Future wind deployment scenarios for South Africa

CSIR Energy Centre

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Outline

1 Background

2 Approach

3 Scenarios

4 New research outcomes

5 Focus on wind

6 Conclusions

Outline

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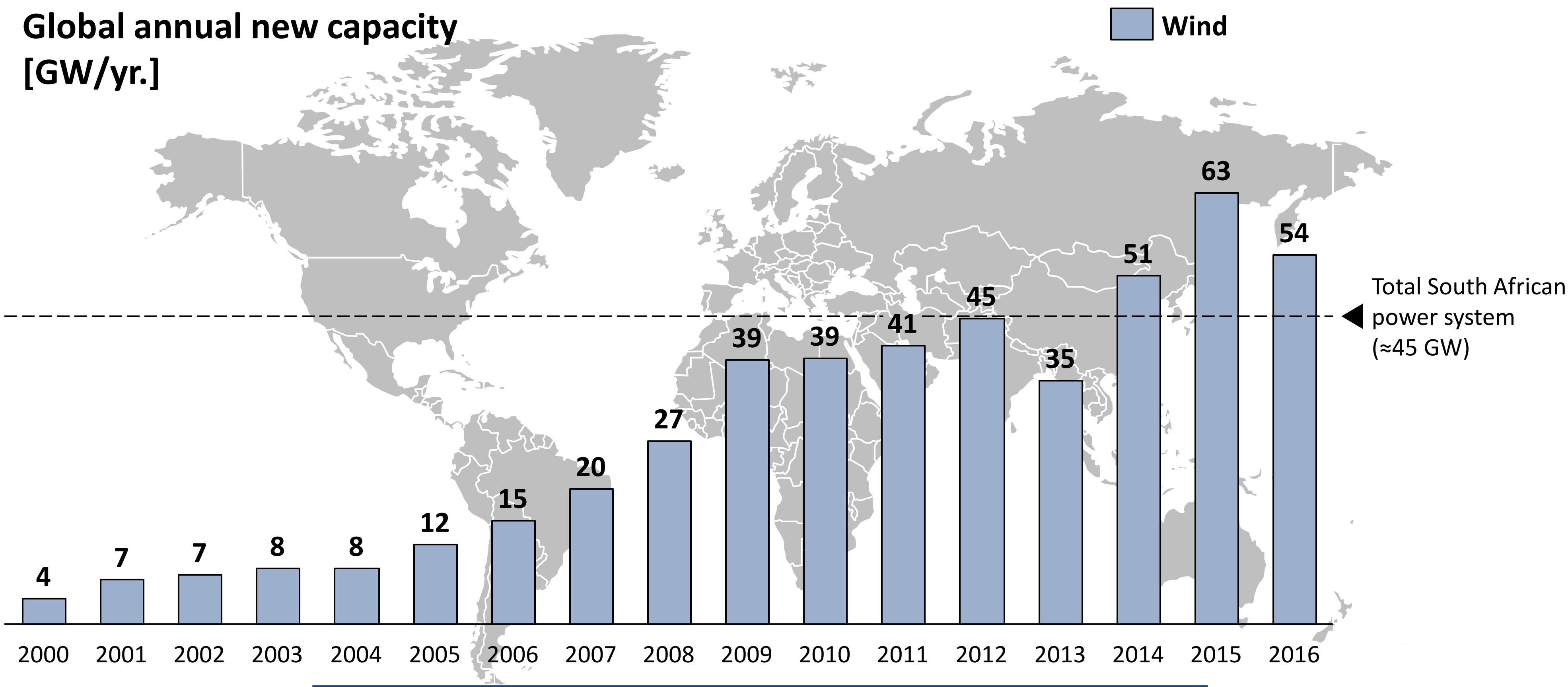
Globally, wind deployment increased significantly in early 2000s and has since had strong deployment levels of 40-60 GW/yr

Global annual new wind capacity (2000-2016)



Most new wind capacity in 2016 was in China (23 GW) with the next closest USA/Germany/India (8.2/5.4/3.6 GW)
South Africa – 0.4 GW

Sources: IEA; GWEC; CSIR analysis

Wind capacity has grown at >20% per year since 2000 with increasingly significant role for wind to meet energy requirements globally

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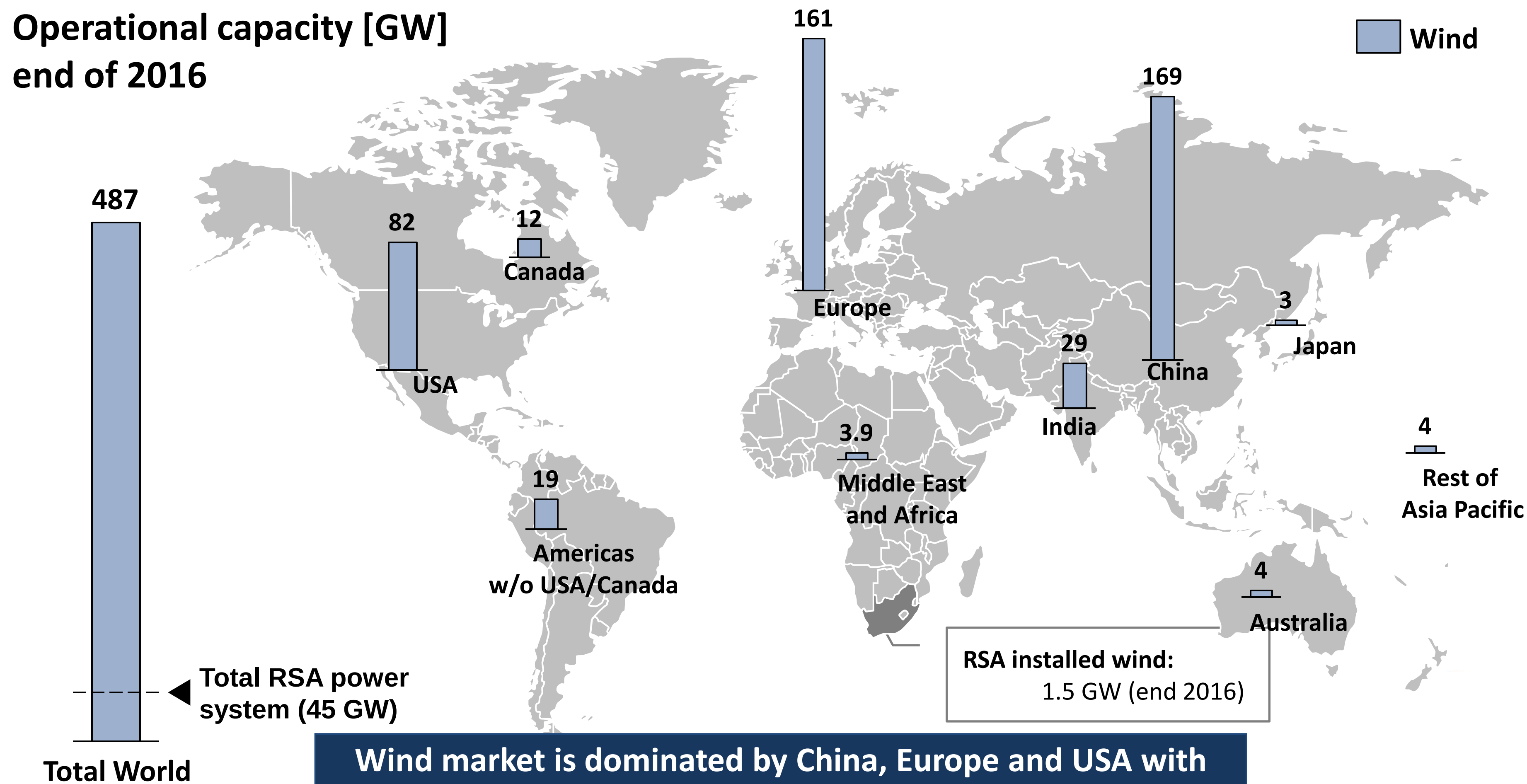

Wind market is dominated by China, Europe and USA with strong growth in India

Sources: GWEC; CSIR analysis

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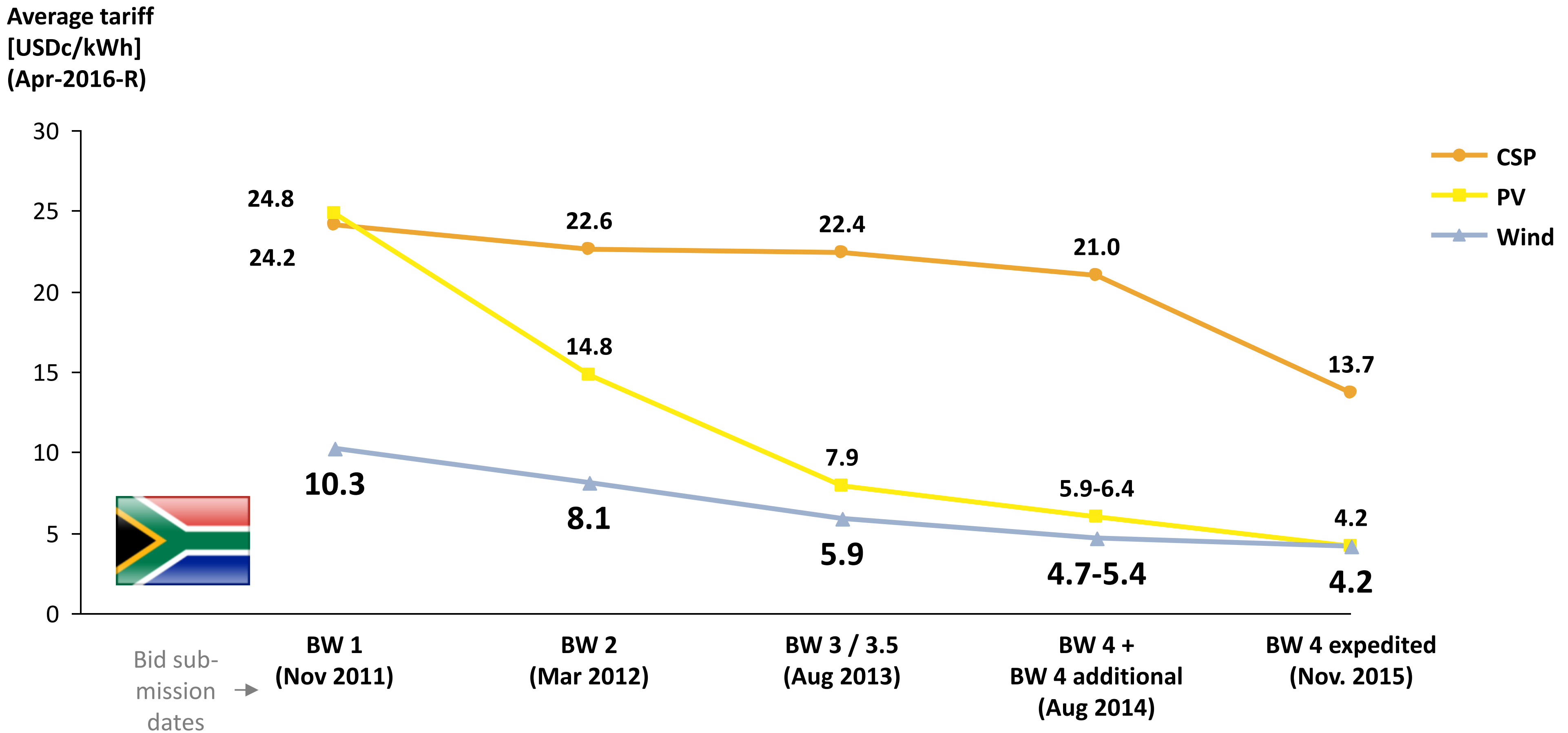
Actual tariffs: Reductions in tariff for new, wind, solar PV and CSP with wind reduction of ~60% in just 4 years

Results of South African Department of Energy REIPPPP



Notes: Assumed USD:ZAR = 14.71; For CSP Bid Window 3 and 3.5, the weighted average of base and peak tariff is indicated, assuming 50% annual capacity factor and 64%/36% base/peak tariff utilisation ratio; BW = Bid Window; Sources: Department of Energy's publications on results of first four bidding windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; StatsSA on CPI; CSIR analysis

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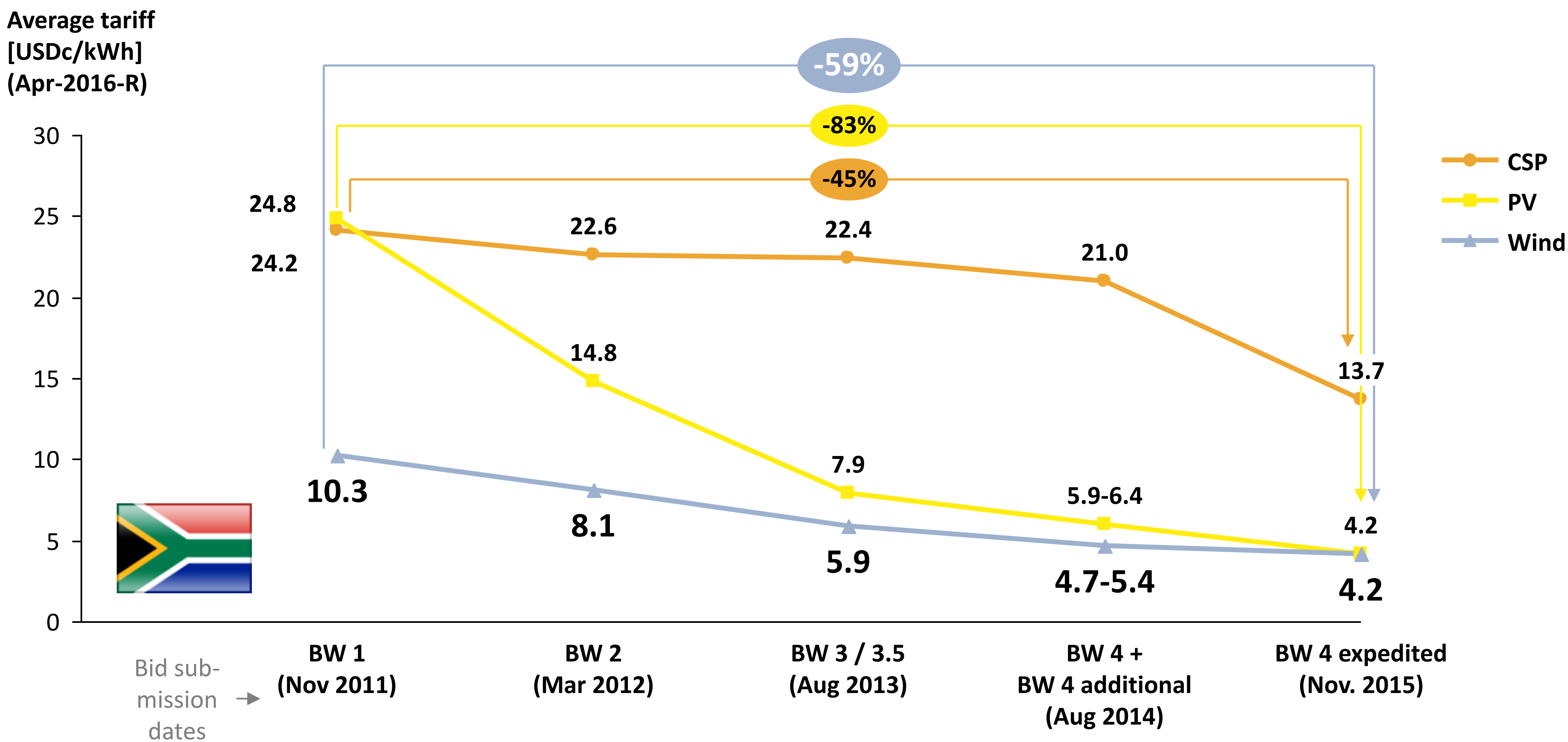

