Energy Mix 2.0: The Potential for a New Paradigm

Presentation at the SANEA Action for Energy Event

Dr Tobias Bischof-Niemz, Head of the CSIR Energy Centre

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Background

CSIR's Approach and Project Team

Comments on IRP Assumptions

IRP Results and Least-cost Scenario

Summary

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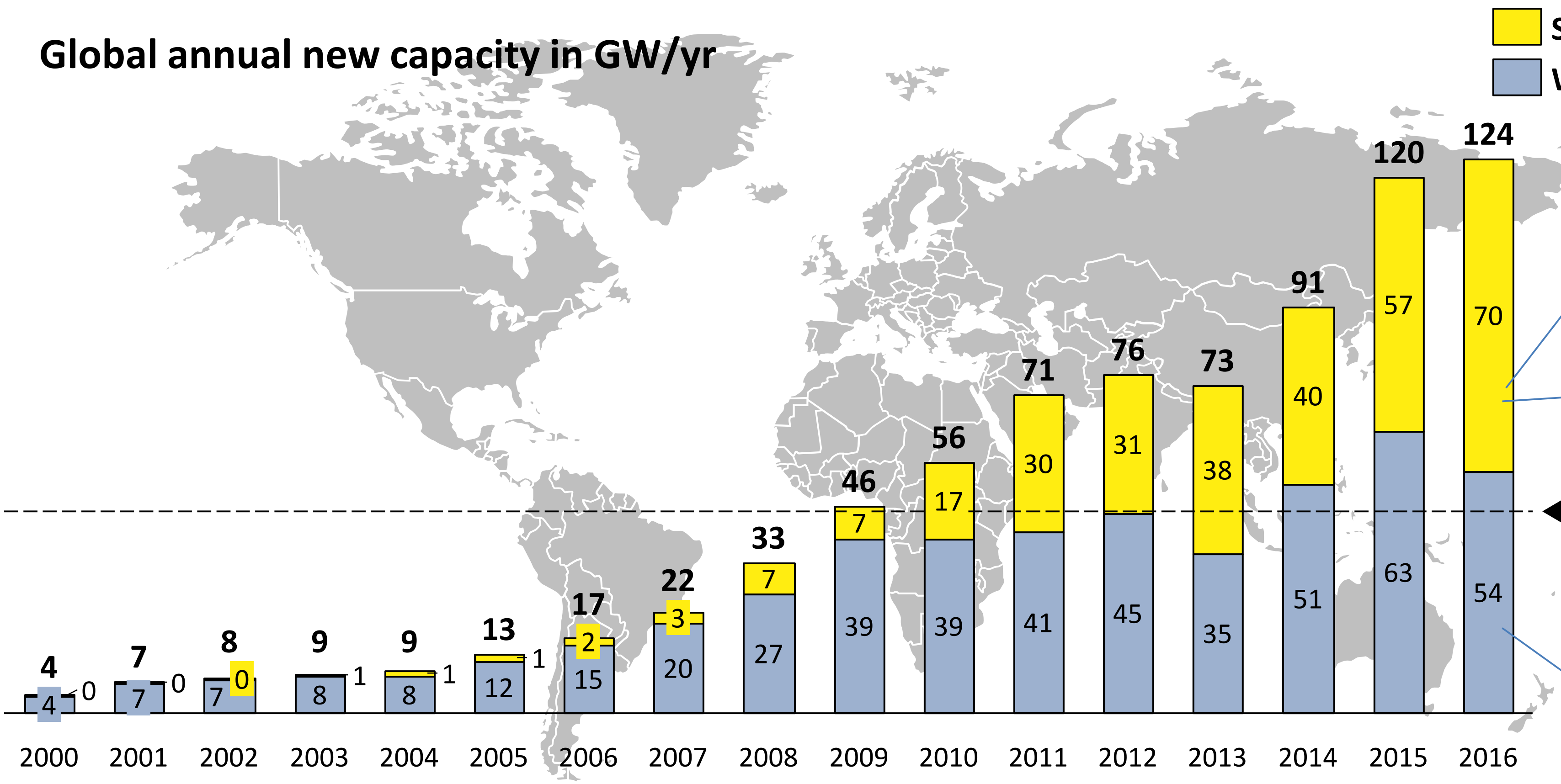
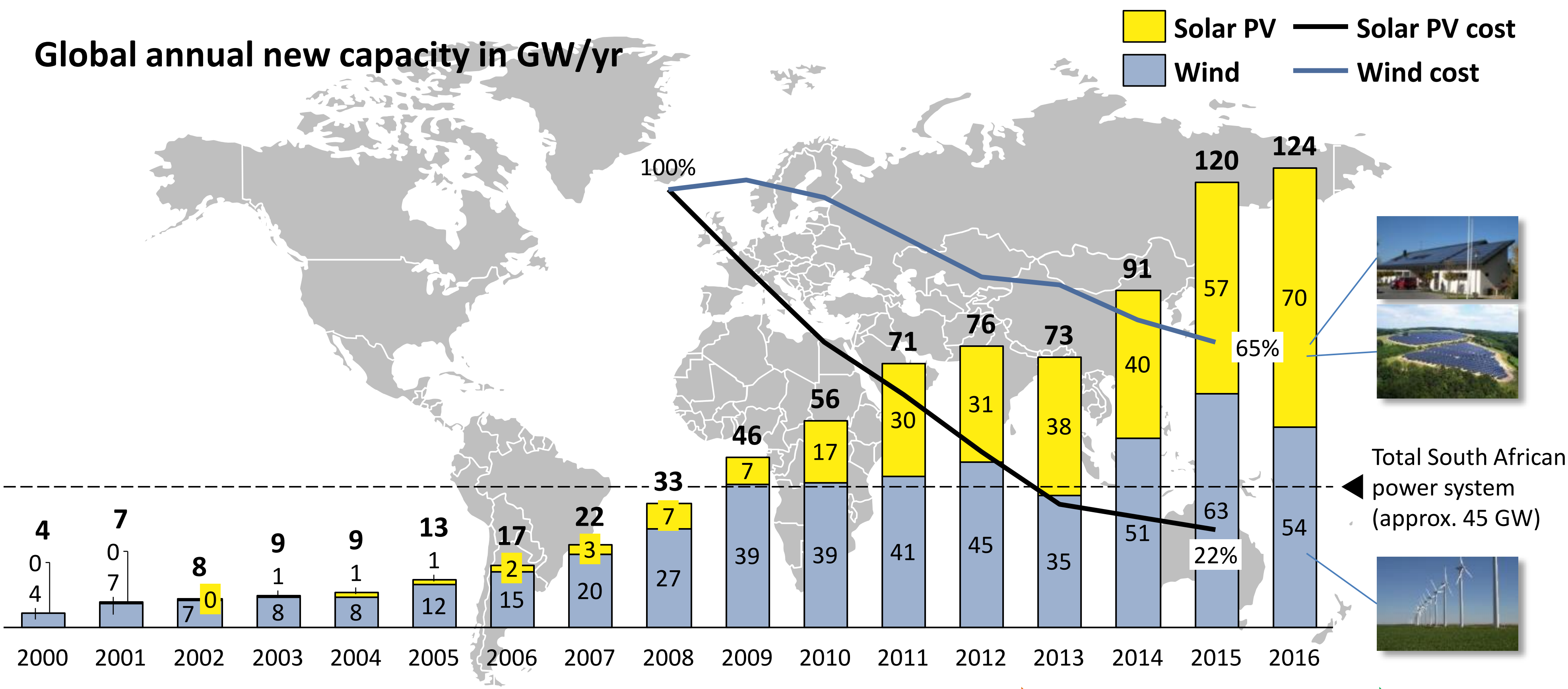
World:
In 2016, 124 GW of new wind and solar PV capacity installed globally



This is all very new: Roughly 80% of the globally existing solar PV capacity was installed during the last five years

