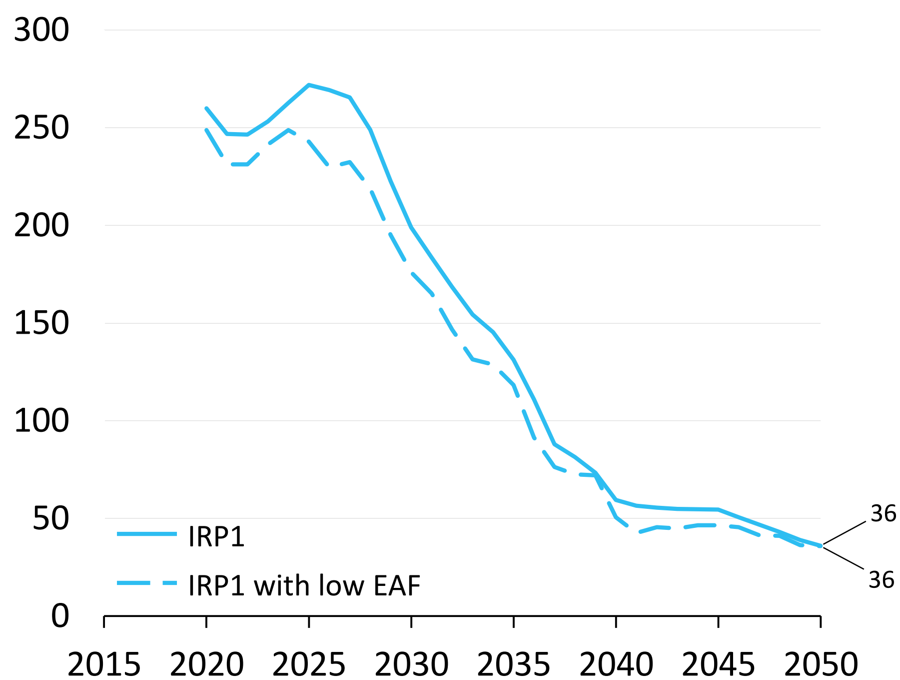
Electricity sector
CO_2 emissions
[Mt/yr]



	2020–2030	2030–2040	2040–2050
Carbon Budget	**2750 Mt**	**1800 Mt**	**920 Mt**
PPD equiv.	**> 2750 Mt**	**2720 Mt**	**2325 Mt**

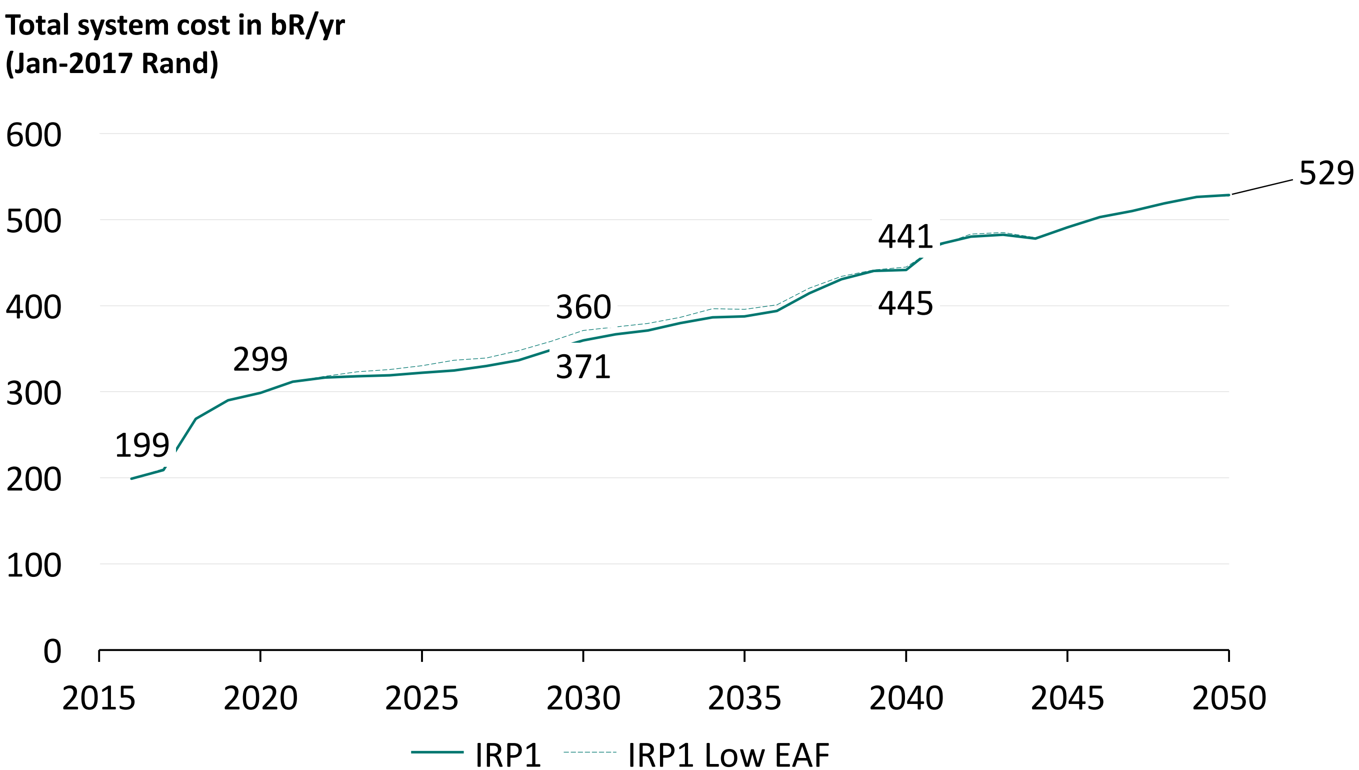
Water usage

Electricity sector
Water usage
[bl/yr]



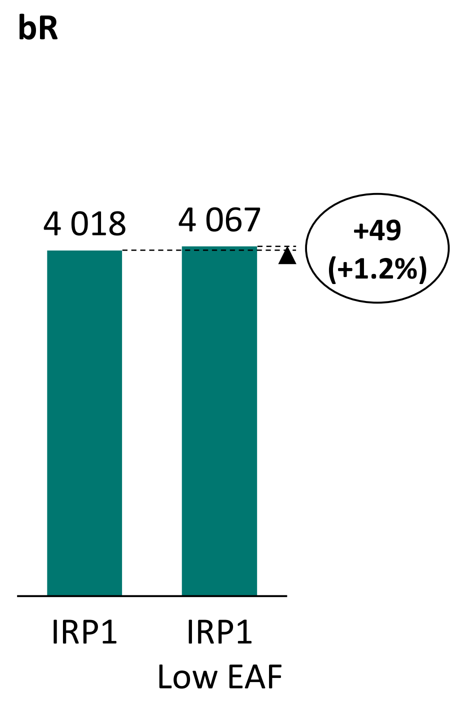
Total system cost: IRP1 with low EAF higher system cost than IRP1 due to additional capacity required

Total System Cost



Net Present Value System Cost

(2016 - 2050)



Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

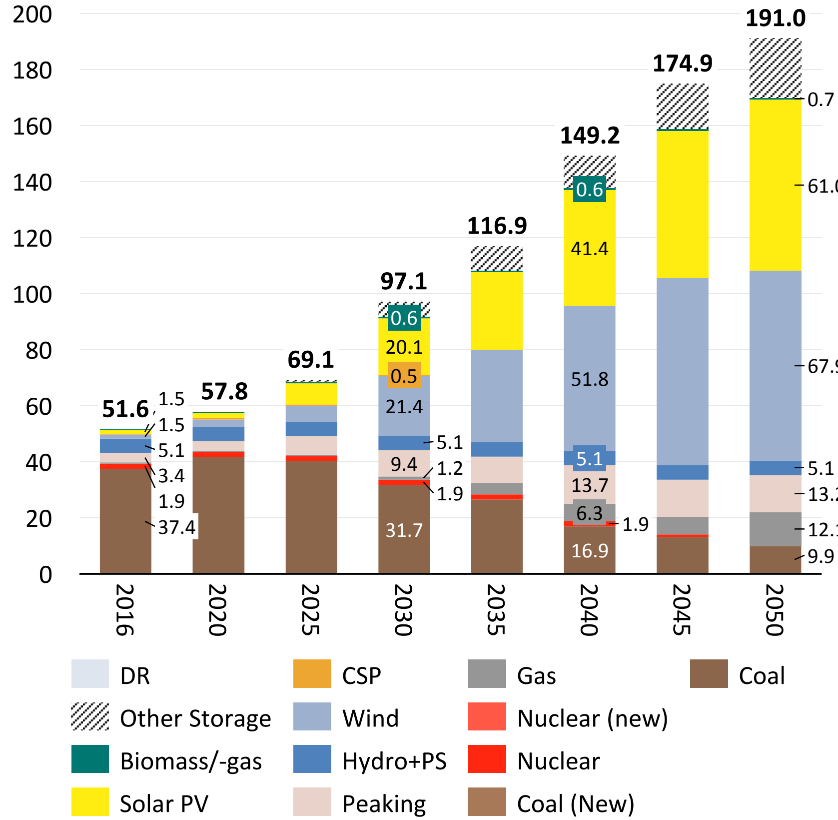
Sources: Draft IRP 2018. CSIR Energy Centre analysis. Eskom on Tx, Dx costs

Formal comments on Draft IRP 2018

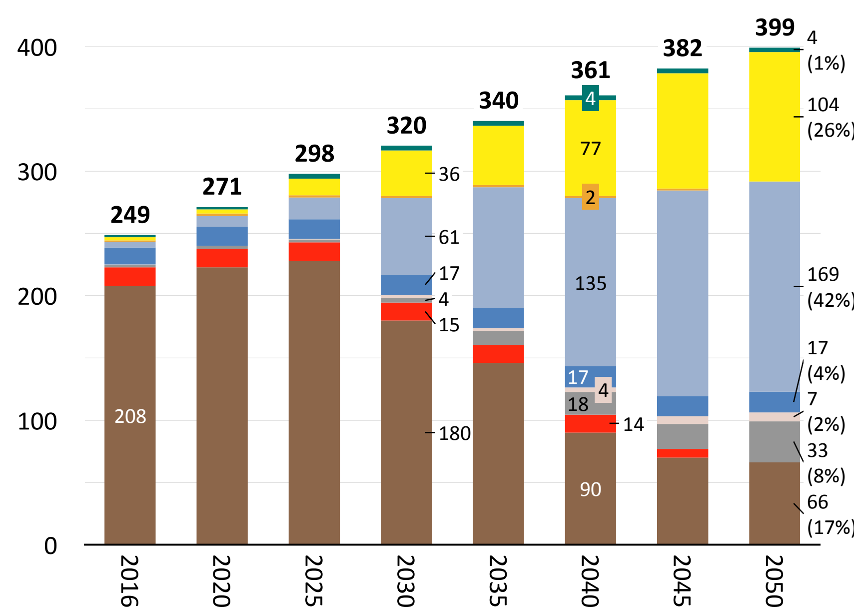
Risk-adjusted scenario with Low EAF requires earlier new-build around 2023 too and increased absolute levels of new-build by 2030

Installed capacity and electricity supplied from 2016 to 2050 for Risk-adjusted scenario with low coal fleet EAF

Installed capacity



Energy mix



Demand: Median

First new-builds:

PV (2023)	*0.4 GW*
Wind (2023)	*0.2 GW*
OCGT (2023)	*1.9 GW*

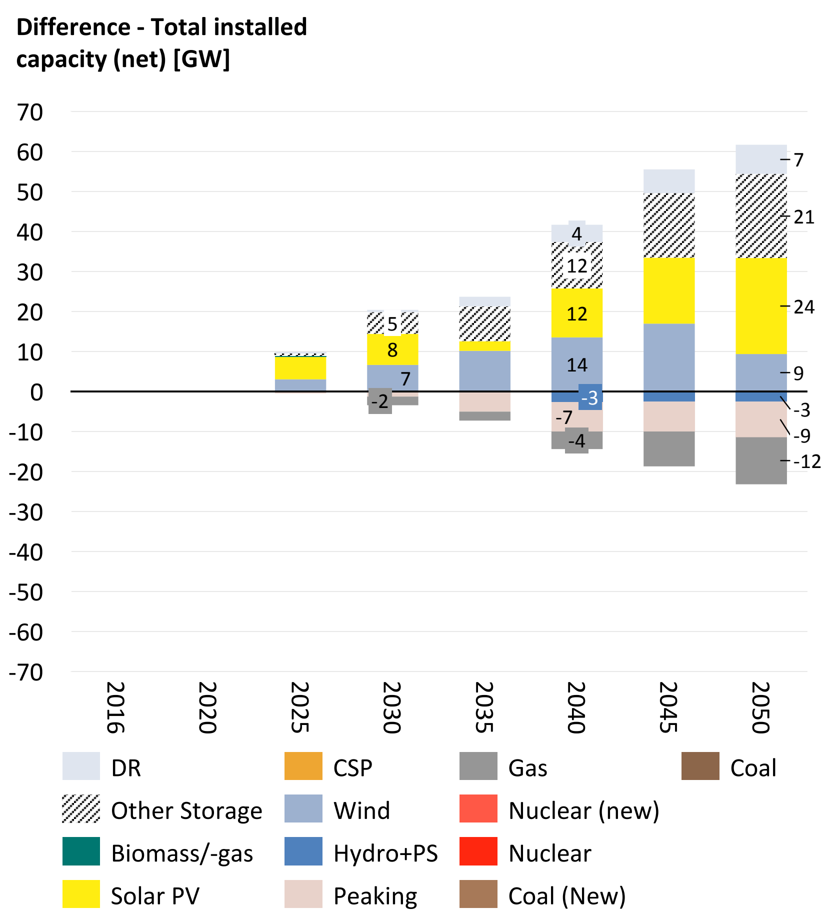
Sources: Draft IRP 2018. CSIR Energy Centre analysis

Difference in capacity and energy mix with low EAF relative to IRP1, increased level of new-build, built earlier to cater for lower coal supply

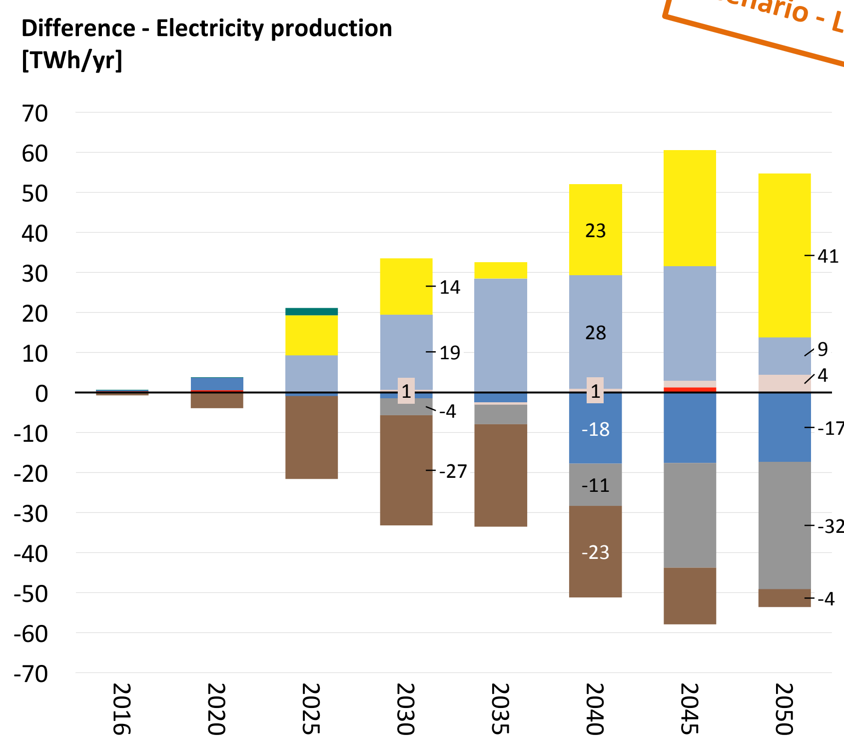
Installed capacity and electricity supplied from 2016 to 2050 for Risk-adjusted scenario with low coal fleet EAF