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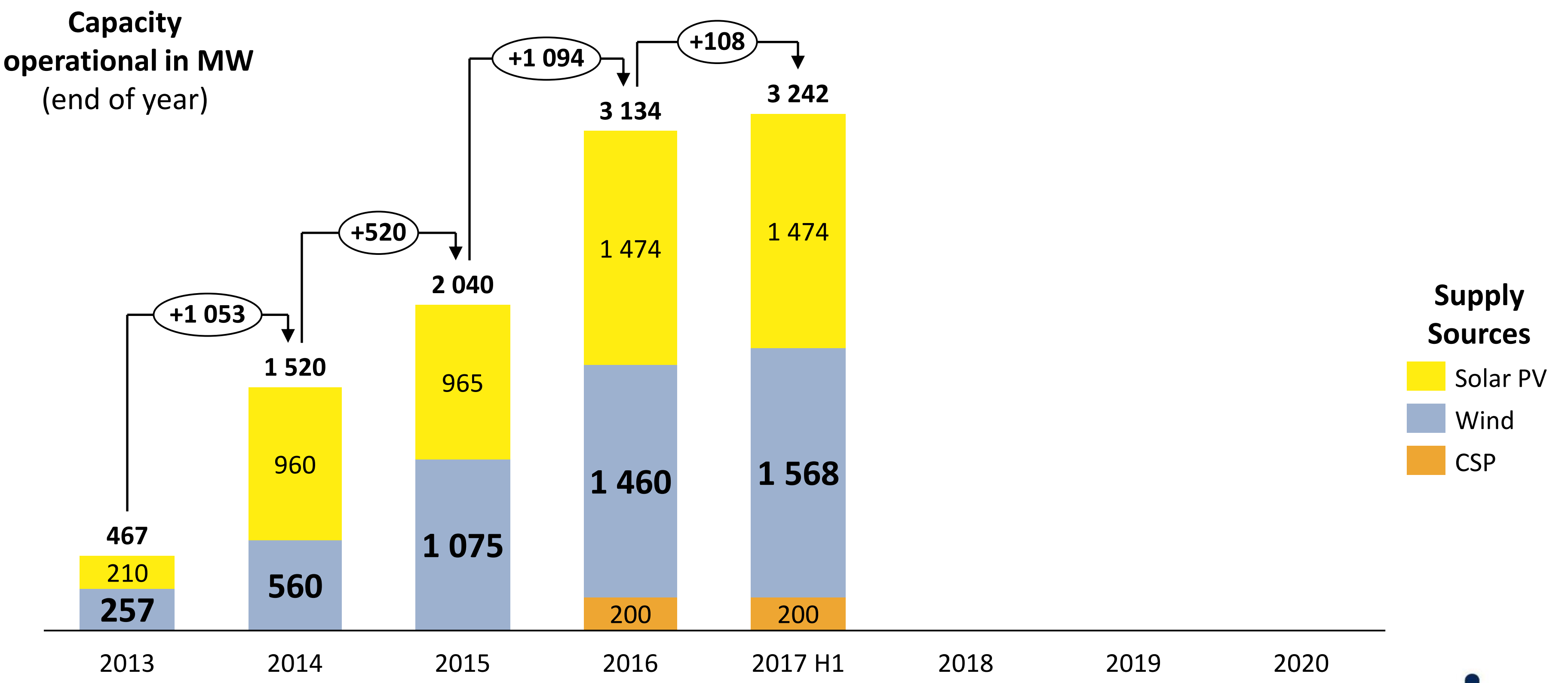
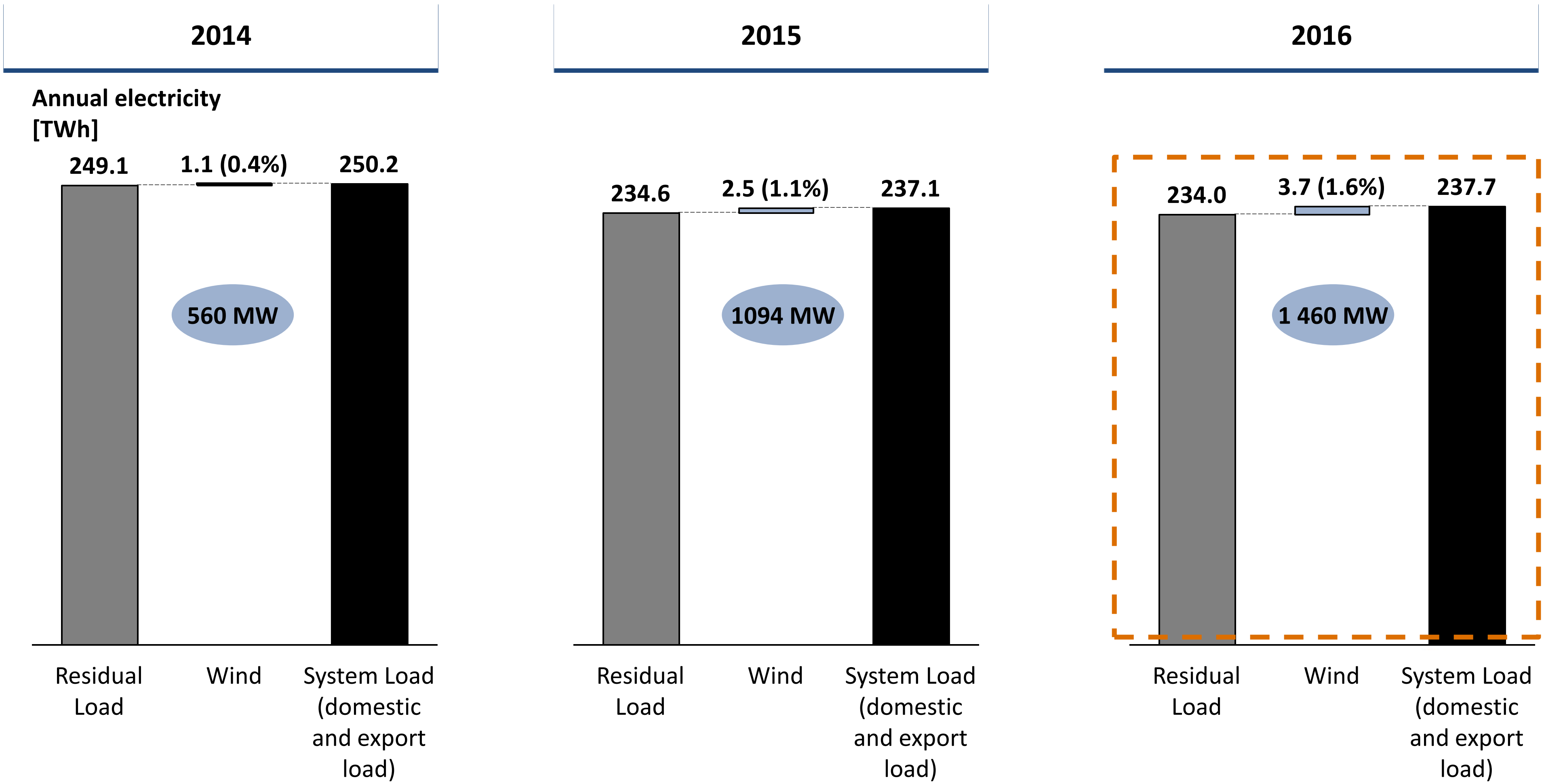
From November 2013 to Jun 2017, 1 568 MW of wind, 1 474 MW of large-scale solar PV and 200 MW of CSP became operational in RSA



Notes: RSA = Republic of South Africa. Solar PV capacity = capacity at point of common coupling. Wind includes Eskom's Sere wind farm (100 MW). 2017 H1 = Jan - Jun 2017
Sources: Eskom; DoE IPP Office

Wind supplied 3.7 TWh (1.6%) of South Africa's system load in 2016 (a growing share from just 0.4% in 2014 and 1.1% in 2015)

Evolution of wind energy contribution to South African electricity mix (2014-2016)



Sources: Eskom; CSIR Energy Centre analysis

Outline

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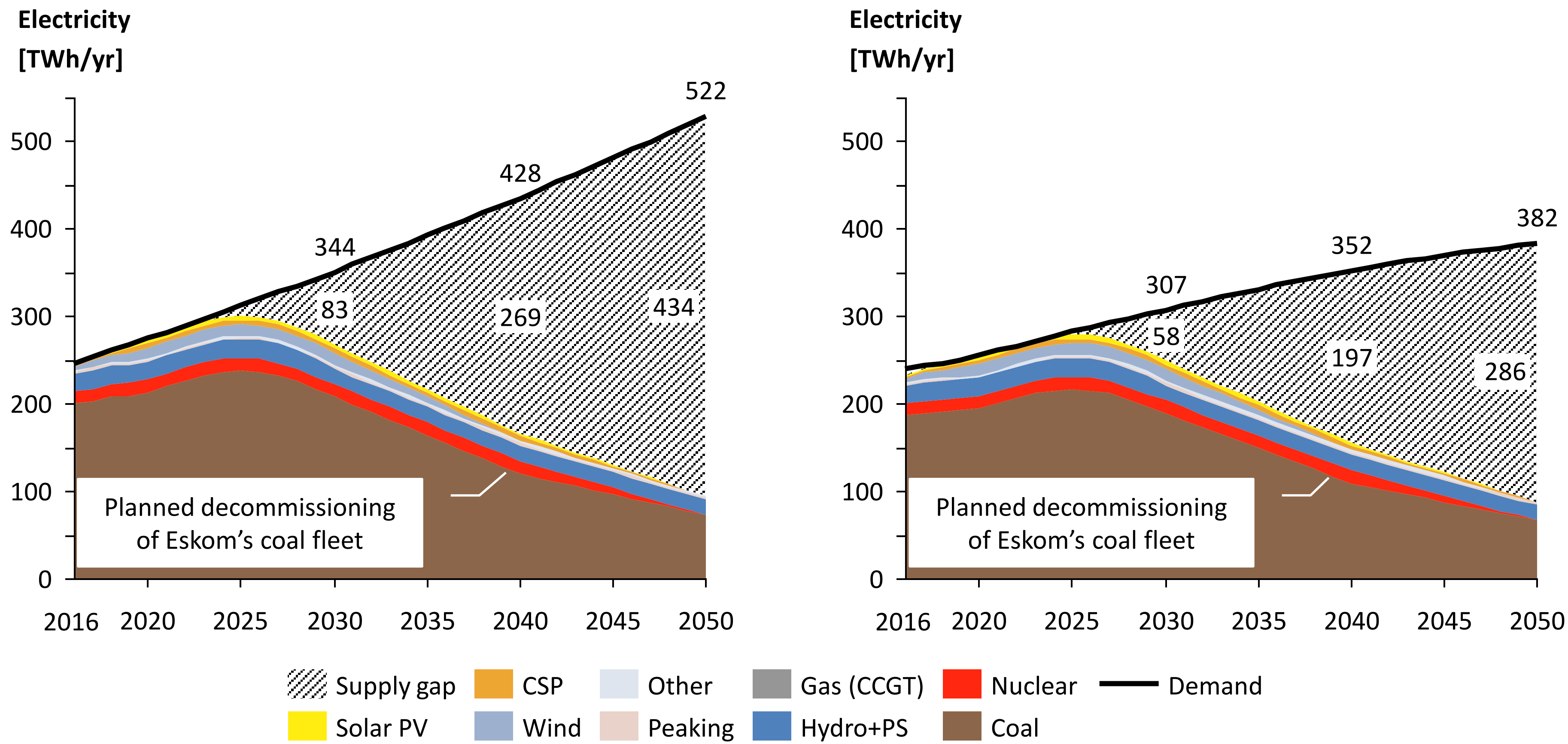
The capacity expansion planning exercise fills the supply gap in the least-cost manner, subject to constraints imposed

Energy supplied to the South African electricity system from existing plants (2016-2050)