Sources: GWEC; EPIA; BNEF; CSIR analysis

World:
Significant cost reductions materialised in the last 5-8 years

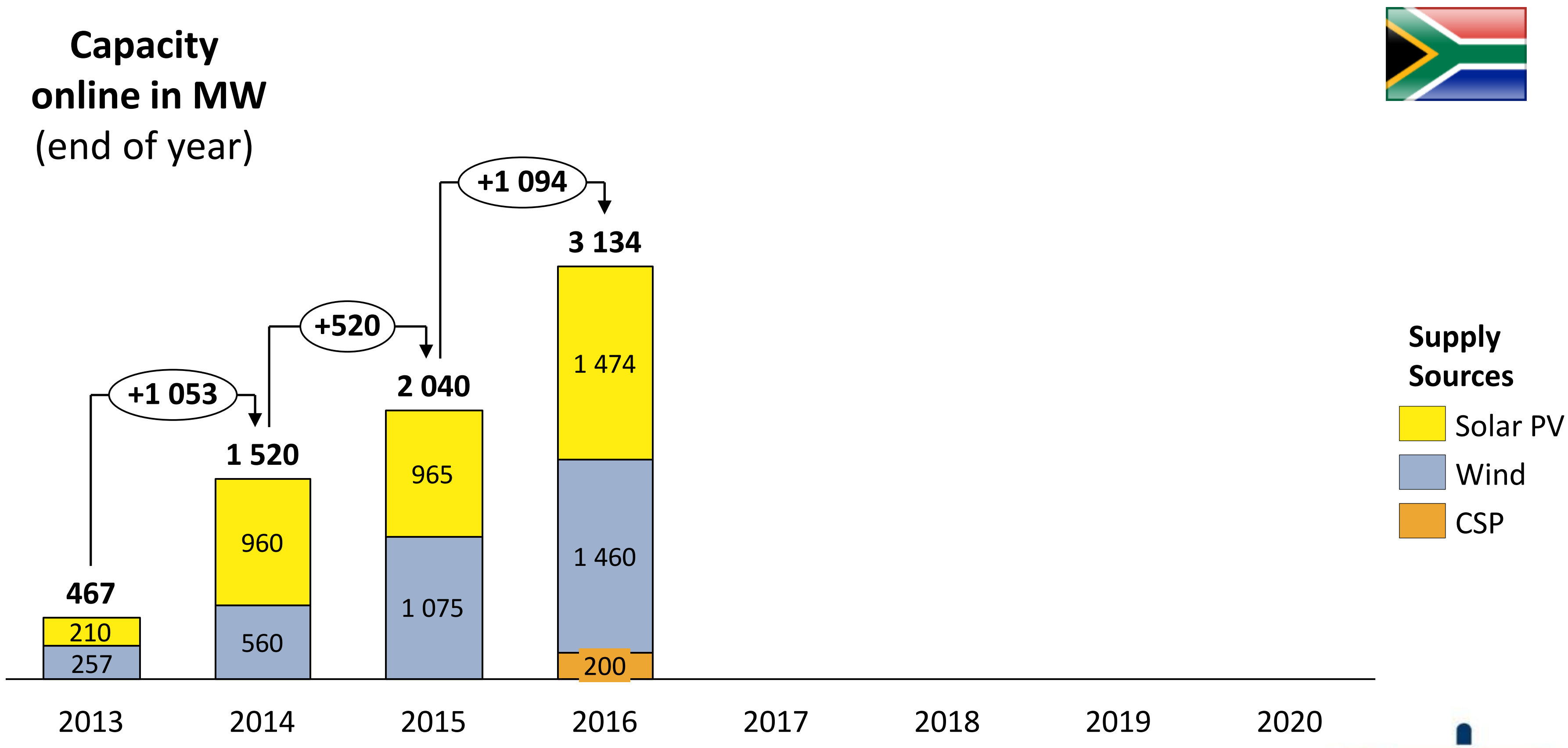


Subsidies

Cost competitive

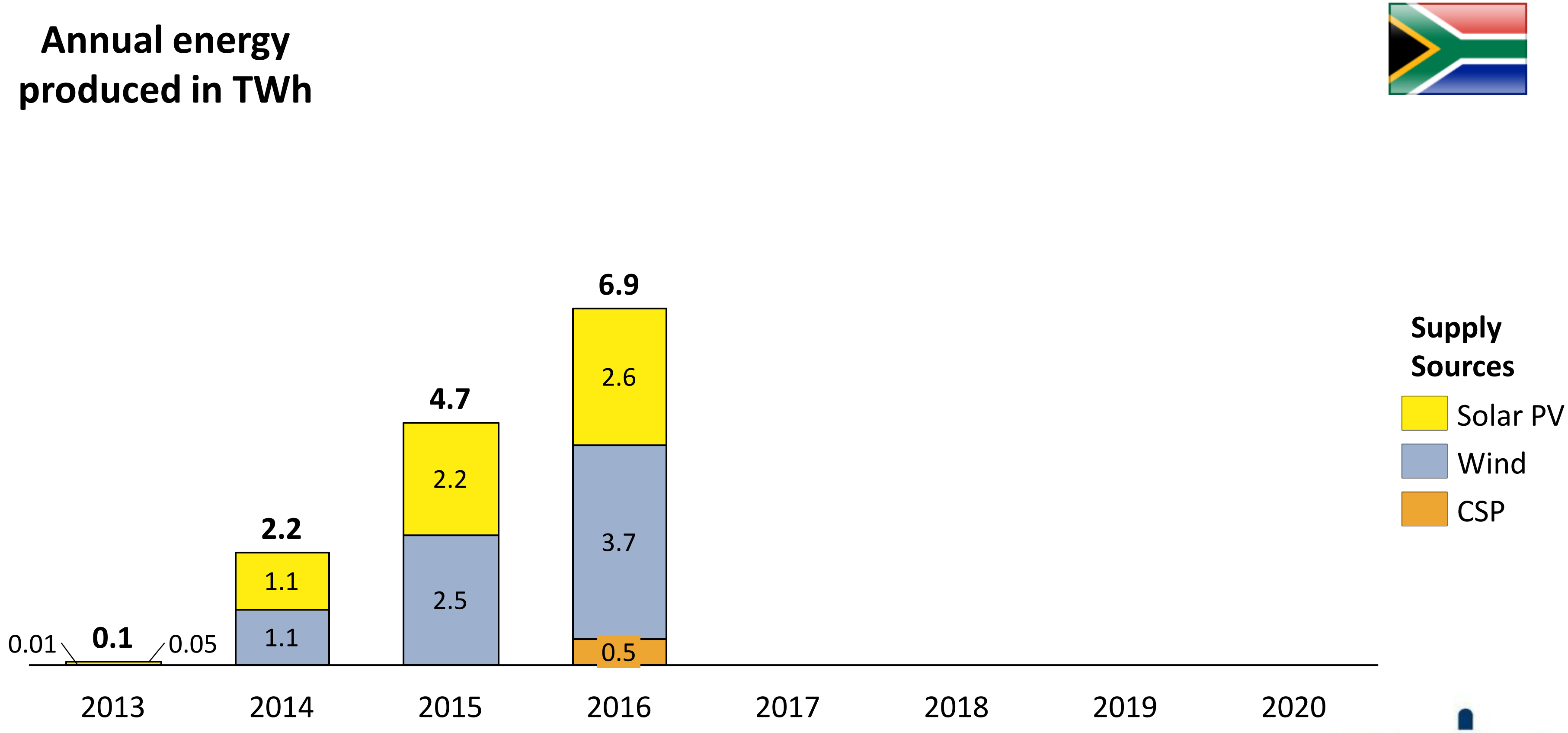
Sources: IEA; GWEC; EPIA; BNEF; CSIR analysis

South Africa:
From 2013 to 2016, 3.1 GW of wind, solar PV and CSP commissioned



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

South Africa:
In 2016, almost 7 TWh electricity produced from wind, solar PV & CSP



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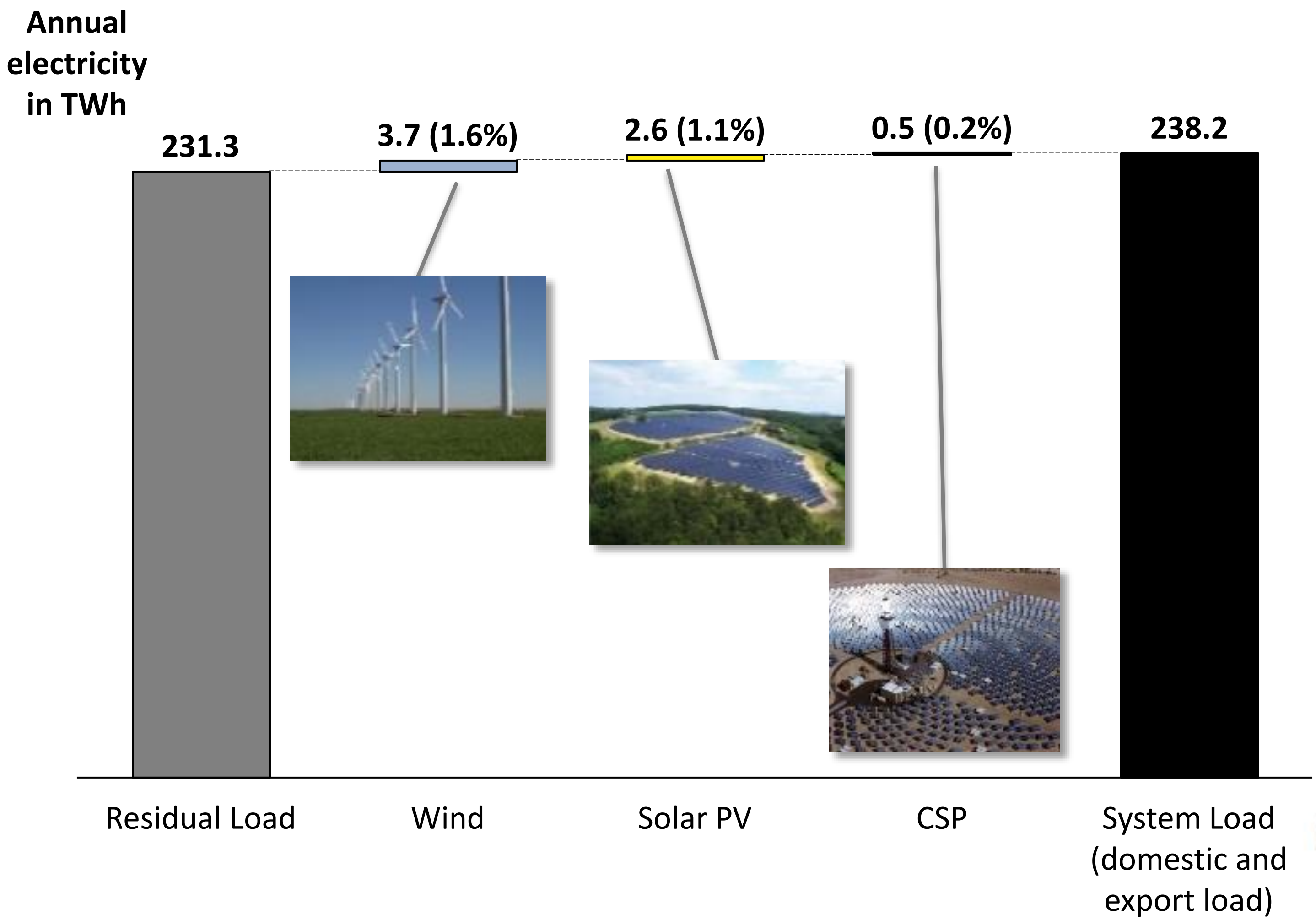
Notes: Wind includes Eskom's Sere wind farm (100 MW)
Sources: Eskom; DoE IPP Office

