Least-cost electricity mix for South Africa by 2040

Scenarios for South Africa’s future electricity mix

CSIR Energy Centre

Cape Town, 3 November 2016

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Background

The Integrated Resource Plan (IRP) is the expansion plan for the South African power system

In its most recent version, the IRP 2010 plans a doubling of power-generation capacity from 2010 to 2030

Since the date of its release in early 2011, two main assumptions have changed

- The demand forecast is now significantly lower than in IRP 2010
- The costs of solar PV and wind are significantly lower than predicted in IRP 2010

The CSIR has therefore conducted a study to re-optimise the South African power mix until 2040

Two scenarios were defined to quantify two different ways of expanding the South African power system

- "Business-as-Usual" – generally aligned with IRP 2010, updated demand forecast, no new optimisation
- "Re-Optimised" – least-cost re-optimisation of the demand/supply gap that widens from 2020-2040

An hourly expansion and dispatch model (incl. unit commitment) using PLEXOS was run for both scenarios to test for adequacy and for economic feasibility

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Sources: CSIR analysis

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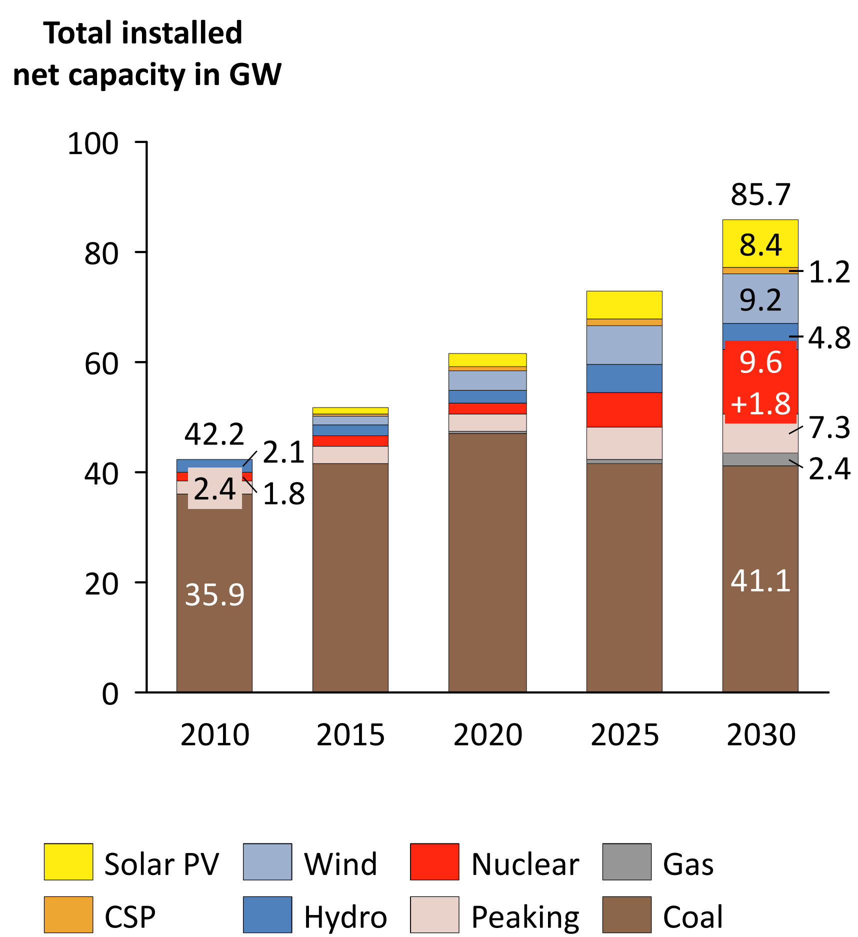
IRP 2010: expansion plan for South Africa's power system until 2030

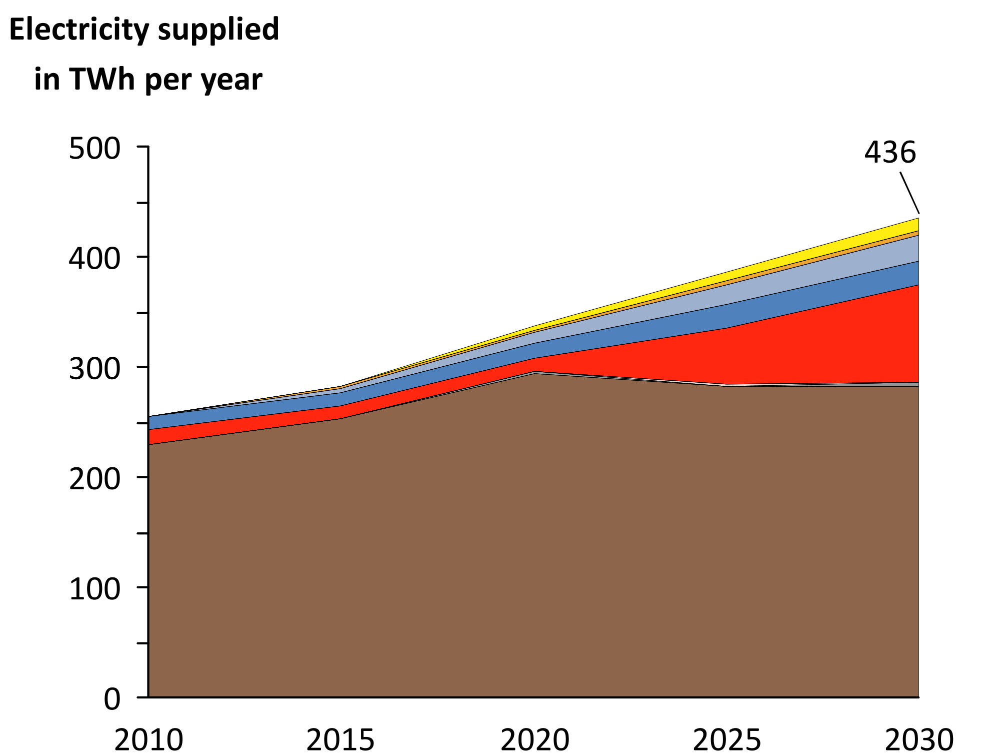
Installed capacity and electricity supplied from 2010 to 2030 as planned in the IRP 2010

Promulgated IRP 2010

Business-as-Usual



Re-Optimised



	2010	2030
Renewables	**5%** (12 TWh/yr)	**14%** (62 TWh/yr)
Carbon free	**10%** (25 TWh/yr)	**34%** (149 TWh/yr)
CO2 emissions [Mt/yr]	**237**	**275**

Note: Renewables include solar PV, CSP, wind, biomass, biogas, landfill and hydro (includes imports); CO_2 emission intensity moves from 912 $kgCO_2/MWh$ (2010) to 600 $kgCO_2/MWh$ (2030)

Sources: DoE IRP 2010-2030; CSIR analysis

Link between planning and real world needs to be established

In-principle process of IRP planning and implementation

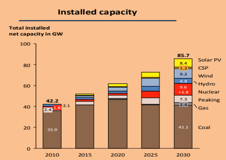
Currently, no feedback loop from procurement results to IRP planning assumptions <u>institutionalised</u>

Planning / simulation world

Inputs
- Demand forecast
- Technology costs **assumptions**
- CO2 limits
- Etc.

IRP model
(least-cost optimisation)

Output
- Capacity expansion plan



Actuals / real world

Inputs
- Ministerial Determinations based on capacity expansion plan

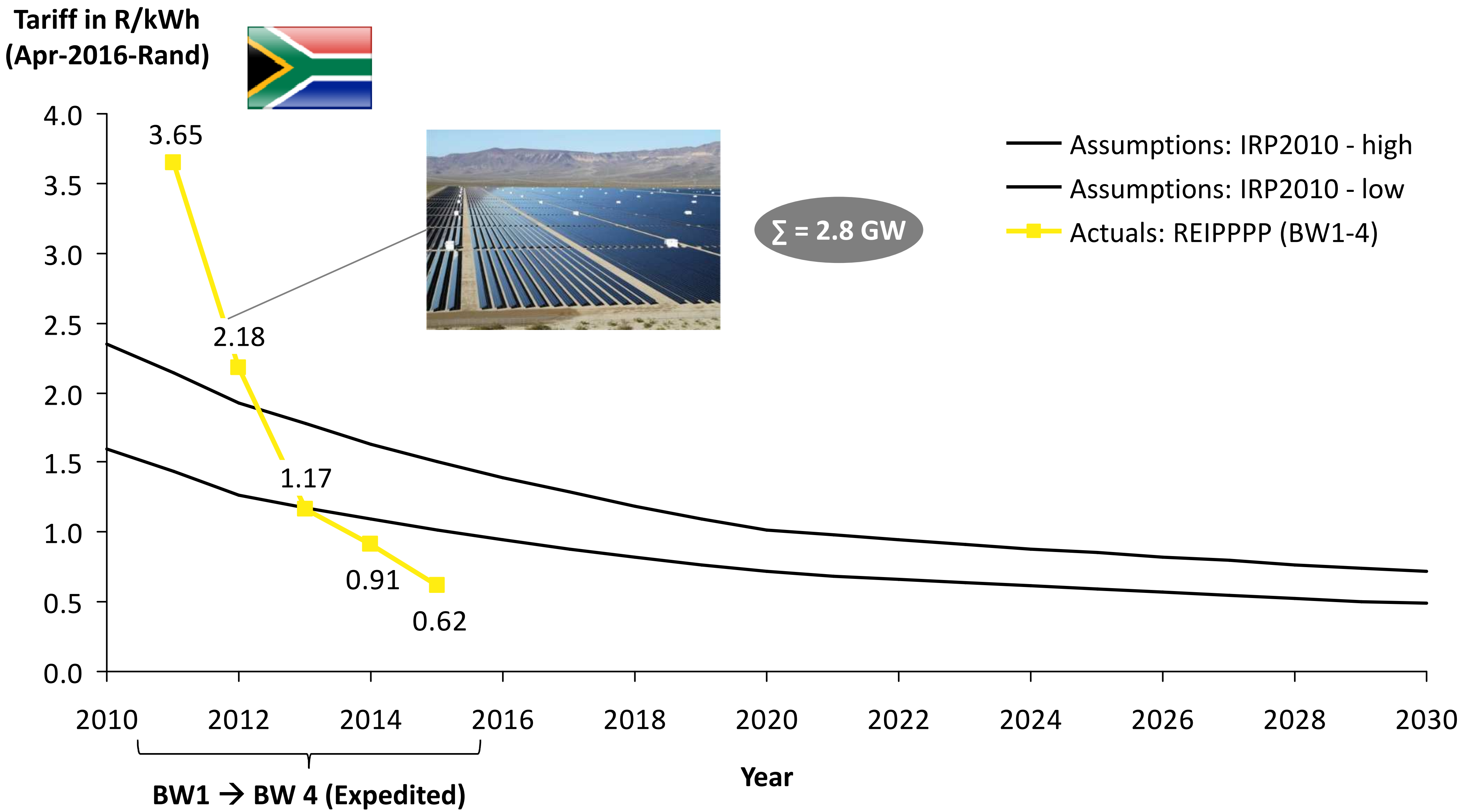
Procurement
(competitive tender e.g. REIPPPP, coal IPPPP)