Risk-adjusted scenario - Low EAF

Installed capacity



Energy mix

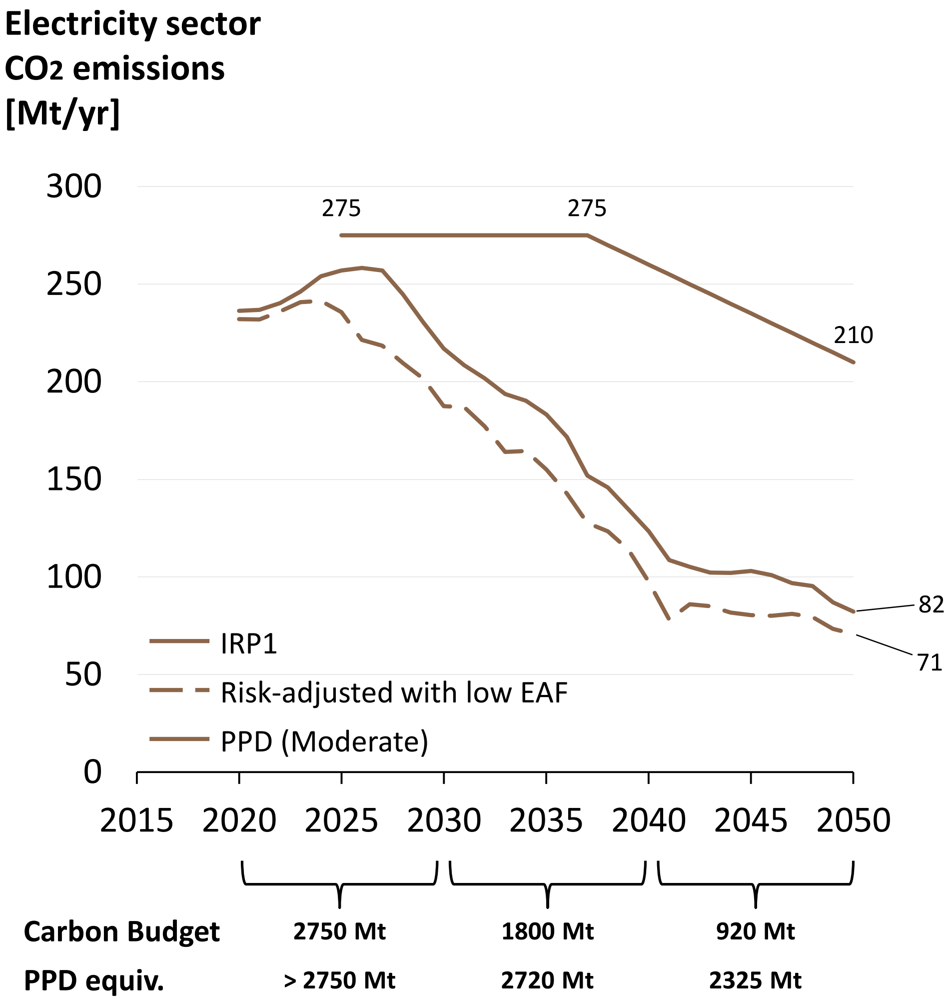


Sources: Draft IRP 2018. CSIR Energy Centre analysis

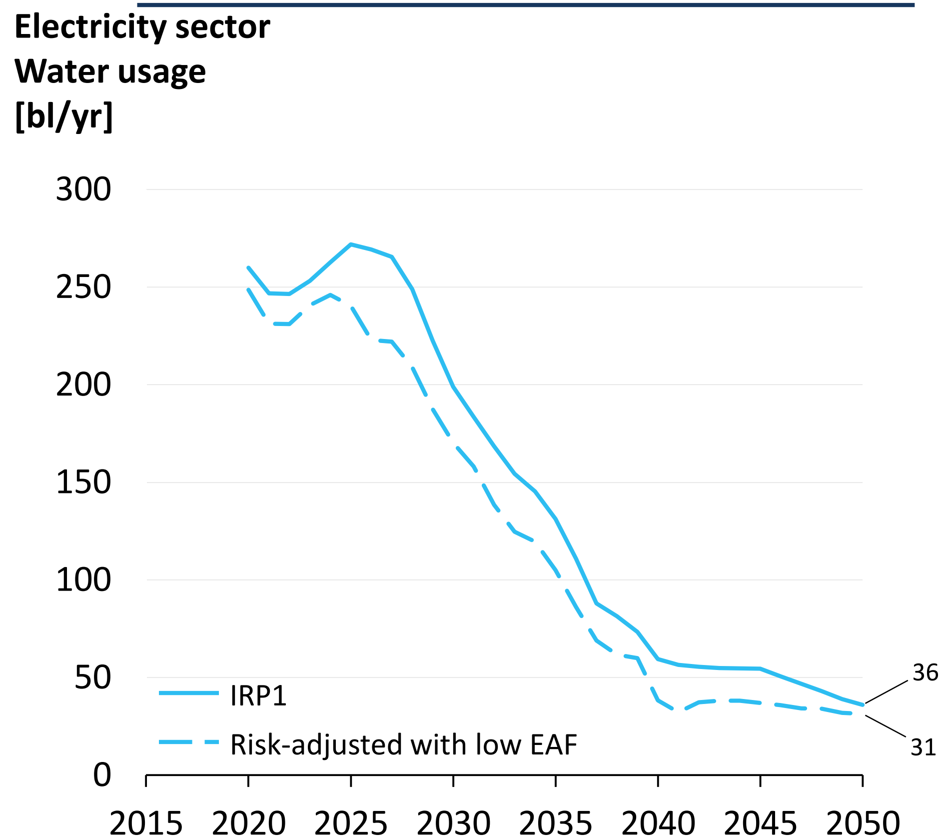
CO_2 emissions trajectories for PPD Moderate never binding while water use declines as expected as coal fleet decommissions

Risk-adjusted scenario with low coal fleet EAF

CO_2 emissions

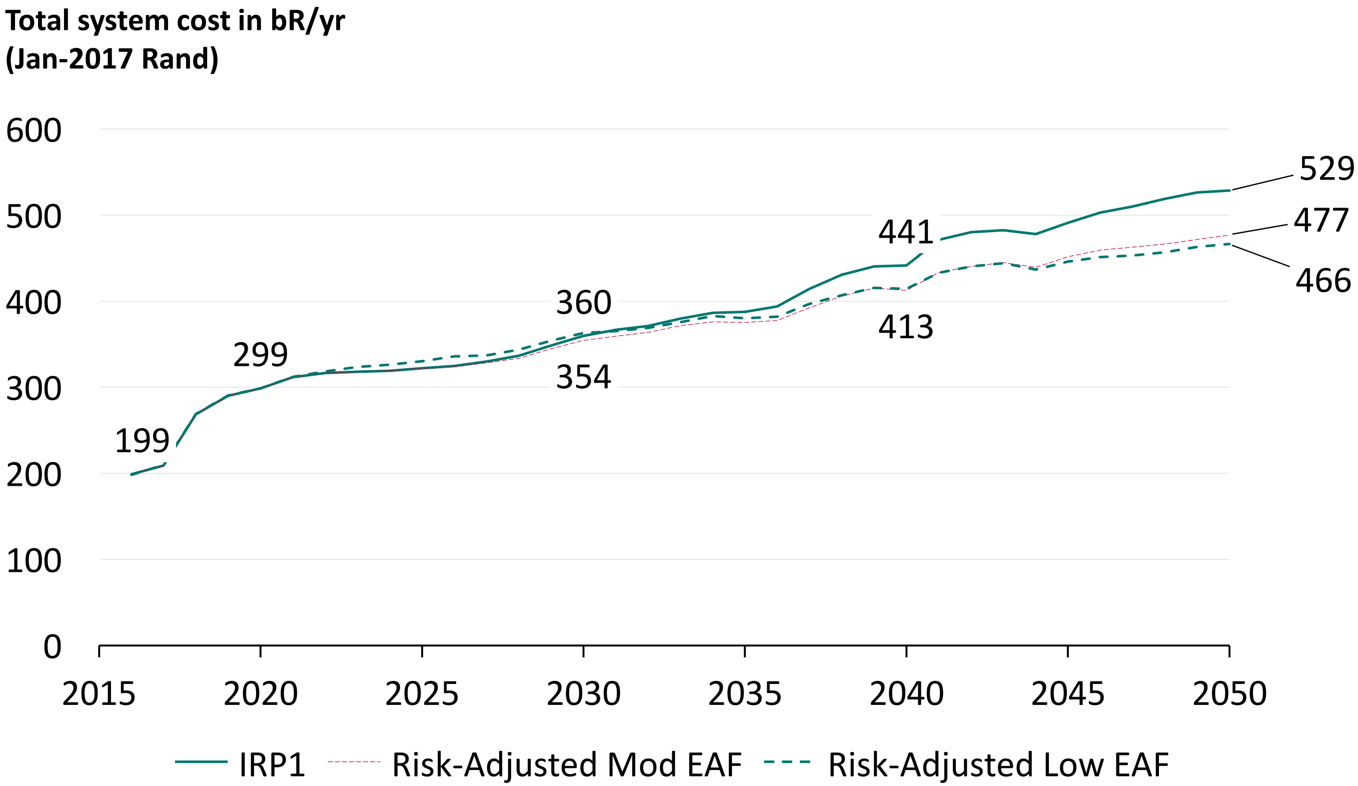


Water usage



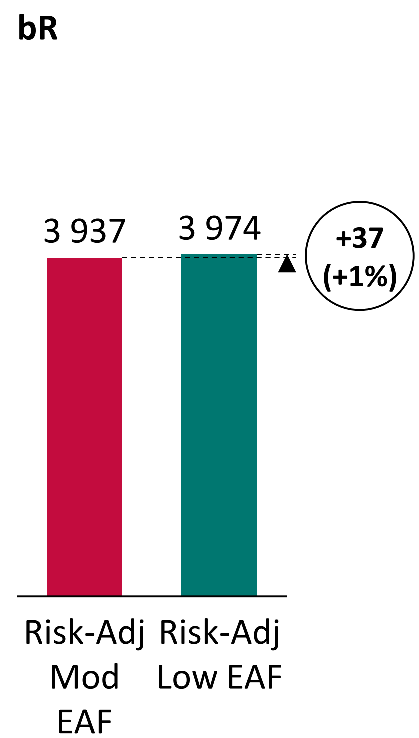
Total system cost: Risk-Adjusted with low EAF results in higher system cost than mod EAF due to additional capacity required pre-2035

Total System Cost



Net Present Value System Cost

(2016 - 2050)



Note: Average tariff projections (and resulting total system cost) consider an offset representative of Tx/Dx/Other costs to align with starting point of 0.84 ZAR/kWh (0.20 ZAR/kWh). From 2017 to 2018, immediate cost reflectivity is considered too (as in Draft IRP 2018) i.e. 0.21 ZAR/kWh offset.

Sources: Draft IRP 2018. CSIR Energy Centre analysis. Eskom on Tx, Dx costs

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Formal comments on Draft IRP 2018

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Formal comments on Draft IRP 2018

CSIR
our future through science

Draft IRP 2018 investigated implications of unconstrained least-cost (IRP1) but RE new-build limits are maintained for all other scenarios

"The scenario without new-build limits provides the least-cost option by 2030"

[DoE, Draft IRP 2018, pp. 34 of 75]

"Imposing new-build limits on RE will not affect the total installed capacity and the energy mix for the period up to 2030"

[DoE, Draft IRP 2018, pp. 34 of 75]

"The scenario without RE annual build limits provides the least-cost option by 2050"

[DoE, Draft IRP 2018, pp. 35 of 75]

"The scenario without RE annual build limits provides the least-cost electricity path to 2050"

[DoE, Draft IRP 2018, pp. 35 of 75]

Why new-build limits (on any technology – needs justification)?

Could be various reasons

- Import/transport link limitations (infrastructure – ports, roads)
- Industry ability to deliver (skills, development, construction)
- Available Tx/Dx networks to evacuate power
- System security/stability

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Draft IRP 2018 RE annual new-build limits have thusfar not been justified

New-build limits on technologies means no more than these limits are allowed to be built in any given year

Limits have been applied to two technologies (others unlimited):

- Solar PV
- Wind

Limits are constant as power system grows

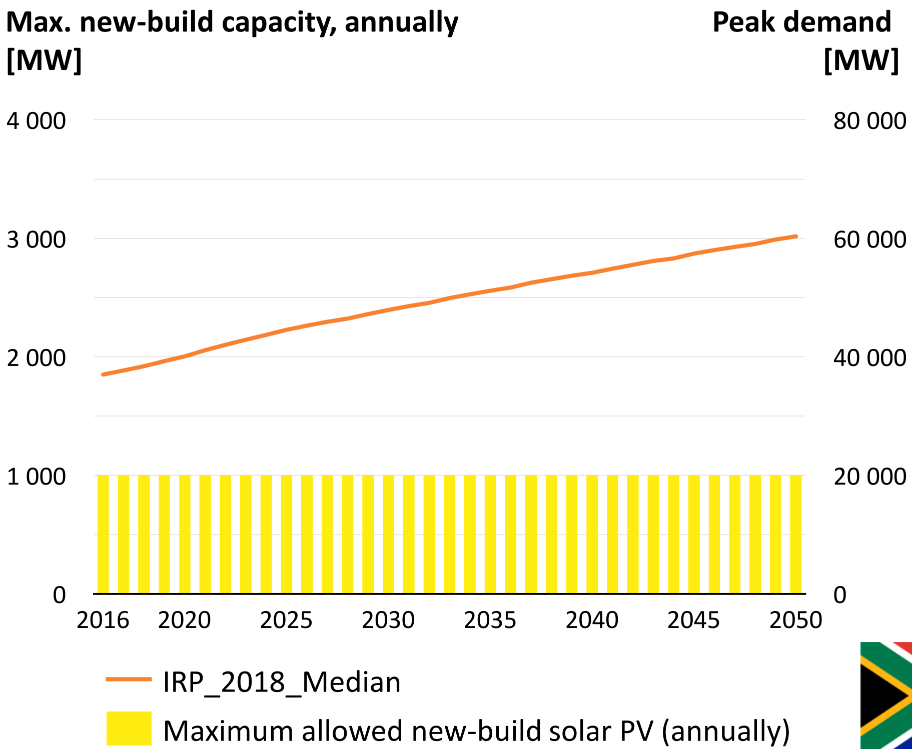
No justification provided for these limits



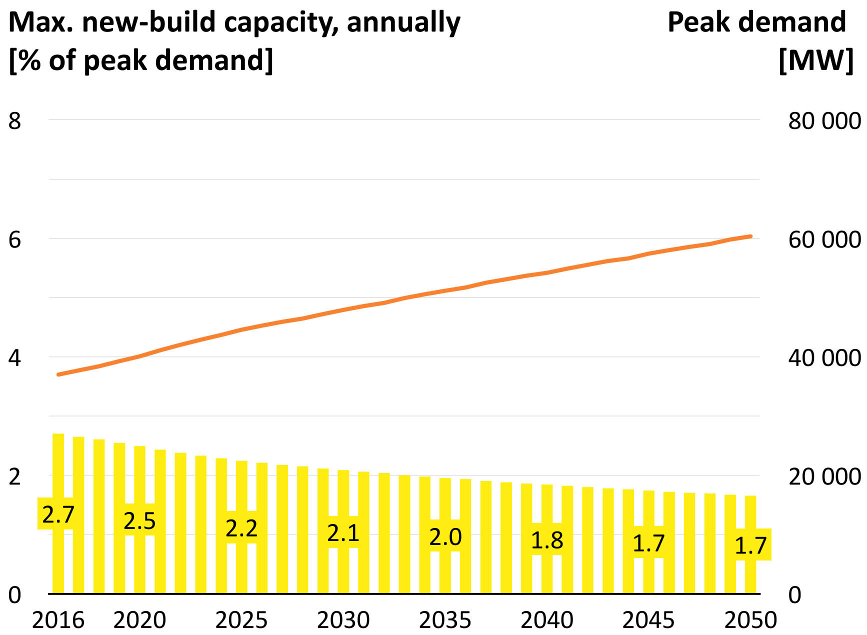
Sources: Scatec; Hopefield

Solar PV is limited to 1000 MW annually resulting in a move from 2.5% of peak demand in 2020 to 1.7% of peak demand by 2050

Absolute



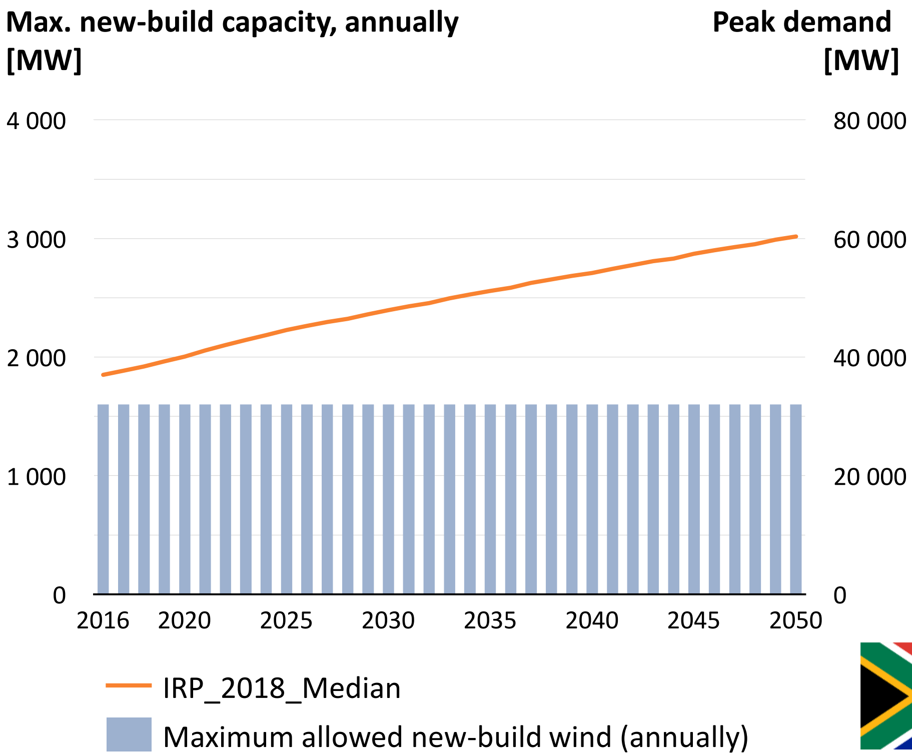
Relative



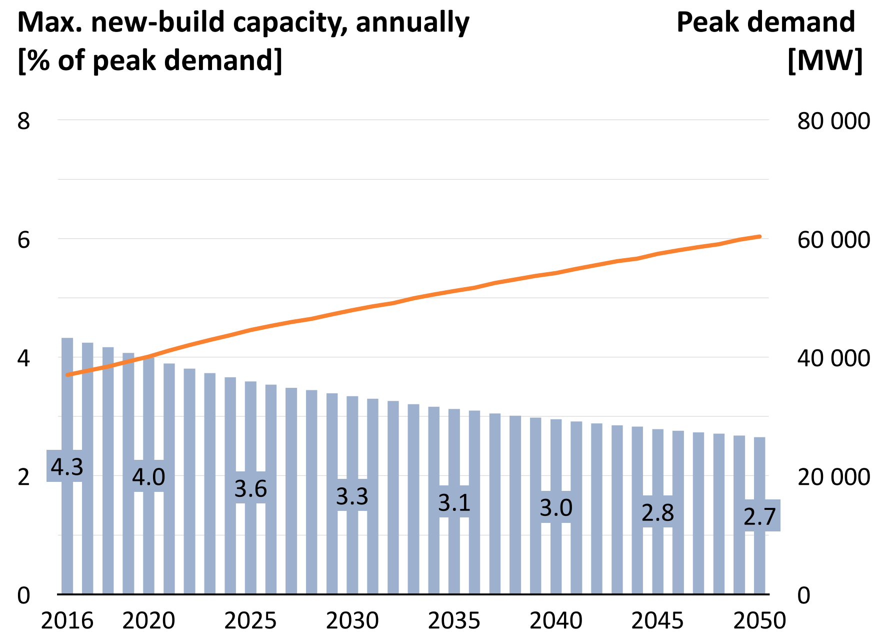
 Sources: Eskom; Draft IRP 2018; CSIR analysis