Whether a high demand forecast is expected in South Africa

… or a low demand forecast – we need electricity infrastructure investment

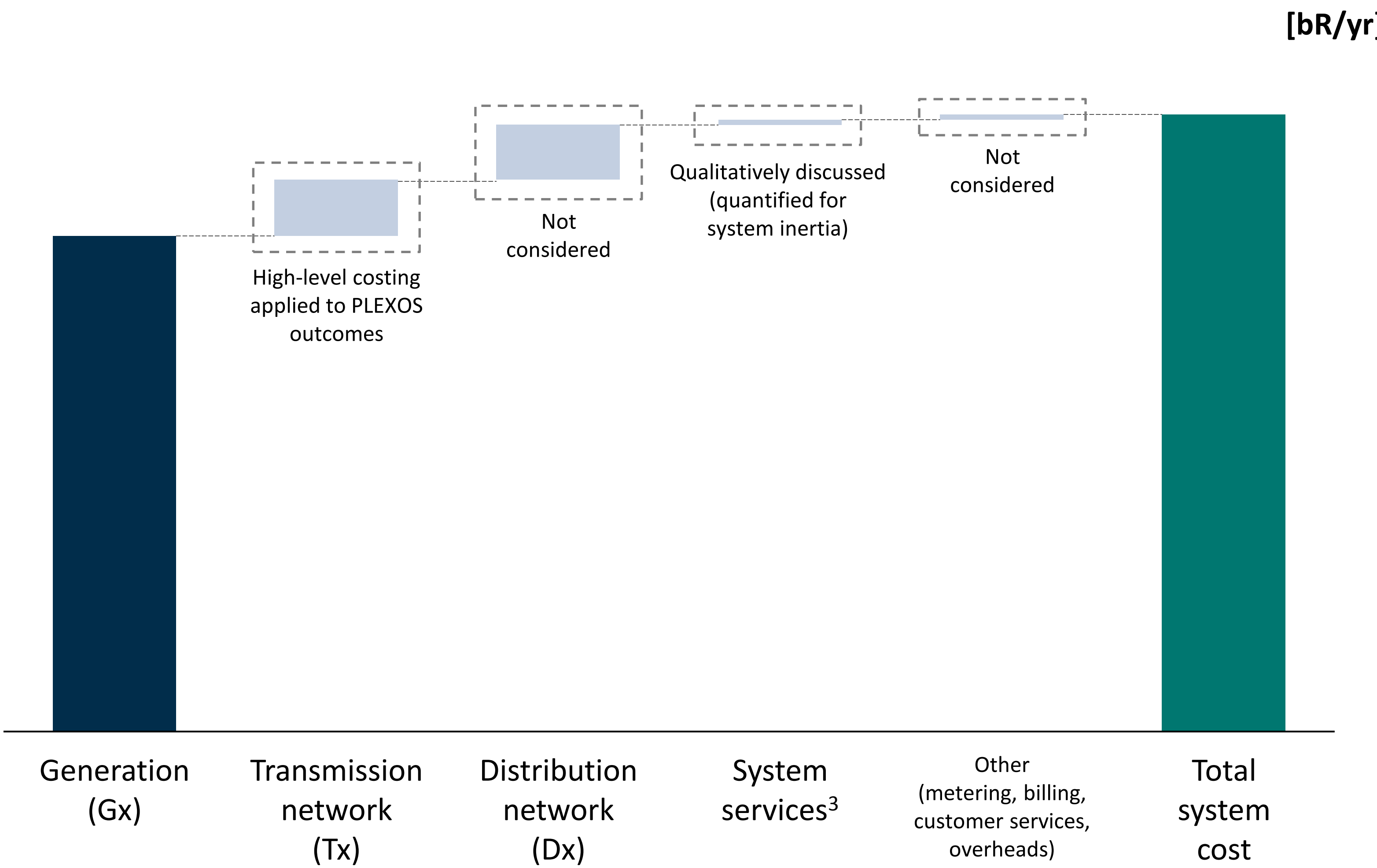


Note: Energy from existing generators is shown representatively; All power plants considered for "existing fleet" that are either Existing in 2016, Under construction, or Procured (preferred bidder)
Sources: DoE (IRP 2016); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

Approach currently optimises the generation component of total system cost (the dominant component) and is technology agnostic

Costs included in Gx optimisation model:
- CAPEX (plant level)
- FOM[1]
- VOM[2]
- Fuel

Costs excluded in Gx optimisation model:
- Externalities e.g. CO_2 emissions costs
- Decommissioning costs
- Waste management and/or rehabilitation
- Major mid-life overhaul
- Shallow grid connection costs for non renewables (included for RE)



[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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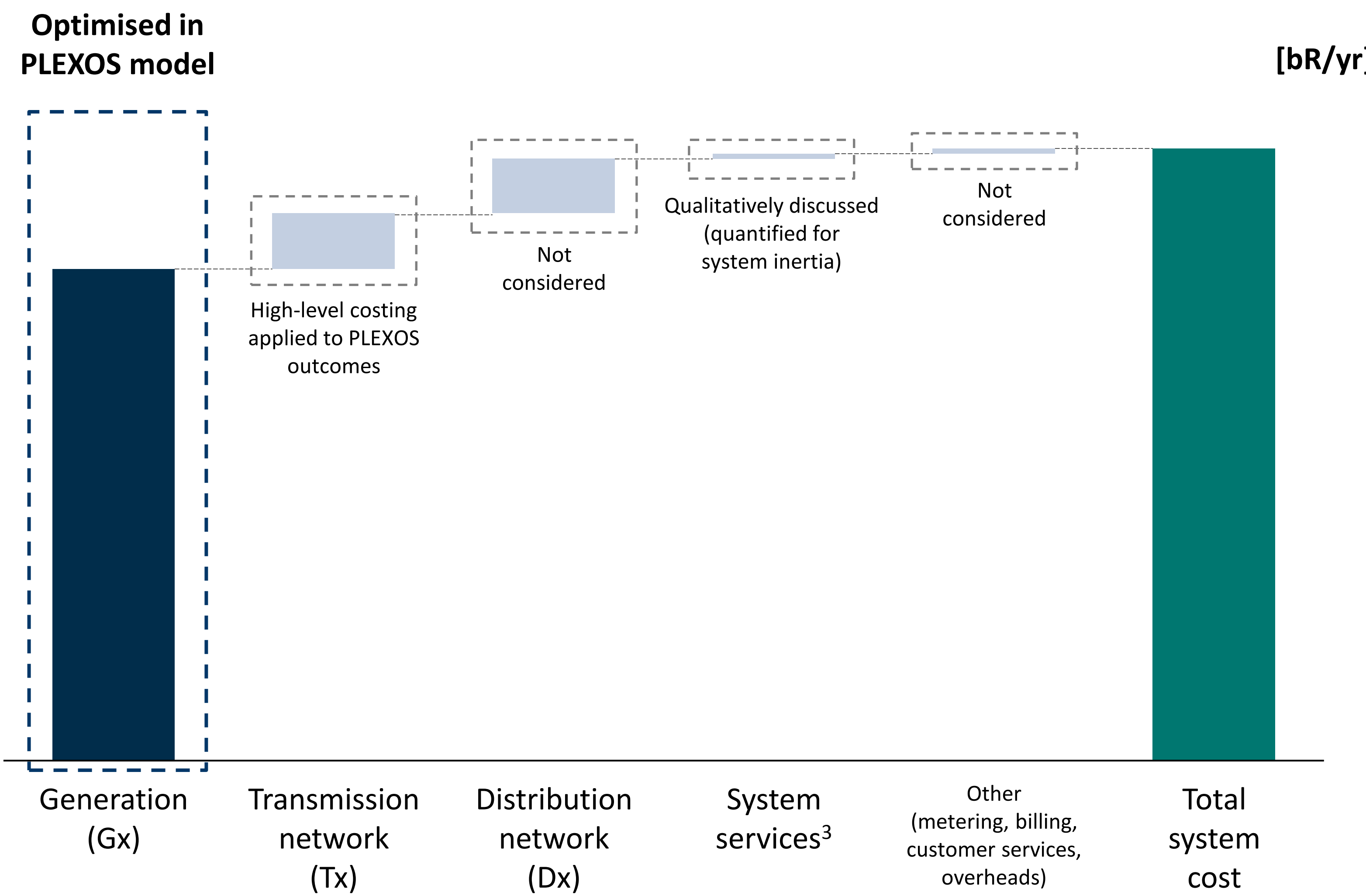

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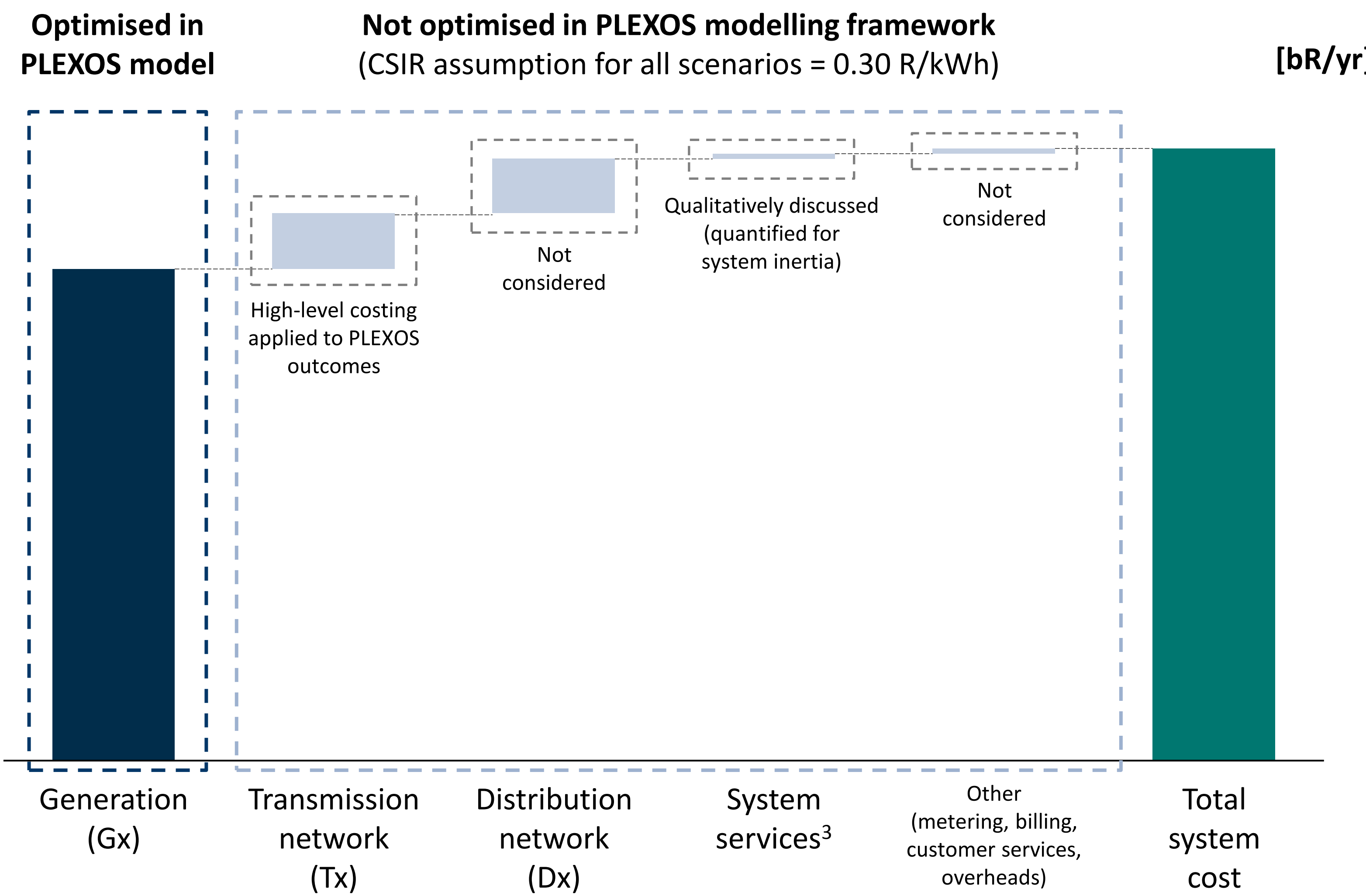

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A range of scenarios investigated including business-as-usual, least-cost and decarbonised – with new outcomes the focus

Reference	Scenario name	Demand	Constraints	Technology costs
BAU-Hi	Business as Usual	High (Fig. 14)	PPD Moderate (Fig. 15); Annual RE limit*	Tab. A.3-A.5
LC-Hi	Least-cost	High (Fig. 14)	PPD Moderate (Fig. 15)	Tab. A.6-A.8
DC-Hi	Decarbonise	High (Fig. 14)	Decarbonise (Fig. 15)	Tab. A.6-A.8
BAU-Lo	Business as Usual	Low (Fig. 14)	PPD Moderate (Fig. 15); Annual RE limit*	Tab. A.3-A.5
LC-Lo	Least-cost	Low (Fig. 14)	PPD Moderate (Fig. 15)	Tab. A.6-A.8
LCP-Hi	Least-cost (plausible)	High (Fig. 14)	PPD Moderate (Fig. 15)	Tab. A.9-A.11
LCP-Lo	Least-cost (plausible)	Low (Fig. 14)	PPD Moderate (Fig. 15)	Tab. A.9-A.11

Part of previous research [1]
(See link below if interested)

New research outcomes

* Annual limit on new-build wind (1.8 GW) and solar PV (1 GW).

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[1] See here (Comments on Draft IRP 2016)