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

Sources: CSIR analysis

Actual solar PV tariffs now well below cost assumptions of IRP 2010

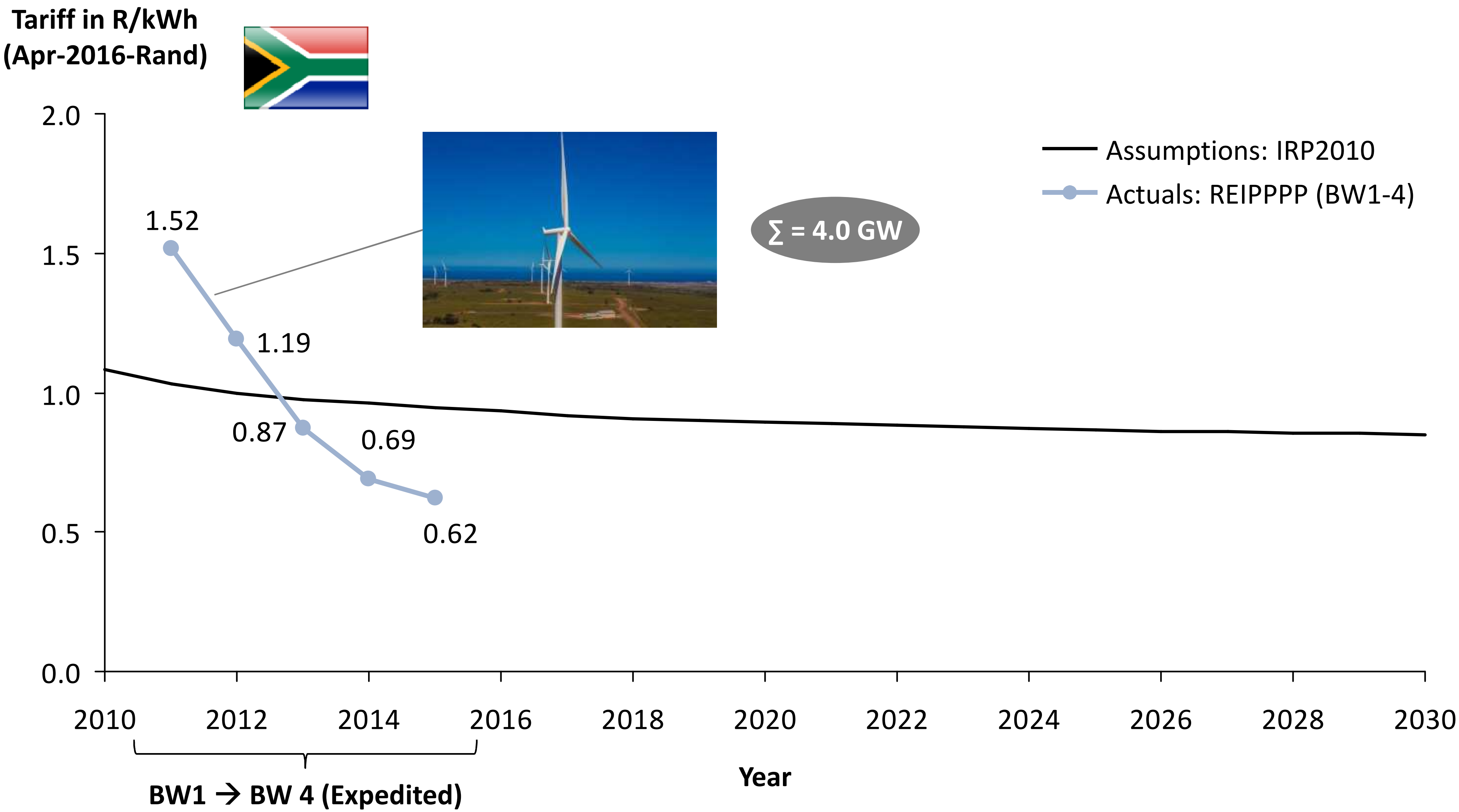
First four bid windows' results (solar PV) of Department of Energy's REIPPPP



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

Actual wind tariffs equally well below cost assumptions of IRP 2010

First four bid windows' results (wind) of Department of Energy's REIPPPP



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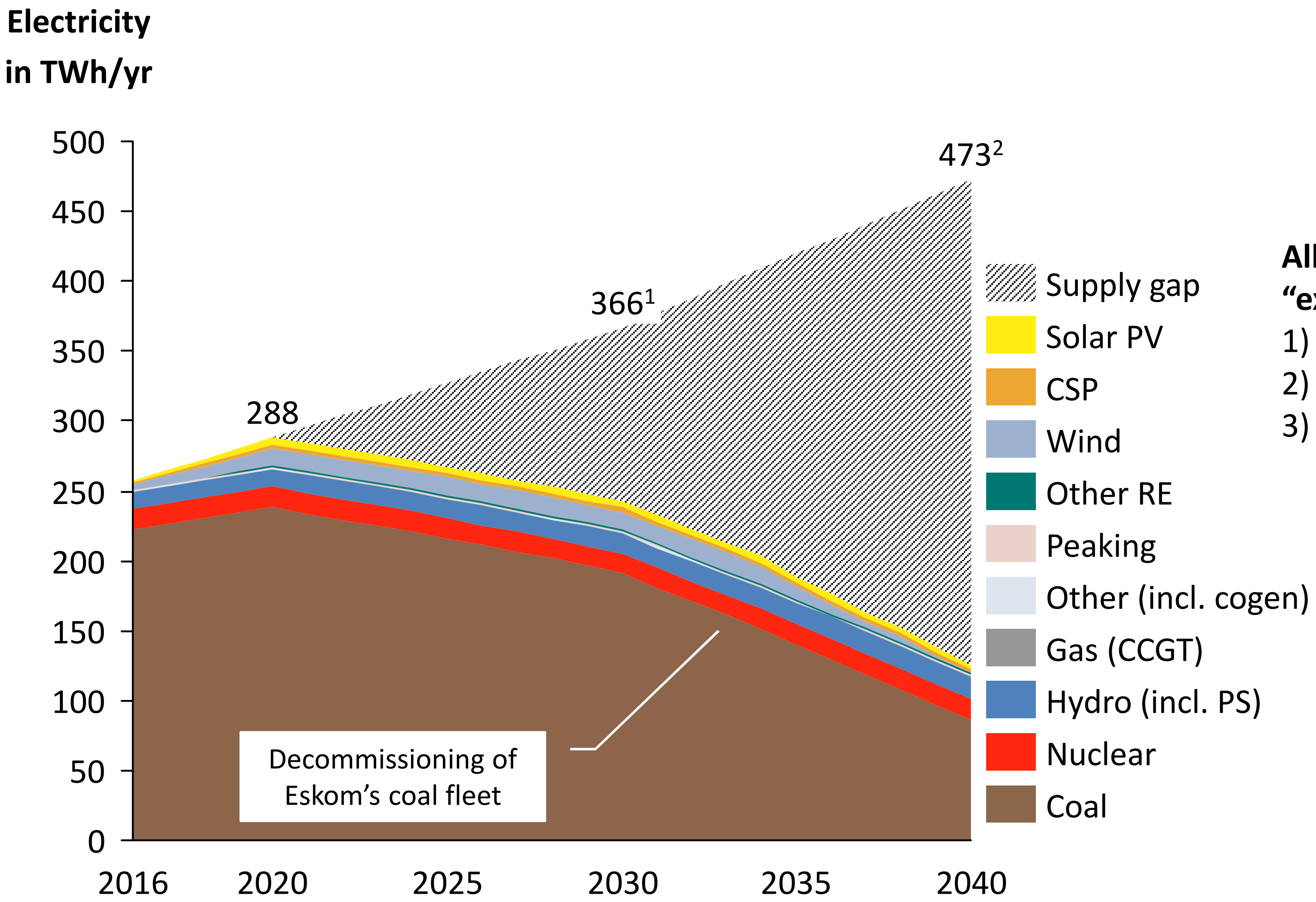
Demand grows, existing fleet phases out – gap needs to be filled

Forecasted supply and demand balance for the South African electricity system from 2016 to 2040



All power plants considered for "existing fleet" that are either:

1) Existing in 2016
2) Under construction
3) Procured (preferred bidder)

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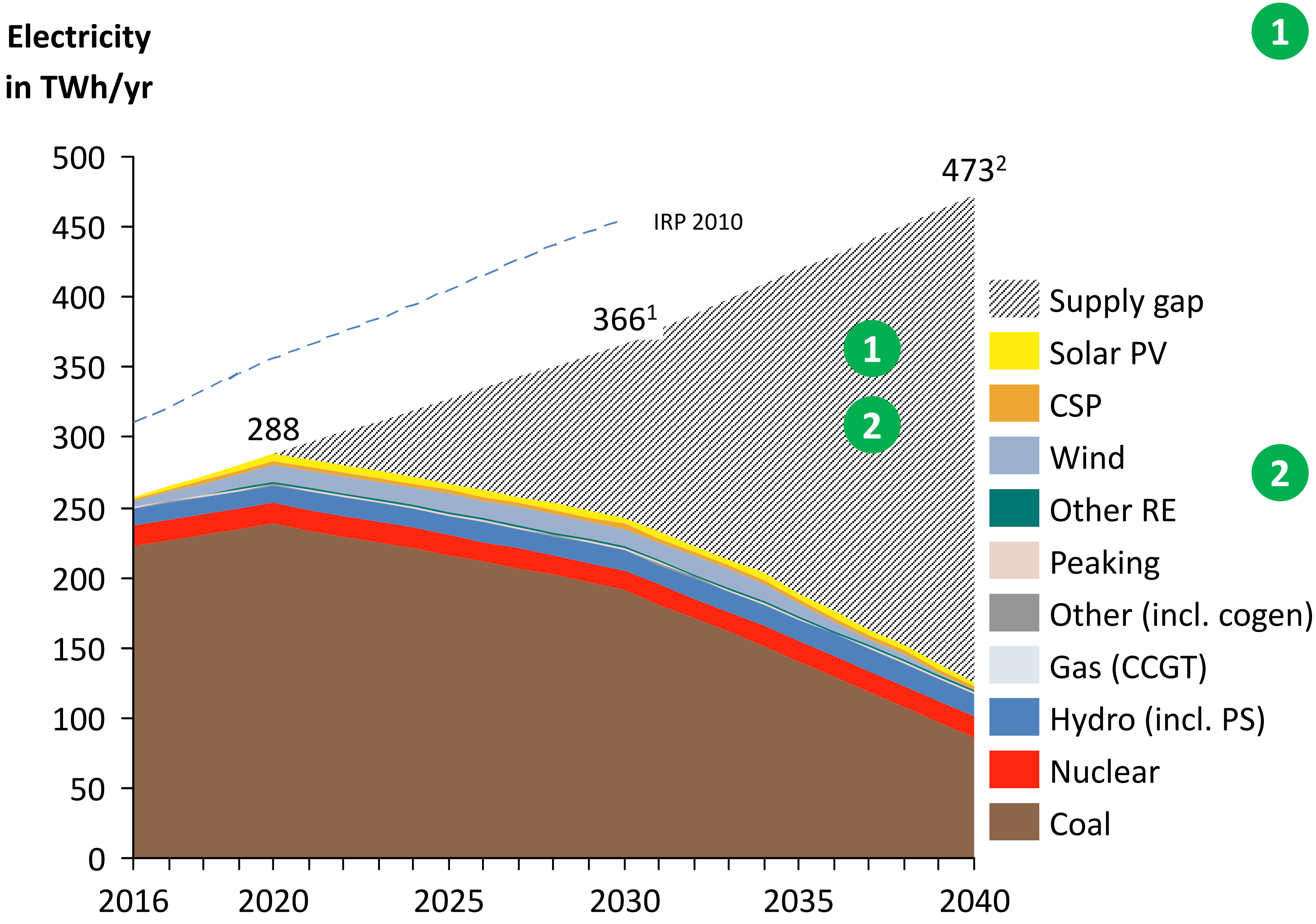
Notes: MTSAO demand forecasts are extrapolated from 2025 to 2040 using CAGR; IRP 2016 under development is using High Growth Low Intensity (CSIR) demand forecast as base case.
1. Peak demand = 53.2 GW 2. Peak demand = 68.7 GW Sources: DoE (IRP 2010); DoE (IRP 2013); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

Two scenarios defined to fill the supply/demand gap until 2040

Forecasted supply and demand balance for the South African electricity system from 2016 to 2040