Wind is limited to 1600 MW annually resulting in a move from 4.0% of peak demand in 2020 to 2.7% of peak demand by 2050

Absolute



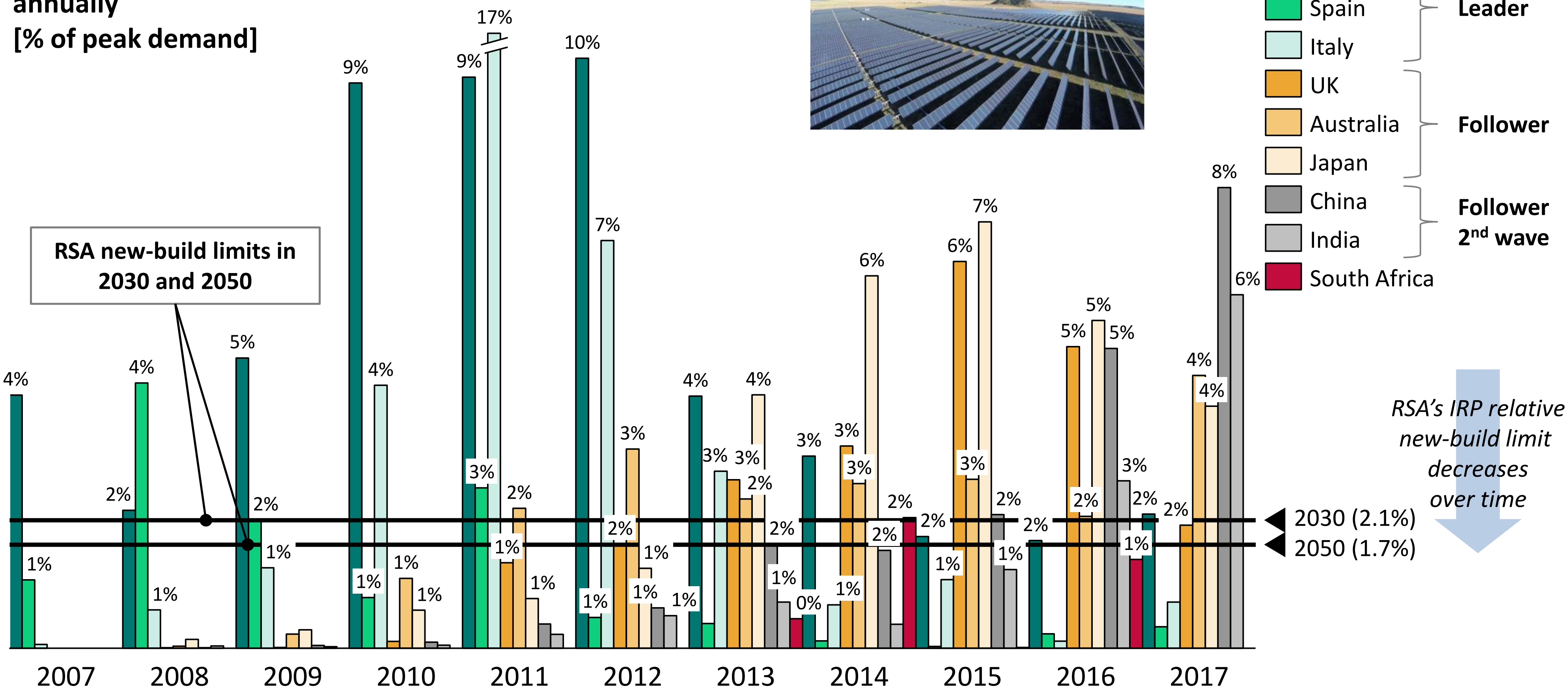
Relative



Sources: Eskom; Draft IRP 2018; CSIR analysis

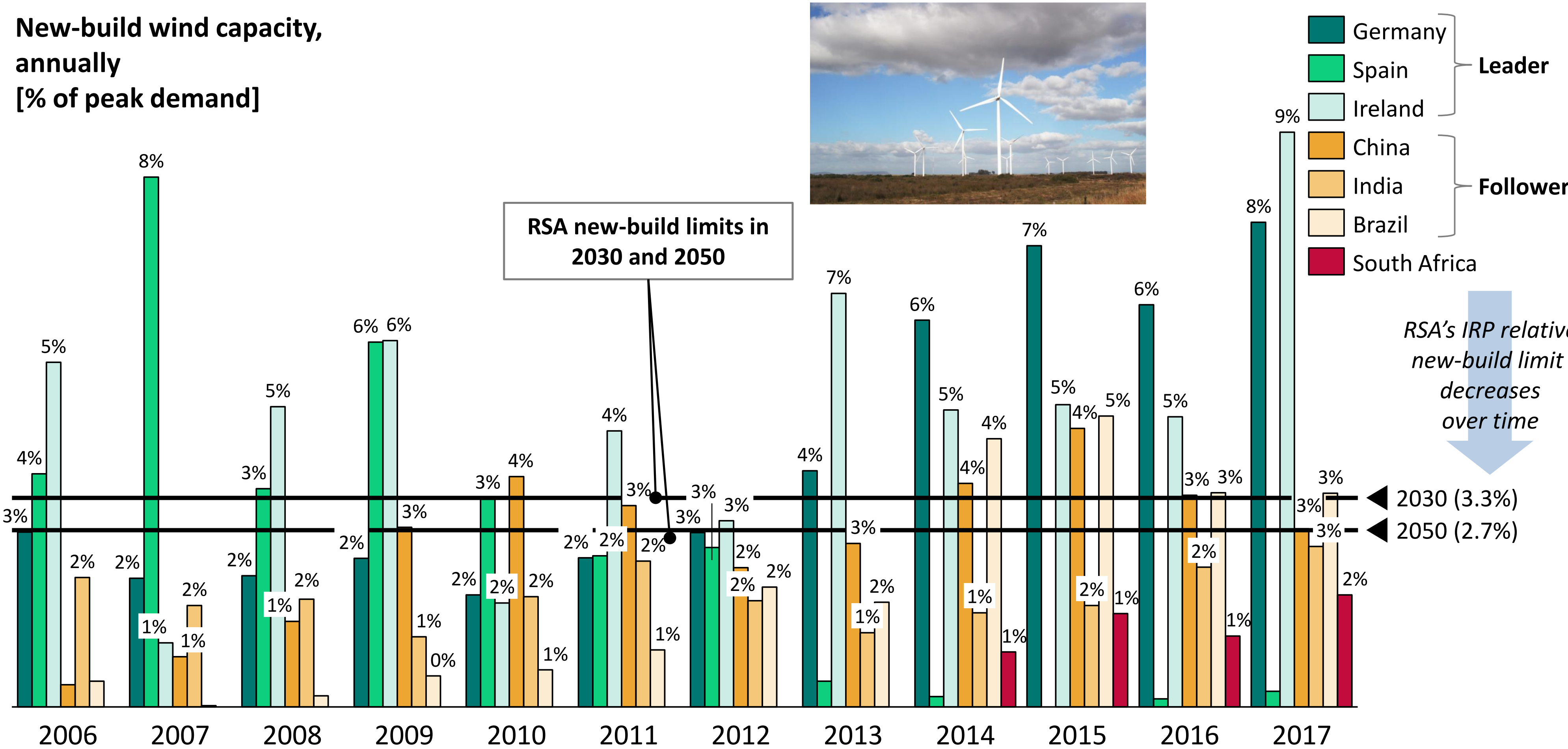
Already happening: Both leader, follower and 2nd wave countries installing more new solar PV per year than South Africa's IRP limits for 2030/2050

New-build solar PV capacity, annually [% of peak demand]



Sources: SolarPowerEurope; CIGRE; websites of System Operators; IRP 2016 Draft; CSIR analysis

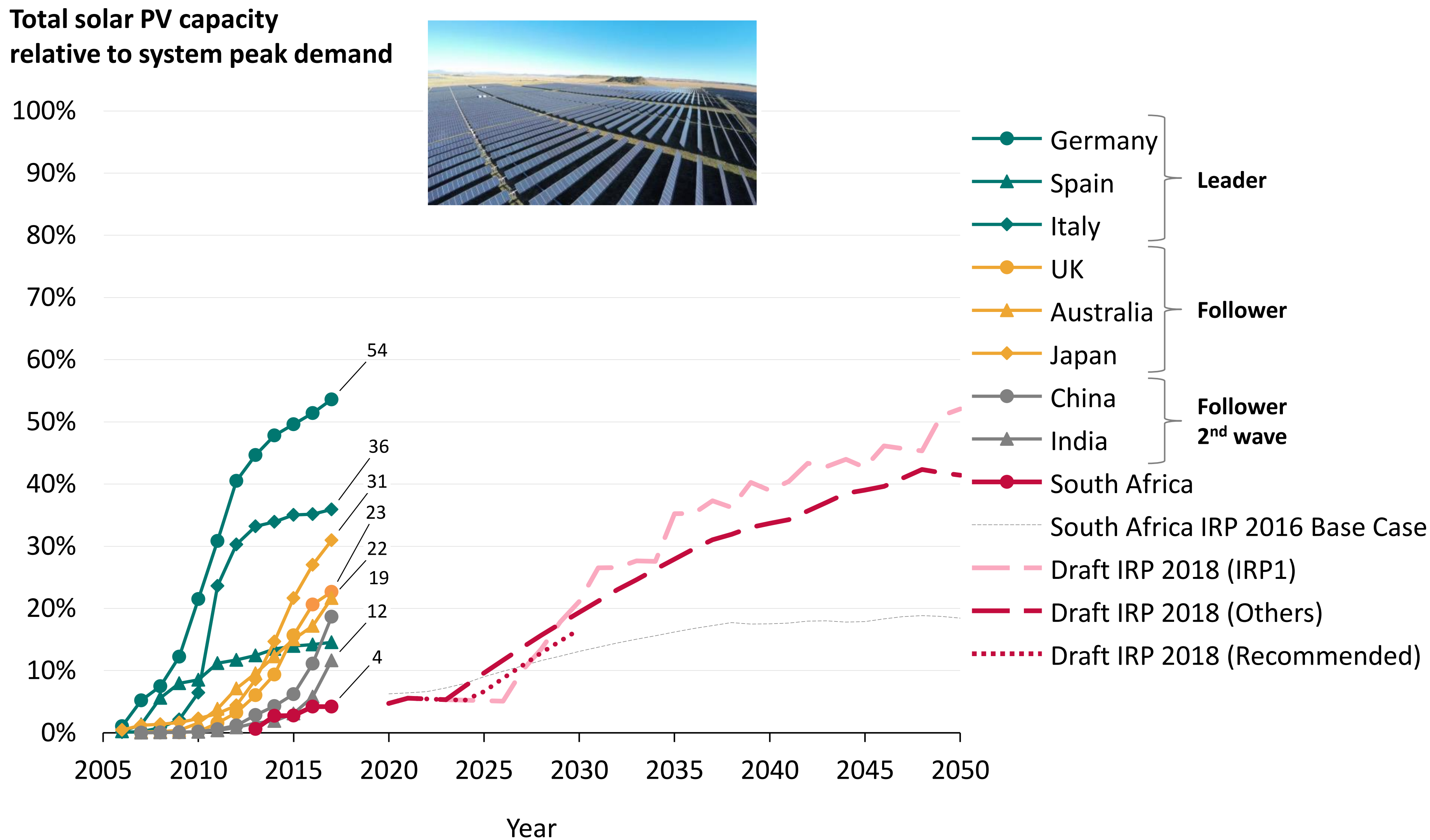
Already happening: Both leader and follower countries are installing more new wind capacity per year than South Africa's IRP limits for 2030/2050



 Sources: GWEC; CIGRE; websites of System Operators; IRP 2016 Draft; CSIR analysis

Submitted to DoE on 25 October 2018

Solar PV penetration in leading countries already up to 1.3x levels expected in Draft IRP 2018 (constrained scenarios) by 2050



Sources: SolarPowerEurope; CIGRE; websites of System Operators; IRP 2016 Draft; CSIR analysis

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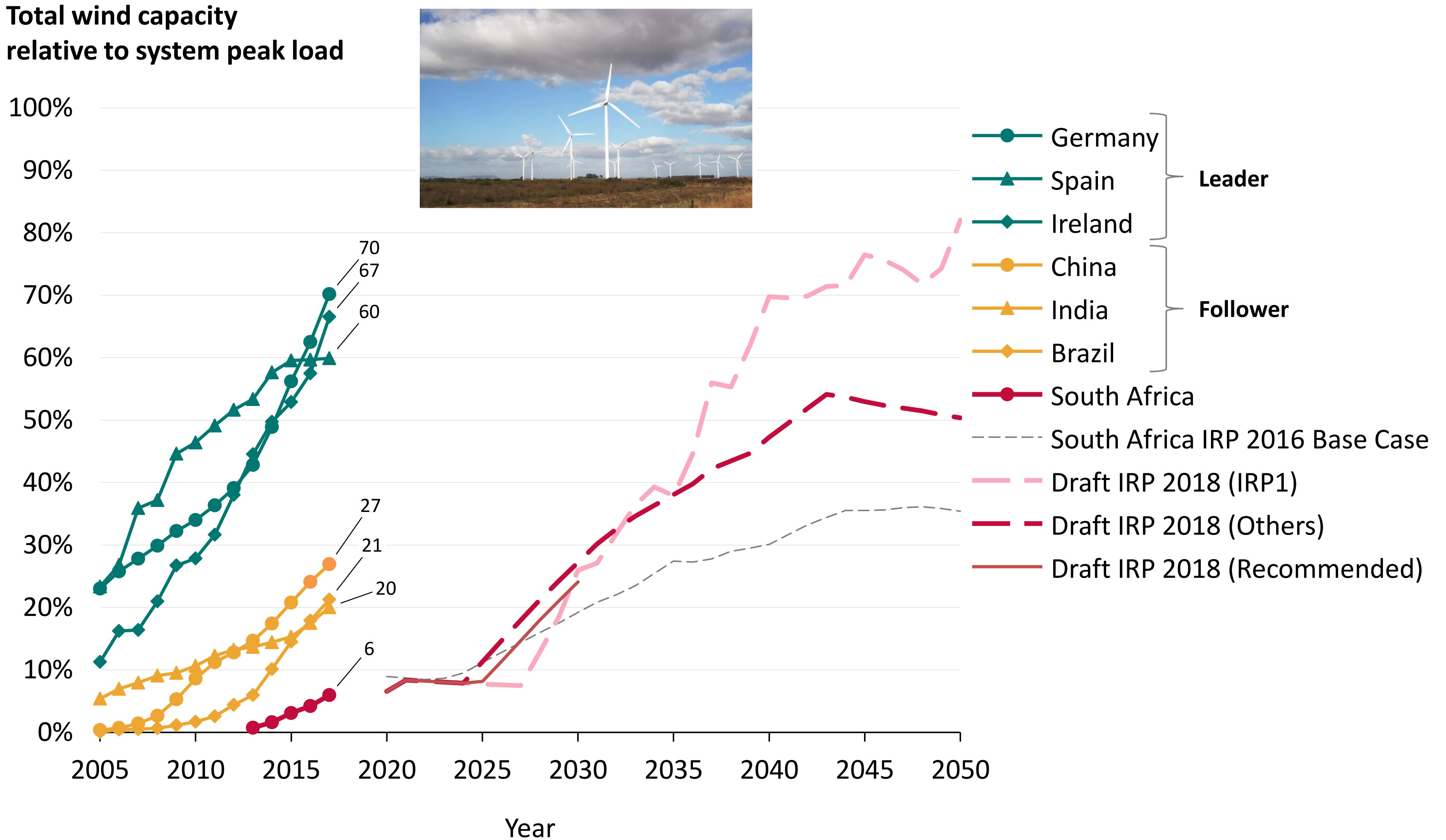
Wind penetration in leading countries is already at levels up to 1.4x Draft IRP 2018 (constrained scenarios) by 2050