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PLEASE REFER TO PAPER

FOR FULL SET OF TECHNOLOGY COST INPUT ASSUMPTIONS

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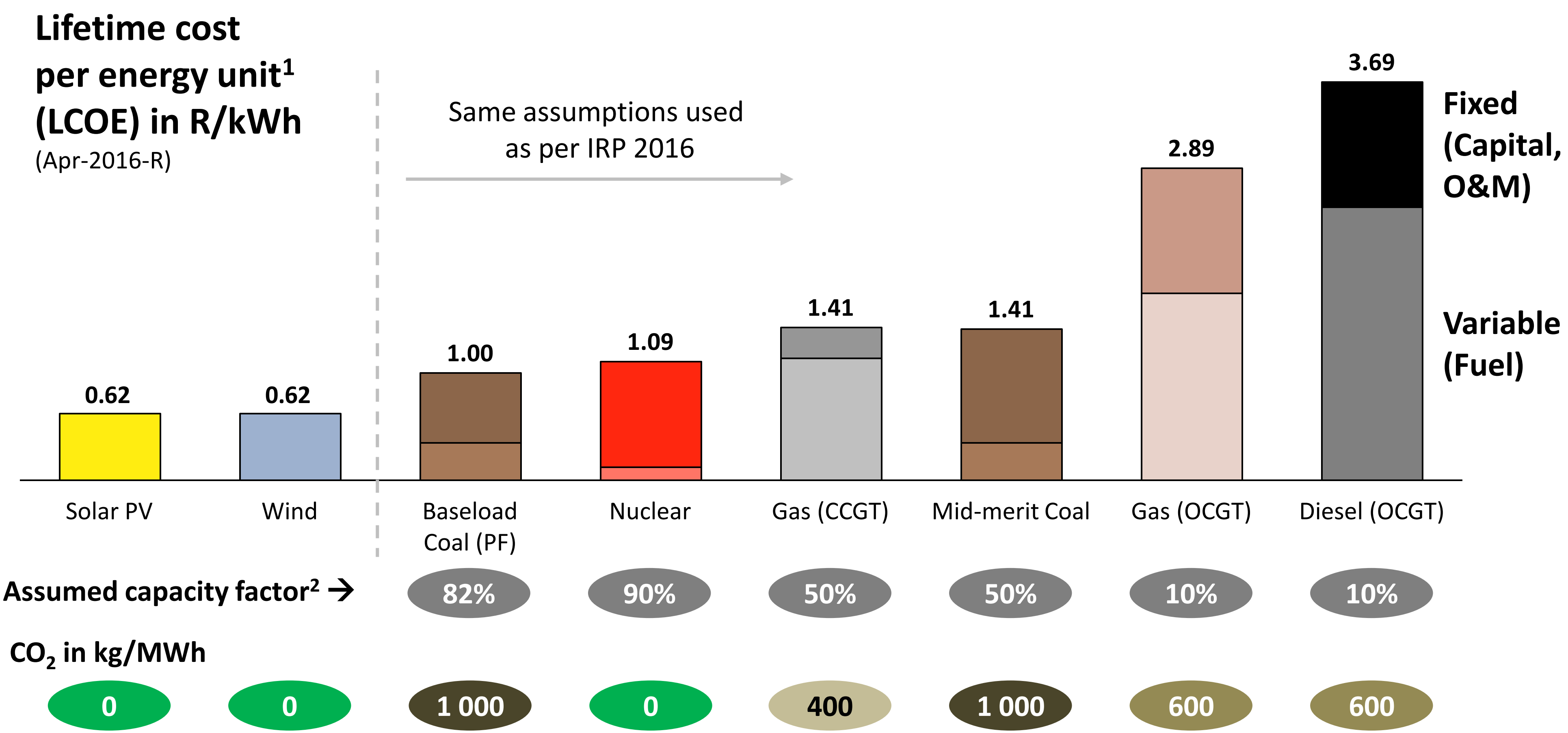
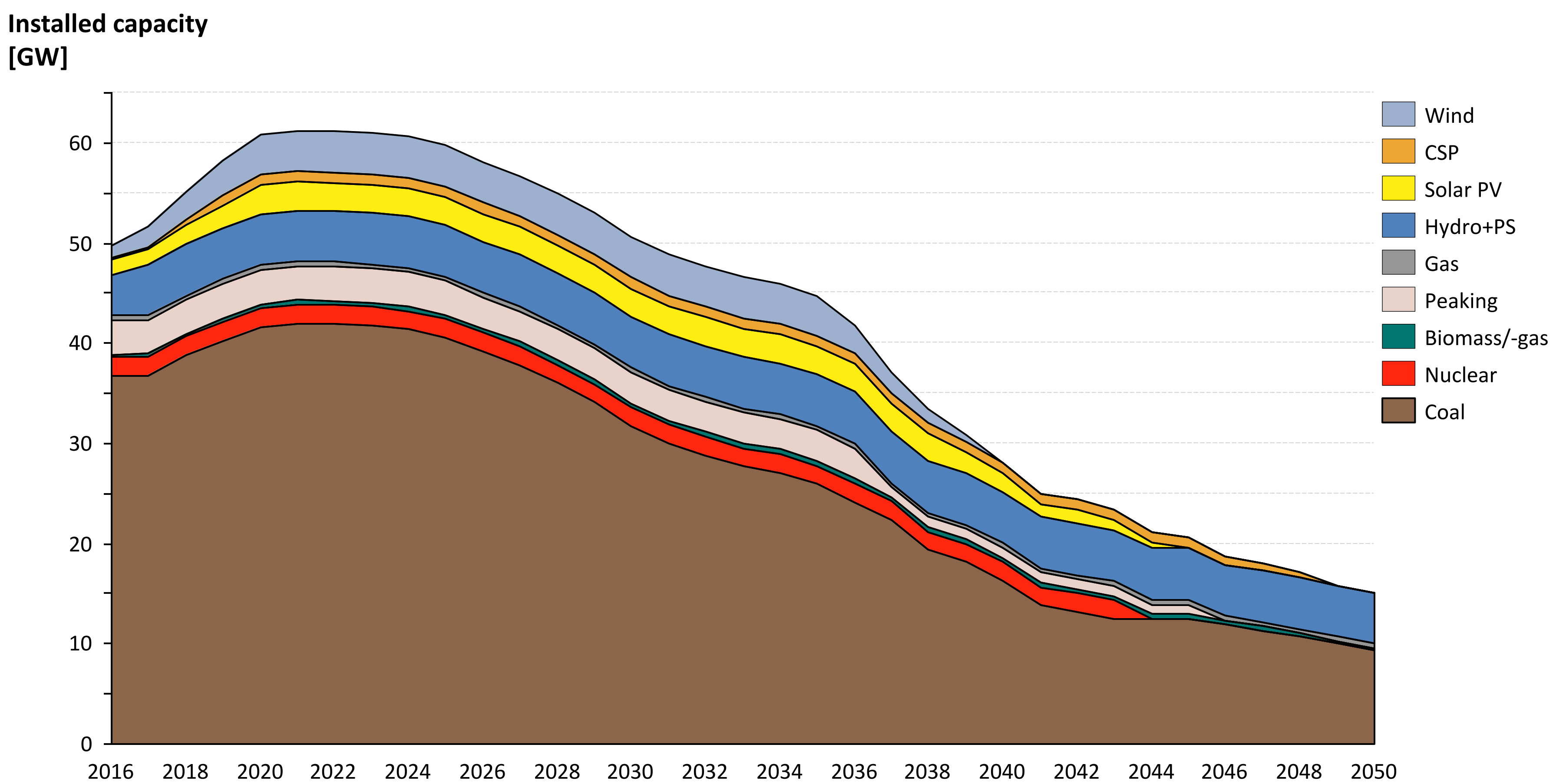
Technology cost characteristics fully modelled – taken from Draft IRP 2016 unless otherwise specified



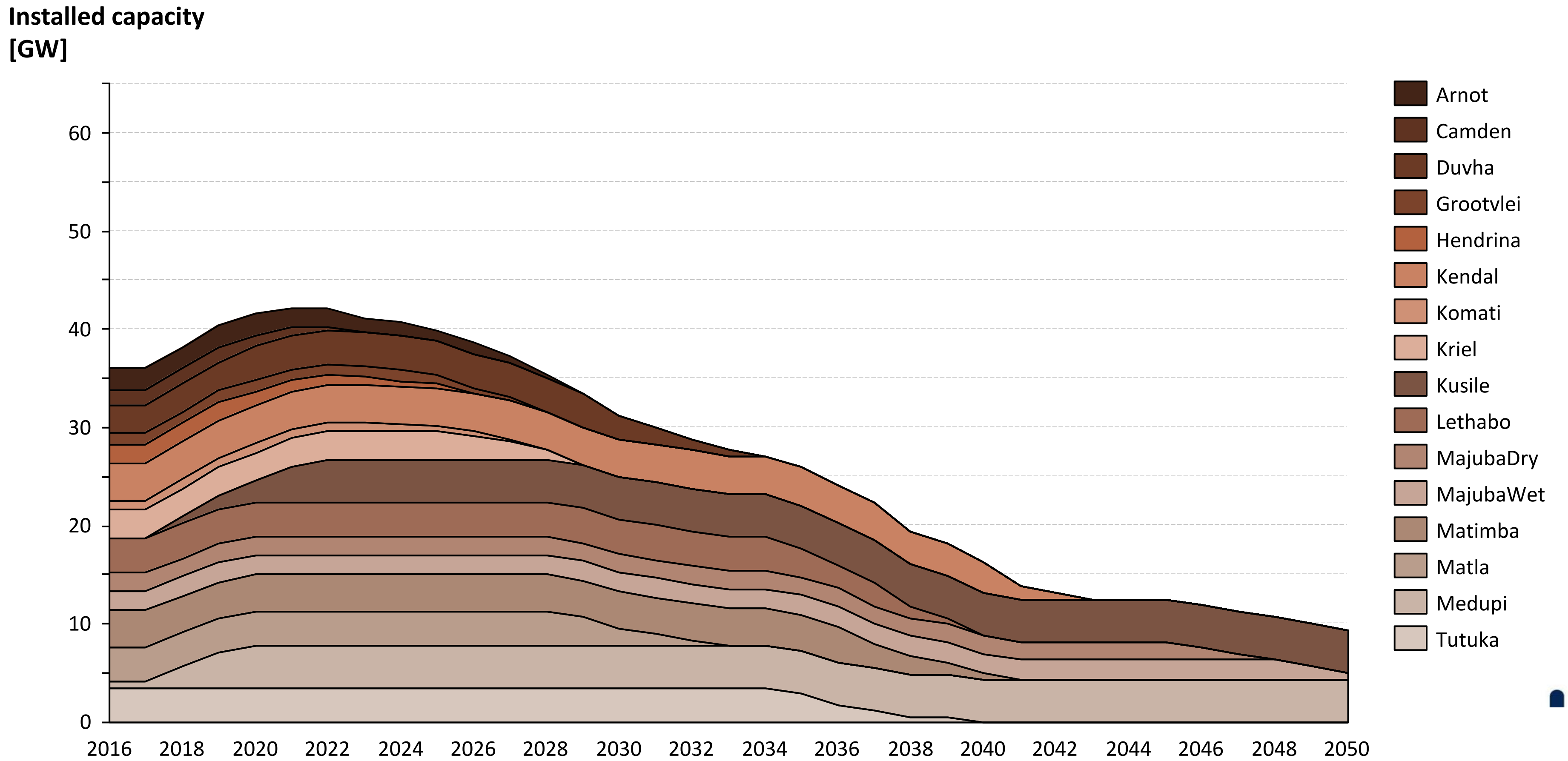
[1] Lifetime cost per energy unit is only presented for brevity. The model inherently includes the specific cost structures of each technology i.e. capex, Fixed O&M, variable O&M, fuel costs etc.
[2] Changing full-load hours for new-build options drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per kWh);
Assumptions: Average efficiency for CCGT = 55%, OCGT = 35%; nuclear = 33%; IRP costs from Jan-2012 escalated to May-2016 with CPI; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; Sources: IRP 2013 Update; Doe IPP Office; StatsSA for CPI; Eskom financial reports for coal/diesel fuel cost; EE Publishers for Medupi/Kusile; Rosatom for nuclear capex; CSIR analysis

South African generation capacity decommissioning schedule – as planned for in the Draft IRP 2016



Sources: Draft IRP 2016

South African coal generation capacity decommissioning schedule - – as planned for in the Draft IRP 2016



Sources: CSIR analysis

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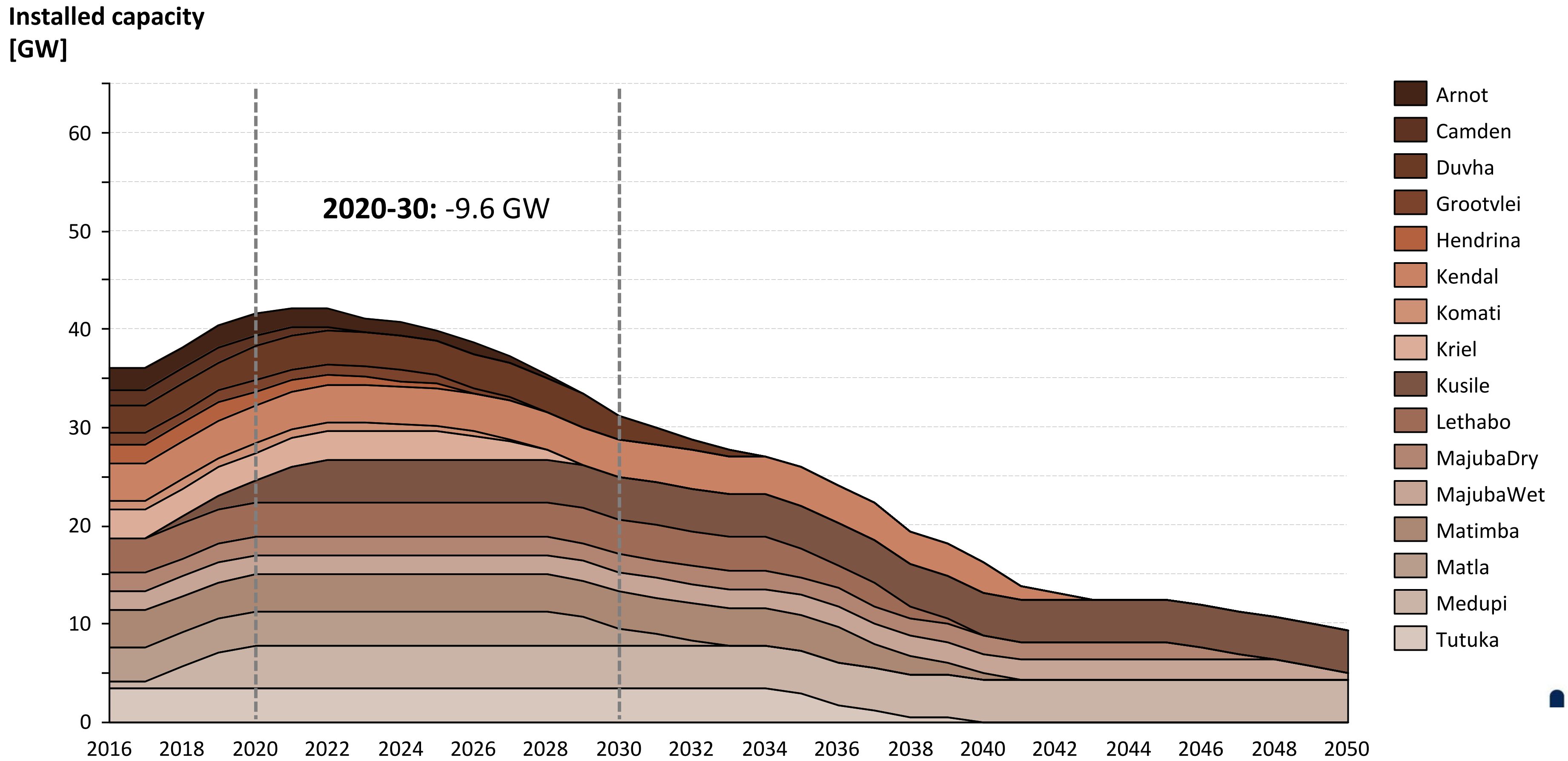