1 Scenario: "Business-as-Usual"

- Generally aligned with IRP 2010, but demand shifted
- Nuclear as per briefing to Portfolio Committee on Energy (11 October 2016)
- New coal, nuclear, some RE
- New capacities fixed as per IRP 2010 (no optimisation)

2 Scenario: "Re-Optimised"

- Coal, nuclear, gas, RE are all available as supply options
- Supply candidates chosen by least cost optimisation to meet energy and capacity requirement

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Notes: MTSAO demand forecasts are extrapolated from 2025 to 2040 using CAGR; IRP 2016 under development is using High Growth Low Intensity (CSIR) demand forecast as base case.
1. Peak demand = 53.2 GW 2. Peak demand = 68.7 GW Sources: DoE (IRP 2010); DoE (IRP 2013); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

Key assumptions: pessimistic regarding solar PV and wind cost, optimistic regarding nuclear cost, no annual limits on solar PV & wind

Technology	Costing Logic	Compared to IRP 2010
Solar PV	Same as IRP 2010 by 2030	Slightly lower until 2030
Wind	Bid Window 4 Expedited tariff kept constant until 2040	Lower
CSP	Same as IRP 2013	Slightly higher
Coal	Coal IPP	Higher
Nuclear	as per IRP with Rosatom low-estimate CAPEX	Similar
Gas	as per IRP with fuel updates	Higher

All other assumptions and methodology fully aligned with IRP 2010, for example:

- Discount rate of 8% (real)
- PLEXOS software package used for long-term optimisation & production cost modelling
- Decommissioning schedule of existing Eskom fleet
- Demand forecast using MTSAO 2016-2021 (extrapolated until 2040), reaches the IRP 2010 assumed 2030 level just before 2040

Important deviation from IRP 2010 though: no annual new-build limits for solar PV and wind (IRP 2010: max. 1 600 MW/yr for wind and max. 1 000 MW/yr for solar PV)

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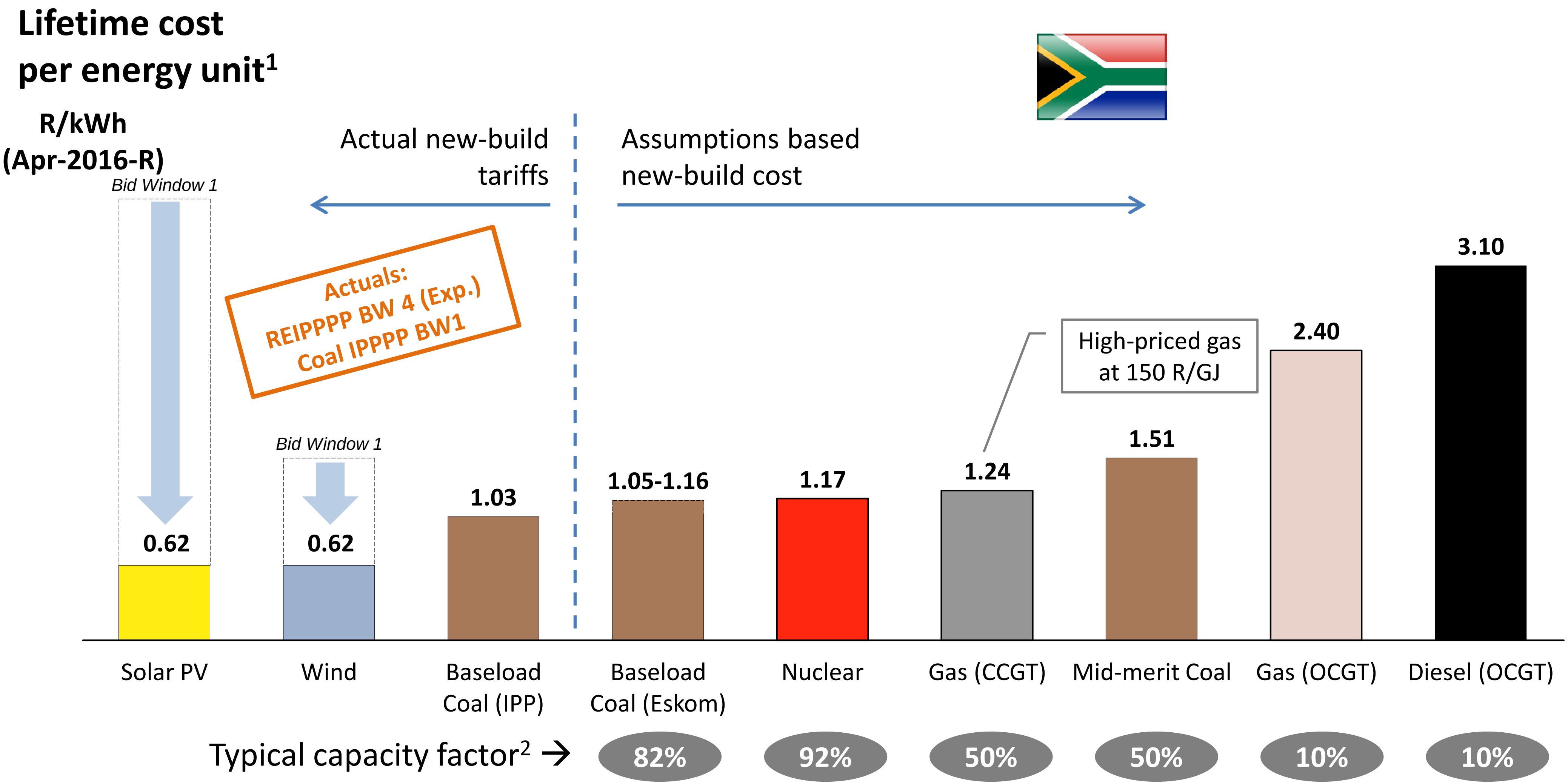
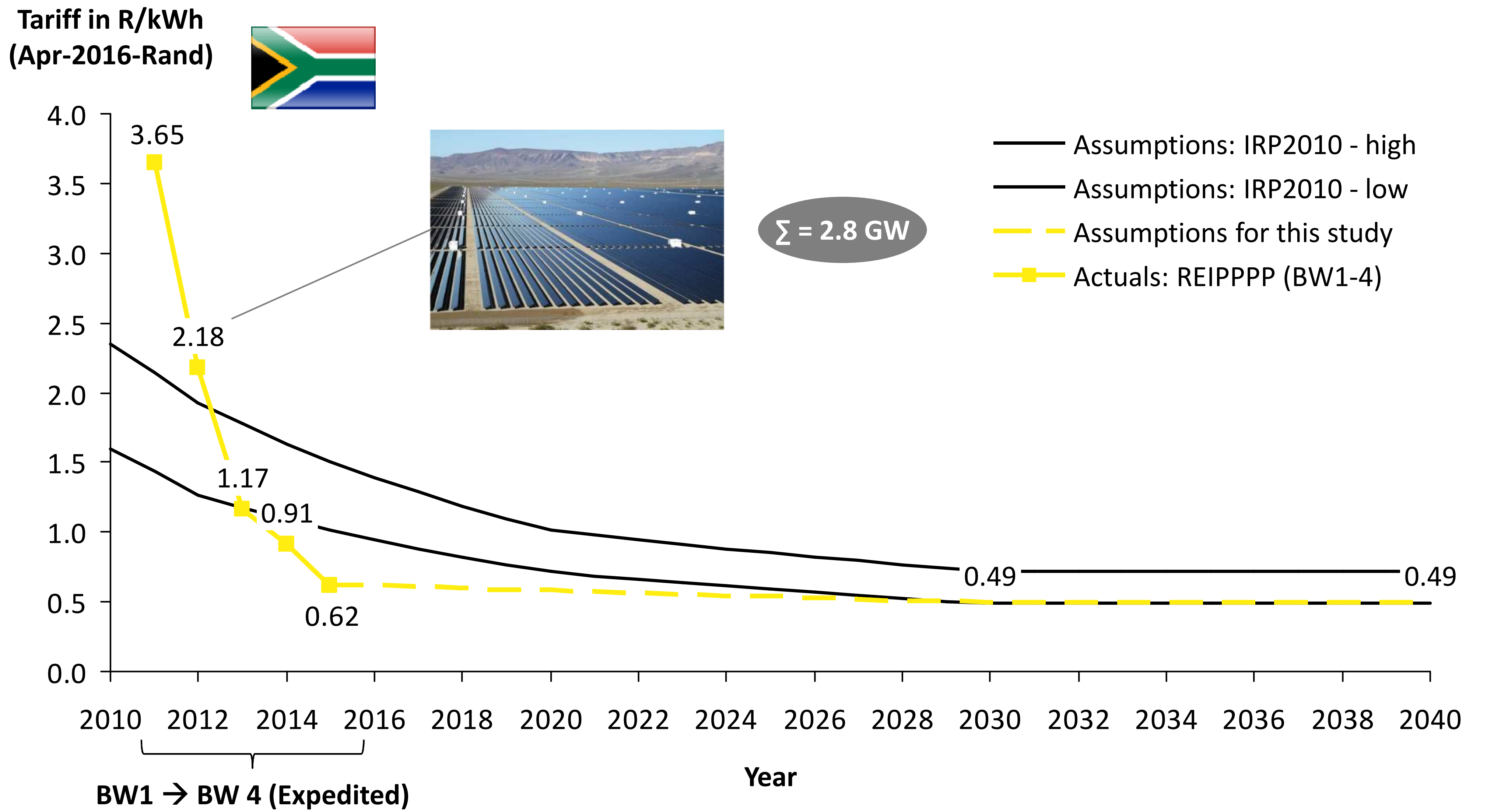
Sources: CSIR analysis

Key input cost assumptions for new supply technologies



[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 conventional 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

Future cost assumptions for solar PV aligned with IRP 2010



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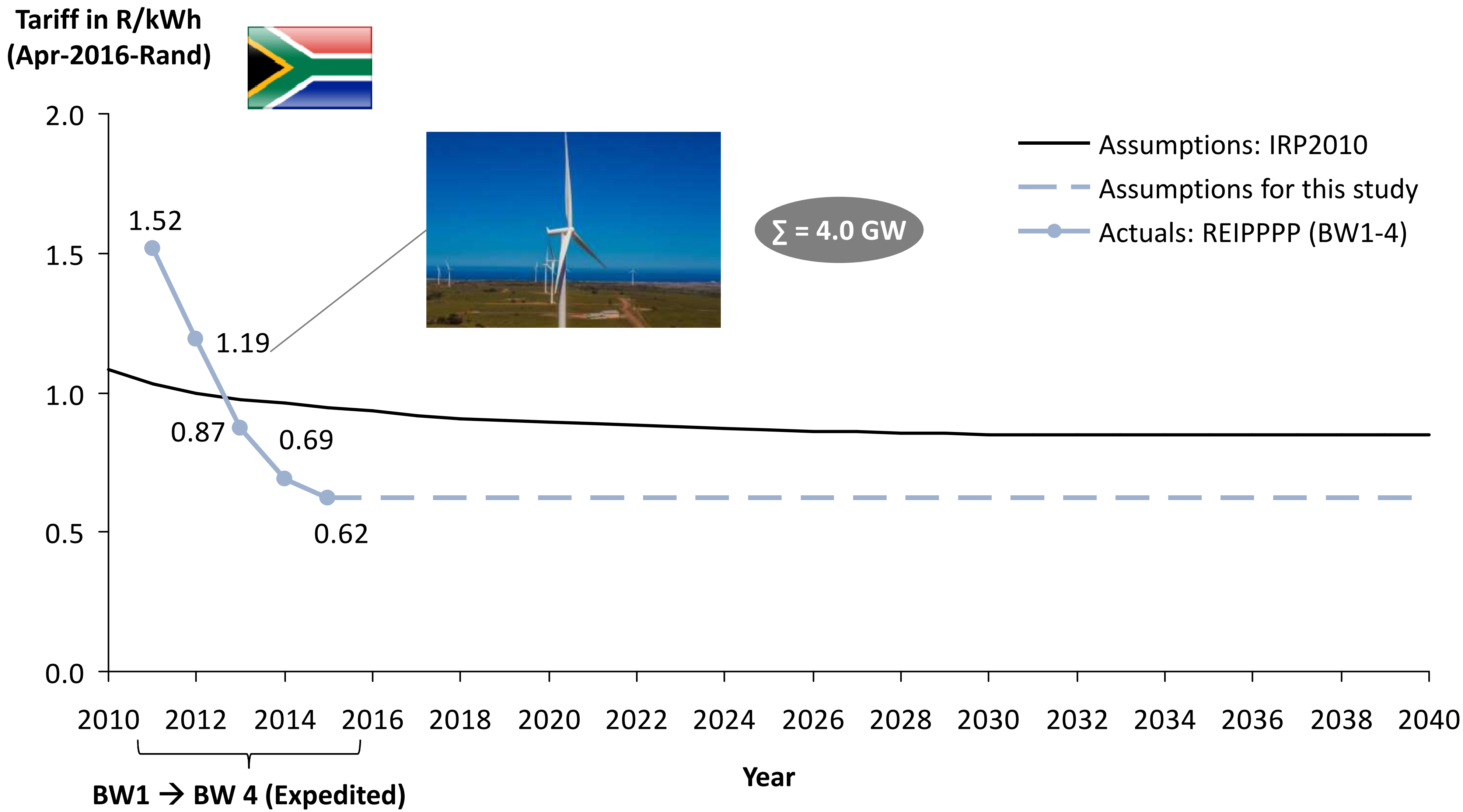
Future cost assumptions for wind aligned with results of Bid Window 4