2016: Wind, solar PV and CSP supplied 3% of the total RSA system load

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



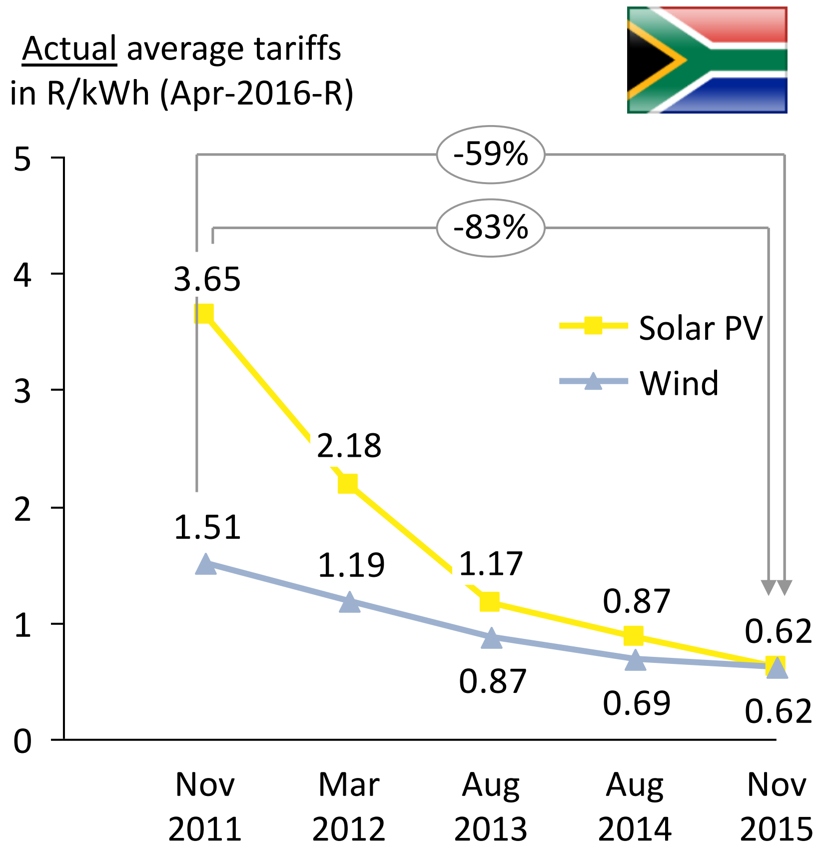
Notes: Wind includes Eskom's Sere wind farm (100 MW)

Sources: Eskom; DoE IPP Office

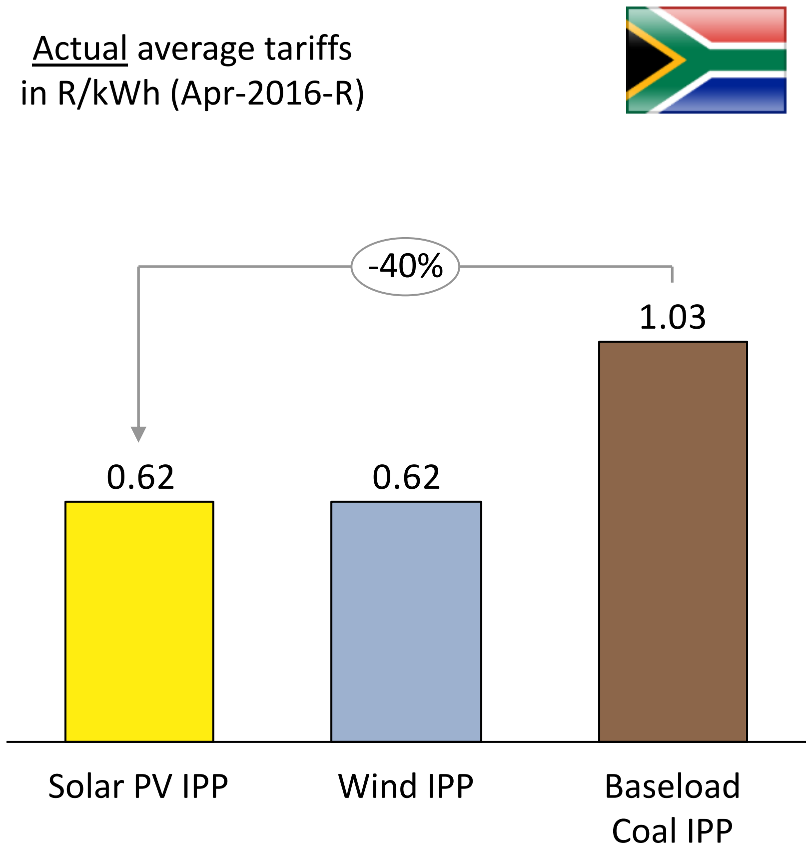
Actual tariffs: new wind/solar PV 40% cheaper than new coal in RSA

Results of Department of Energy's RE IPP Procurement Programme (REIPPPP) and Coal IPP Proc. Programme

Significant reductions in actual tariffs ...



... have made new solar PV & wind power 40% cheaper than new coal in South Africa today



Notes: Exchange rate of 14 USD/ZAR assumed Sources: http://www.energy.gov.za/files/renewable-energy-status-report/Market-Overview-and-Current-Levels-of-Renewable-Energy-Deployment-NERSA.pdf; http://www.saippa.org.za/Portals/24/Documents/2016/Coal%20IPP%20factsheet.pdf; http://www.ee.co.za/wp-content/uploads/2016/10/New_Power_Generators_RSA-CSIR-14Oct2016.pdf; StatsSA on CPI; CSIR analysis

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Summary

Integrated Resource Plan (IRP) aims for optimal electricity mix for RSA

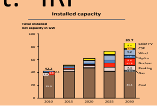
In-principle process of IRP planning and implementation

Planning / simulation world

Inputs
- Demand forecast
- Technology costs **assumptions**
- CO_2 limits
- Etc.

IRP Model (PLEXOS)
(techno-economical least-cost optimisation)

Output
- Capacity exp. plan
- After policy adjustment: "IRP"



Actuals / real world

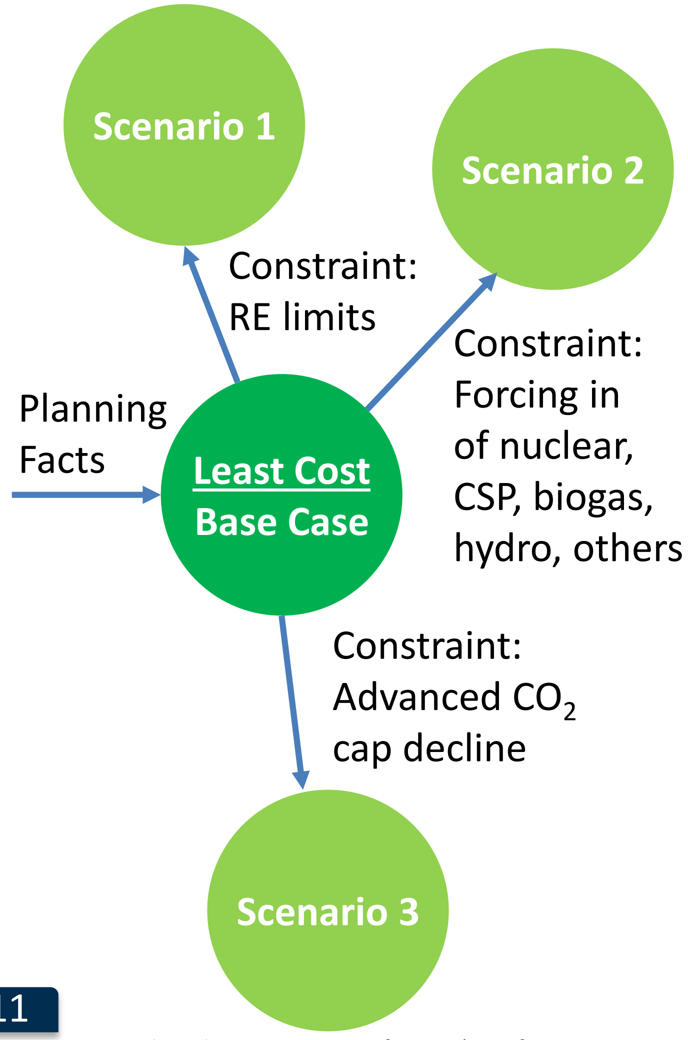
Inputs
- Ministerial Determinations based on IRP capacities