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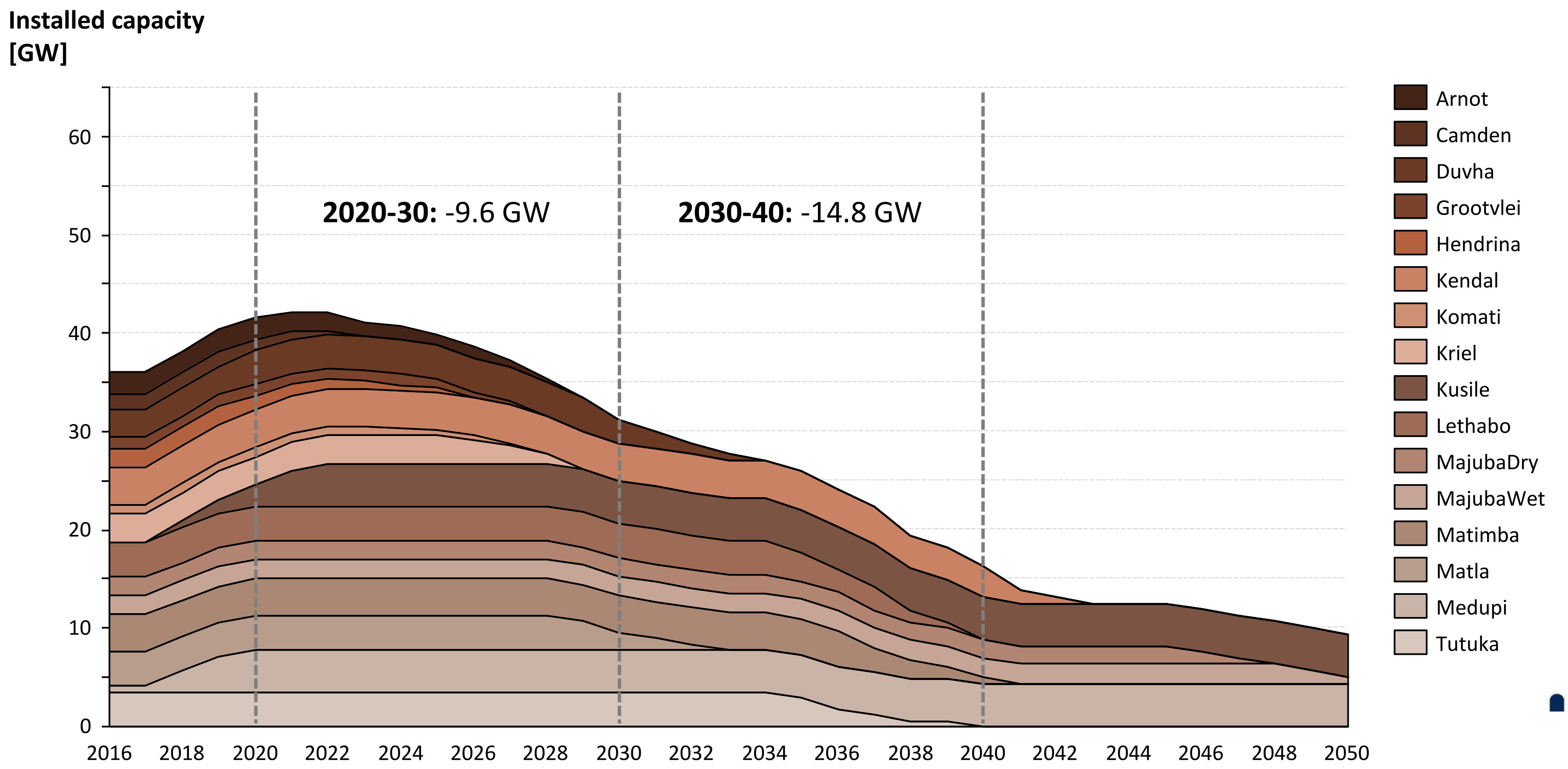

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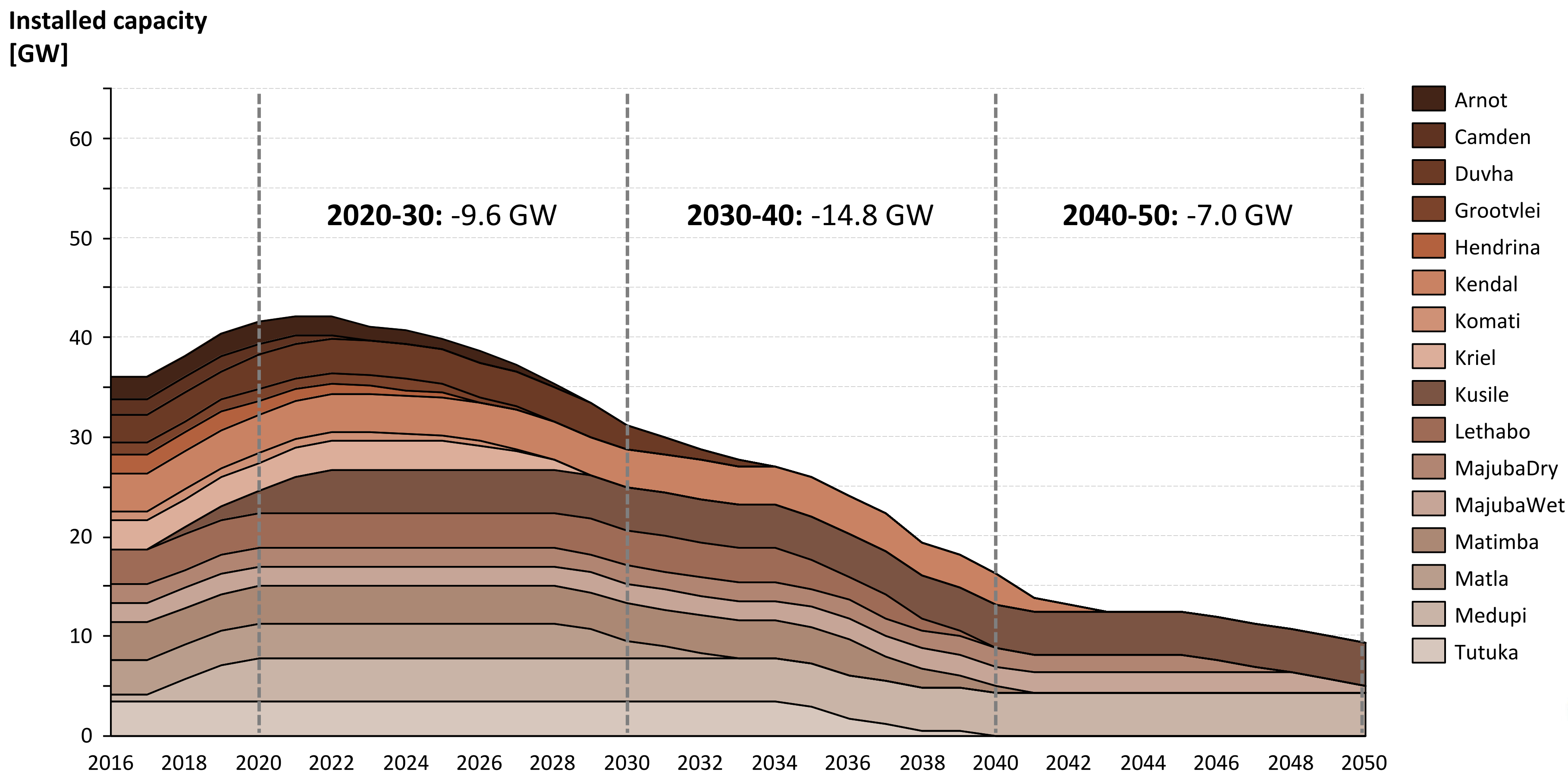
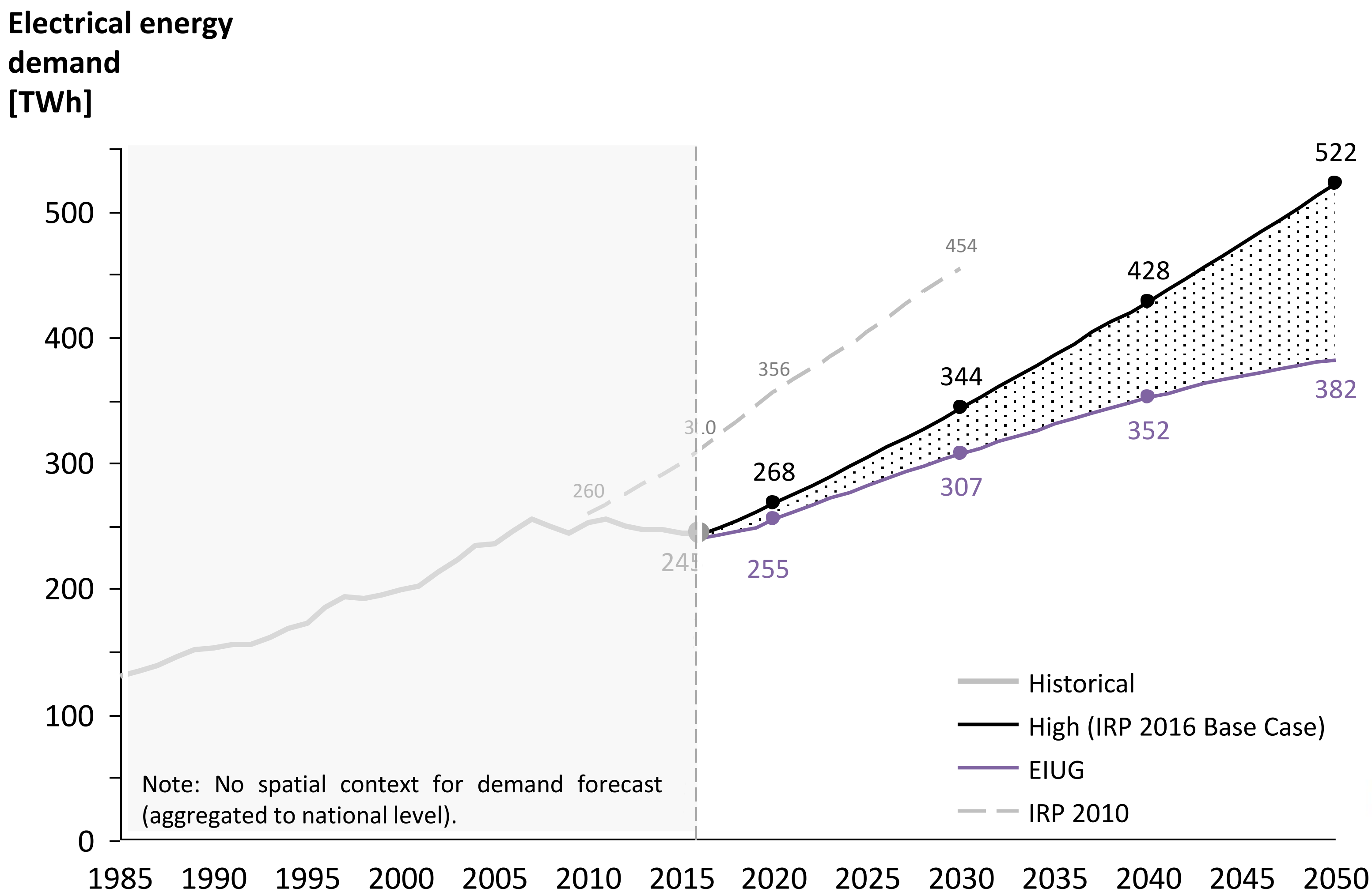


Sources: CSIR analysis

Two demand forecasts considered (high and low) – from Draft IRP 2016



Sources: DoE; EIUG; CSIR analysis

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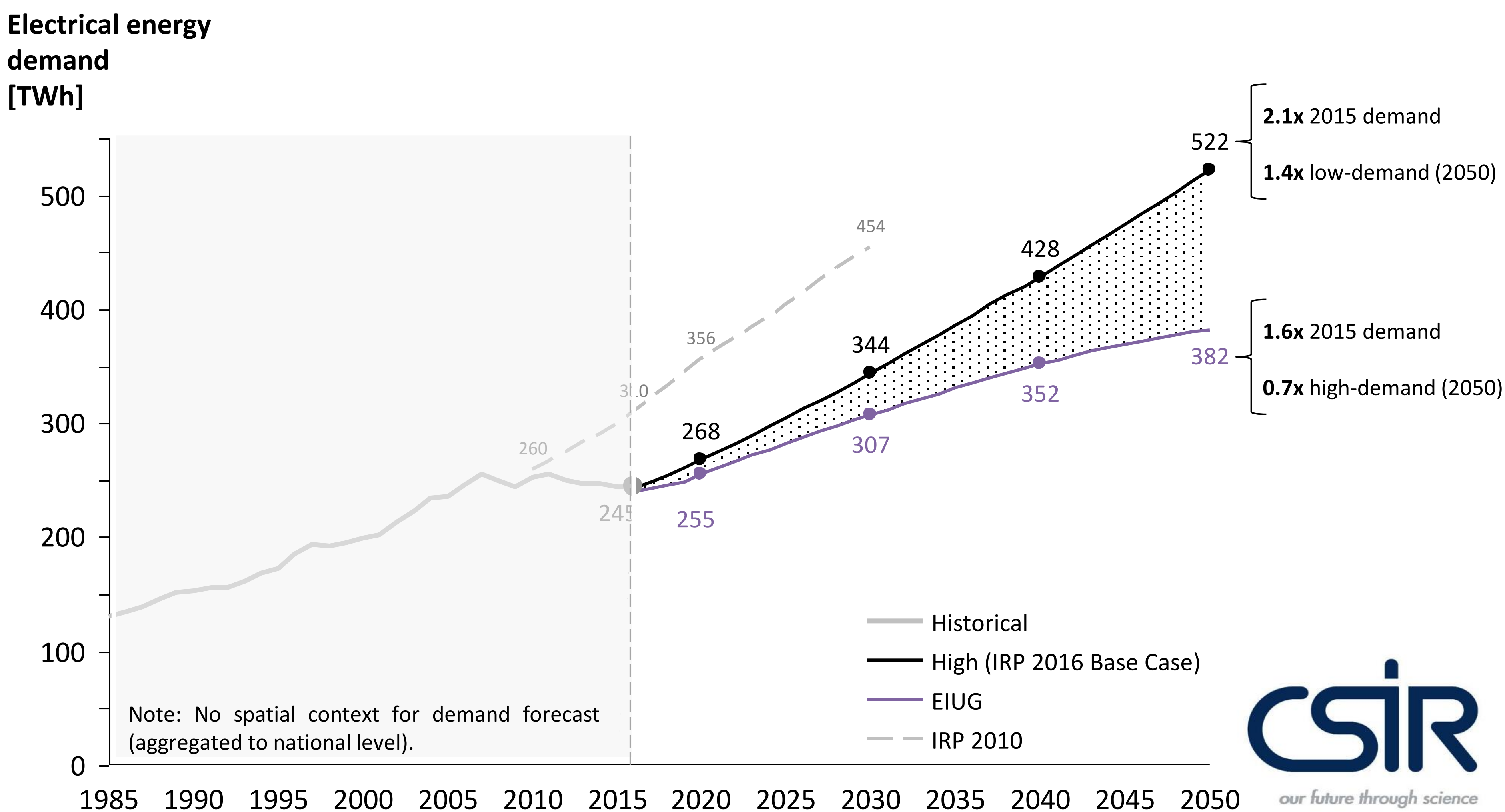