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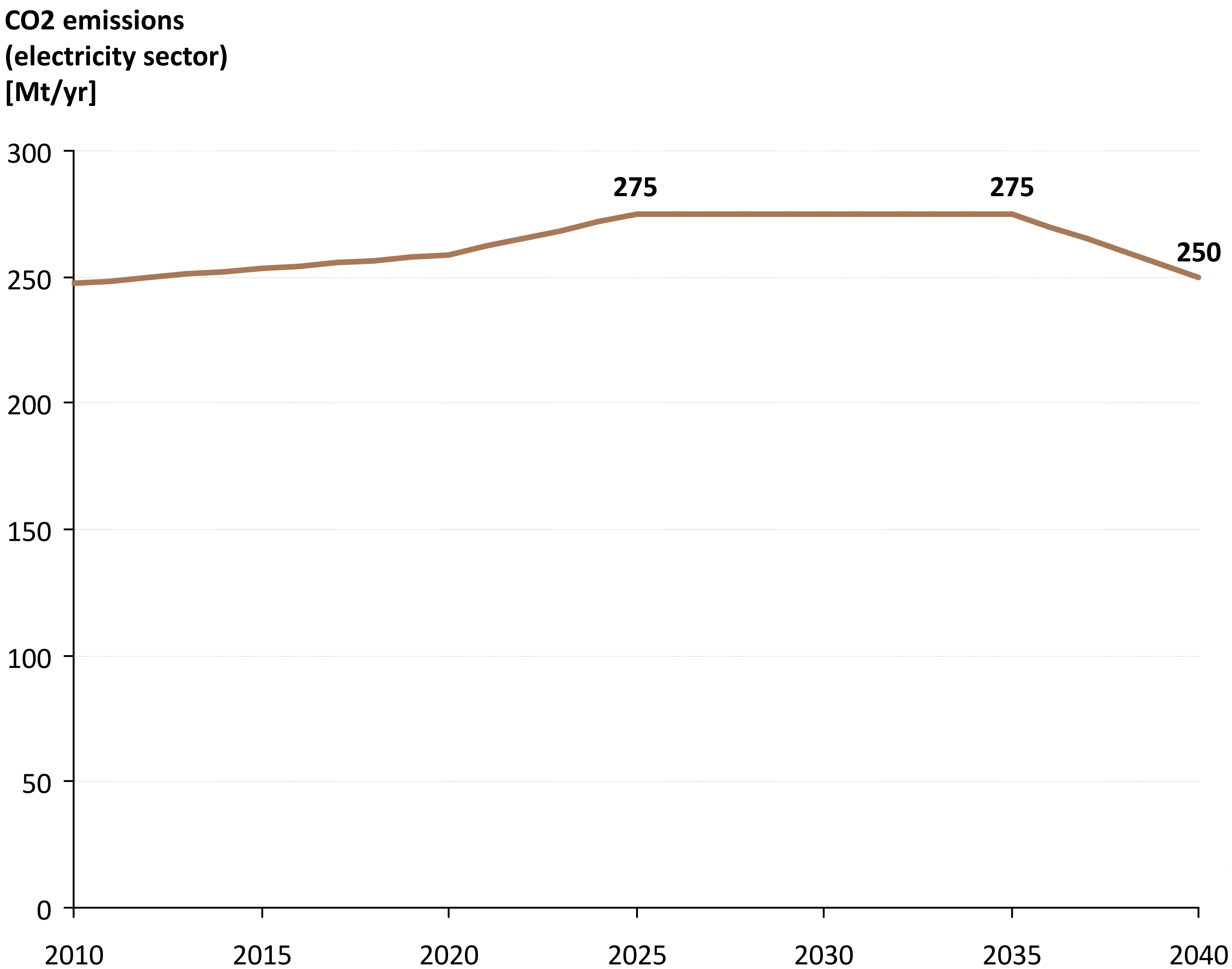
CO2 emissions constrained by RSA's Peak-Plateau-Decline objective

PPD that constrains CO2 emission from electricity sector



PPD = Peak Plateau Decline

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

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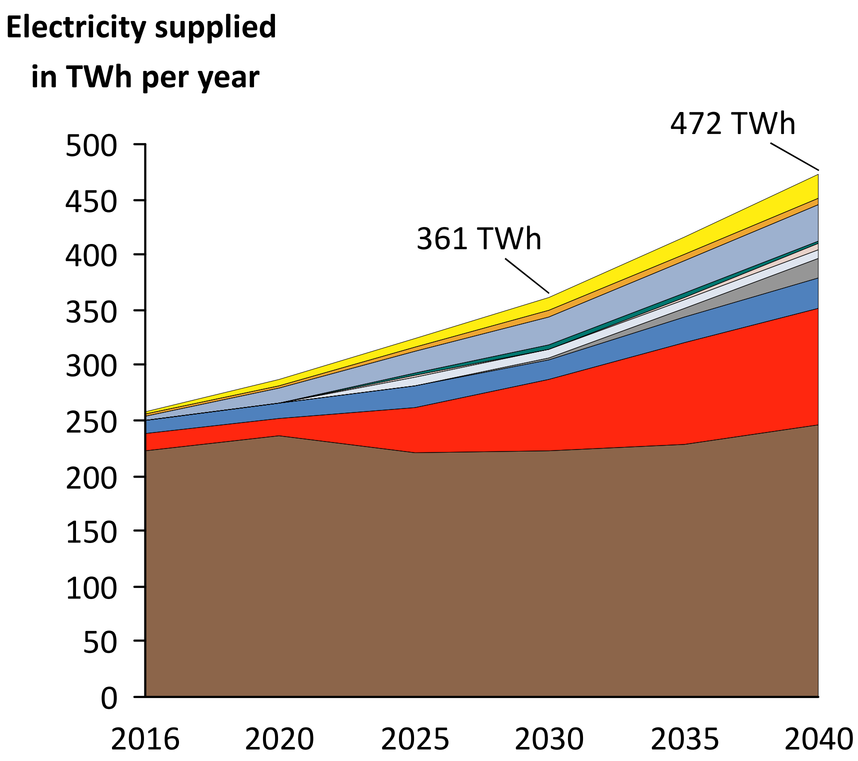
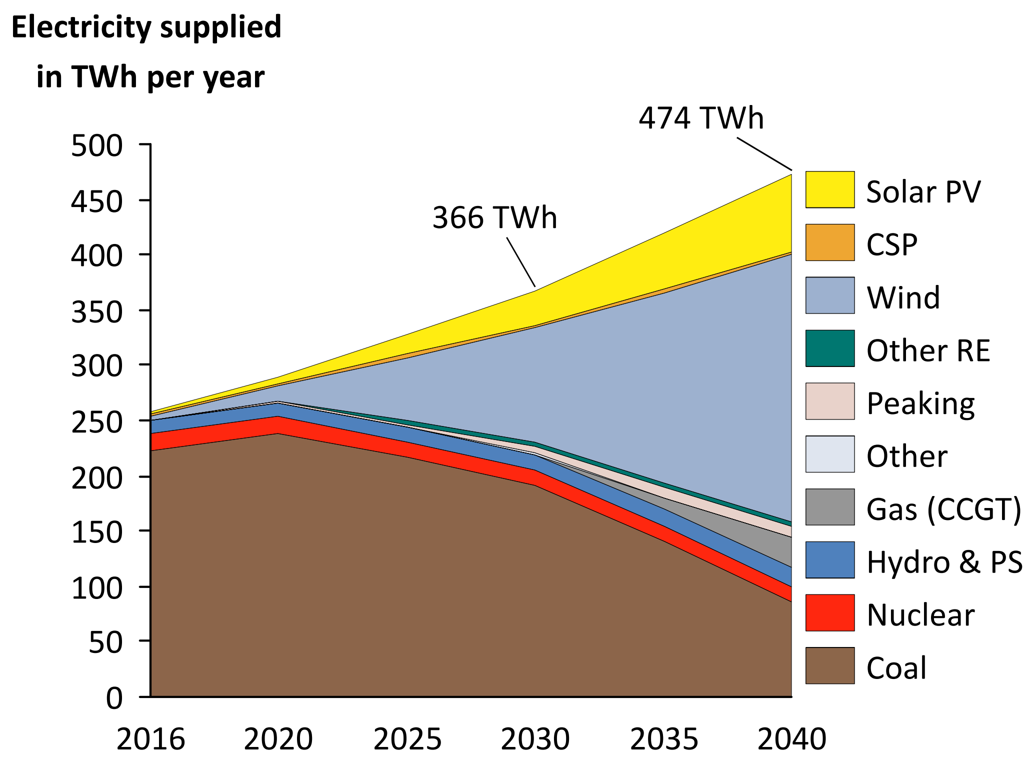
Least-cost: 70% RE energy in South African electricity sector by 2040