Sources: GWEC; CIGRE; websites of System Operators; IRP 2016 Draft; CSIR analysis

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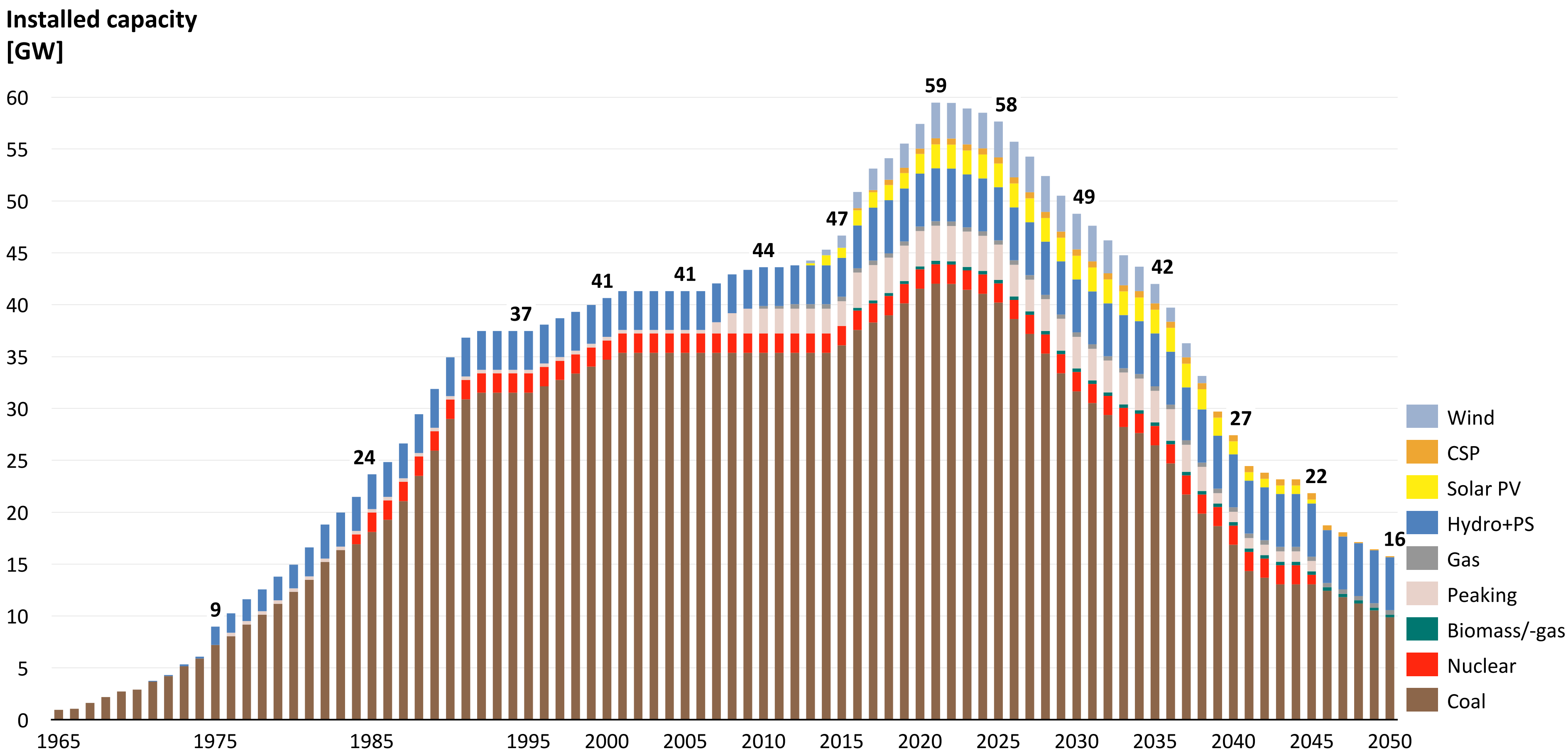
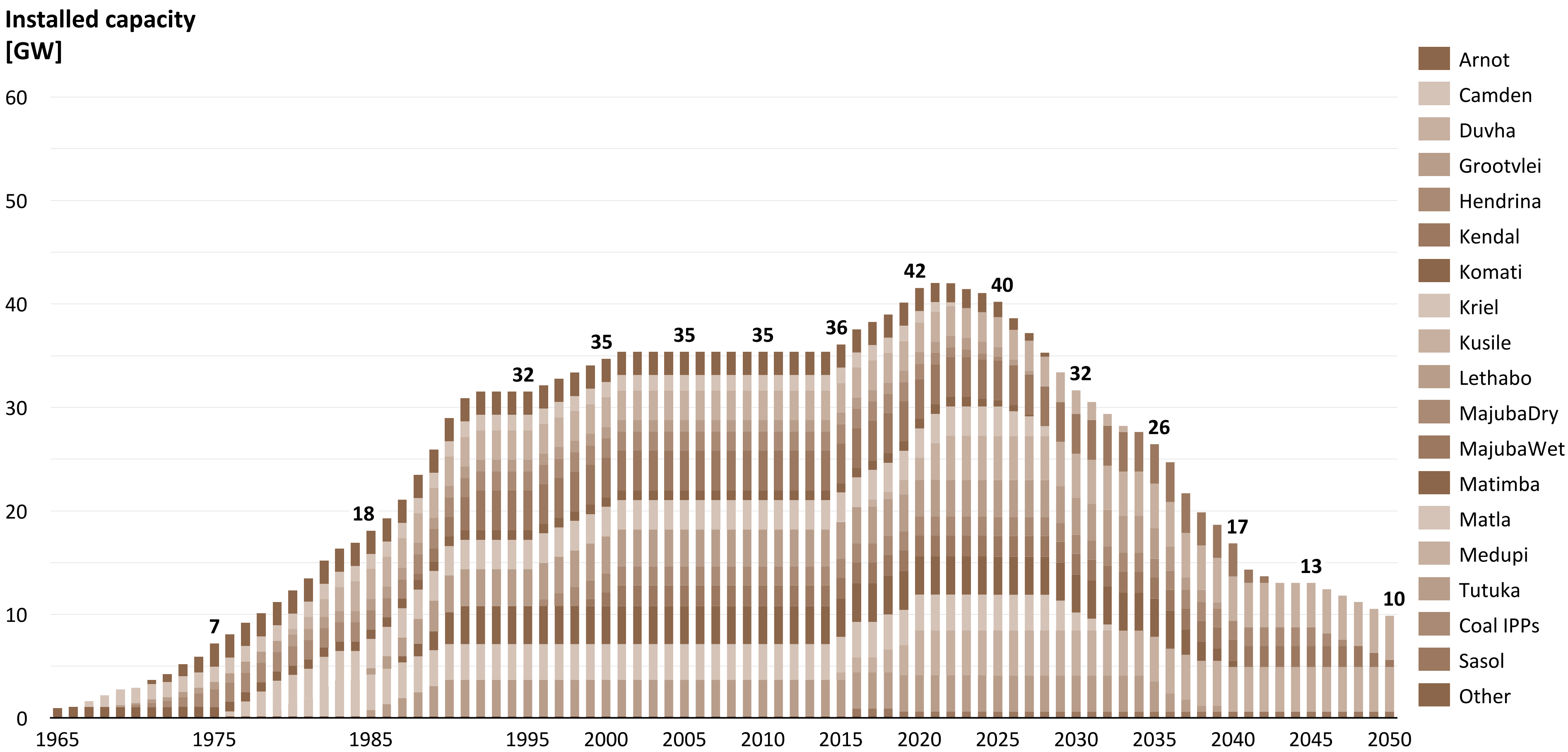
Some historical perspective - installed capacity reveals the considerable coal build-out South Africa pursued previously



Sources: Draft IRP 2018; CSIR analysis

Initial smaller coal, followed by large 6-pack build-out, more recently Medupi & Kusile – most decommissions in Draft IRP 2018 time horizon



Sources: Draft IRP 2018; CSIR analysis

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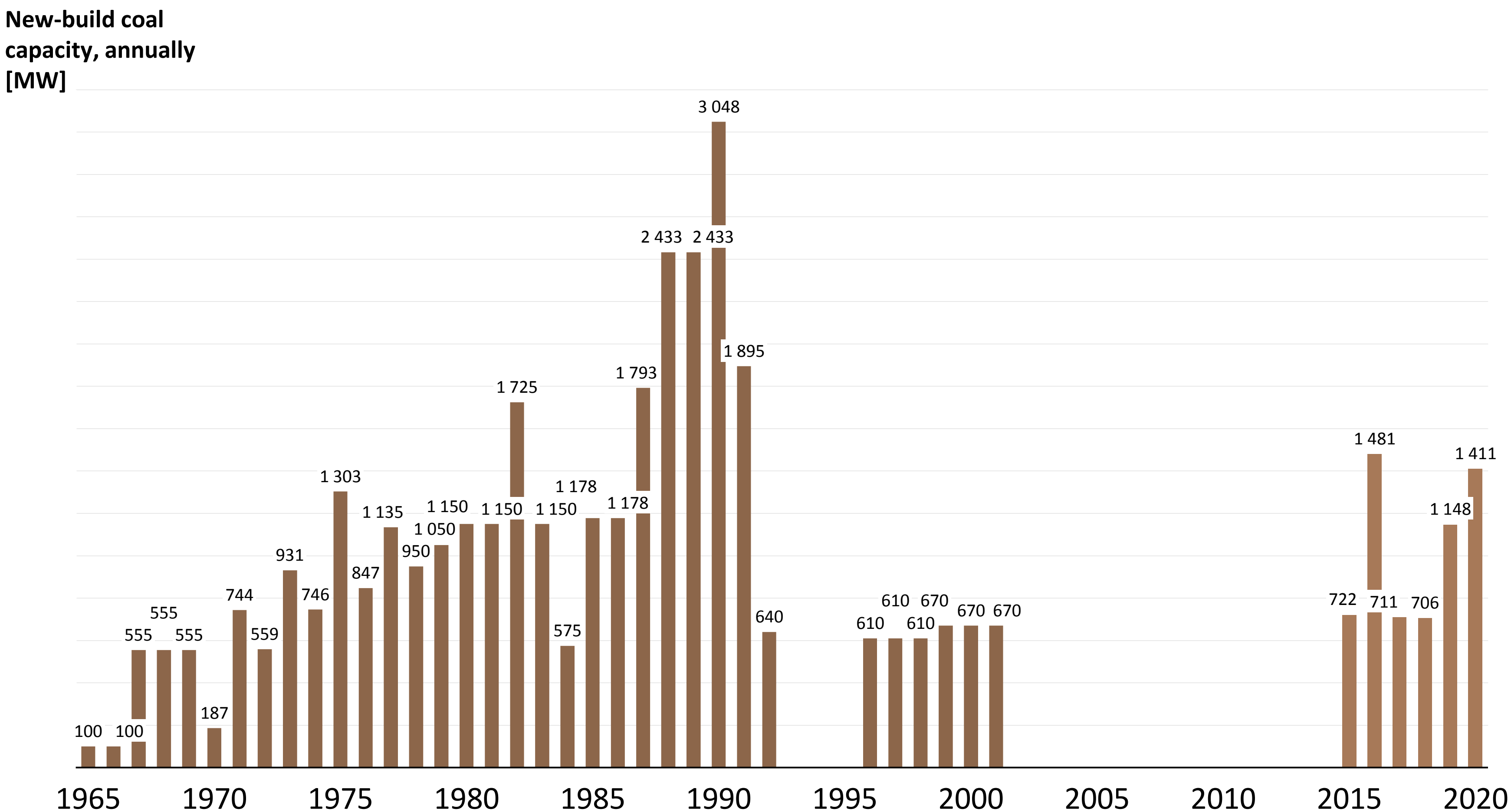
South Africa embarked on a significant new-build capacity programme previously… in coal – why not now in any other technologies?



 Sources: Draft IRP 2018

Formal comments on Draft IRP 2018

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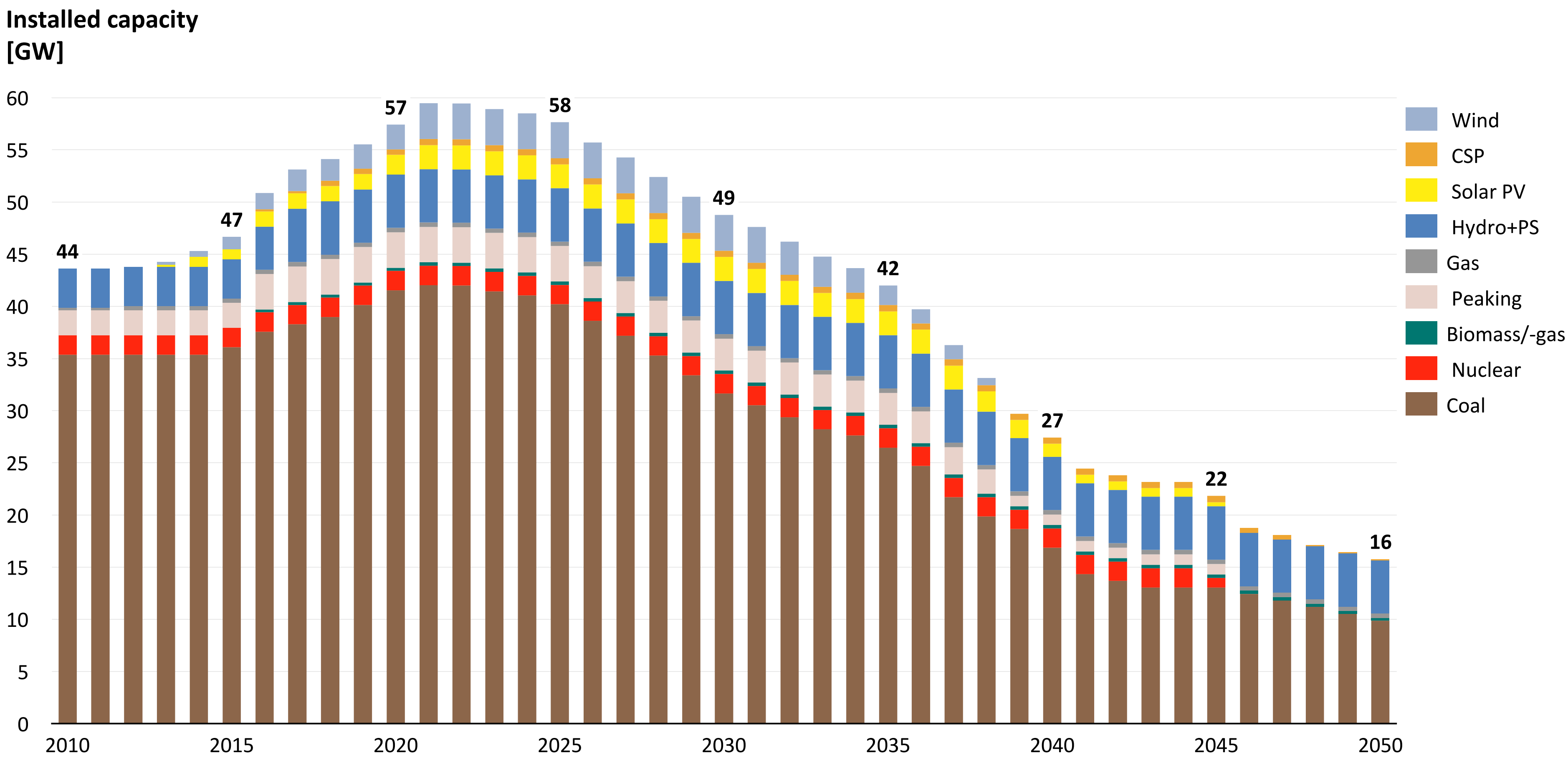
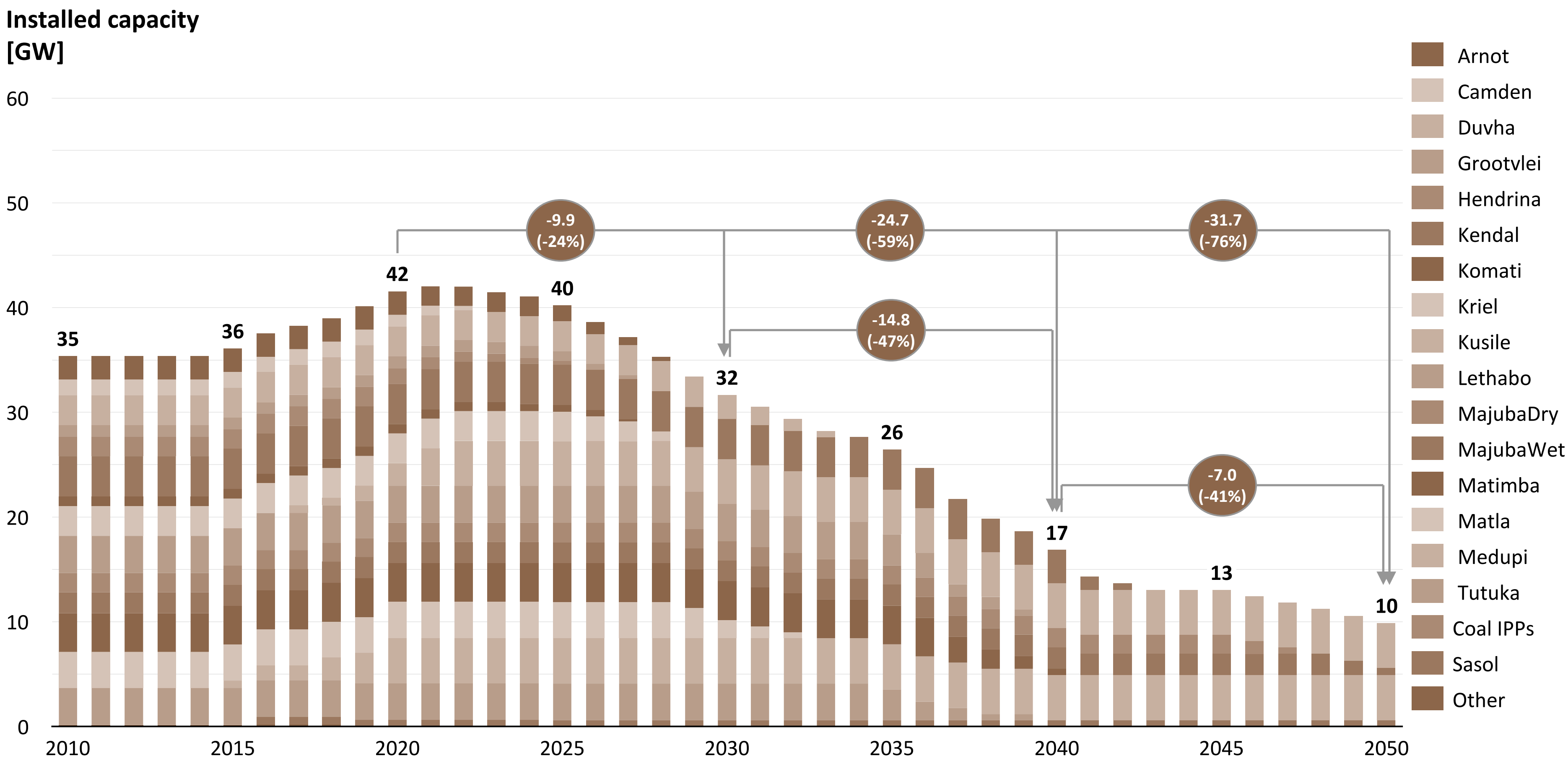
Even currently under-construction and committed capacity will be part of planned decommissioning and will require new-build