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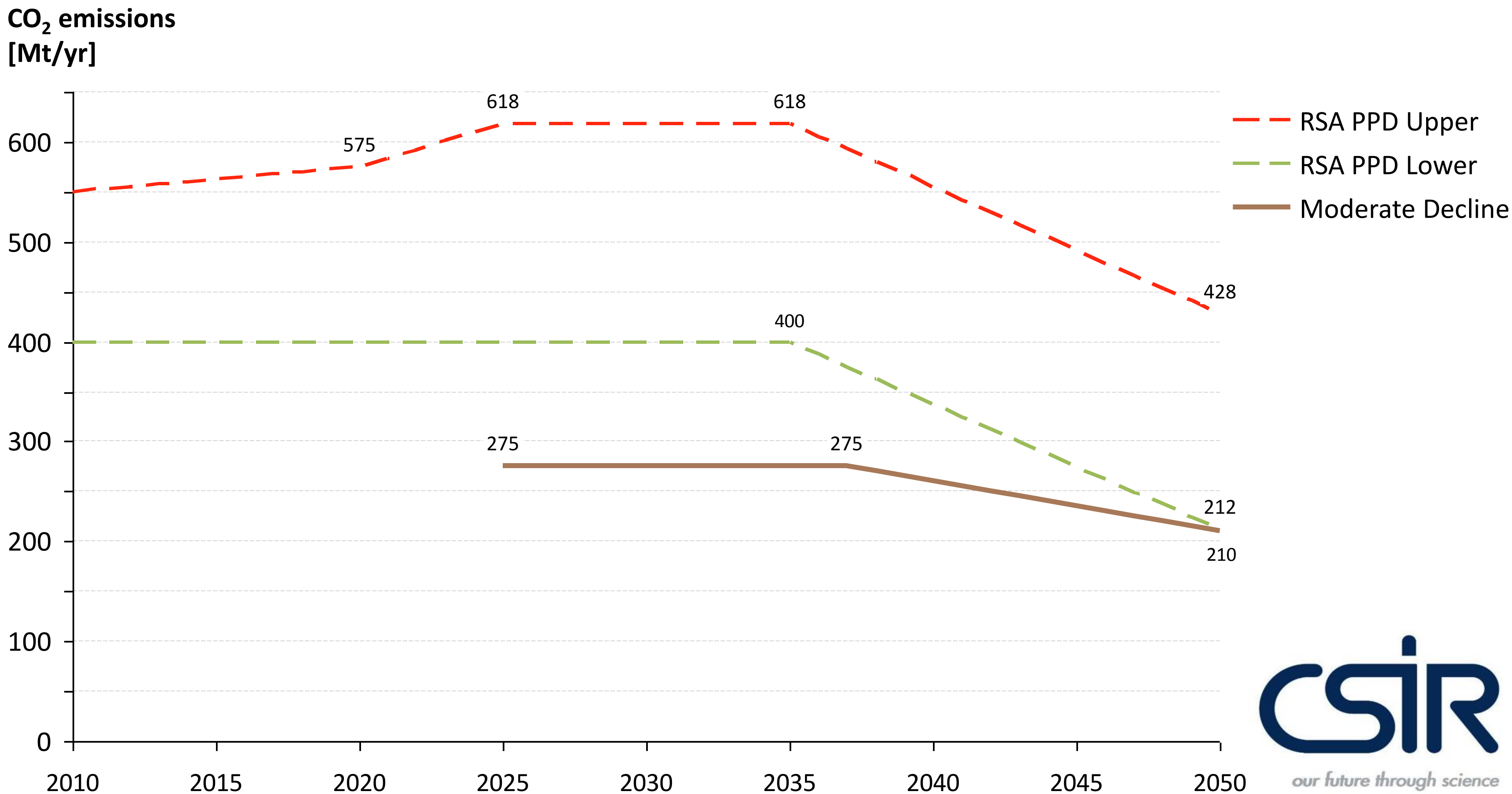
Sources: DoE; EIUG; CSIR analysis

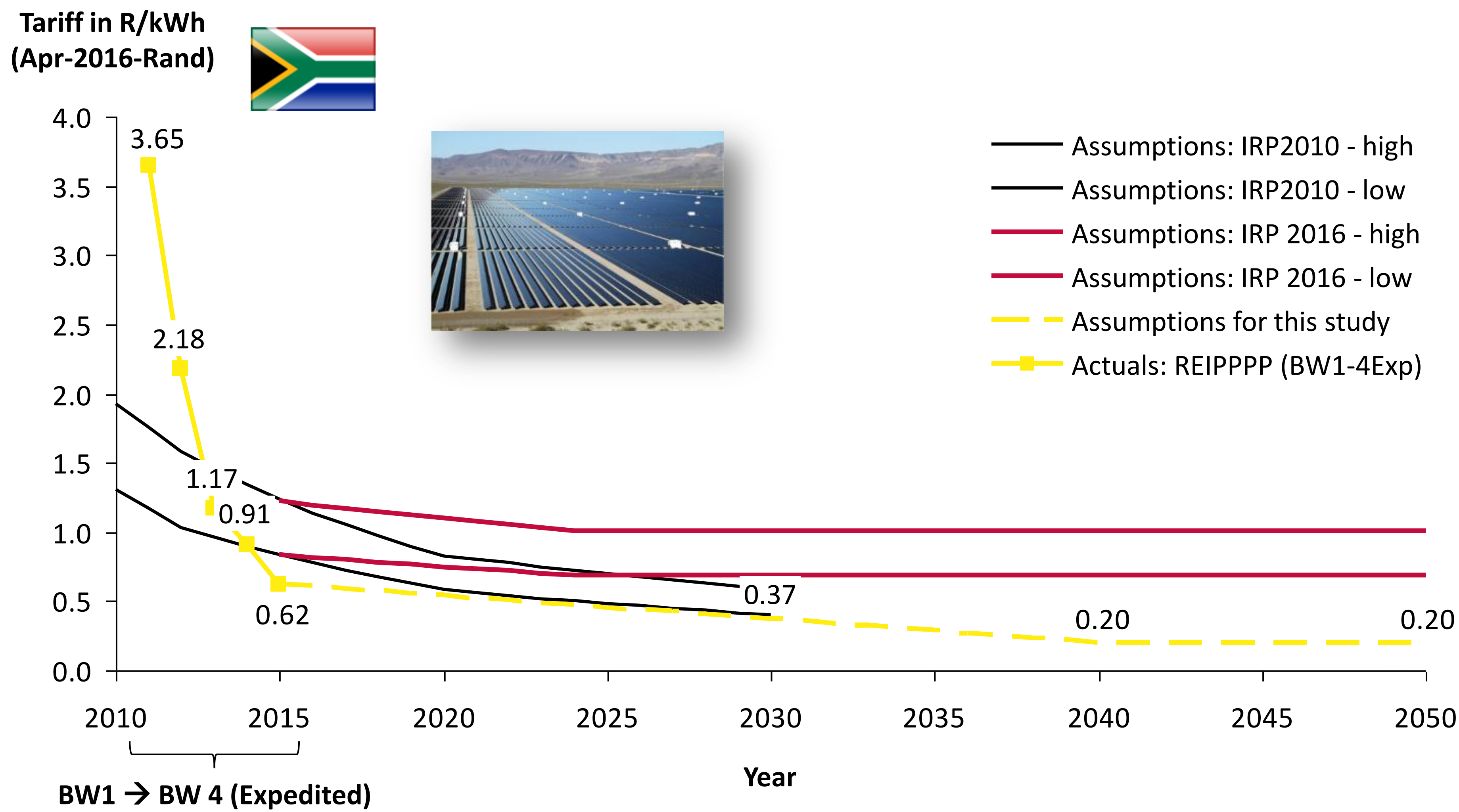
Electricity sector CO_2 emissions trajectories constrain the model over time to 2050 – from Draft IRP 2016



PPD = Peak Plateau Decline

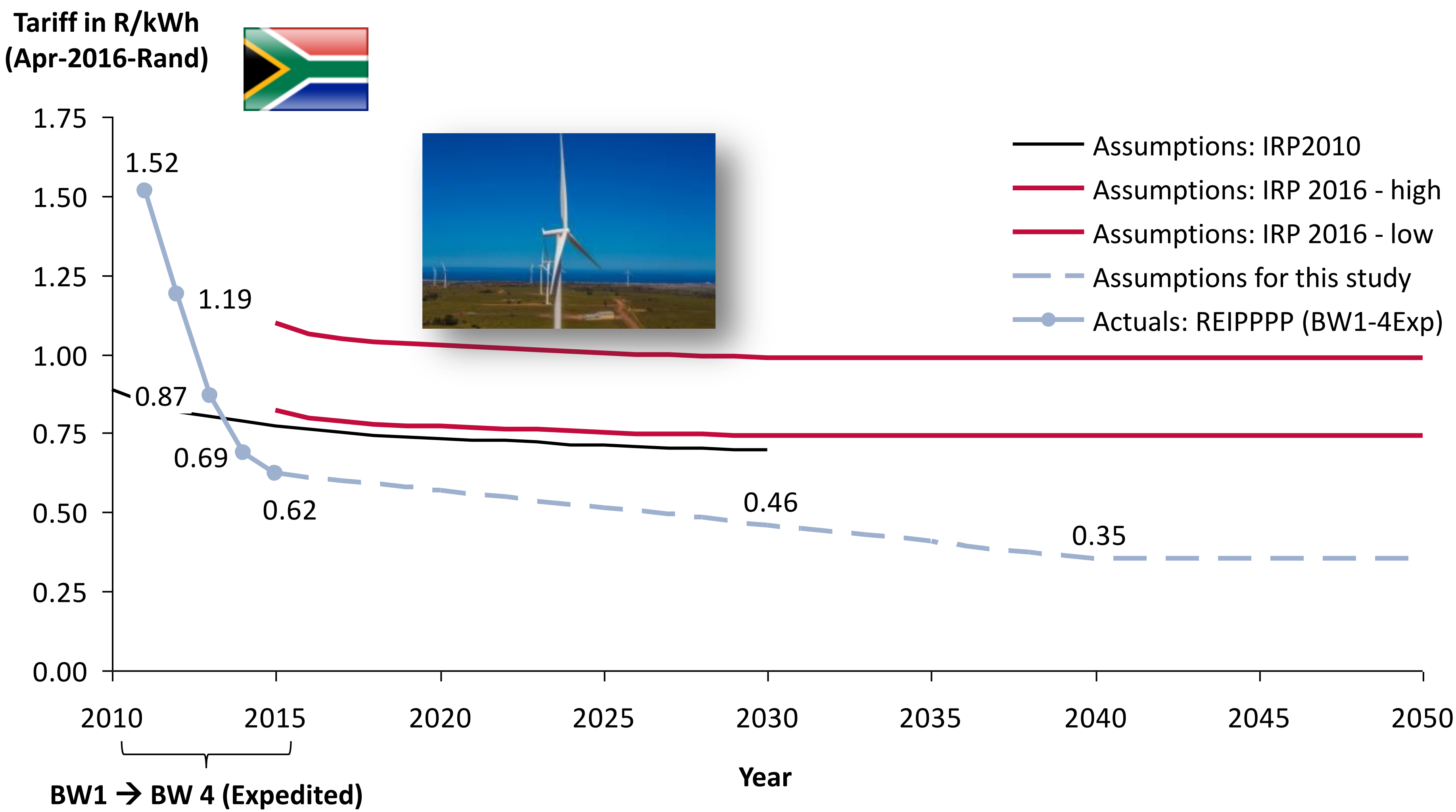
Sources: DoE (IRP 2010-2030 Update); StatsSA; CSIR analysis

Solar PV: Future cost assumptions for solar PV aligned with latest projections from BNEF (≈70% reduction by 2040)



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; South African Department of Energy (DoE); DoE IPP Office; Draft IRP 2016; BNEF; IRENA; CSIR analysis

Wind: Future cost assumptions for solar PV aligned with latest projections from BNEF (≈40% reduction by 2040)



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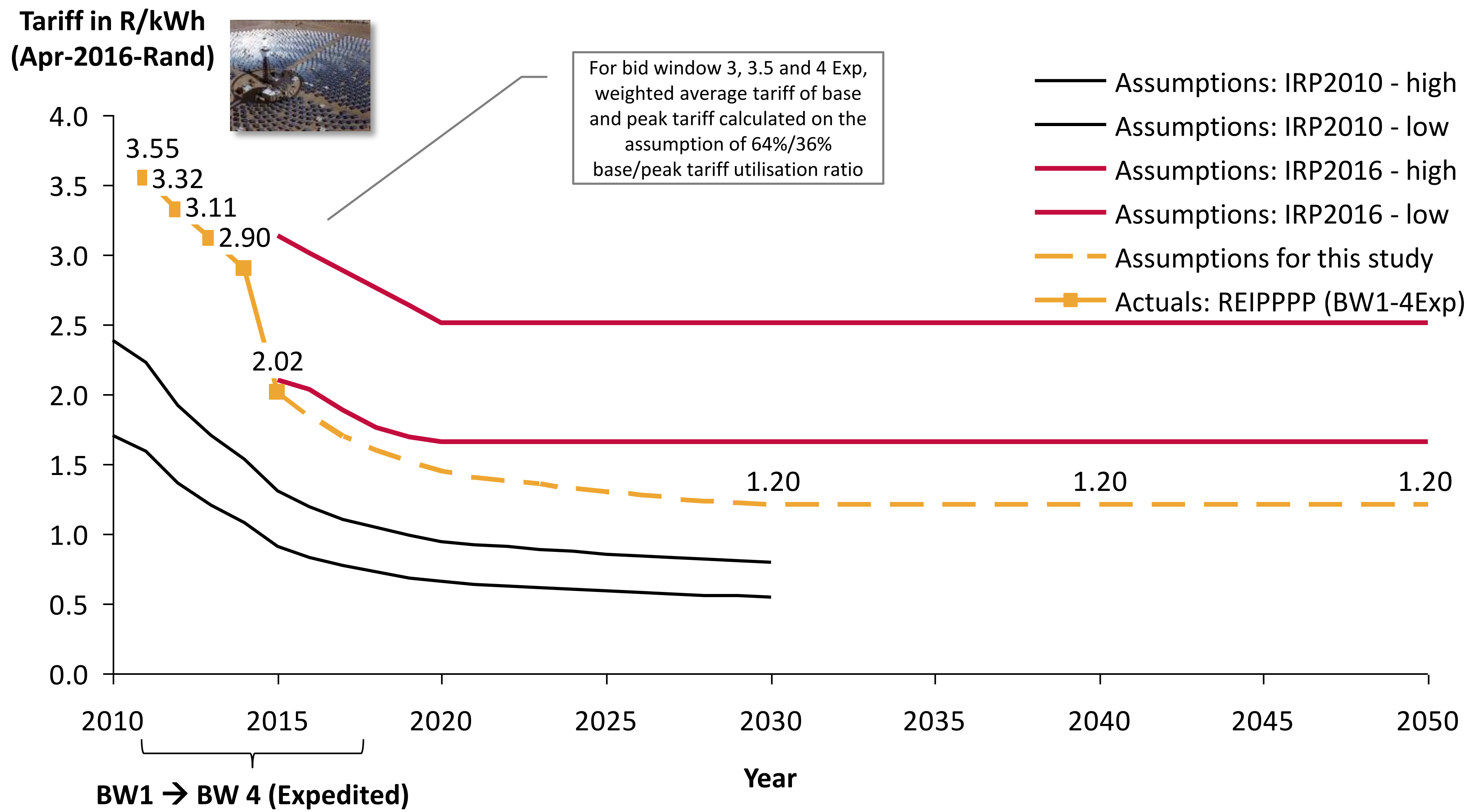
Previous CSIR cost input assumptions for CSP (same cost decline as per IRP 2010)