Comparison of energy supply for Business-as-Usual and a Re-Optimised scenario

1 Business-as-Usual



2 Re-Optimised



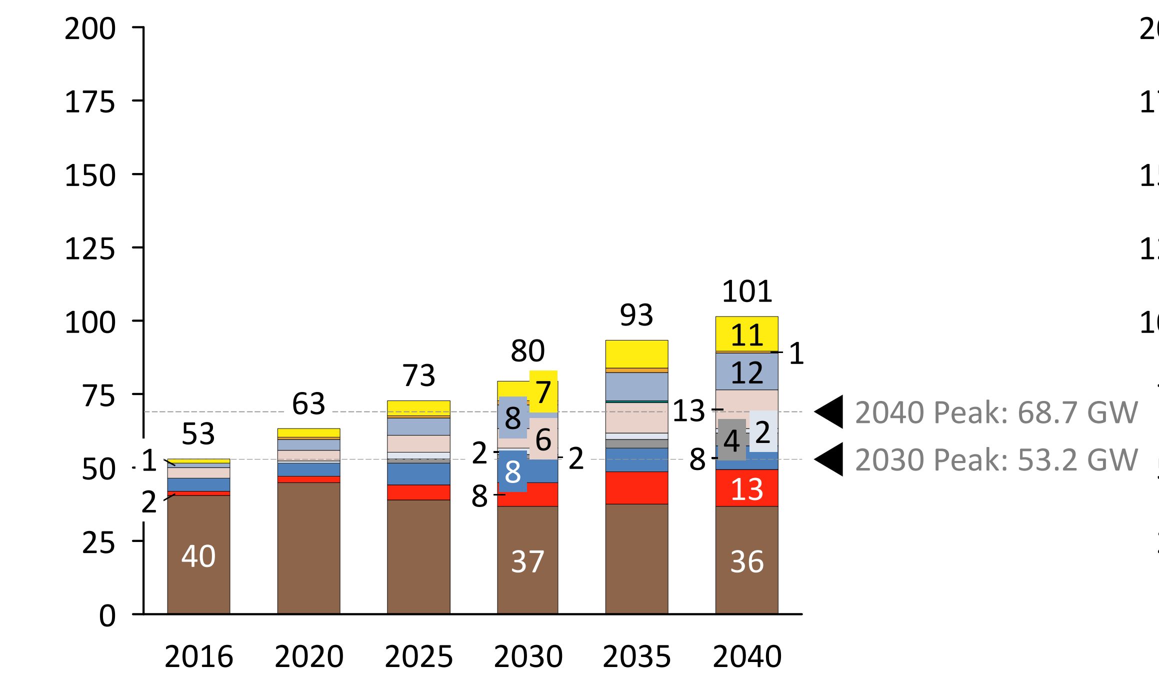
	Business-as-Usual				Re-Optimised		
	7% (18 TWh/yr)	**18%** (64 TWh/yr)	**19%** (91 TWh/yr)	**Renewables**	**7%** (18 TWh/yr)	**40%** (146 TWh/yr)	**71%** (332 TWh/yr)
	217 Mt/yr →		**250 Mt/yr**	**CO2**	**217 Mt/yr** →		**100 Mt/yr**

Sources: CSIR analysis

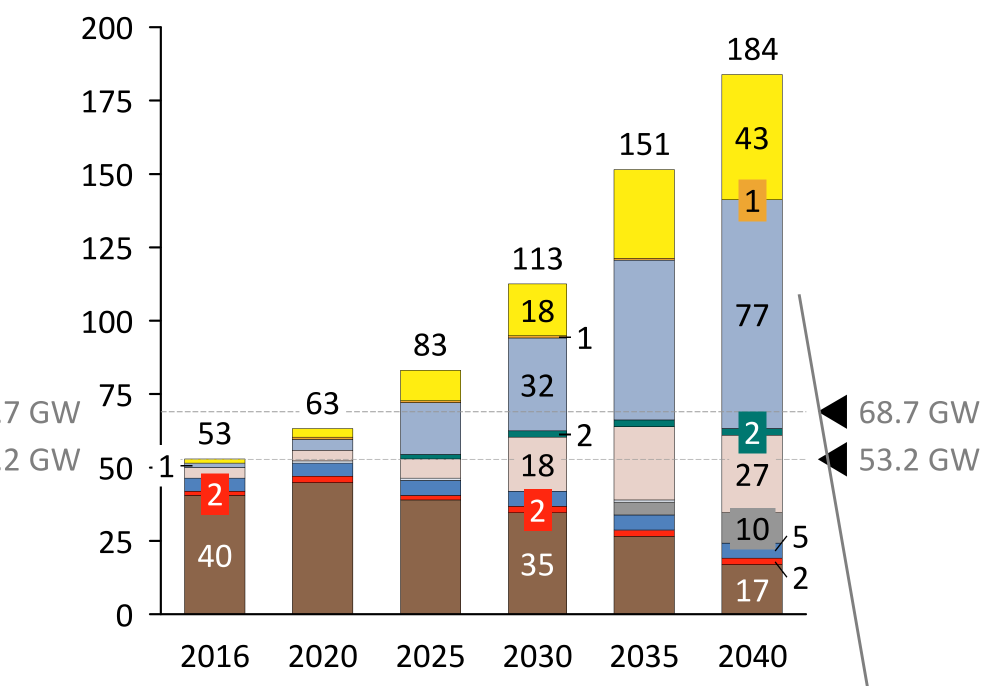
Significant solar PV and wind capacities rolled out until 2040

Comparison of generation capacity for Business-as-Usual and a Re-Optimised path to 2040

1 Business-as-Usual



2 Re-Optimised



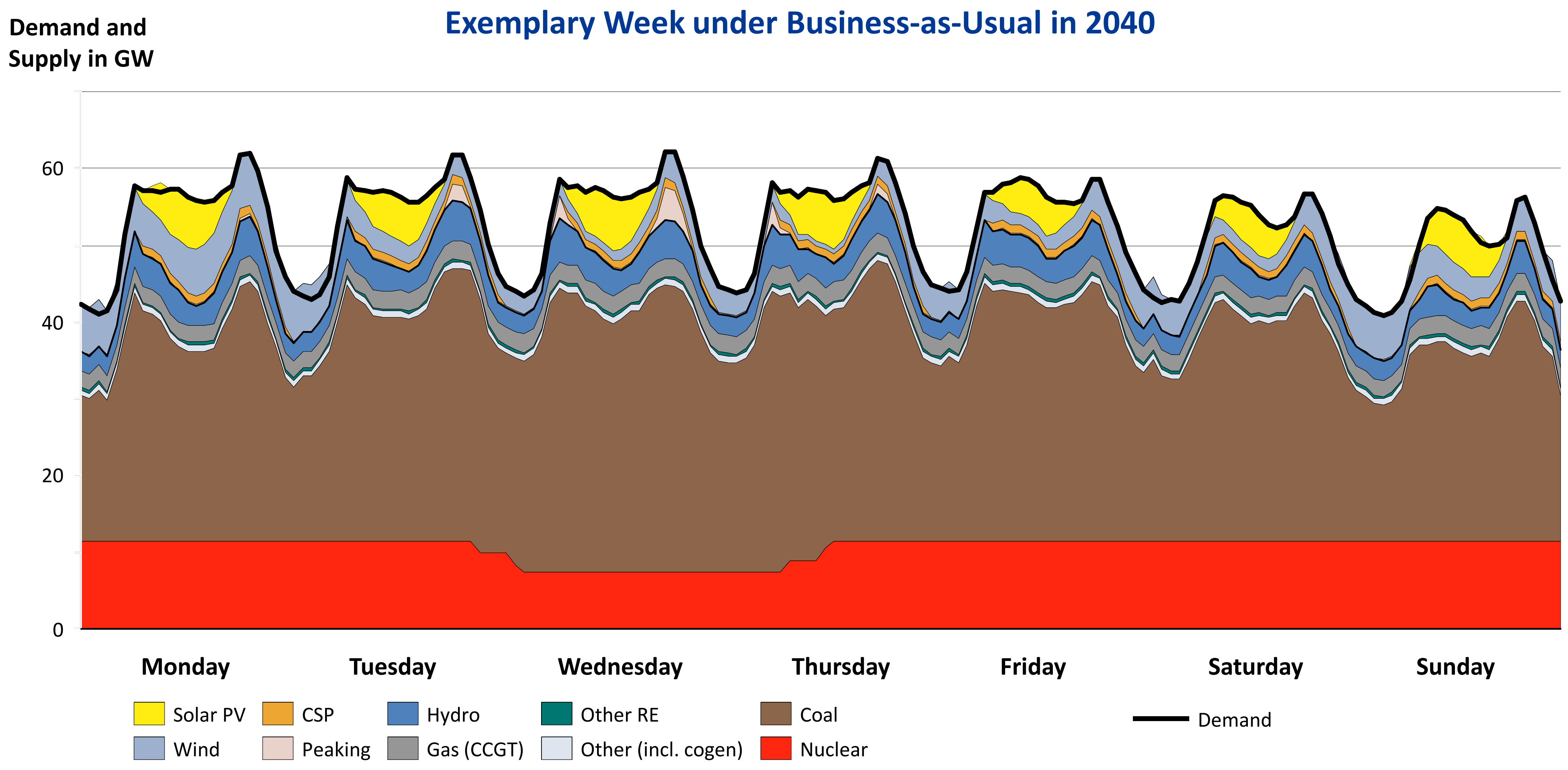
Solar PV | Wind | Peaking | Gas (CCGT) | Nuclear

CSP | Other RE | Other (incl. cogen) | Hydro (incl. PS) | Coal

Note: ratio wind/PV can be varied within relatively wide range without significant increase of total cost