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

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

Sources: CSIR analysis

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

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Sources: based on Department of Energy's Draft IRP 2016, page 7; http://www.energy.gov.za/IRP/2016/Draft-IRP-2016-Assumptions-Base-Case-and-Observations-Revision1.pdf

The CSIR has embarked on power-system analyses to determine the least-cost expansion path for the South African electricity system

The Integrated Resource Plan (IRP) is the expansion plan for the South African power system until 2050

- Starting point of the IRP Base Case: pure techno-economic analysis to determine least-cost way to supply electricity
- Later process steps: least-cost mix can be policy adjusted to cater for aspects not captured in techno-economic model

Draft IRP 2016 Base Case entails a limitation: Amount of wind and solar PV capacity that the model is allowed to build per year is limited, which is neither technically nor economically justified/explained (no techno-economical reason provided)

The CSIR is therefore conducting a study to determine the Least Cost electricity mix in RSA until 2050

- Majority of assumptions kept exactly as per the Draft IRP 2016 Base Case
- First and most important deviation from IRP 2016: no new-build limits on renewables (wind/solar PV)
- Second (smaller) deviation: costing for solar PV and wind until 2030 aligned with latest IPP tariff results
- Scope of the CSIR study: purely techno-economical optimisation of the costs directly incurred in the power system

Two scenarios from the Draft IRP 2016 are compared with the Least Cost case

- "Draft IRP 2016 Base Case" – new coal, new nuclear
- "Draft IRP 2016 Carbon Budget" – significant new nuclear
- "Least Cost" – least-cost without constraints

An hourly capacity expansion and dispatch model (incl. unit commitment) using PLEXOS is run for all scenarios to test for technical adequacy → same software platform as by Eskom/DoE for the IRP

Sources: CSIR analysis

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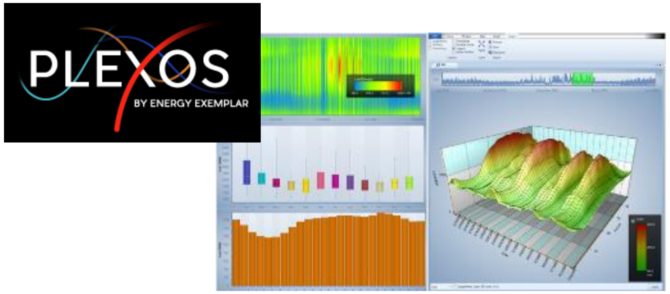
CSIR uses an industry standard software package for expansion planning of the power system – same package as used by DoE/Eskom

Commercial software used by DoE & CSIR …

Co-optimisation of long-term investment & operational decisions in hourly time resolution from today to 2050

- What mix to build?
- How to operate the mix once built?
- Objective function: least cost, subject to an adequate (i.e. reliable) power system



Key technical limitations of power generators covered

- Maximum ramp rates (% of installed capacity/h)
- Minimum operating levels (% of installed capacity)
- Minimum up & down times (h btw start/stop)
- Start-up and shut-down profiles

… covers all key cost drivers of a power system

Costs covered in the model include

- All capacity-related costs of all power generators
  - CAPEX of new power plants (R/kW)
  - Fixed Operation and Maintenance (FOM) cost (R/kW/yr)
- All energy-related costs of all power generators
  - Variable Operation and Maintenance (VOM) cost (R/kWh)
  - Fuel cost (R/GJ)
- Efficiency (heat rate) losses due to more flexible operation
- Reserves provision (included in capacity costs)

Costs not covered in the model currently used are

- Any grid-related costs (note: transmission-level grid costs typically ~10-15% of generation costs)
- Costs related to add. system services (e.g. inertia requirements, black-start and reactive power)

Sources: CSIR analysis

CSIR team has significant expertise from power system planning, system operation and grid perspective

Dr Tobias Bischof-Niemz

- Head of the CSIR Energy Centre
- Member of the Ministerial Advisory Council on Energy (MACE)
- Member of IRP2010/2013 team at Eskom, energy planning in Europe for large utilities

Joanne Calitz

- Senior Engineer: Energy Planning (CSIR Energy Centre)
- Previously with Eskom Energy Planning
- Medium-Term Outlook and IRP for RSA

Robbie van Heerden

- Senior Specialist: Energy Systems (CSIR Energy Centre)
- Former General Manager and long-time head of System Operations at Eskom

Mamahloko Senatla

- Researcher: Energy Planning (CSIR Energy Centre)
- Previously with the Energy Research Centre at University of Cape Town

Crescent Mushwana

- Research Group Leader: Energy Systems (CSIR Energy Centre)
- Former Chief Engineer at Eskom strategic transmission grid planning

Jarrad Wright

- Principal Engineer: Energy Planning (CSIR Energy Centre)
- Commissioner: National Planning Commission (NPC)
- Former Africa Manager of PLEXOS

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Draft IRP 2016 limits the annual build-out rates for solar PV and wind

The imposed new-build limits for solar PV and wind mean that the IRP model is not allowed in any given year to add more solar PV and wind capacity to the system than these limits

No such limits are applied for any other technology. No techno-economical reason/justification is provided for these limits. No explanation given why the limits are constant until 2050 while the power system grows

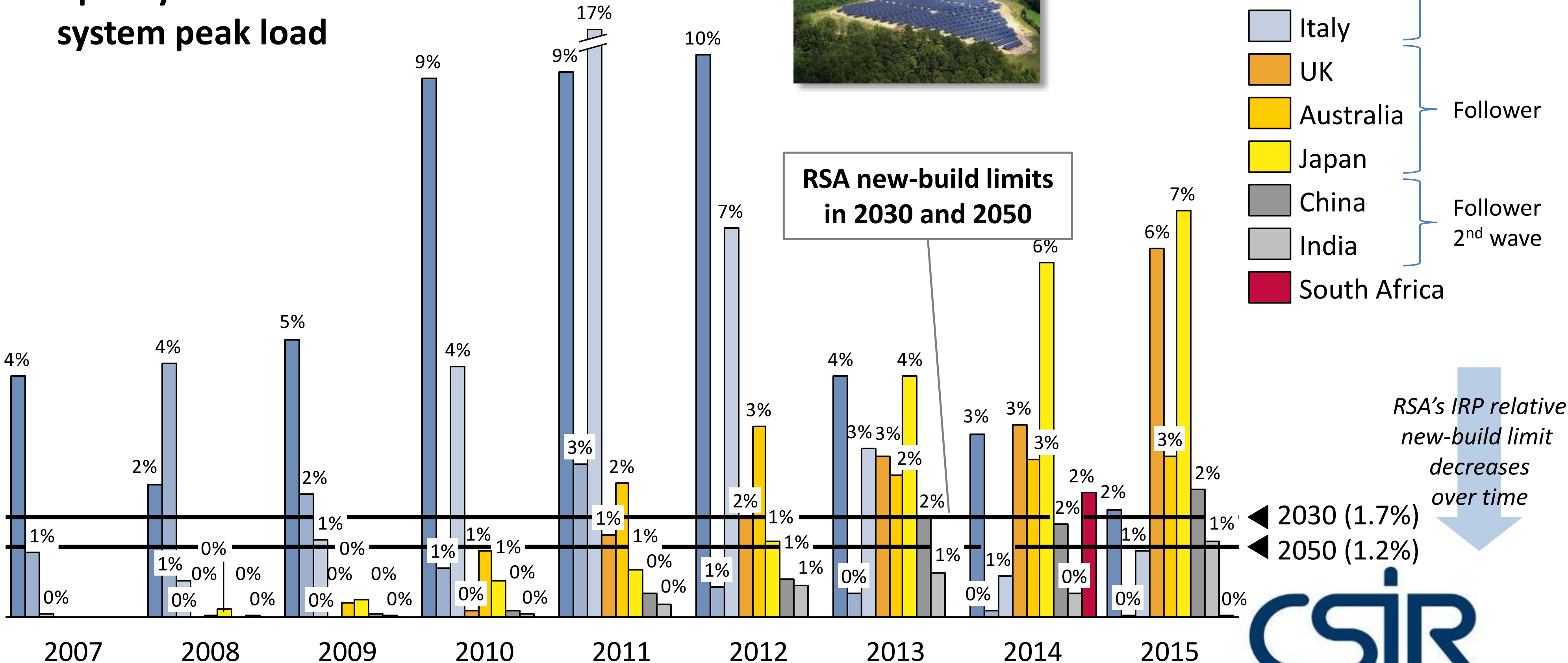
Year	System Peak Load in MW (as per Draft IRP)	New-build limit Solar PV in MW/yr (as per Draft IRP)	Relative new-build limit Solar PV (derived from IRP)	New-build limit Wind in MW/yr (as per Draft IRP)	Relative new-build limit Wind (derived from IRP)
2020	44 916	1 000	2.2%	1 600	3.6%
2025	51 015	1 000	2.0%	1 600	3.1%
2030	57 274	1 000	1.7%	1 600	2.8%
2035	64 169	1 000	1.6%	1 600	2.5%
2040	70 777	1 000	1.4%	1 600	2.3%
2045	78 263	1 000	1.3%	1 600	2.0%
2050	85 804	1 000	1.2%	1 600	1.9%