Sources: Draft IRP 2018; CSIR analysis

New-build largely driven by the planned decommissioning of the existing coal fleet - mostly post 2030



Sources: Draft IRP 2018; CSIR analysis

Should we freely optimise the decommissioning of the existing coal fleet or finish the last 2 units at Kusile?

Should we build new coal capacity in South Africa?

Should a freely optimised existing coal fleet be decommissioned any earlier/later?

Should the last 2 units at Kusile be completed in light of alternatives?

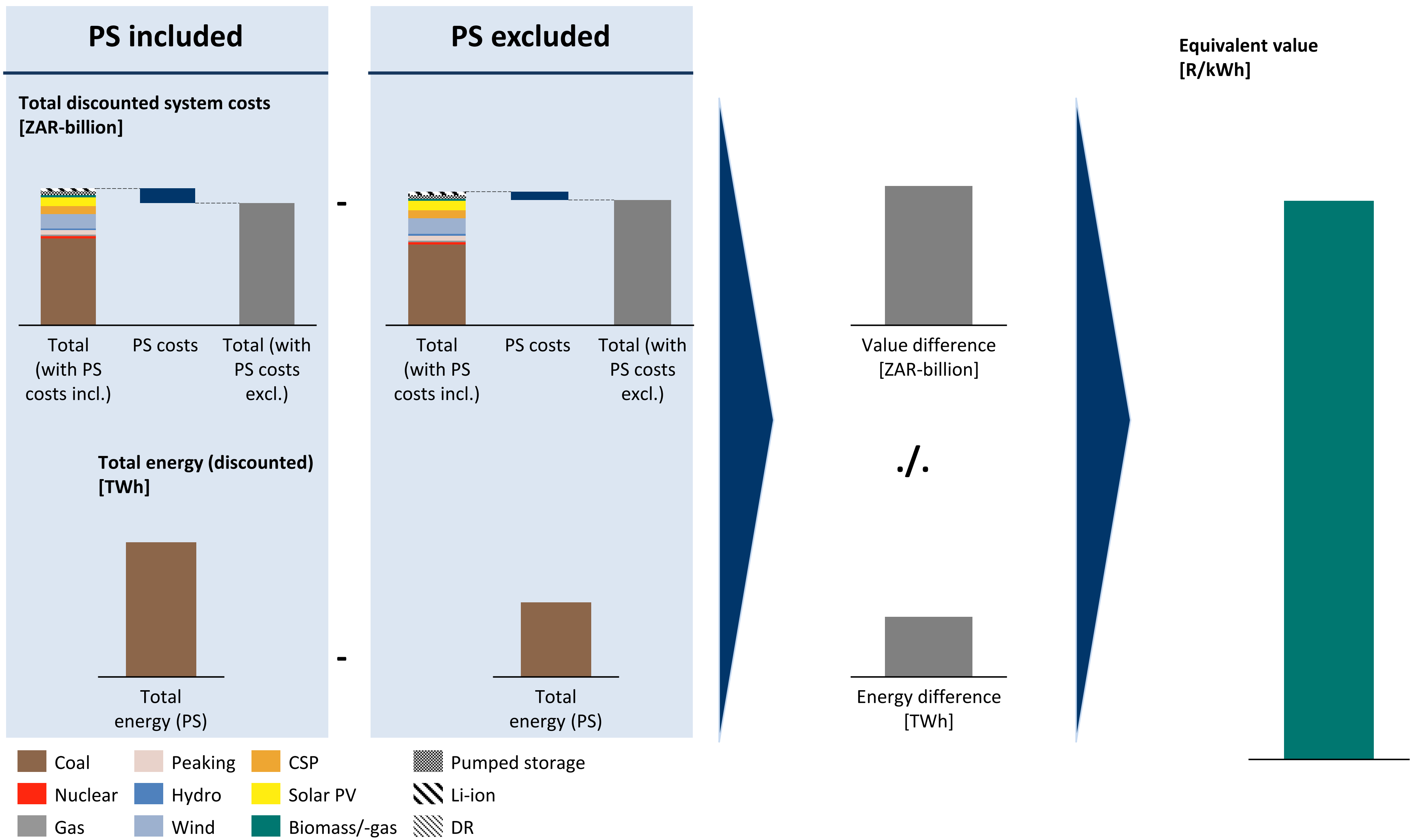
This has been studied in previous work

Steyn, G., Burton, J. & Steenkamp, M. Eskom's financial crisis and the viability of coal-fired power in South Africa. (2017).

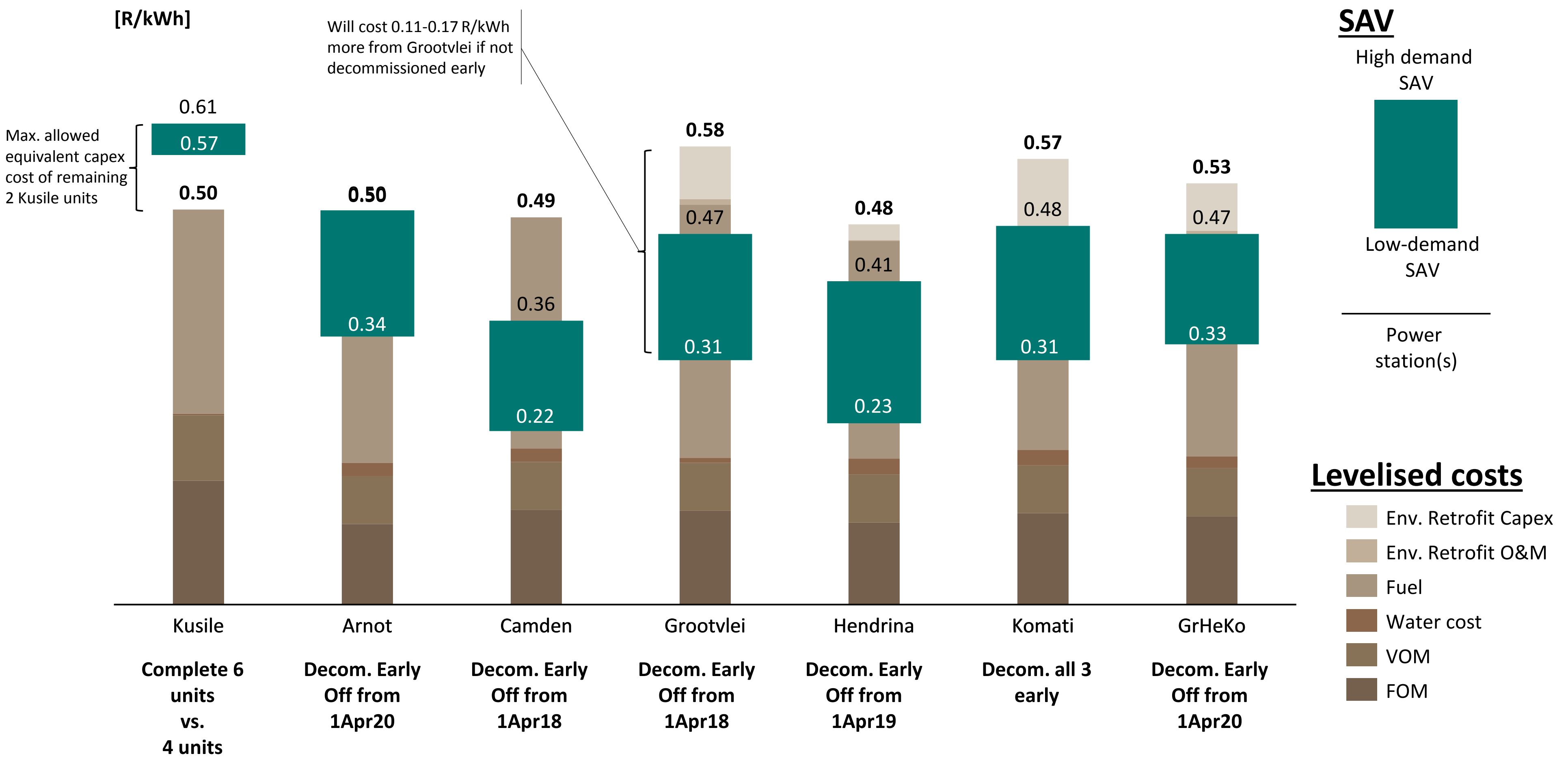
Wright, J. G., Calitz, J., Bischof-Niemz, T. & Mushwana, C. The long-term viability of coal for power generation in South Africa (Technical Report as part of "Eskom's financial crisis and the viability of coal-fired power in South Africa). (2017).

Summary of outcomes are presented here for reference

System Alternate Value (SAV) approach attempts to obtain the present value of a power station over the full time horizon



Early decommissioning of oldest selected coal-fired power stations would result in significant savings and a cheaper power system



Source: Wright (2017), Steyn (2017)

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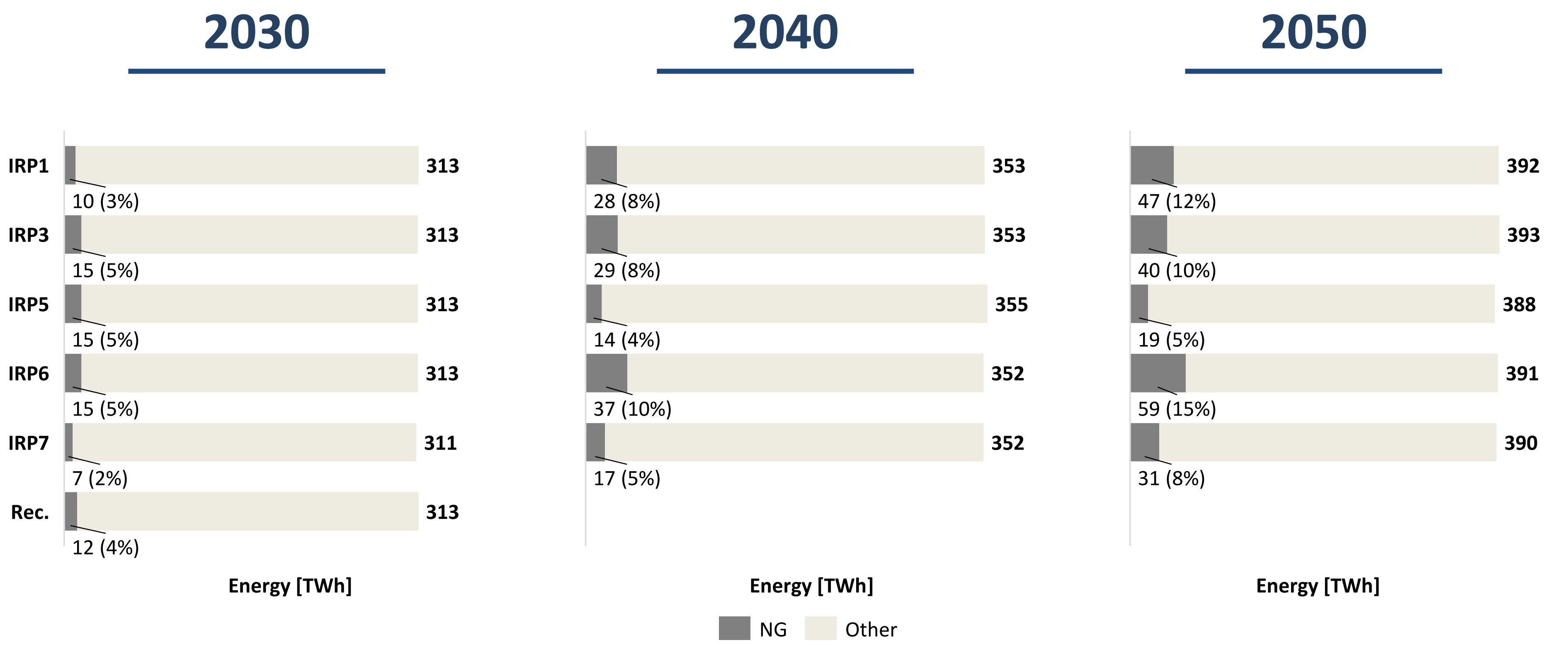
Need for natural gas: Understanding domestic natural gas options

Natural gas source not critical in IRP at this stage but... whether it is domestic/imported is important

What is the energy security risk of importing all of the natural gas required in Draft IRP 2018 scenarios?

Sources: PetroSA; Eskom; Excellerate

The role of natural gas in the energy mix (likely via imported LNG at this stage) is relatively small to 2030 (2-5%) and up to 15% by 2050

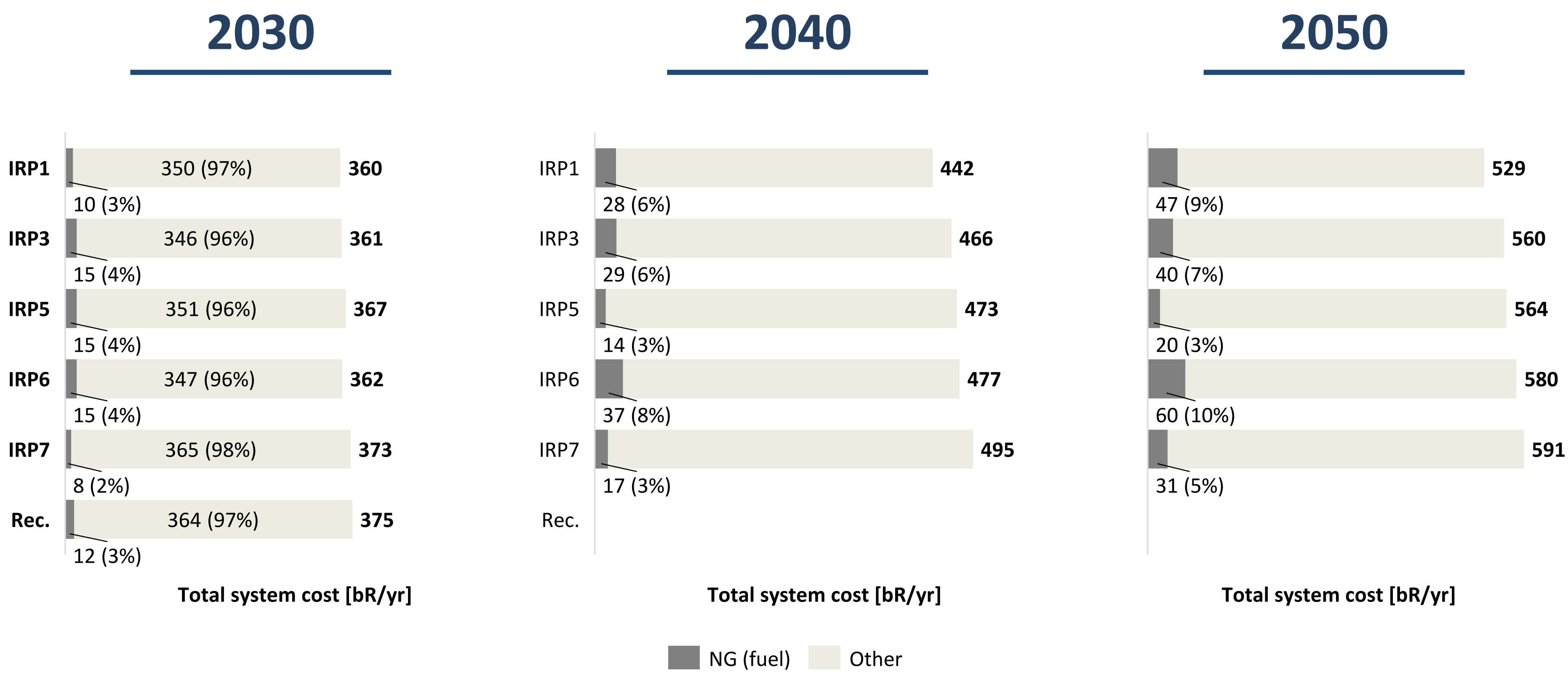


Domestic sources of flexibility and/or storage could replace some/all of these relatively small volumes of (imported) natural gas in the electricity sector

e.g. UCG, CBM, shale gas, offshore, hydrogen, DSR, biomass/-gas, CSP, storage (pumped, batteries)s