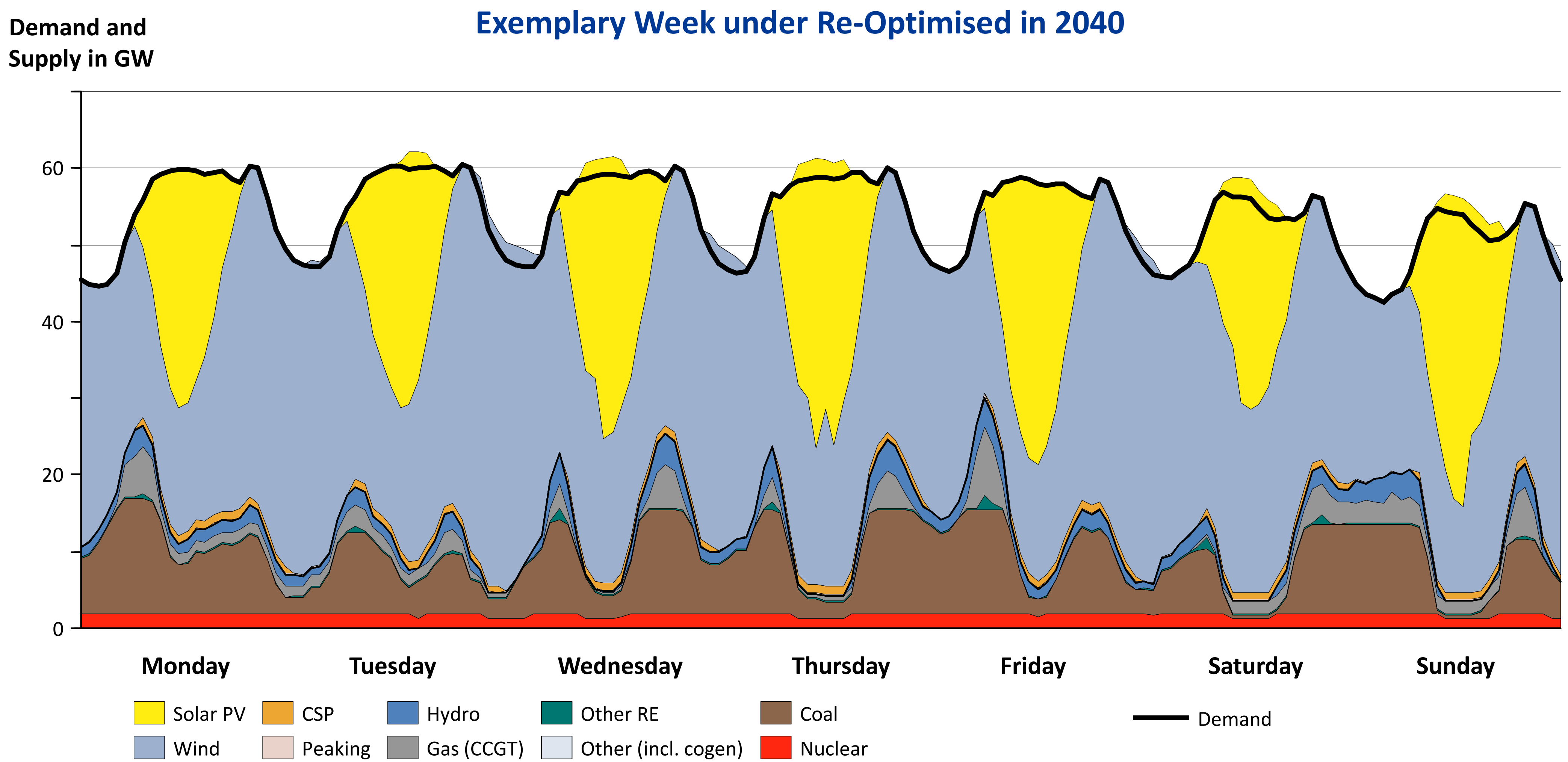
Sources: CSIR analysis

1 Business-as-Usual: Coal and nuclear dominate the 2040 energy mix



Sources: CSIR analysis

2 Re-Optimised: Wind and solar PV dominate the 2040 energy mix

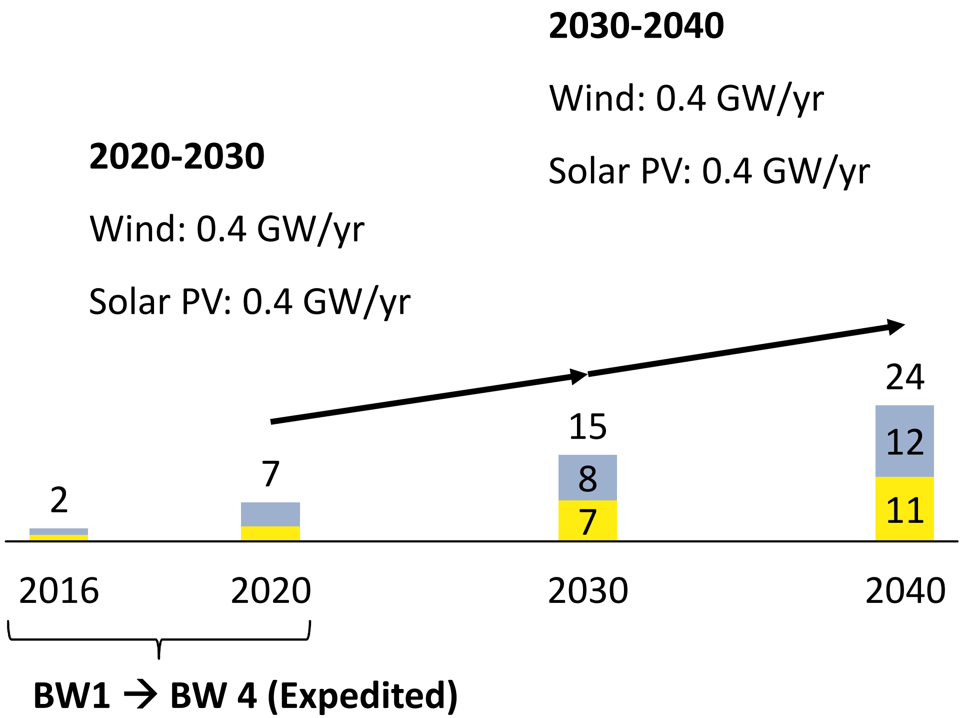


Sources: CSIR analysis

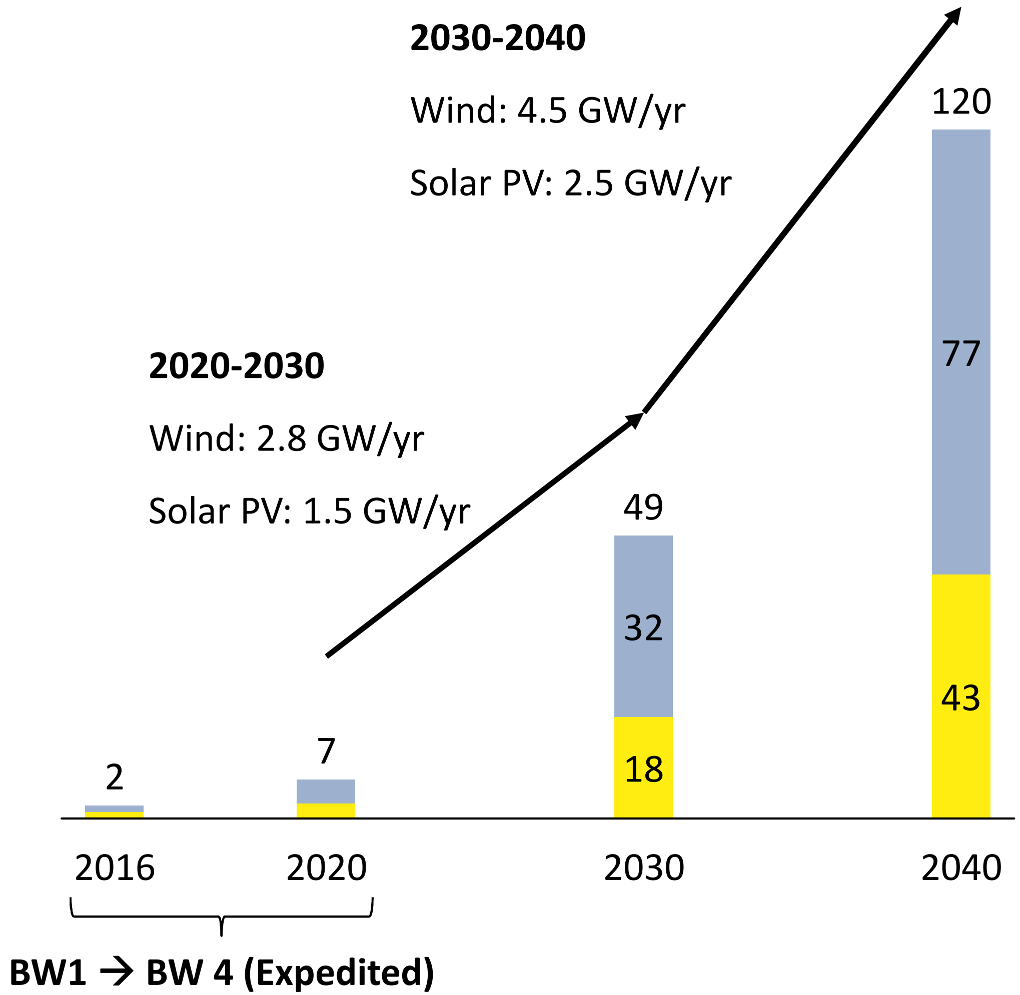
Re-Optimised scenario creates a steady, significant & increasing market

Roadmap of investment for wind and solar PV to 2040

1 Business-as-Usual

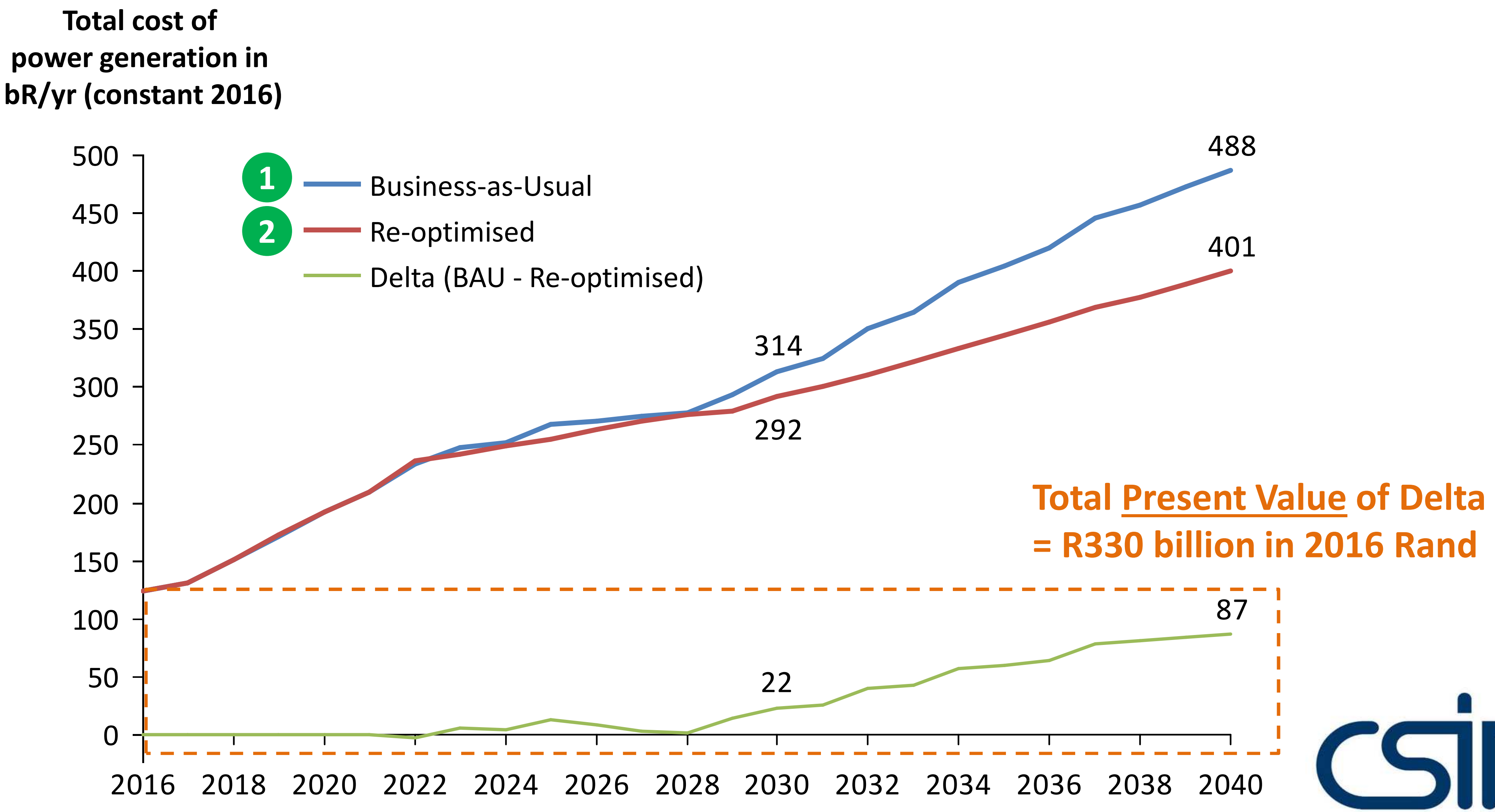


2 Re-Optimised



Sources: CSIR analysis

Re-Optimised R87 billion/year cheaper by 2040 (without cost of CO2)