Note: Relative new-build limit = New-build limit / system peak load

Sources: IRP 2016 Draft; CSIR analysis

Today: Both leading and follower countries are installing more new solar PV capacity per year than South Africa's IRP limits for 2030/2050

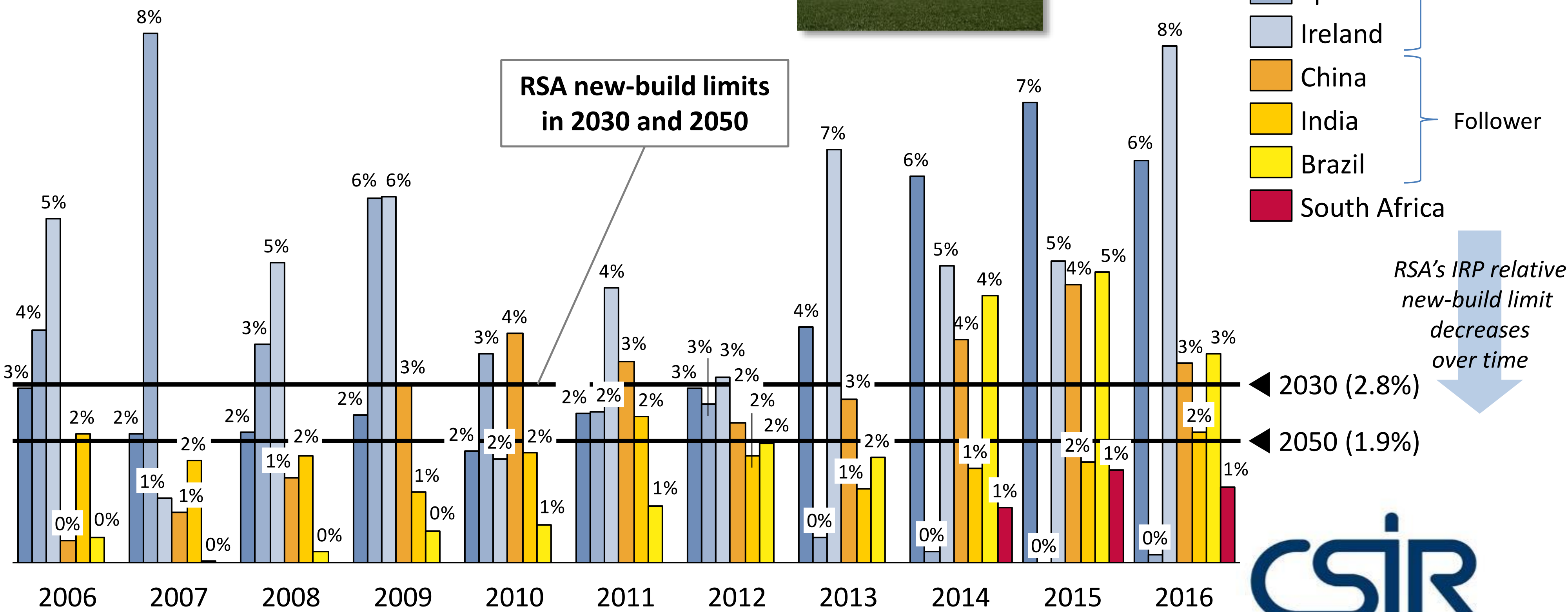
Annual new solar PV capacity relative to system peak load



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

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

Annual new wind capacity relative to system peak load



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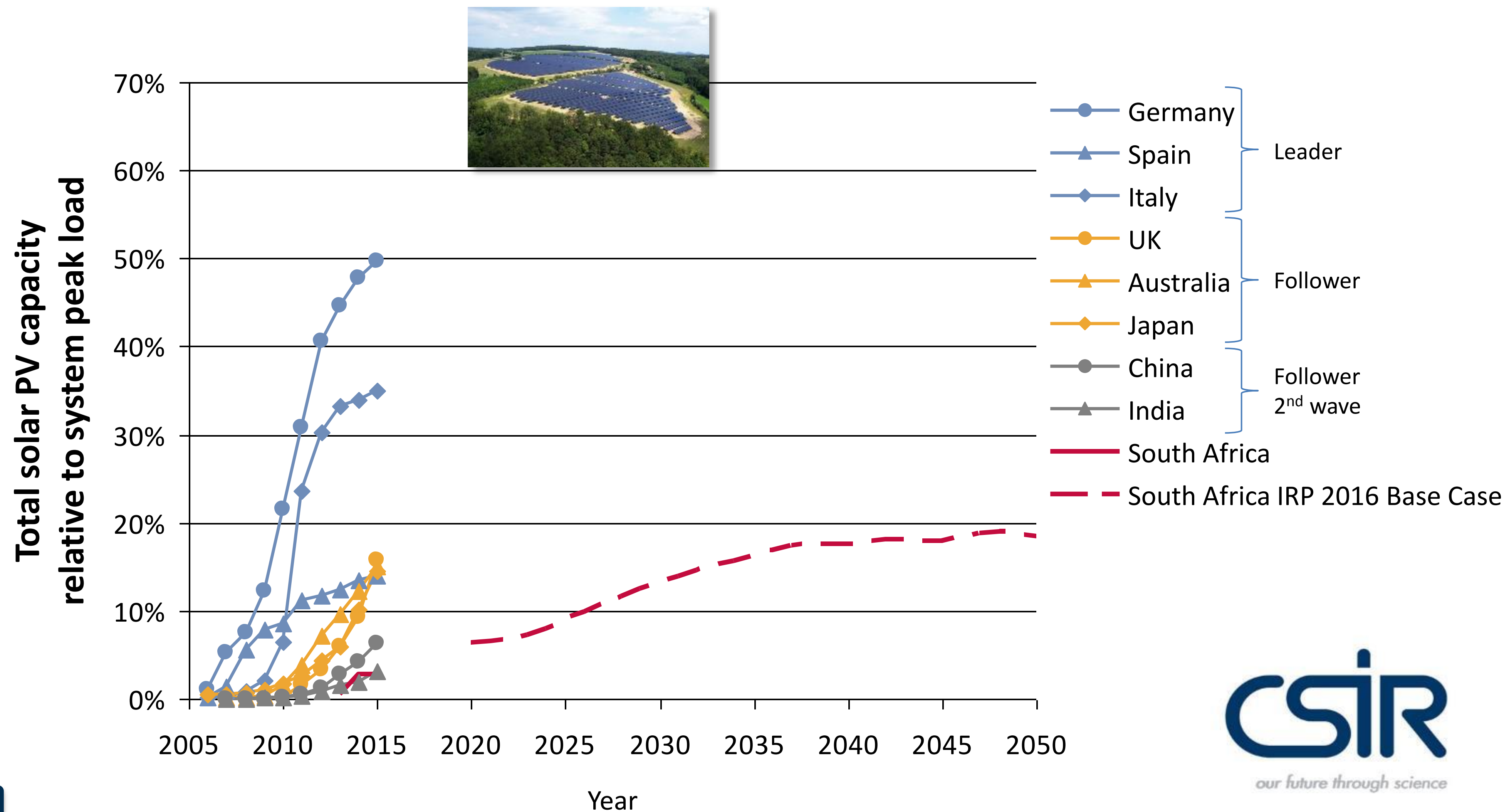
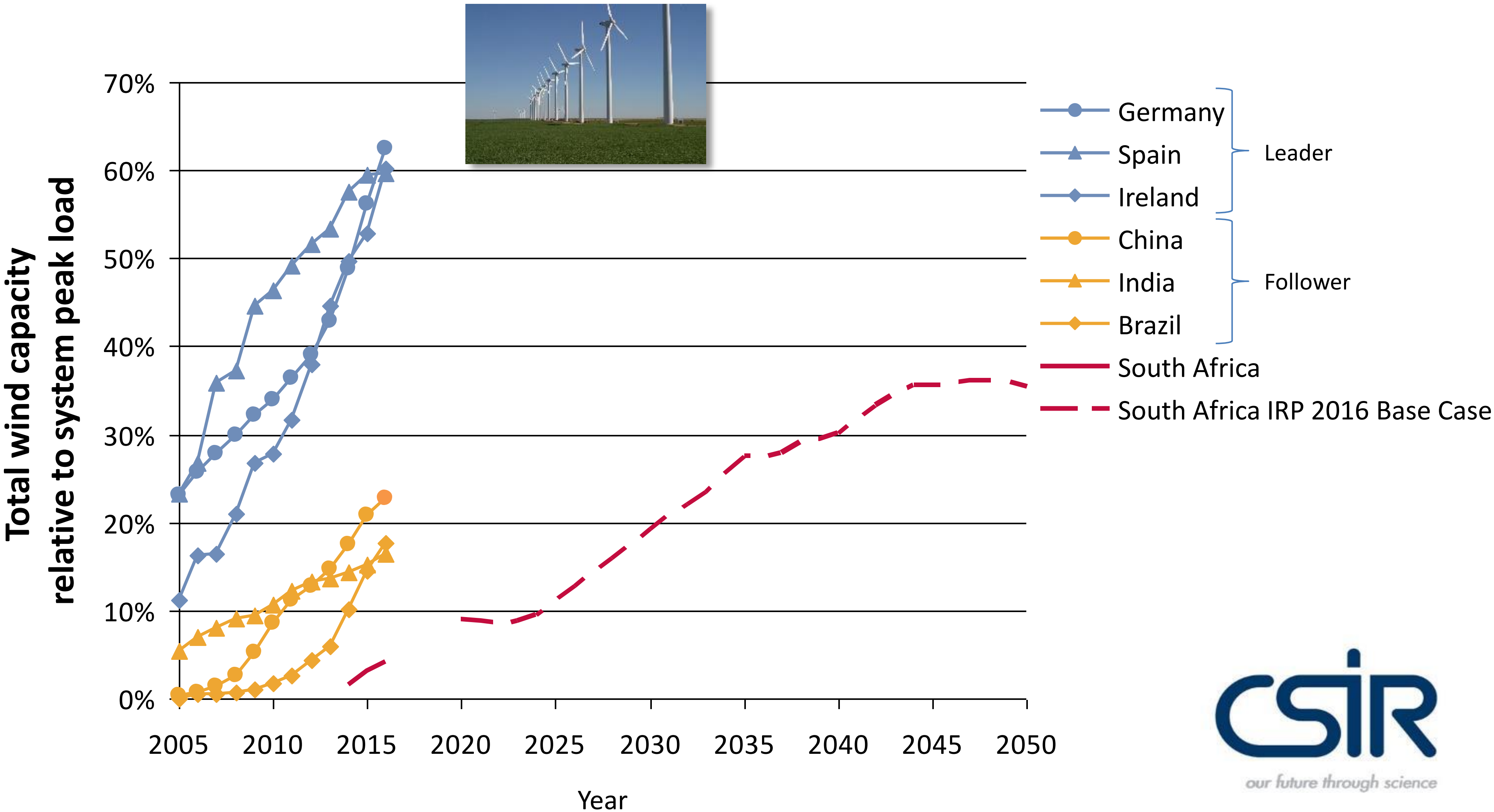
Sources: GWEC; CIGRE; websites of System Operators; IRP 2016 Draft; CSIR analysis