NG – Natural gas; Sources: Draft IRP 2018

Total system cost contribution of NG fuel requirements (likely via imported LNG at this stage) is 2-4% to 2030 and up to 10% by 2050



NG – Natural gas; Sources: Draft IRP 2018

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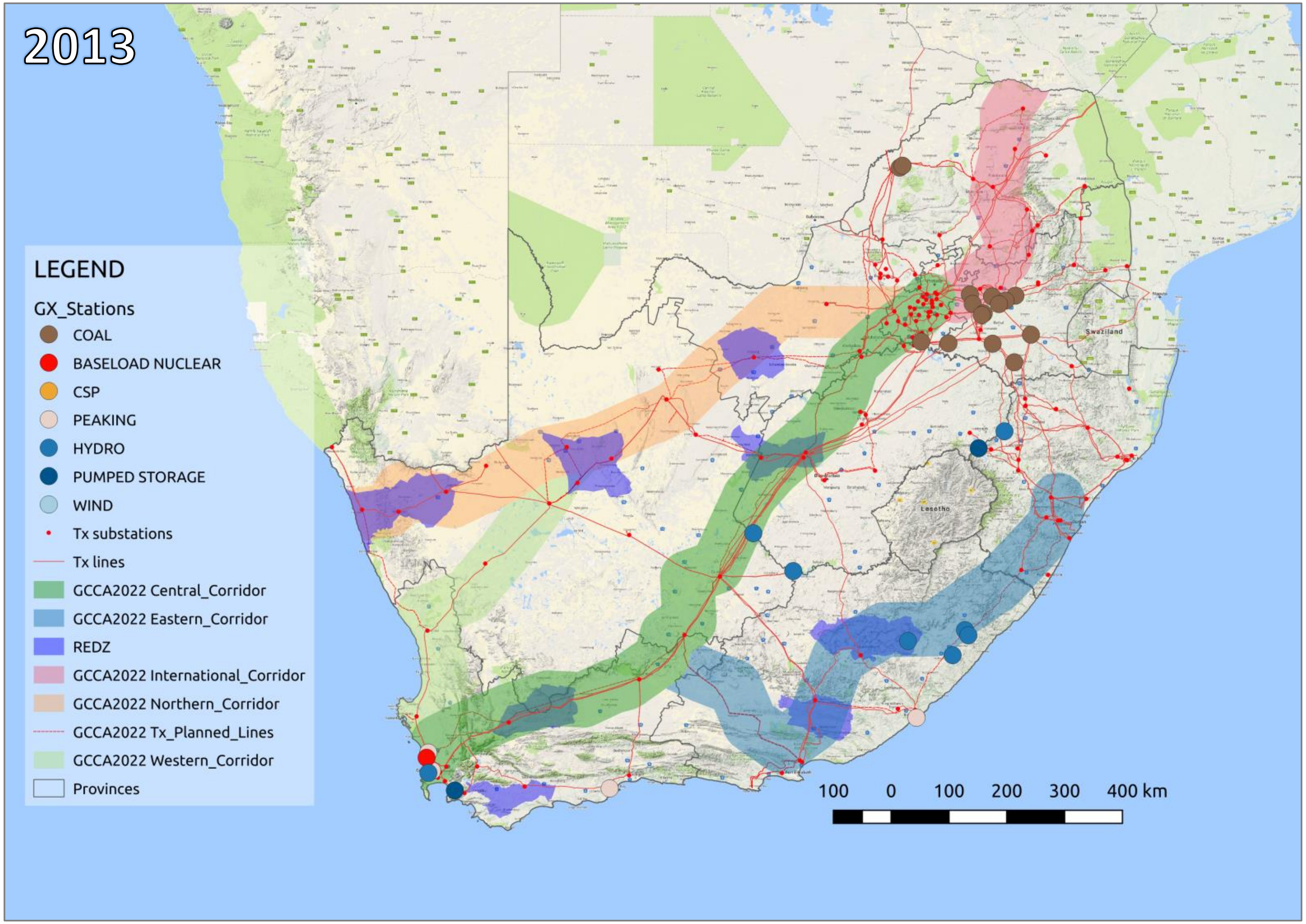
Just 5 years ago – power generation capacity was concentrated around Mpumalanga (coal) with some hydro, peaking and nuclear



Sources: Eskom; CSIR analysis

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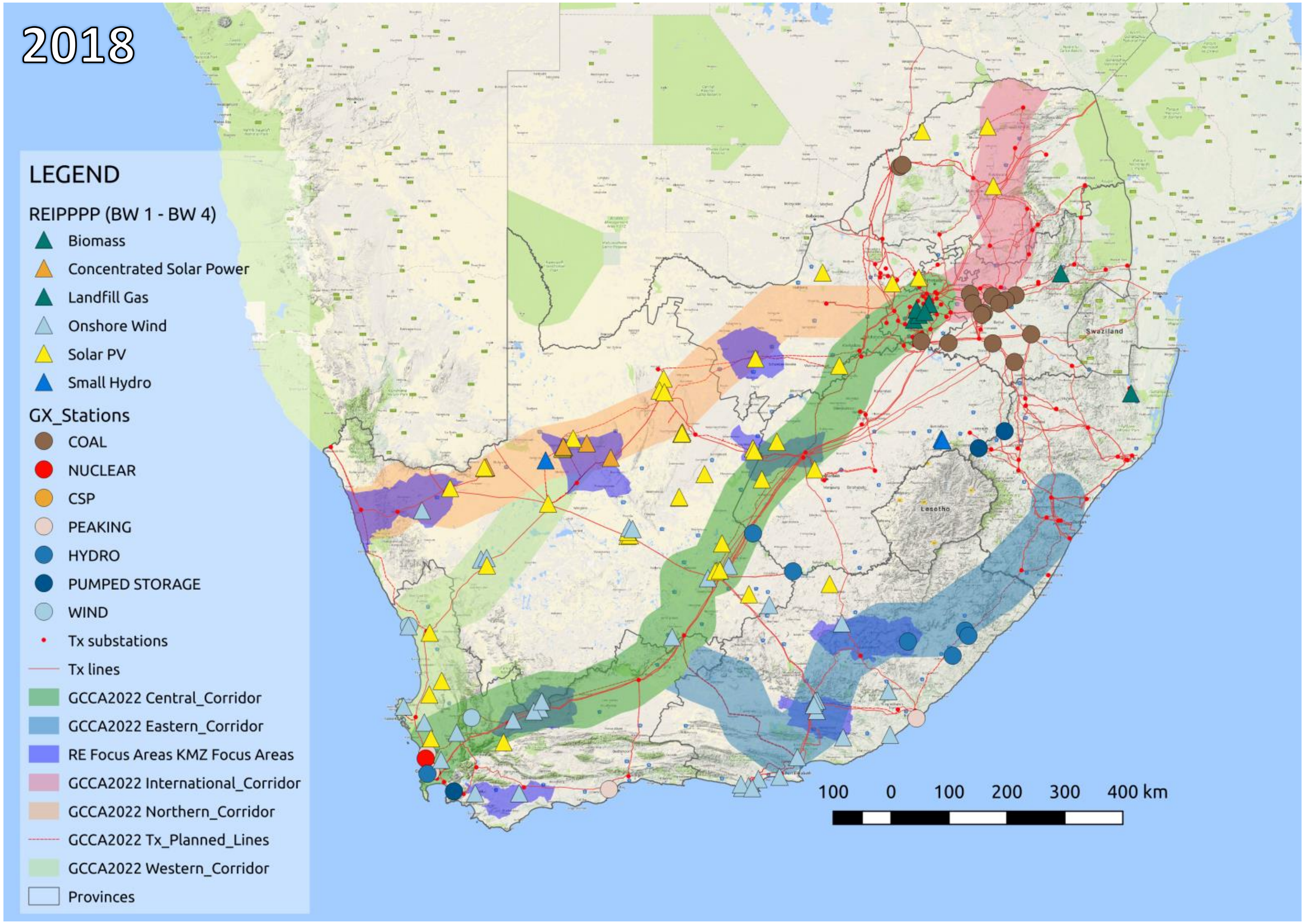
By 2018 – generation capacity (albeit still small) has already started to distribute across the country - not only in Mpumalanga anymore



Sources: Eskom; CSIR analysis

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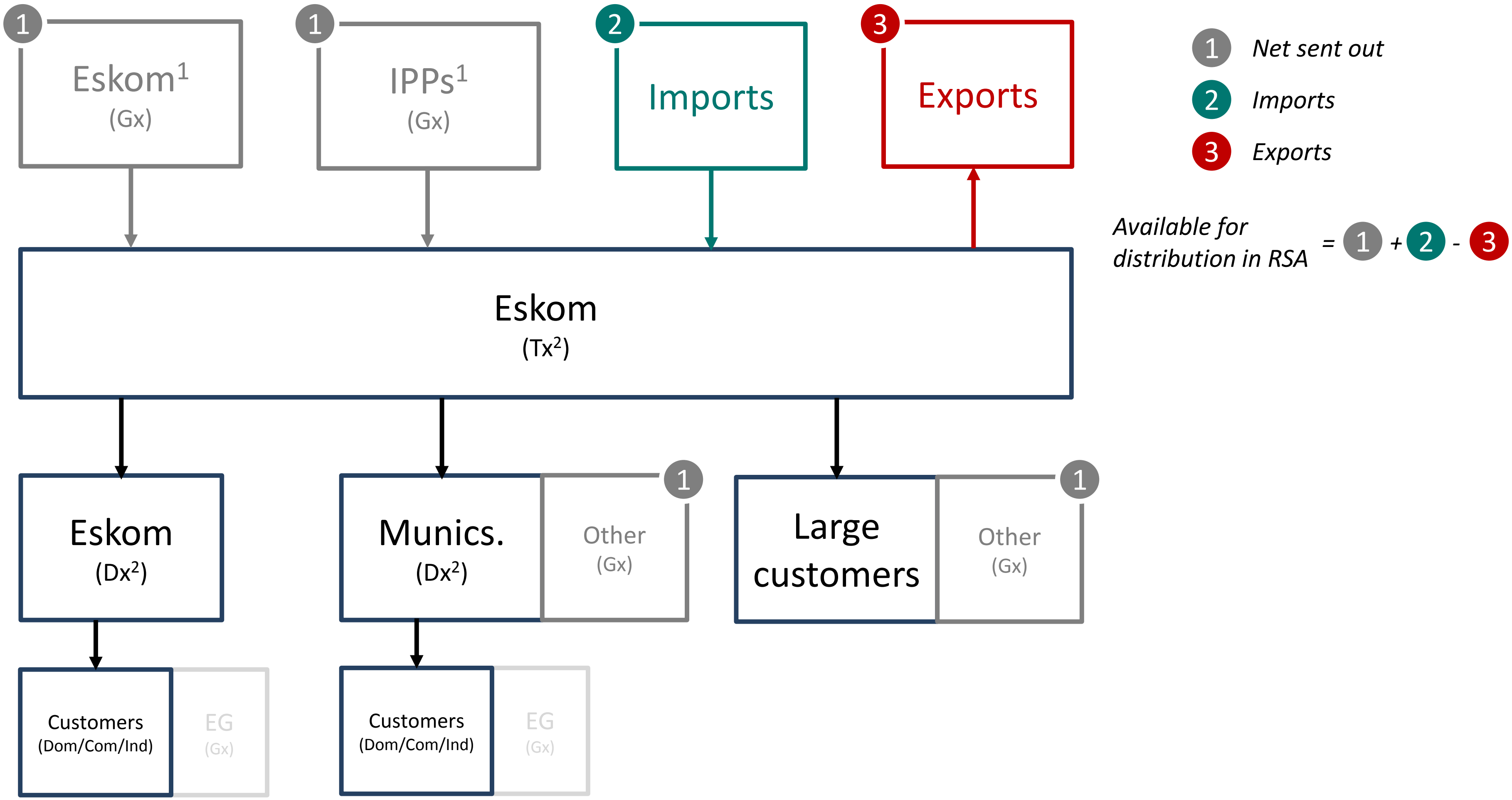
IRP meets energy demand for RSA – expressed as equivalent demand (assumes EG as reduced demand)

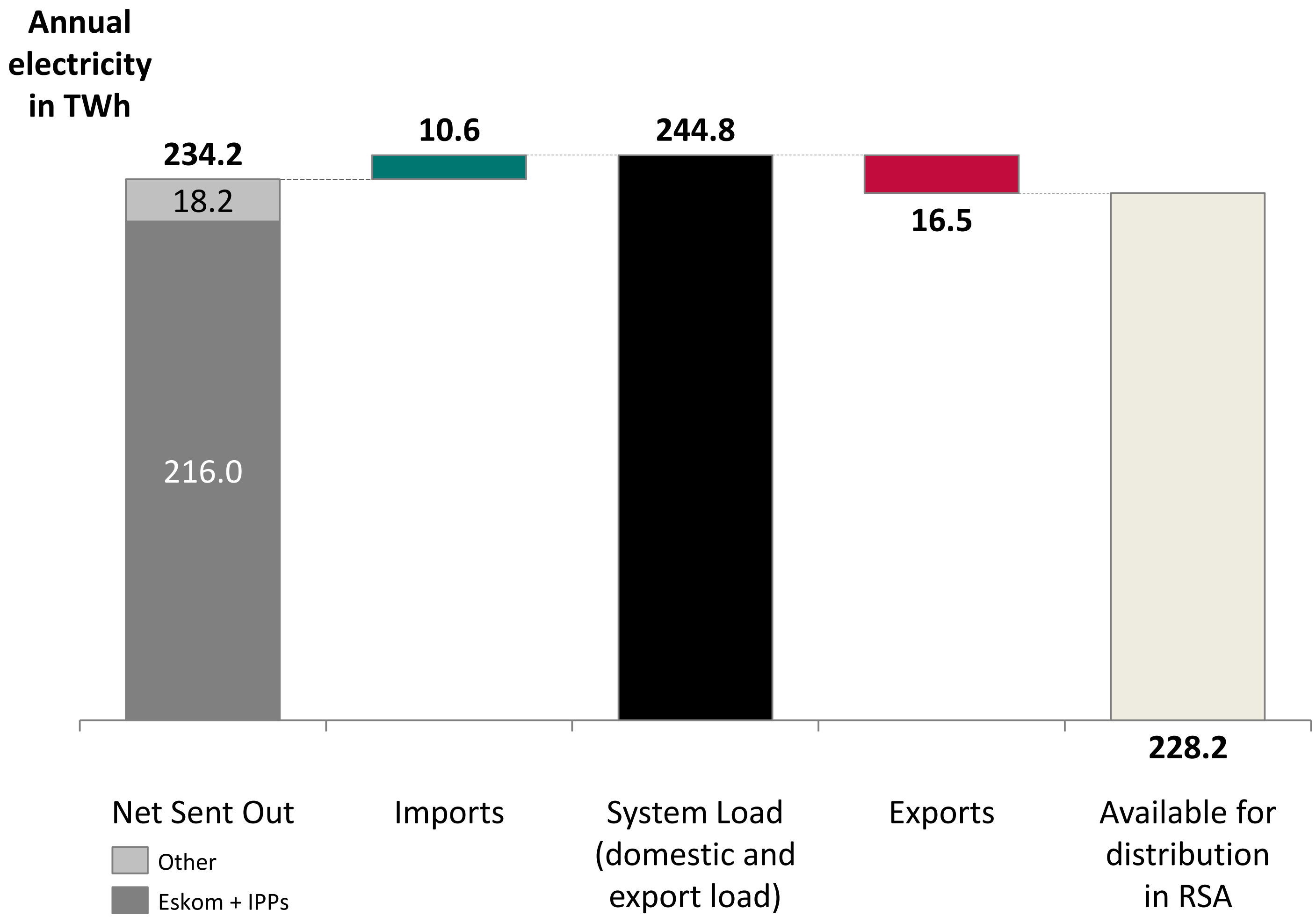


EG = Embedded Generation; Gx = Generation; Tx = Transmission; Dx = Distribution

[1] Power generated less power station load; Minus pumping load (Eskom owned pumped storage); [2] Transmission/distribution networks incur losses before delivery to customers