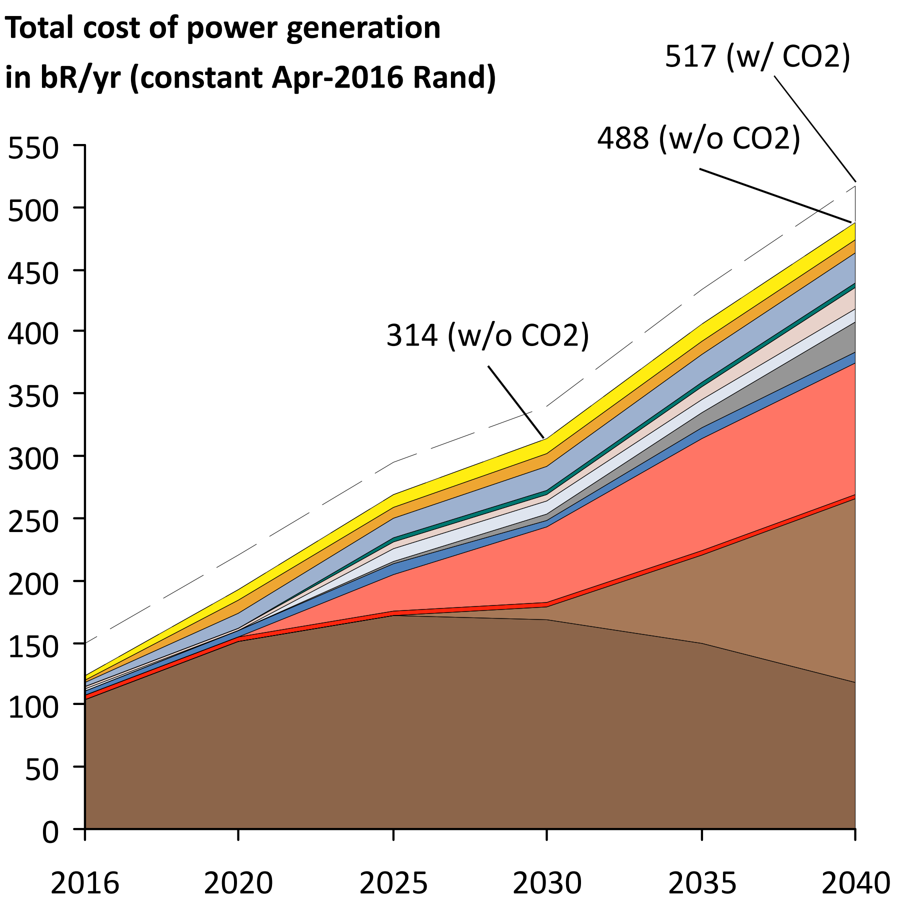


Sources: CSIR analysis

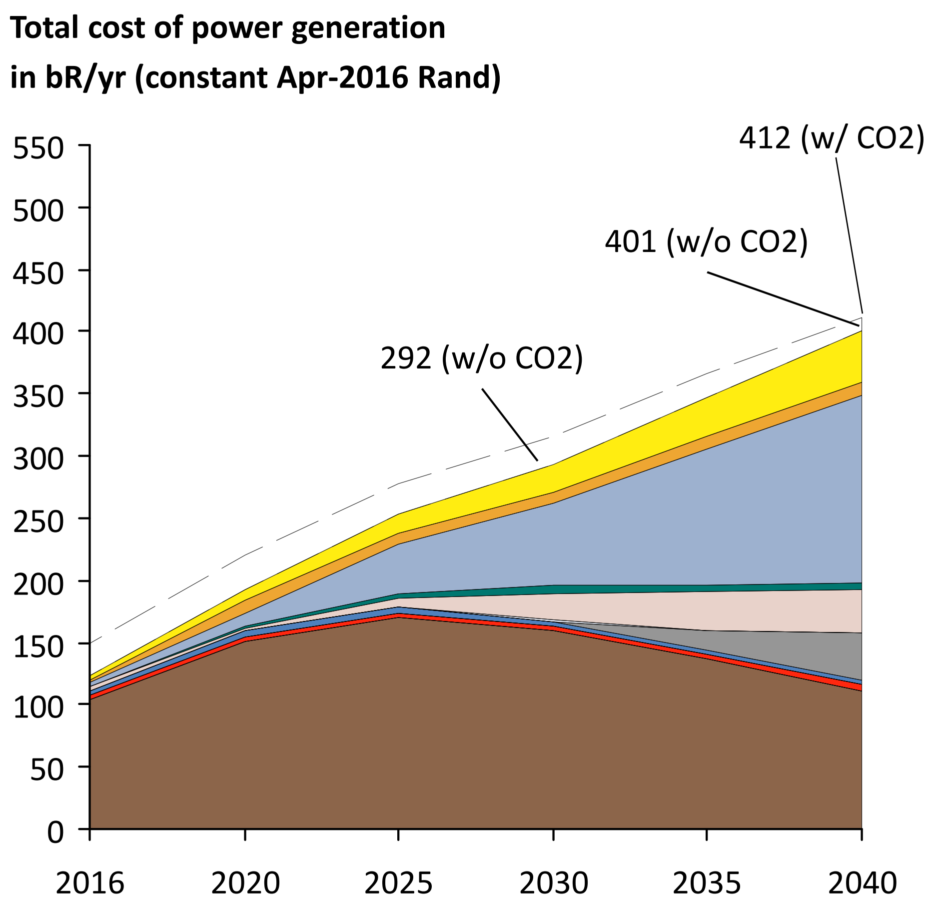
Business-as-Usual incurs large cost from building new coal and nuclear

Comparison of total electricity system costs average electricity tariff of BAU and Re-Optimised mix

1 Business-as-Usual



2 Re-Optimised

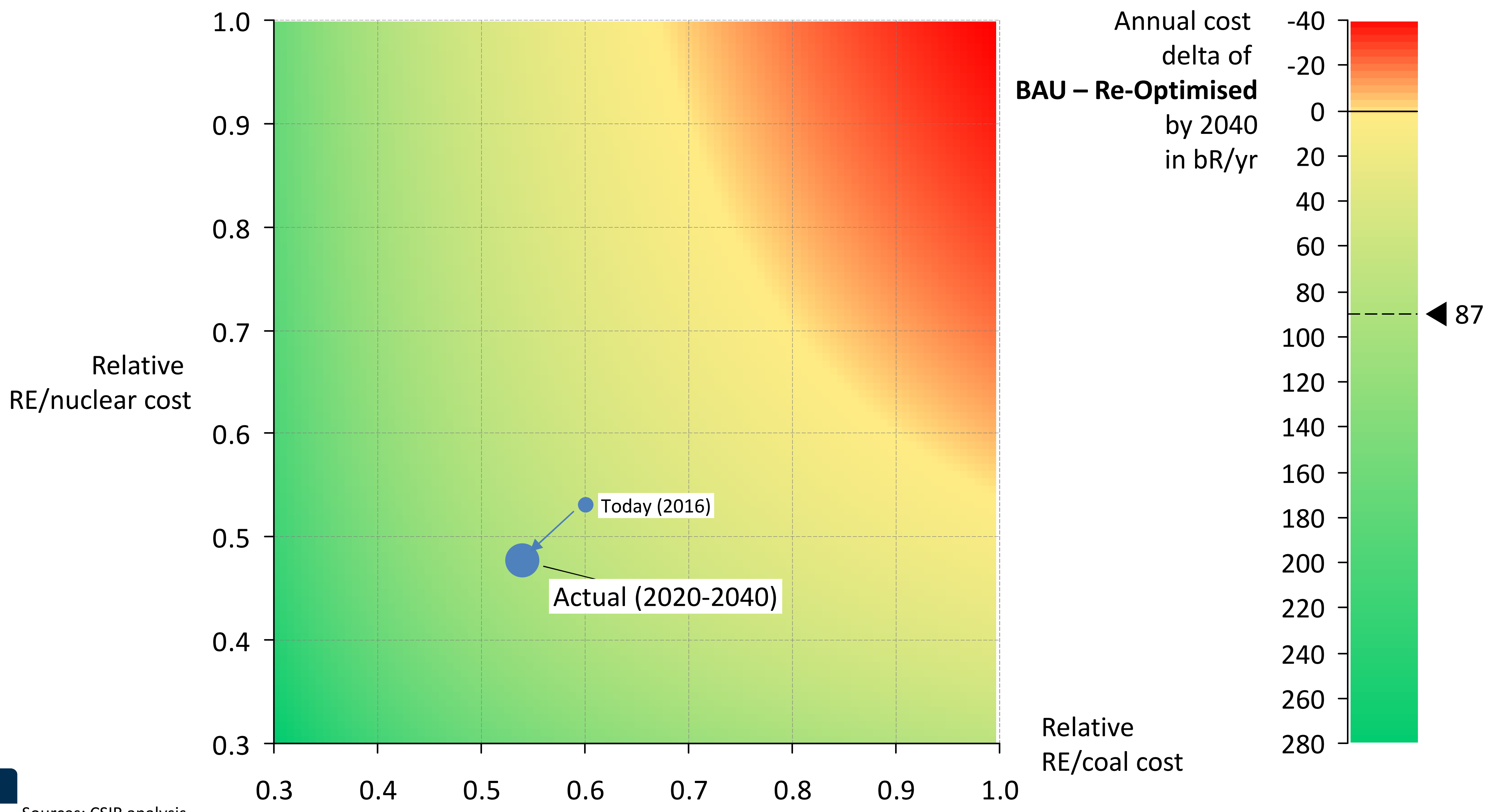


Cost of CO2 | CSP | Other RE | Other (incl. cogen) | Hydro (incl. PS) | Nuclear (existing) | Coal (existing)

Solar PV | Wind | Peaking | Gas (CCGT) | Nuclear (new) | Coal (new)

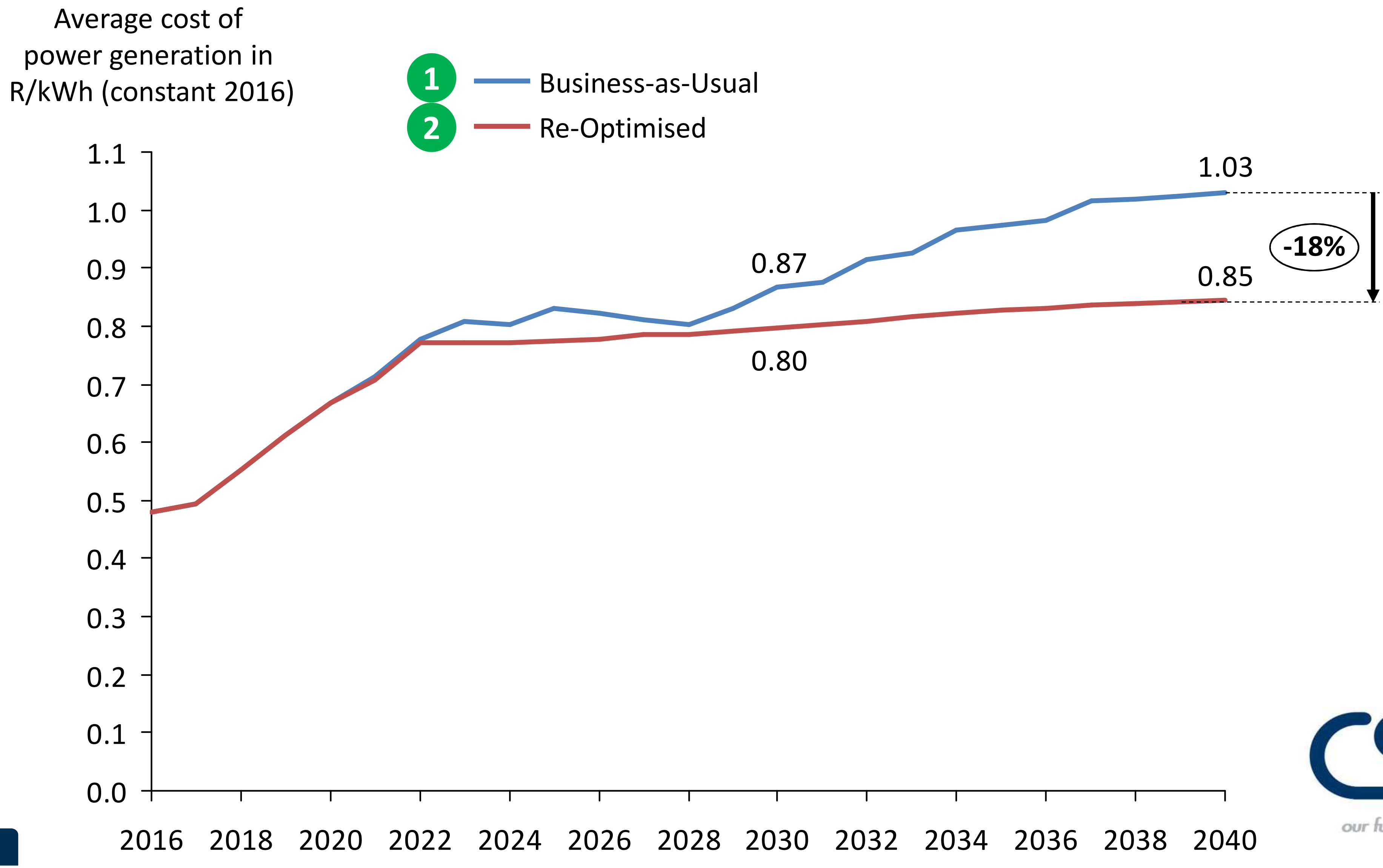
Sources: CSIR

Sensitivity on cost difference: Even if RE were 50% more expensive than assumed, Re-Optimised is still cheaper than Business-as-Usual