Solar PV penetration in leading countries today is 2.5 times that of South Africa's Draft IRP 2016 Base Case for the year 2050



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

Wind penetration in leading countries today is 1.7-1.8 times that of South Africa's Draft IRP 2016 Base Case for the year 2050



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

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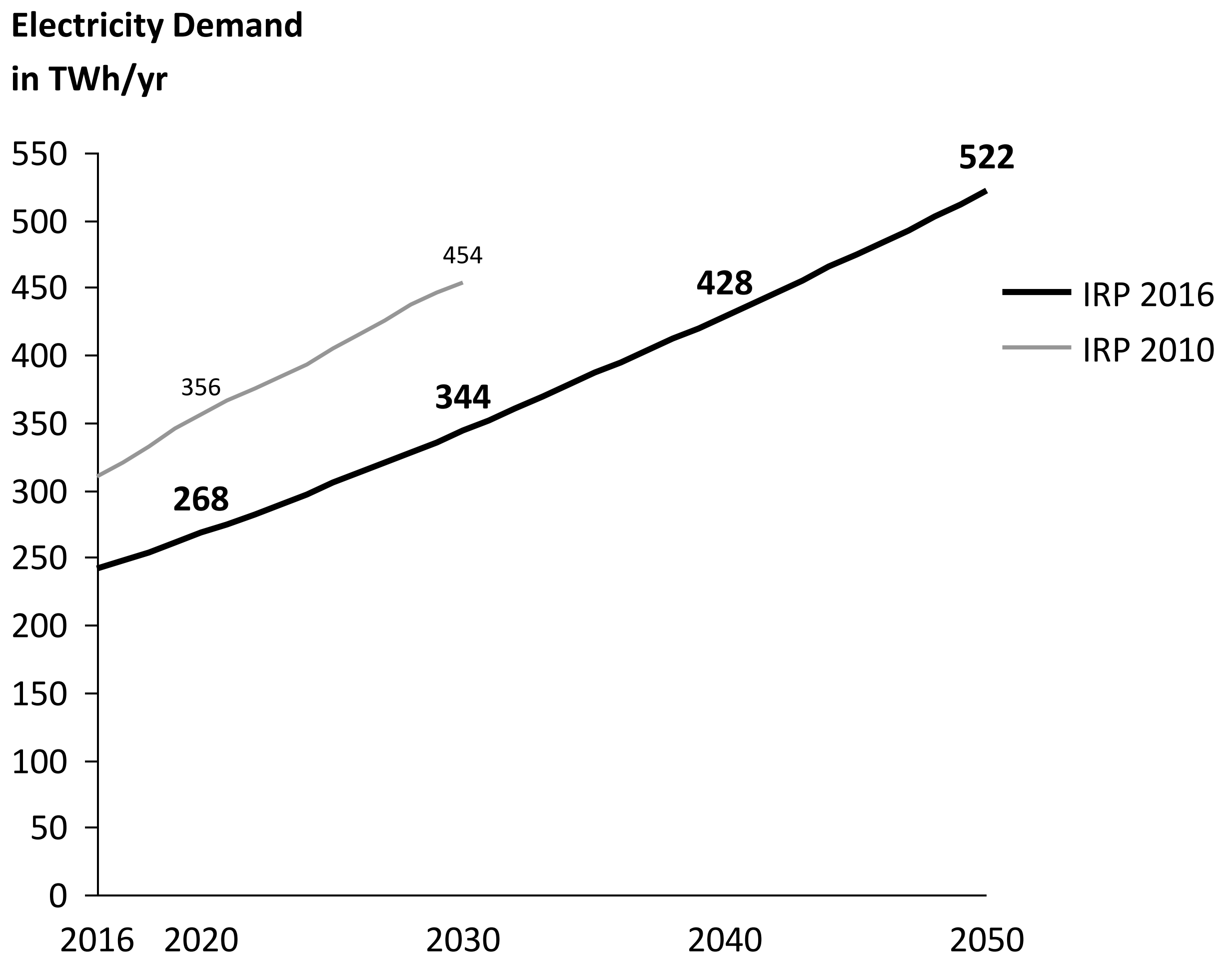
Input as per IRP 2016: Demand is forecasted to double by 2050