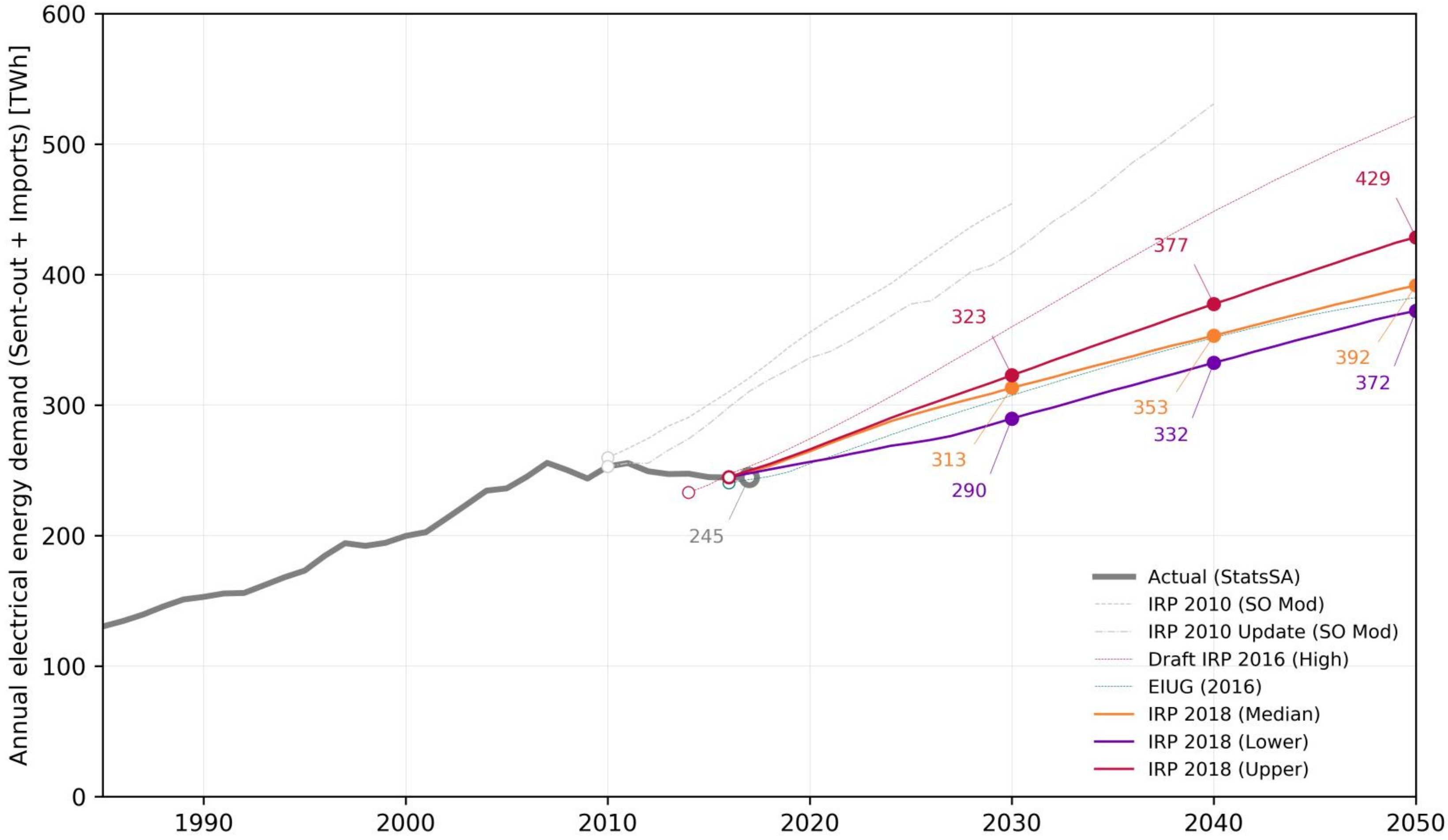
From Jan-Dec 2016, 234 TWh of net electricity was sent out in SA with imports of almost 11 TWh means system load was 245 TWh

Actuals captured in wholesale market for Jan-Dec 2016 (i.e. without embedded plants)



Notes: "Net Sent Out" = Total domestic generation (less auxillary load) minus pumping load of Eskom pumped storage stations (not shown seperately)
Sources: Eskom; Statistics South Africa

IRP 2018 expects demand growth to be more certain, slower - average growth from 2016 of 1.2-2.0%/yr to 2030, 1.2-1.7%/yr to 2050



Sources: StatsSA; Draft IRP 2018

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Lower demand forecast implies 3 things: Increased EE, fuel switching and... Embedded Generation – but how much?

> ***"Due to the limited data at present and for the purpose of this IRP Update, these developments were not modelled as standalone scenarios, but considered to be covered in the low-demand scenario. The assumption was that the impact of these would be lower demand in relation to the median forecast demand projection."***
>
> *[DoE, Draft IRP 2018, pp. 21 of 75]*

In the Draft IRP 2018, it is clearly stated that the relative to the Median demand forecast, the Lower demand forecast is representative of a combination of:

- Embedded Generation (likely mostly solar PV)
- Energy efficiency (EE)
- Fuel switching

Growth of embedded generation (EG) market being implicitly included can then be calculated based on:

- Share of EG in the difference between Median and Lower demand forecasts
- Almost all EG will likely be solar PV (with associated capacity factor)

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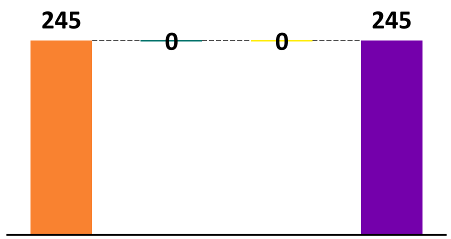
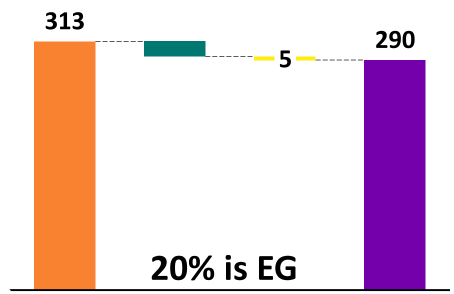
Between 1.1 - 5.8 GW of embedded generation (assumed to be PV dominated) is implicitly considered in the Draft IRP 2018 by 2030

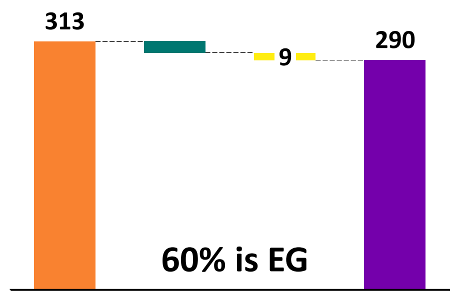
2016
(TWh)

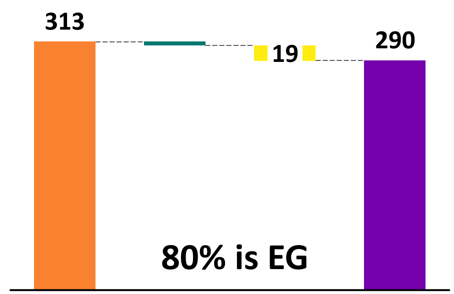


Median demand forecast
EE/fuel switching
EG
Lower demand forecast

2030
(TWh)







2030
(MW)

1100-1500 MW
(80-100 MW/yr)

3300 – 4400 MW
(230-310 MW/yr)

4400 - 5800 MW
(310-420 MW/yr)

Sources: StatsSA; Draft IRP 2018; CSIR analysis

Formal comments on Draft IRP 2018

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Demand profile is assumed unchanged in Draft IRP 2018 – updated aproached to demand profile will need to be pursued in future

Demand profile will change as constituent components of the demand forecast change

Not just purely an energy demand forecast and fitted peak load (assuming similar demand profile)

Updated approaches will be required linking with EG to ensure sufficiently accurate capacity expansion

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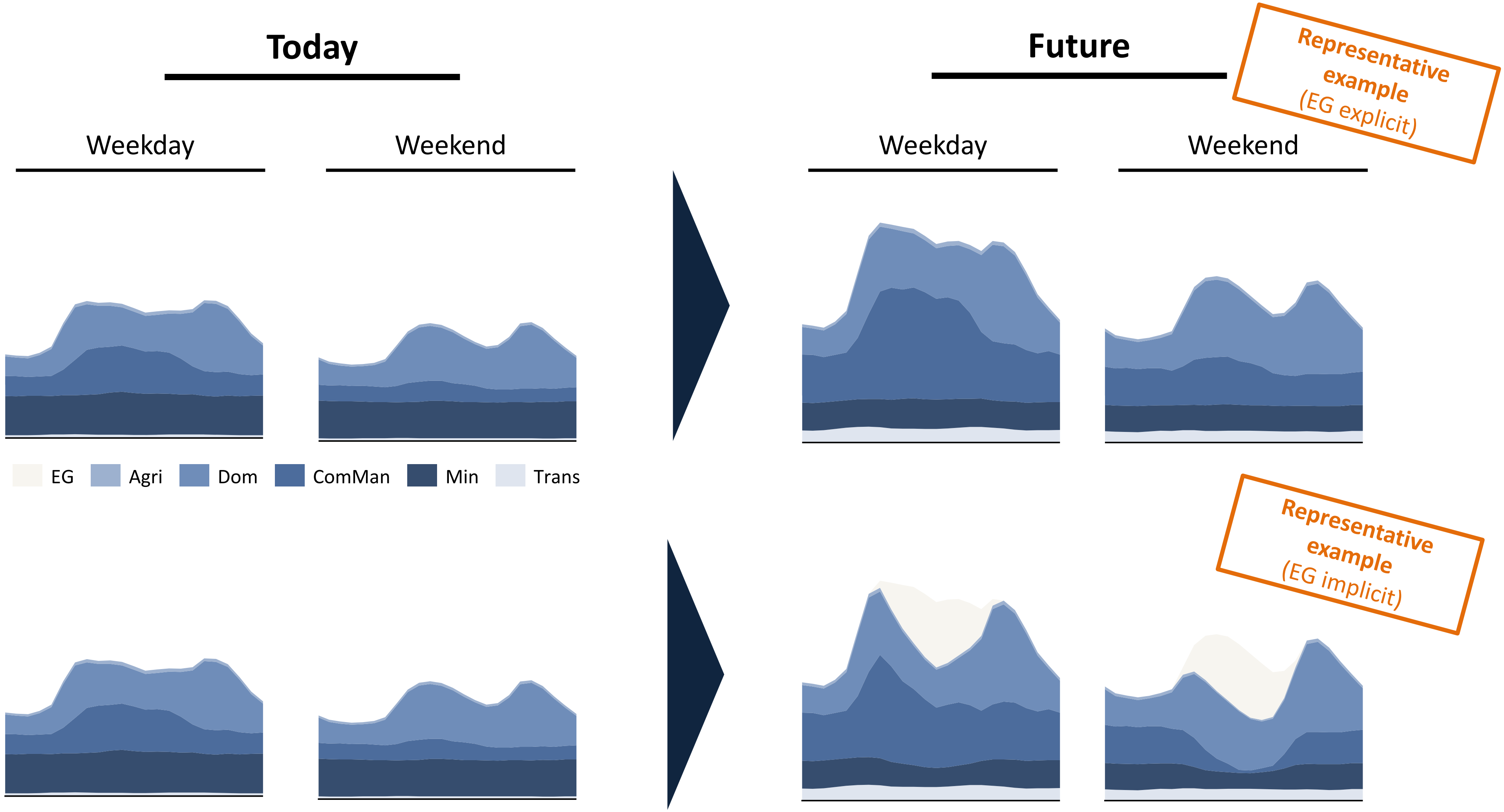
Change in demand profile will result in very different capacity expansion options



Formal comments on Draft IRP 2018

Formal comments on Draft IRP 2018

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Good to include shallow grid connection costs explicitly in Draft IRP 2018 based on extensive grid planning experience at Eskom

Draft IRP 2018 includes collector network costs in the various Eskom Customer Load Networks (CLNs) as well as shallow grid connection costs for VRE (solar PV and wind) and all other technologies

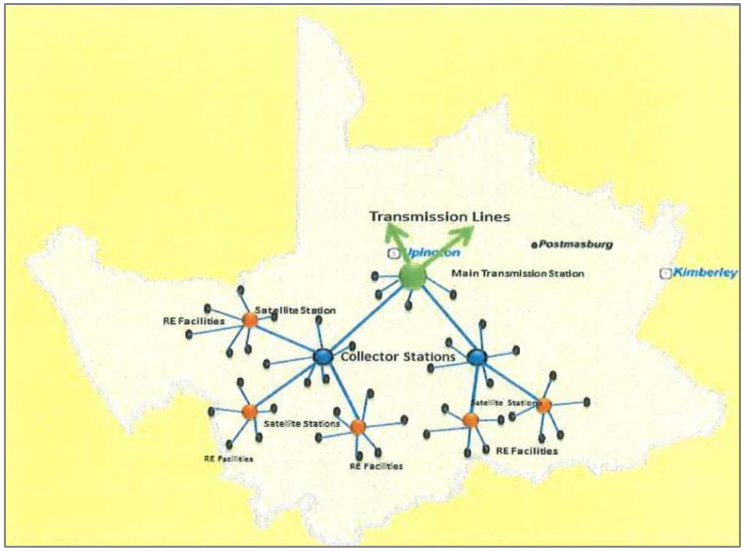
This is a welcome inclusion and is a good starting point to start to incorporate technology specific network costs previously not considered

Good objectives:

- Avoid premature congestion at Eskom Main Transmission Substations (MTSs)
- Minimising absolute number of MTSs
- Connect more smaller VRE plants in a specific area
- Allow more orderly network development
  and increased utilisation i.e. more efficient integration

Network costs based on unitised costing of individual equipment

Transmission substations, Satellite stations,
Transformers, Transmission/Distribution bays,
Overhead lines, Static VAr Compensators (SVCs)



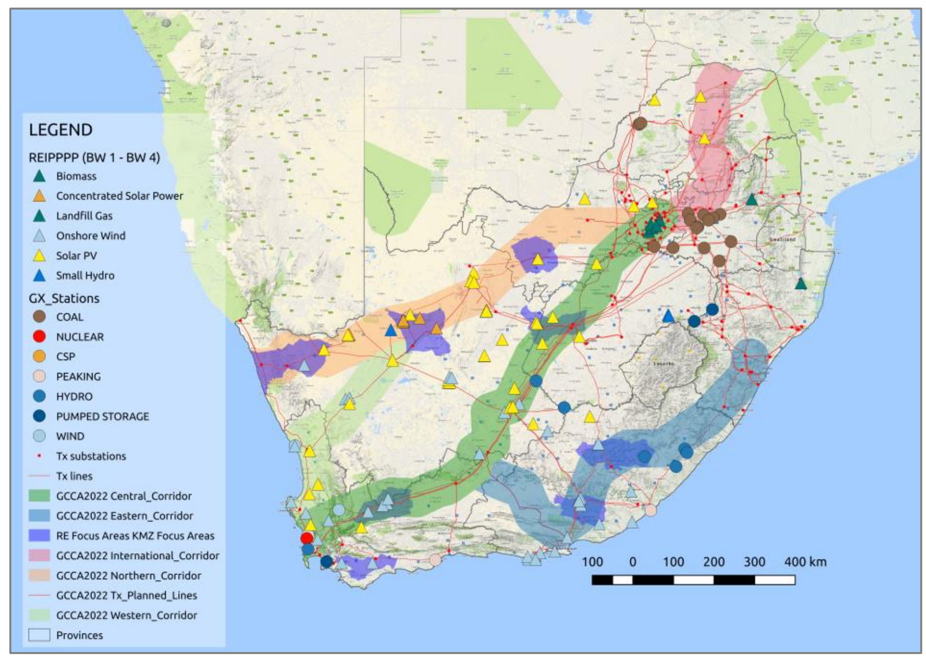
Deep network costs are not included in Irp but covered as part of periodic and well established TDP and SGP developed by Eskom

Deep network costs (backbone strengthening) not included in Draft IRP 2018 (or any previous IRP iteration) but instead established based on periodic TDPs and SGPs developed by Eskom Grid Planning

What is most important is how these deep network costs change on a relative basis across scenarios

Generally, these costs do not change significantly across scenarios and thus would not materially impact least-cost outcomes

In future iterations of the IRP, there should be a continued pursuit to include geospatial components of supply, networks and demand side options (co-optimisation) where feasible and tractable



TDP – Transmission Development Plan; SGP – Strategic Grid Plan

Formal comments on Draft IRP 2018

1 Executive Summary

2 Background

3 Draft IRP 2018 scenarios

4 Draft IRP 2018 employment impacts

5 Draft IRP 2018 energy planning risks

6 System services and technical considerations

6.1 Networks

6.2 System services

a RoCoF and frequency stability

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Formal comments on Draft IRP 2018

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System services and ensuring security of supply to enable any range of future energy mixes

System services and security of supply

Frequency stability/control (system inertia and RoCoF) – *particular focus in these comments*

Transient stability and fault level (system strength)