Sources: CSIR analysis

Unit cost of power generation: Re-Optimised case is almost 20 cents/kWh cheaper than BAU by 2040



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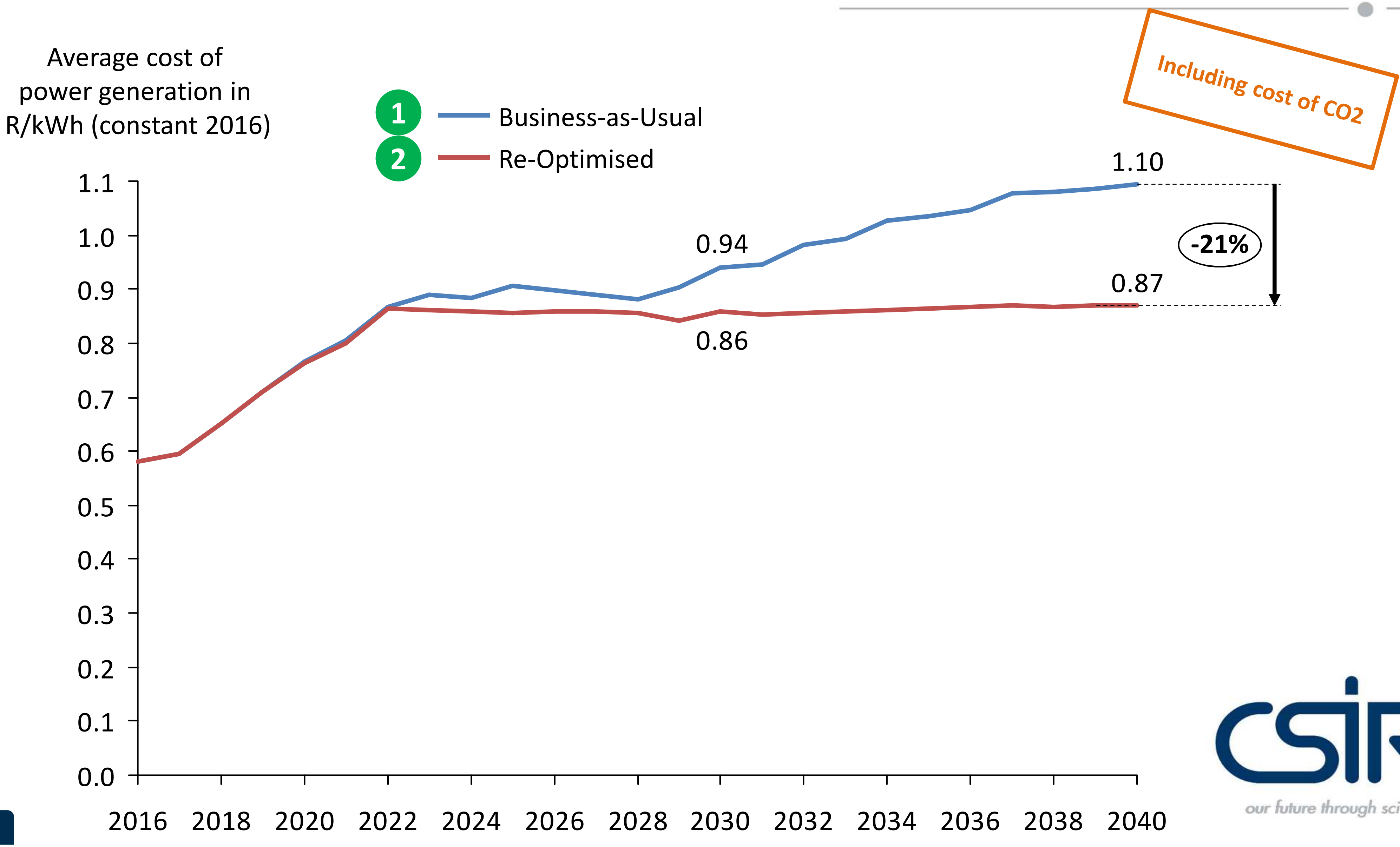
Sources: CSIR analysis

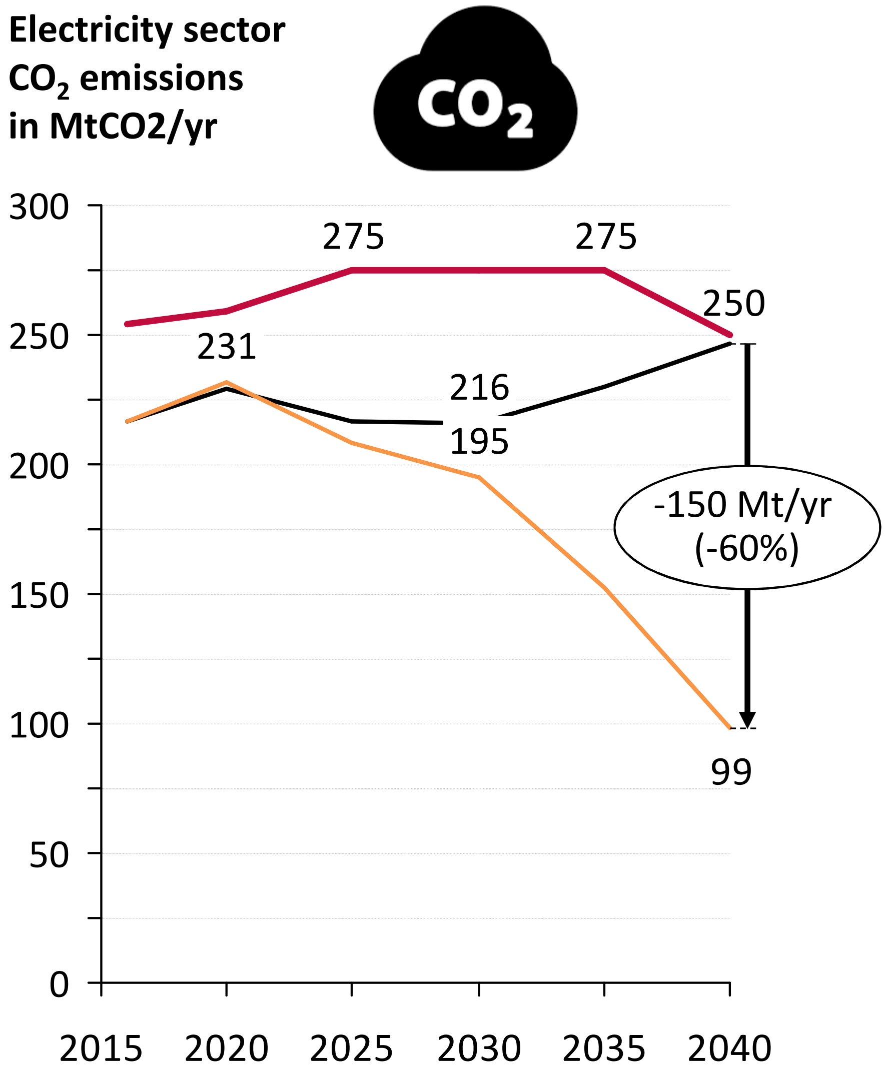
Factoring in cost of CO2 emissions: Re-Optimised case is 23 cents/kWh cheaper than BAU by 2040

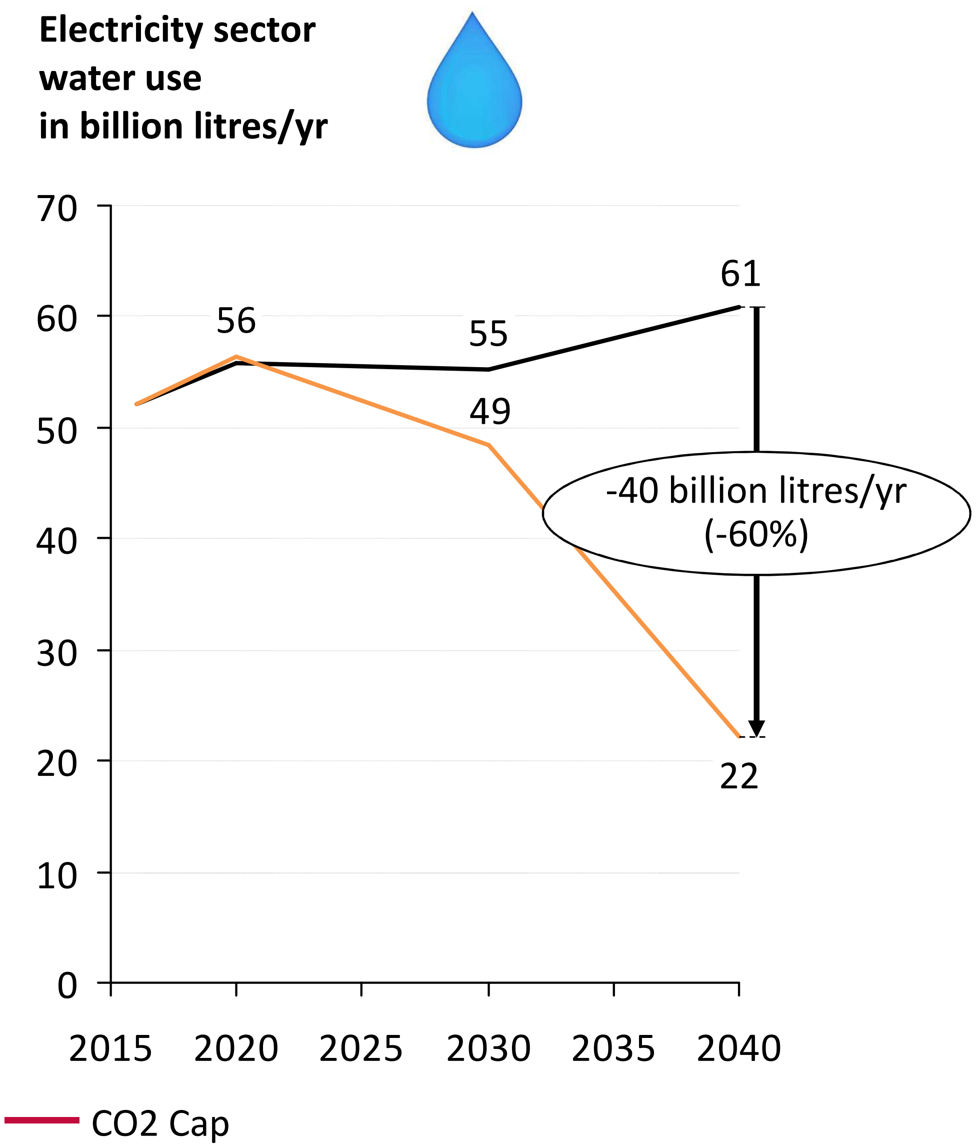


Sources: CSIR analysis

Re-Optimised: CO2 emissions and water use significantly lower

Comparison of CO2 emissions and water use for BAU and a Re-Optimised scenario to 2040





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South Africa can get 70% renewable energy share by 2040 at least cost

Solar PV, wind and natural gas is the cheapest new-build mix for the South African power system

It is the cost-optimal expansion to aim for a 70% renewable energy share by 2040

This "Re-Optimised" mix is almost <u>R90 billion per year</u> cheaper by 2040 than the Business-as-Usual scenario (without factoring in cost of CO2 emissions – difference is > R100 billion per year with CO2)

The Re-Optimised mix will furthermore reduce South Africa's CO2 emissions by 60% compared to BAU

Avoiding CO2 emissions and least-cost is not a trade-off anymore – South Africa can de-carbonise its electricity sector at <u>negative</u> carbon-avoidance cost

Building out the required capacities until 2040 will provide a steady anchor offtake for a South African solar PV and wind manufacturing industry

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Sources: CSIR analysis

Ha Khensa

Re a leboha

Siyathokoza

Enkosi

Thank you

Re a leboga

Ro livhuha

Siyabonga

Dankie

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