Forecasted demand for the South African electricity system from 2016 to 2050

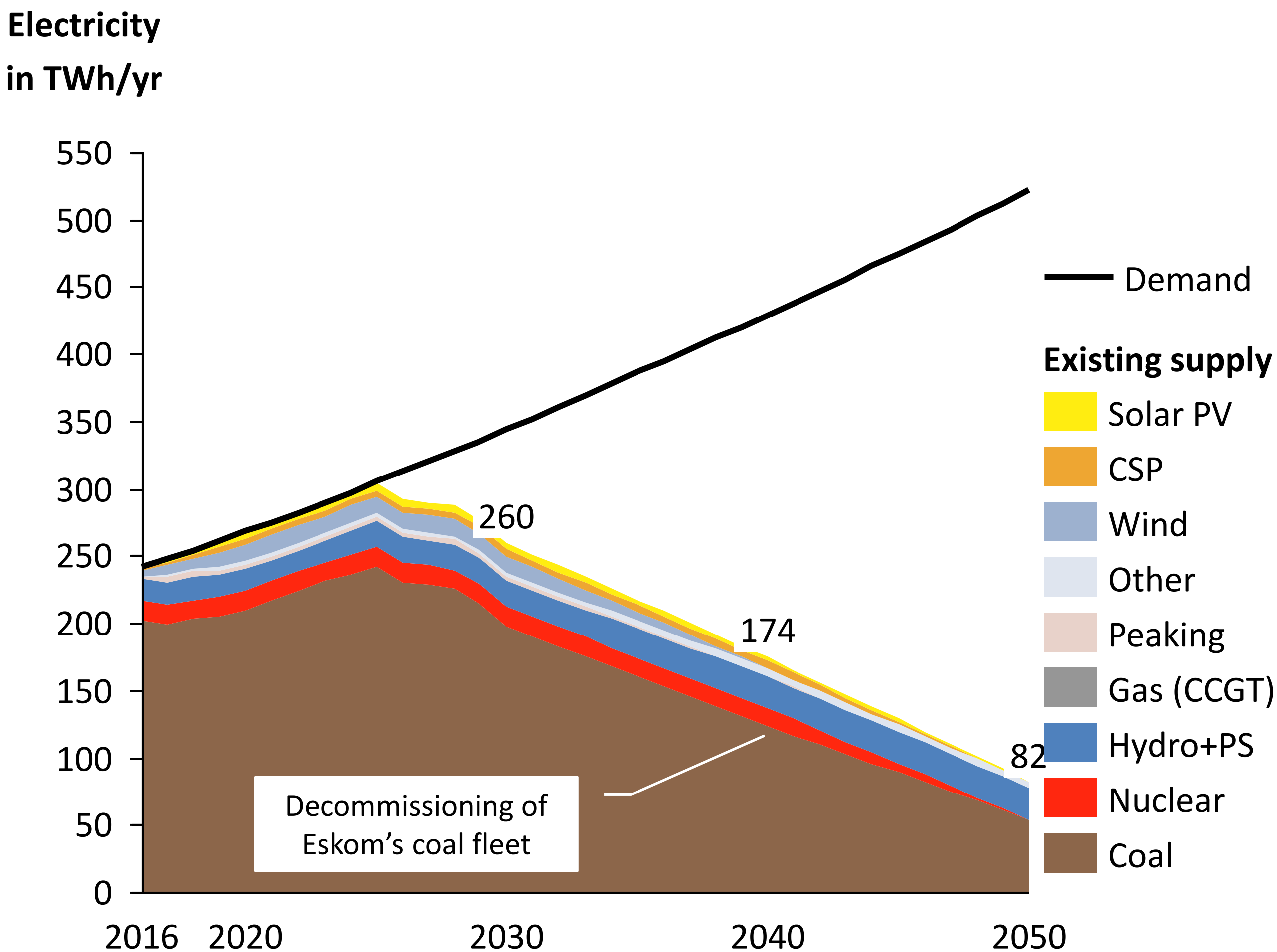


Note: by 2050 the electricity demand per capita would still be less than that of Australia today

Sources: DoE (IRP 2016); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

Input as per IRP 2016: Decommissioning schedule for existing plants

Energy supplied to the South African electricity system from existing plants between 2016 and 2050



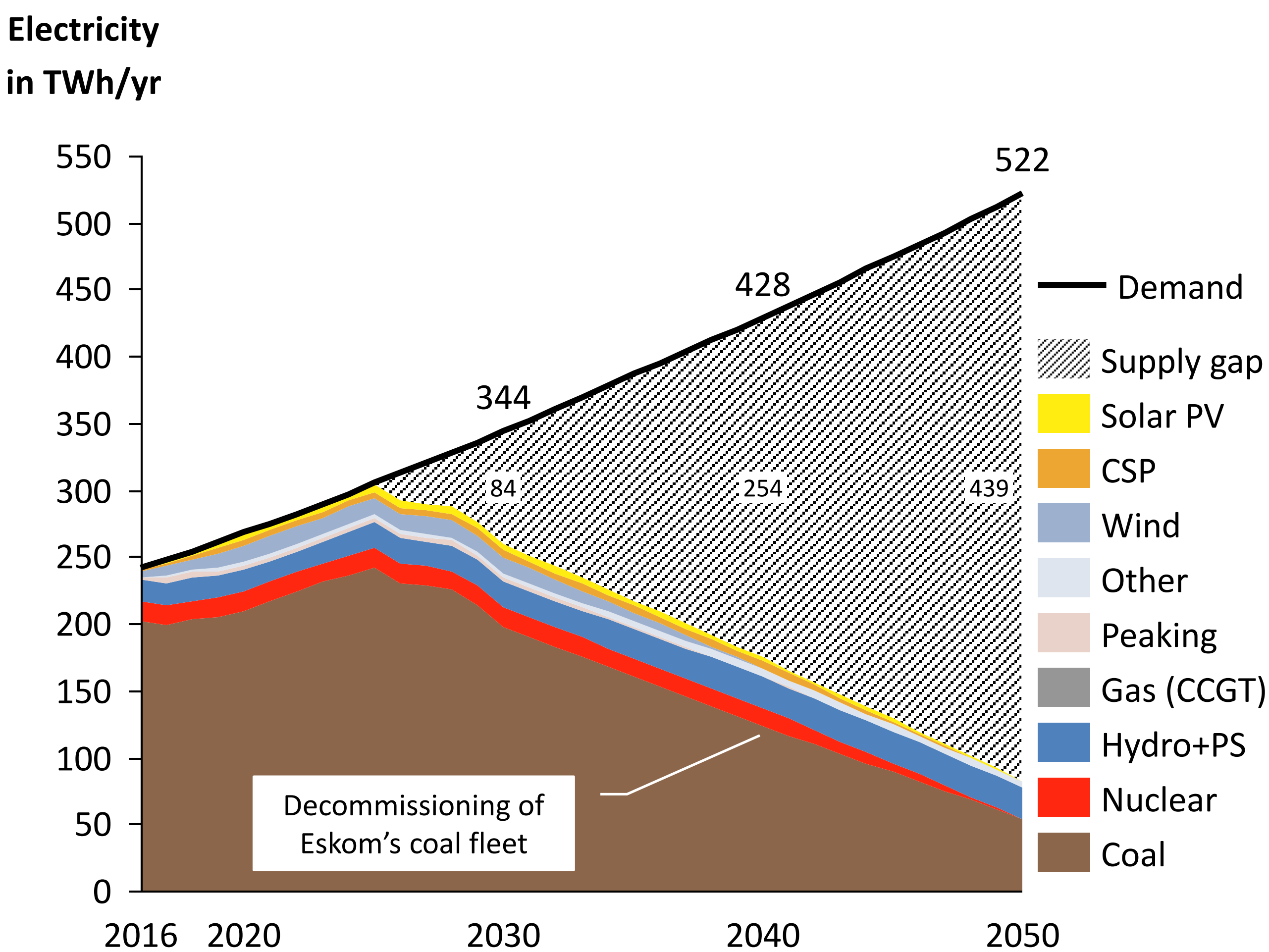
All power plants considered for "existing fleet" that are either:

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

Sources: DoE (IRP 2016); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

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 2050

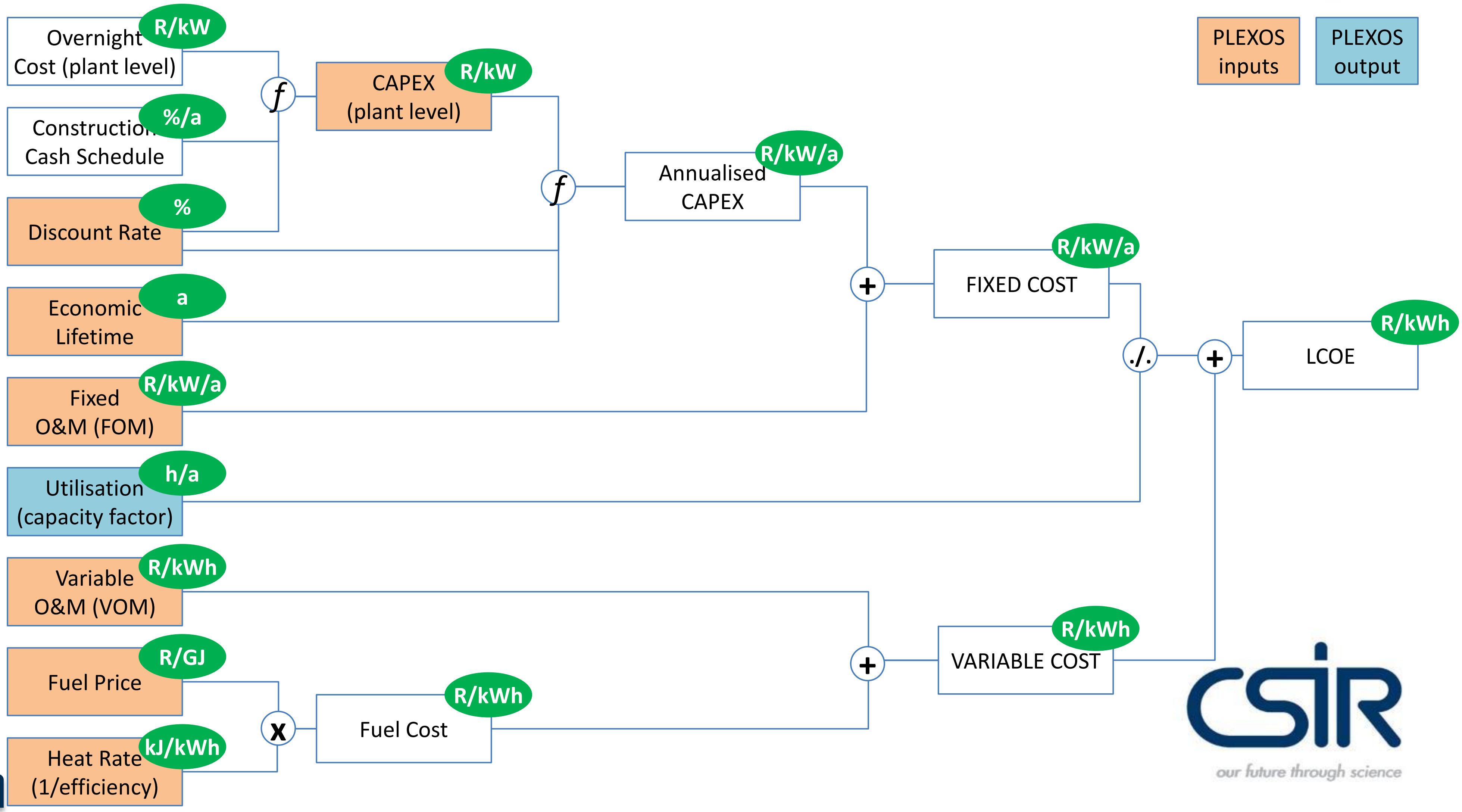


The IRP model fills the supply gap in the least-cost manner, subject to any constraints imposed on the model