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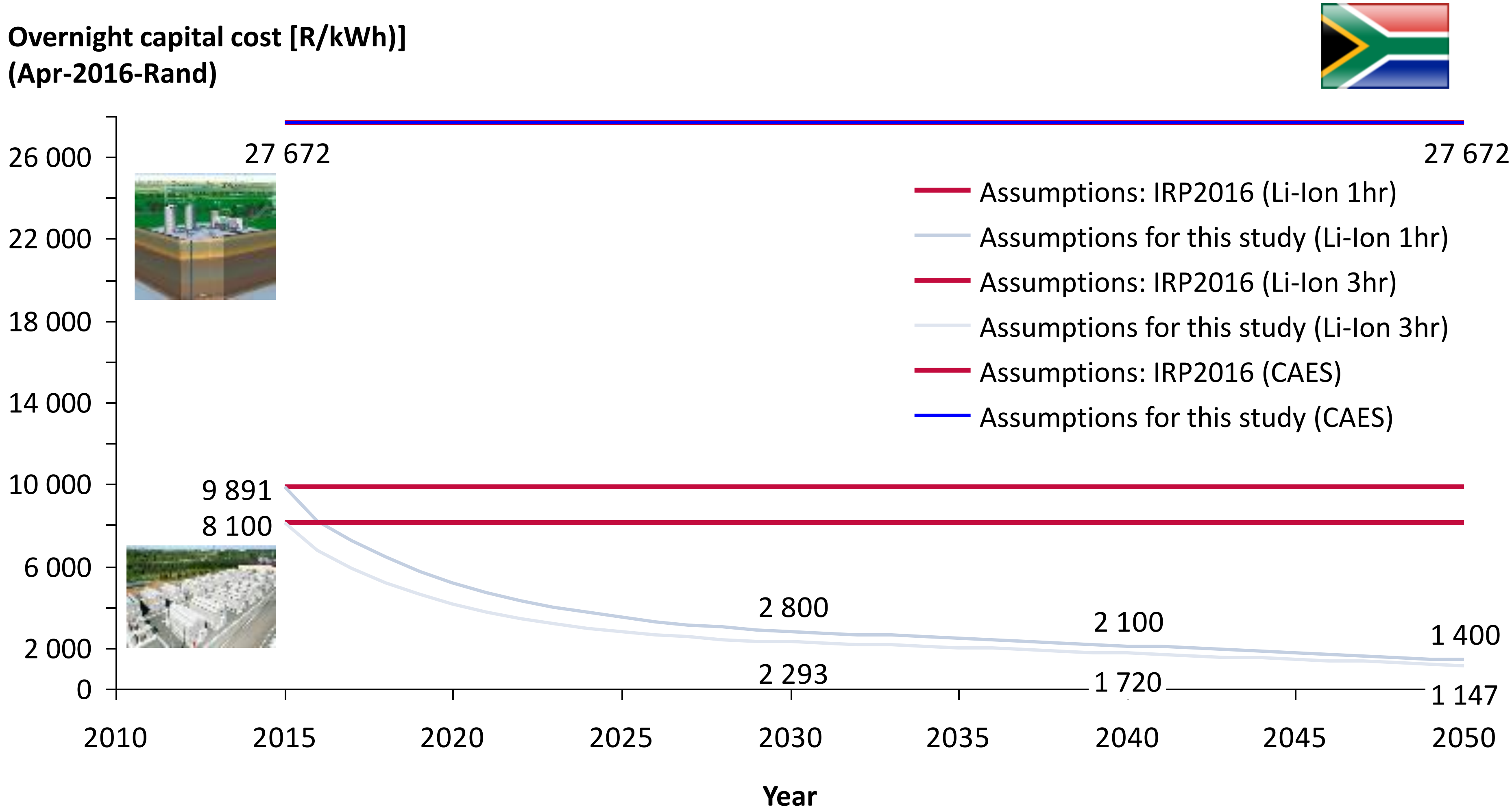
Stationary storage (Li-Ion): Assumed 200 $/kWh (2030), 150 $/kWh (2040), 100 $/kWh (2050) – from BNEF, IRENA



Sources: StatsSA for CPI; Draft IRP 2016; BNEF, IRENA; CSIR

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;

Electric vehicle demand shaping can provide ~96 GW/4.2 GW (demand increase/decrease) with ~100 GWh/d daily dispatchable energy 2050

Property	Unit	2016-2019	2020	2030	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]	-	100	4 600	44 300	95 800
EVs (demand decrease)	[MW]	-	100	400	2 000	4 200

Sources: CSIR estimates; StatsSA; eNaTis

Outline

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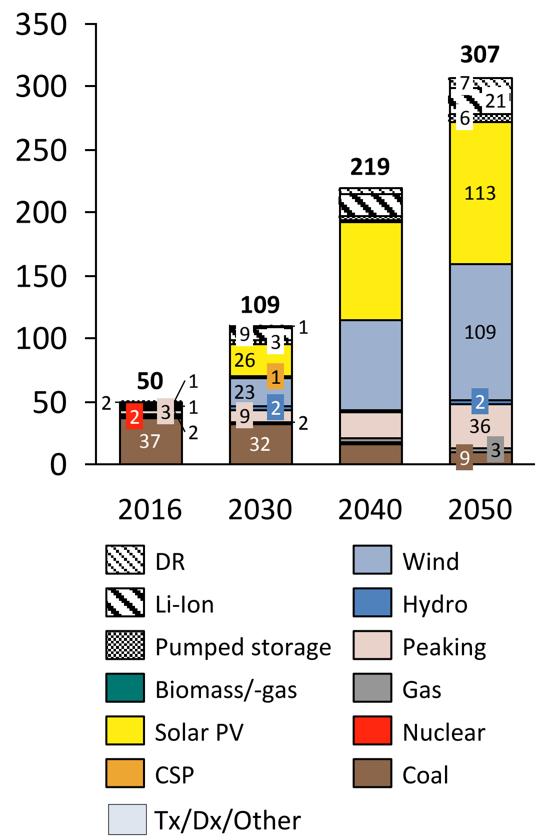
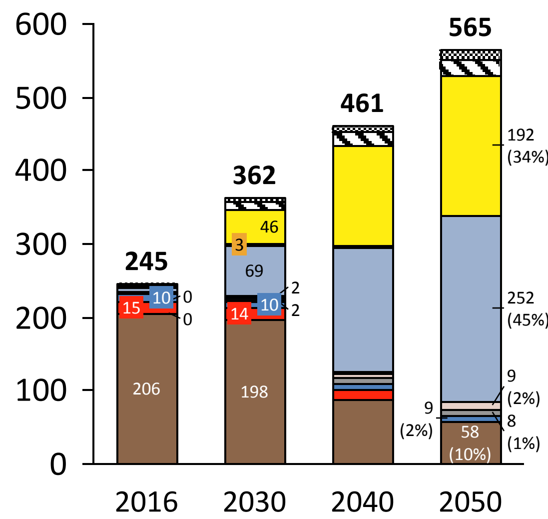
LC (high-demand) with updated technology cost assumptions – flexible capacity with more solar PV/wind and…. storage is deployed

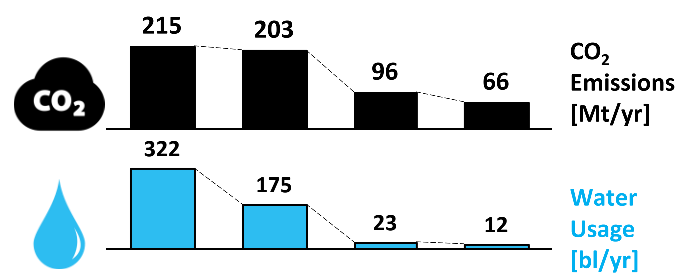
Scenario: Least-cost - new outcomes (High Demand)

Installed Capacity

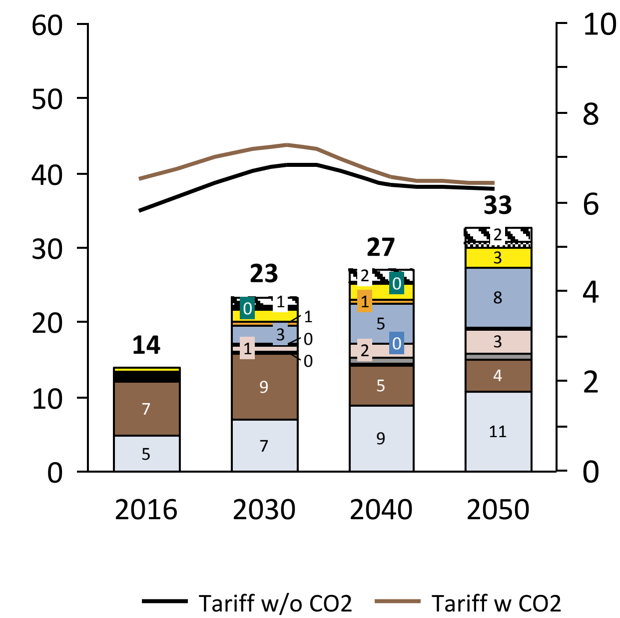


Energy Produced





System cost and average tariff



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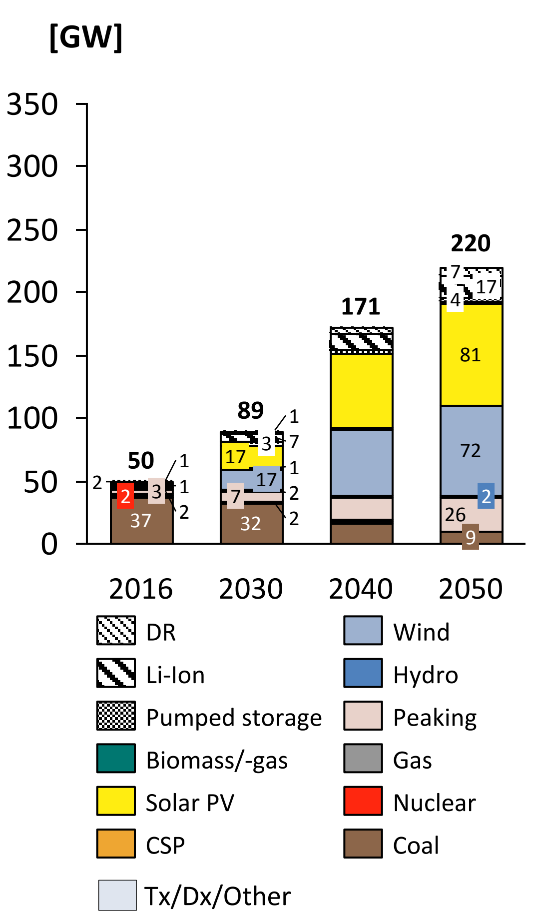
¹ Includes an assumed 2 USDc/kWh (0.30 R/kWh) for transmission, distribution and customer services

LC (low-demand) with updated technology cost assumptions – similar to high demand… just at a smaller scale

Scenario: Least-cost - new outcomes (Low Demand)

Installed Capacity



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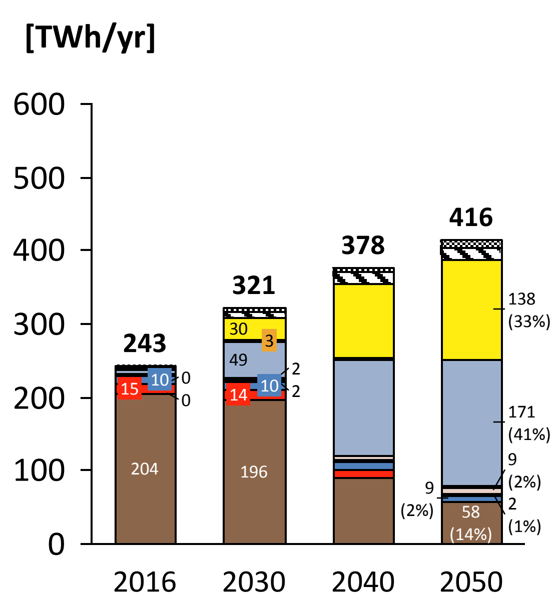

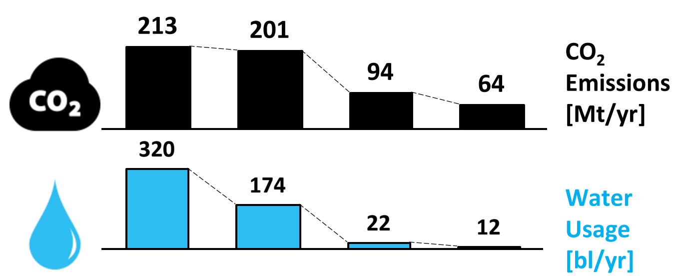

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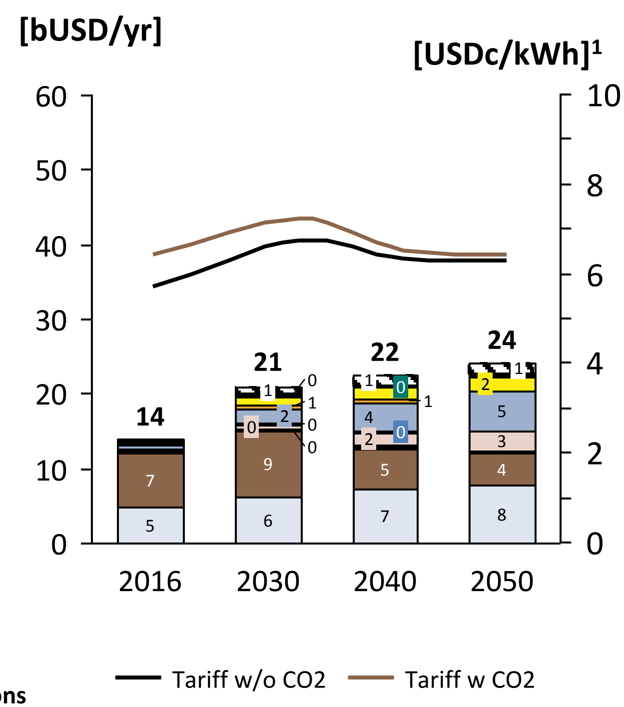