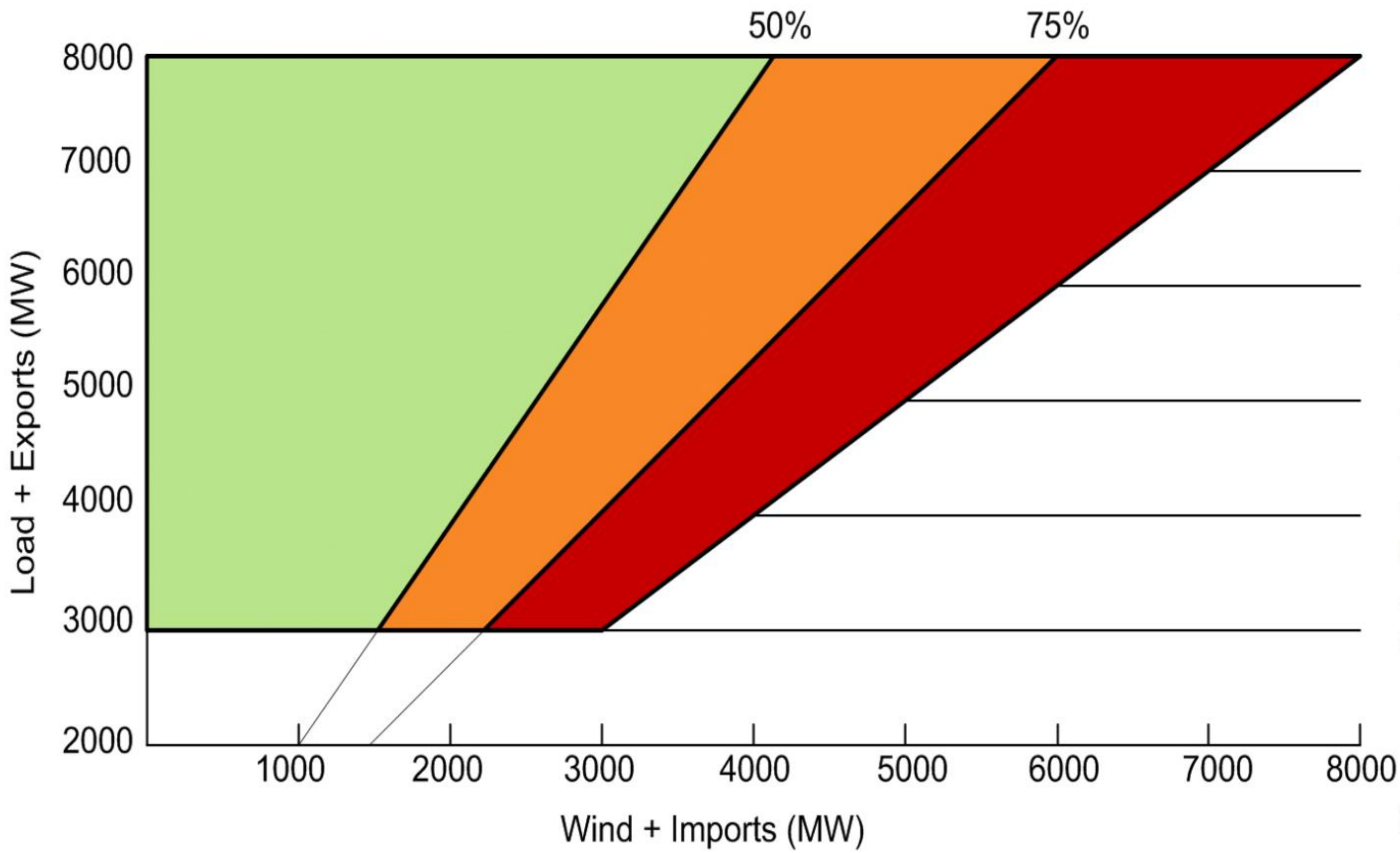
Voltage and reactive power control

Variable resource forecasting

All of these should inform a programme of research and effort required by all key stakeholders to ensure any future energy mix is secure

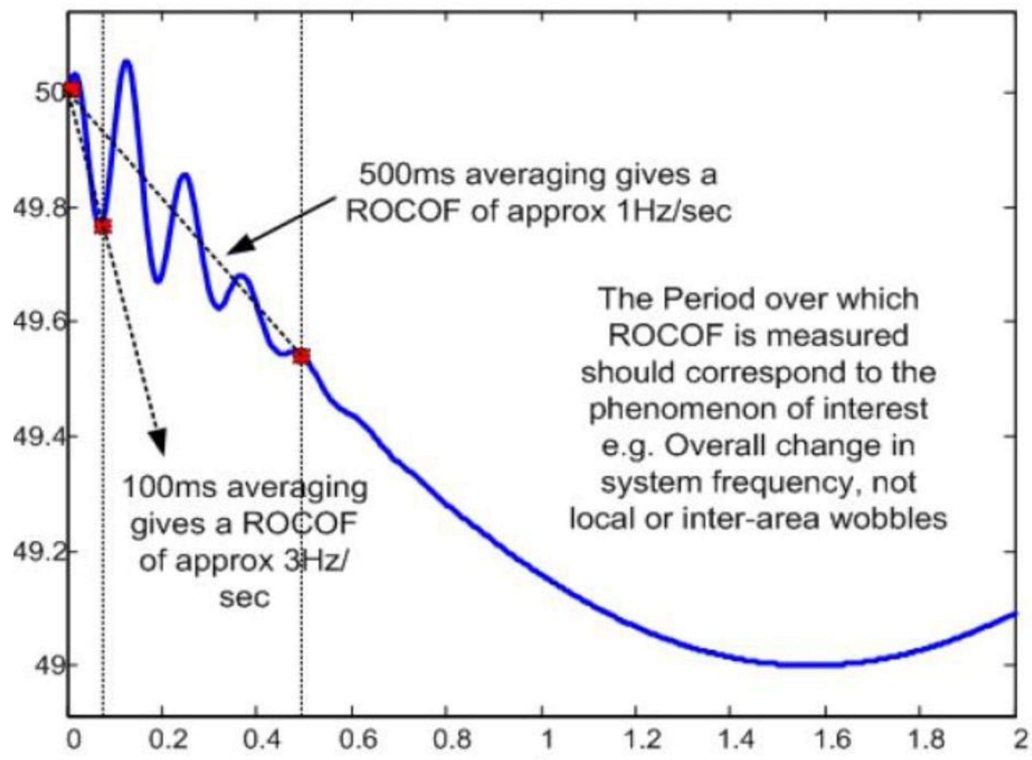
System operators are managing high non-synchronous penetration – Ireland SNSP limits and services to manage low inertia power systems

SNSP [%] = System Non-Synchronous Penetration = (Wind/PV + Imports)/(Demand + Exports)



 Sources: David Cashman (EirGrid), DS3 and beyond, 2017, IEA Working Group

Averaging window is important – for frequency stability typically a 500 ms averaging window for RoCoF is considered



The RocoF should not exceed a particular threshold within the pre-defined averaging window e.g. 500 ms

 Sources: EirGrid, SONI

The demand for system inertia is driven by two assumptions: the maximum allowable RoCoF & the largest assumed system contingency

Key assumptions:

Maximum allowed $RoCoF$:	0.5 Hz/s
Largest contingency (P_{cont}):	2 400 MW
Kinetic energy lost in contingency event $E_{kin(cont.)}$:	5 000 MWs

$$E_{kin.(min)} = P_{cont.} \frac{f_n}{2(RoCoF)} + E_{kin(cont.)}$$

Term “inertia” is used a bit loosely to describe the amount of kinetic energy that is stored in the rotating masses of all synchronously connected power generators (and loads to be precise)

f_n = System frequency = 50 Hz

Demand for inertia

124 800 MW.s of system inertia are required at any given point in time in order for RoCoF to stay below 0.5 Hz/s in the first 500 ms after the largest system contingency occurred

 Sources: P. Kundur, Power System Stability and Control, 1994

As a starting point – we have assessed system inertia on an hourly basis via UCED in PLEXOS and some high level assumptions

Technology	Inertia constant [MWs/MVA]
Coal (old)	4.0
Coal (new)	2.0
OCGT/ICE	6.0
CCGT/CC-GE	6.0
Biomass	2.0
Hydro/PS	3.0
Imports	0.0
Nuclear	5.0
Wind	0.0
PV	0.0
CSP	2.0
DR	0.0

Supply of inertia

Depending on what mix of power stations is operational at any given point in time, the total actual system inertia will be different

For example, if 20 GW of old coal, 10 GW of new coal and 2 GW of nuclear are online, system inertia is:

≈20 GW * 4 MWs/MVA +
10 GW * 2 MWs/MVA + 2 GW * 5 MWs/MVA
= 110 000 MWs

If wind, PV and 5 GW of CCGTs are online, system inertia is only 47 000 MW.s

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Sources: P. Kundur, Power System Stability and Control, 1994

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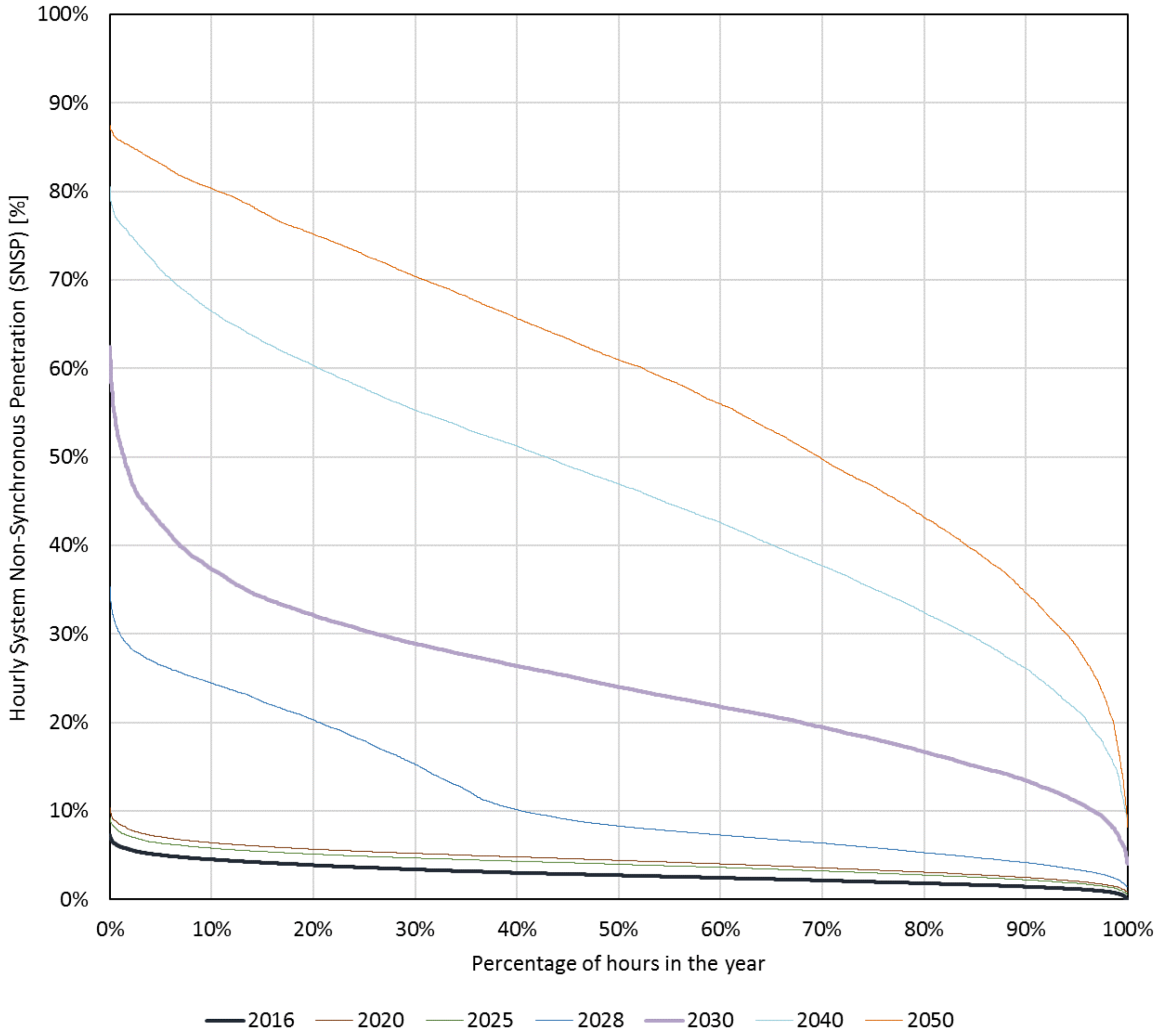
SNSP levels in IRP1 of Draft IRP 2018 only above 25% from 2028 and 37% by 2030 for 10% of the time but above 80% by 2050



IRP1

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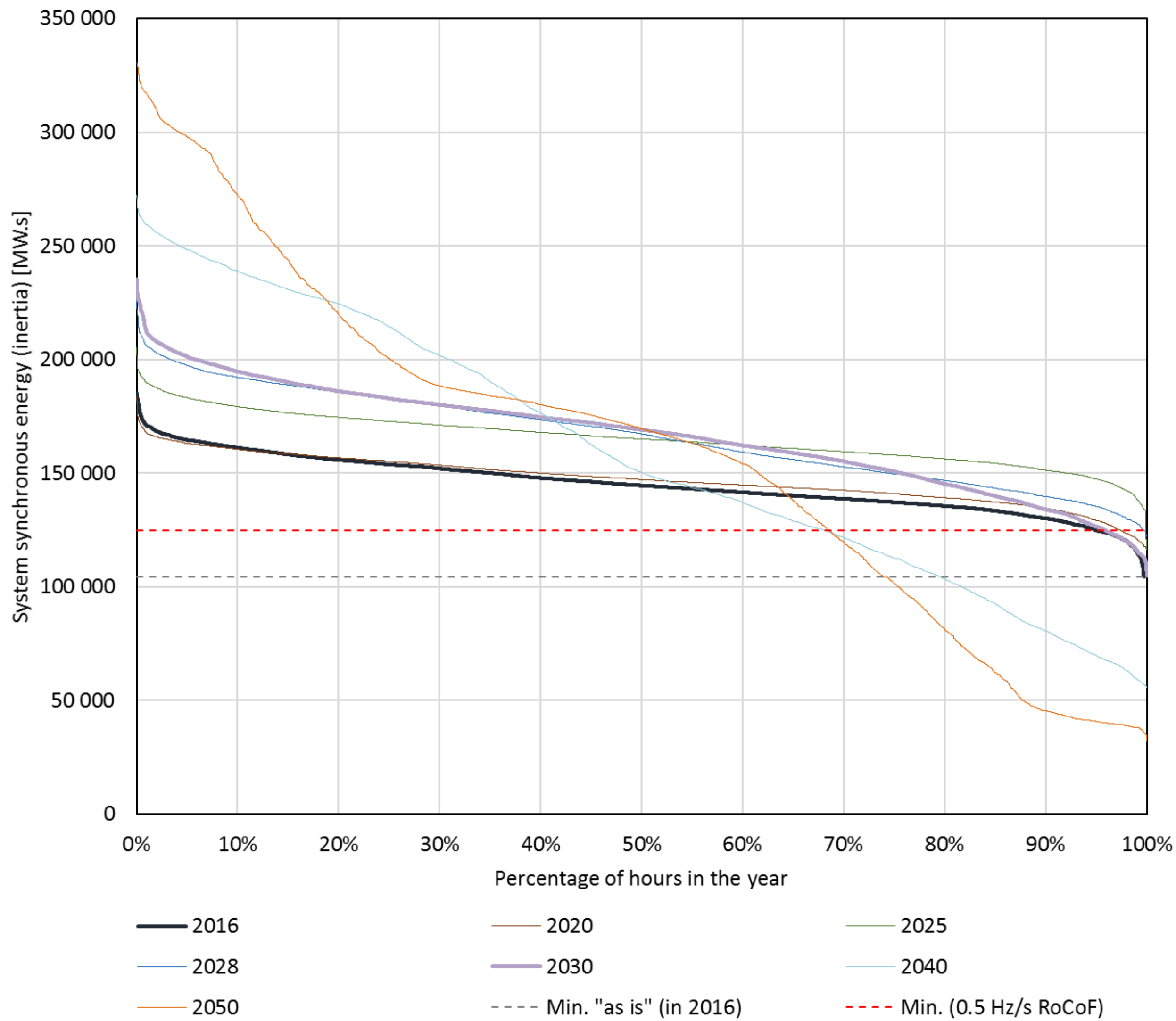
System synchronous energy for IRP1 – confirmation that the power system really does only start to change until after 2030



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Minimal cost of ensuring acceptable RoCoF levels even at very high non-synchronous generation penetration levels

		2016	2020	2025	2028	2030	2040	2050
Minimum inertia needed	[MW.s]	104 482	104 482	104 482	104 482	104 482	104 482	104 482
Minimum inertia (actual)	[MW.s]	104 482	116 485	116 609	122 260	104 992	55 832	31 907
Additional inertia needed	[MW.s]	-	-	-	-	-	48 650	72 575
Number of hours	[hrs]	24	-	-	-	-	1 799	2 282
Share of hours	[%]	0.3%	0.0%	0.0%	0.0%	0.0%	20.5%	26.1%
Rotating stabilisers needed	[MW]	-	-	-	-	-	1 220	1 810
Annual cost for rotating stabilisers	[bR/yr]	-	-	-	-	-	3.7	5.6
(% of system costs)	[%]	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	1.2%

The worst-case cost to ensure RoCoF levels are acceptable post-2030 is at most ≈1% of total system costs

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Thank you

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