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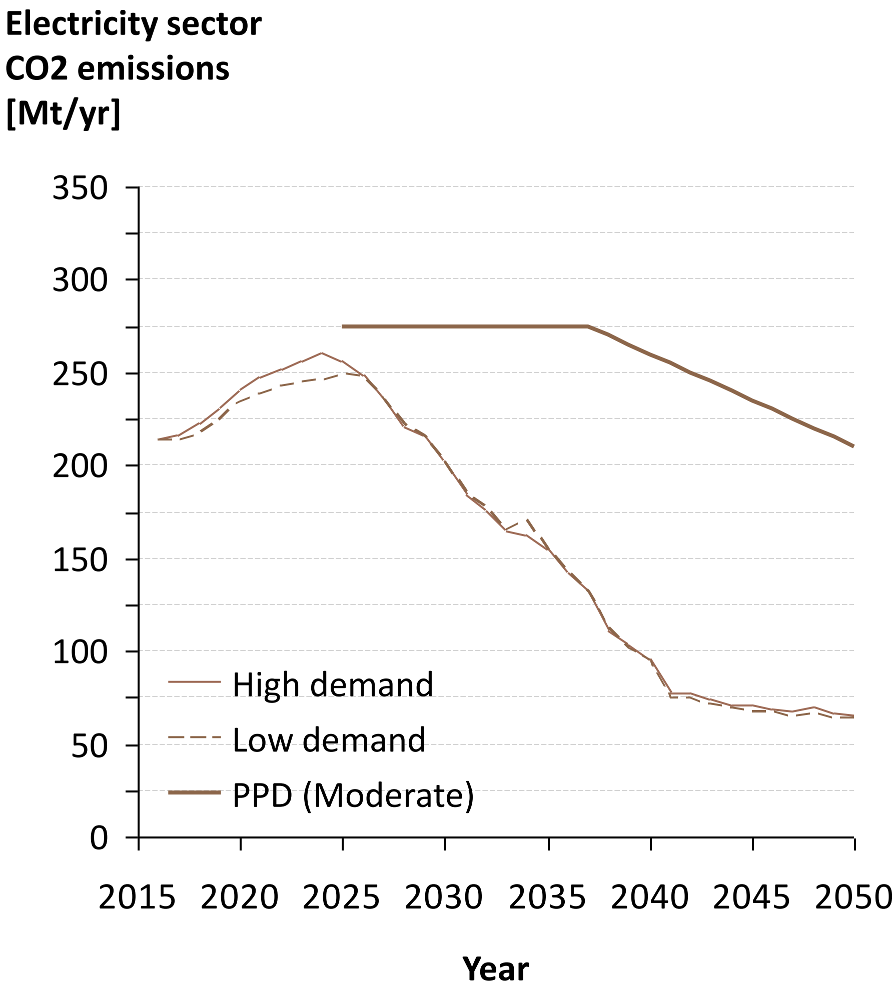
[1] Includes an assumed 2 USDc/kWh (0.30 R/kWh) for transmission, distribution and customer services

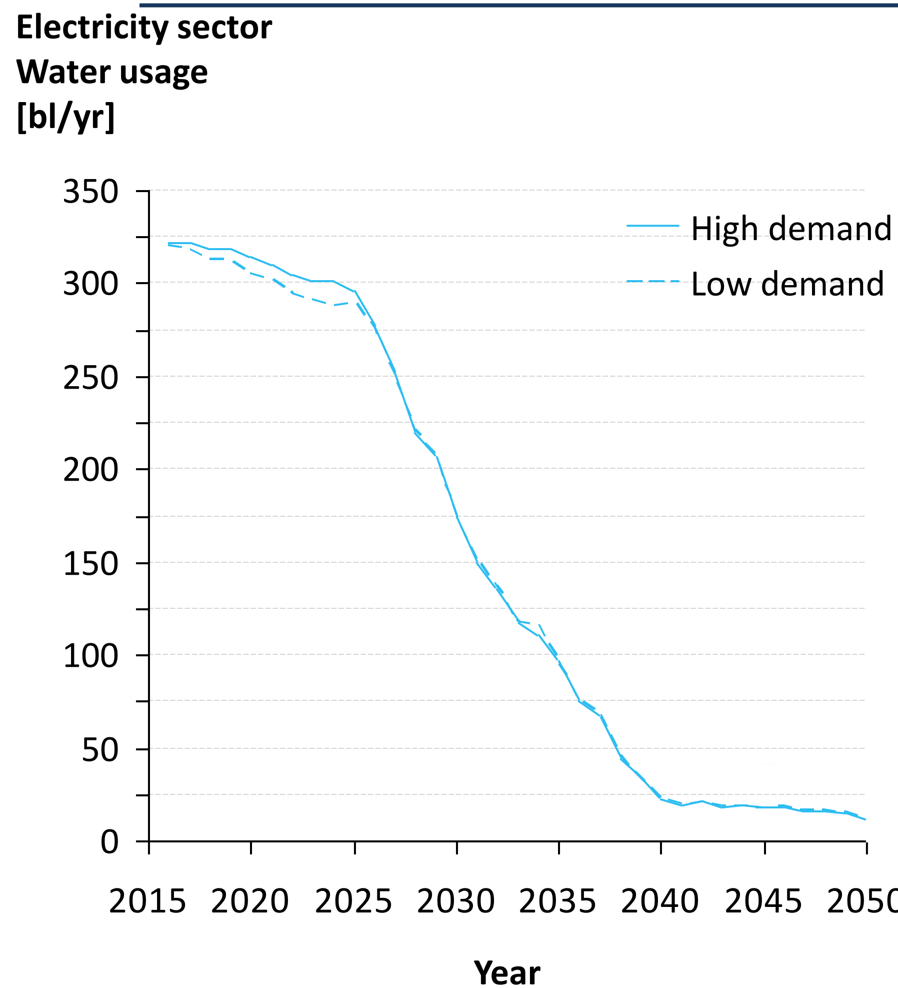
CO2 emissions trajectory is never binding and water use declines as coal fleet decommissions for high and low demand

Scenario: Least-cost (new outcomes)

CO2 emissions



Water usage



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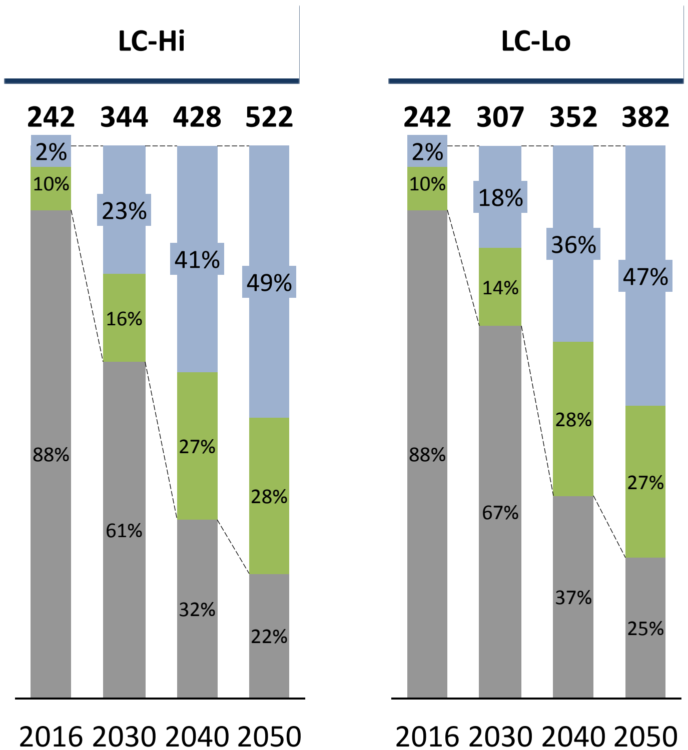
LC optimal to aim for 15-20% wind (≈15-25~GW) by 2030, 35-40% (≈40-60 GW) by 2040 and 45-50% (≈60-85 GW) by 2050

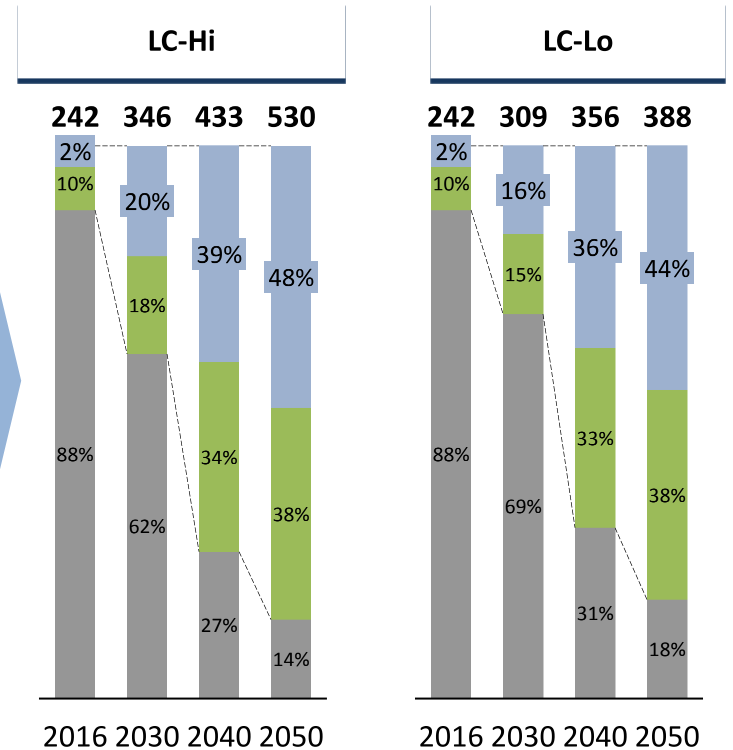
Previous outcomes
(share of energy mix)



Lower technology costs:

- Solar PV
- Wind
- Li-Ion storage

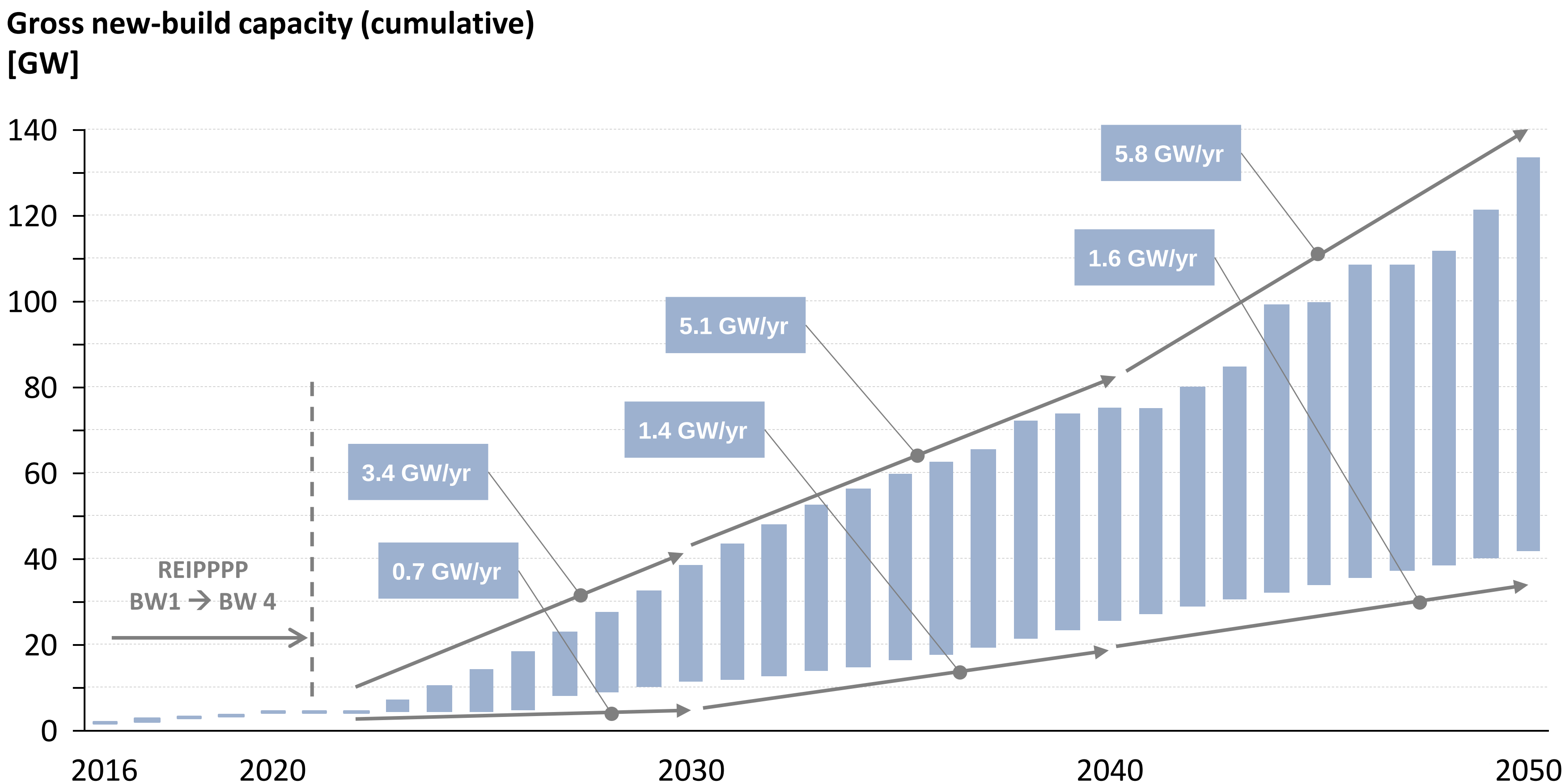
New outcomes
(share of energy mix)



Wind | Other RE[1] | Other

Note: For reference, total energy supplied is shown for each year;
[1] Other RE includes domestic and imported renewable energy.

Combining all of these outcomes (previous and new) – a growing wind market is expected… albeit at varying scales of deployment



In least-cost planning outcomes:

1.4-2.1 GW/a (2020-2030) **2.7-5.1 GW/a** (2030-2040) **3.3-5.8 GW/a** (2040-2050)

Outline

our future through science

Conclusions

Deployment of wind in South Africa is primarily as a result of:

- Favourable technology costs;
- A world-class wind resource; and
- Large geographical land area.

Any new-build capacity in South Africa should include wind as part of the energy mix combined with solar PV and flexible supply/demand options

Conservatively (previous outcomes), LC[1] planning outcomes result in wind installed capacity of:

- ≈15-25~GW (2030);
- ≈40-60 GW (2040); and
- ≈60-85 GW (2050).

With plausible reductions in costs of wind, installed wind capacity (new outcomes):

- Similar by 2030, ≈15-25 GW;
- Much higher to 2040, ≈55-70 GW; and
- ≈70-110 GW by 2050.

Consistent and growing build-out of wind capacity with LC[1] deployment of:

- 1.4-2.1 GW/a (2020-2030);
- 2.7-5.1 GW/a (2030-2040); and
- 3.3-5.8 GW/a (2040-2050).

[1] least-cost; [2] business-as-usual