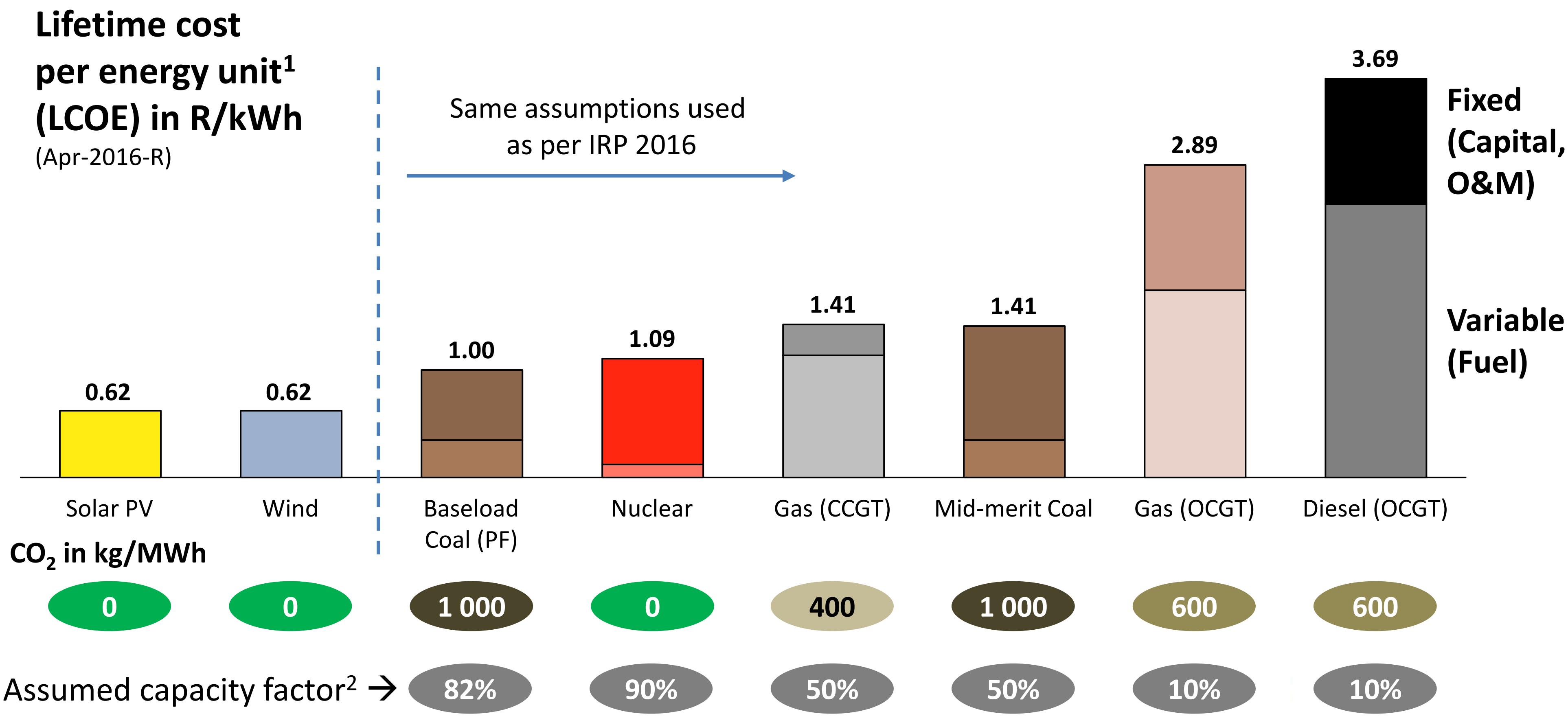
Note: All power plants considered for "existing fleet" that are either Existing in 2016, Under construction, or Procured (preferred bidder)

Sources: DoE (IRP 2016); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis

PLEXOS actual inputs are individual cost items that together with the utilisation of the plant (a model output) allow to calculate LCOE

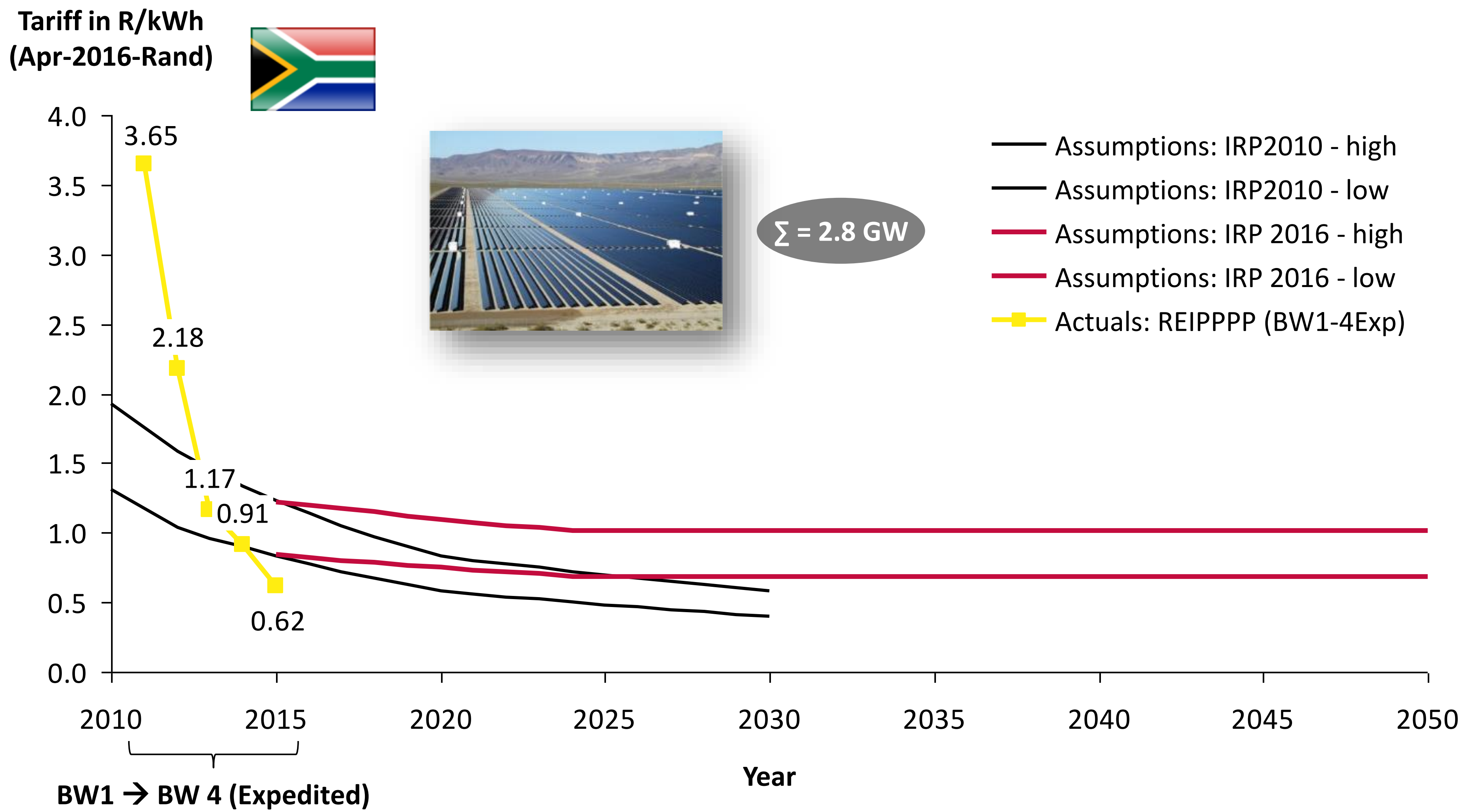


Inputs as per IRP 2016:
Key resulting LCOE from cost assumptions for new supply technologies



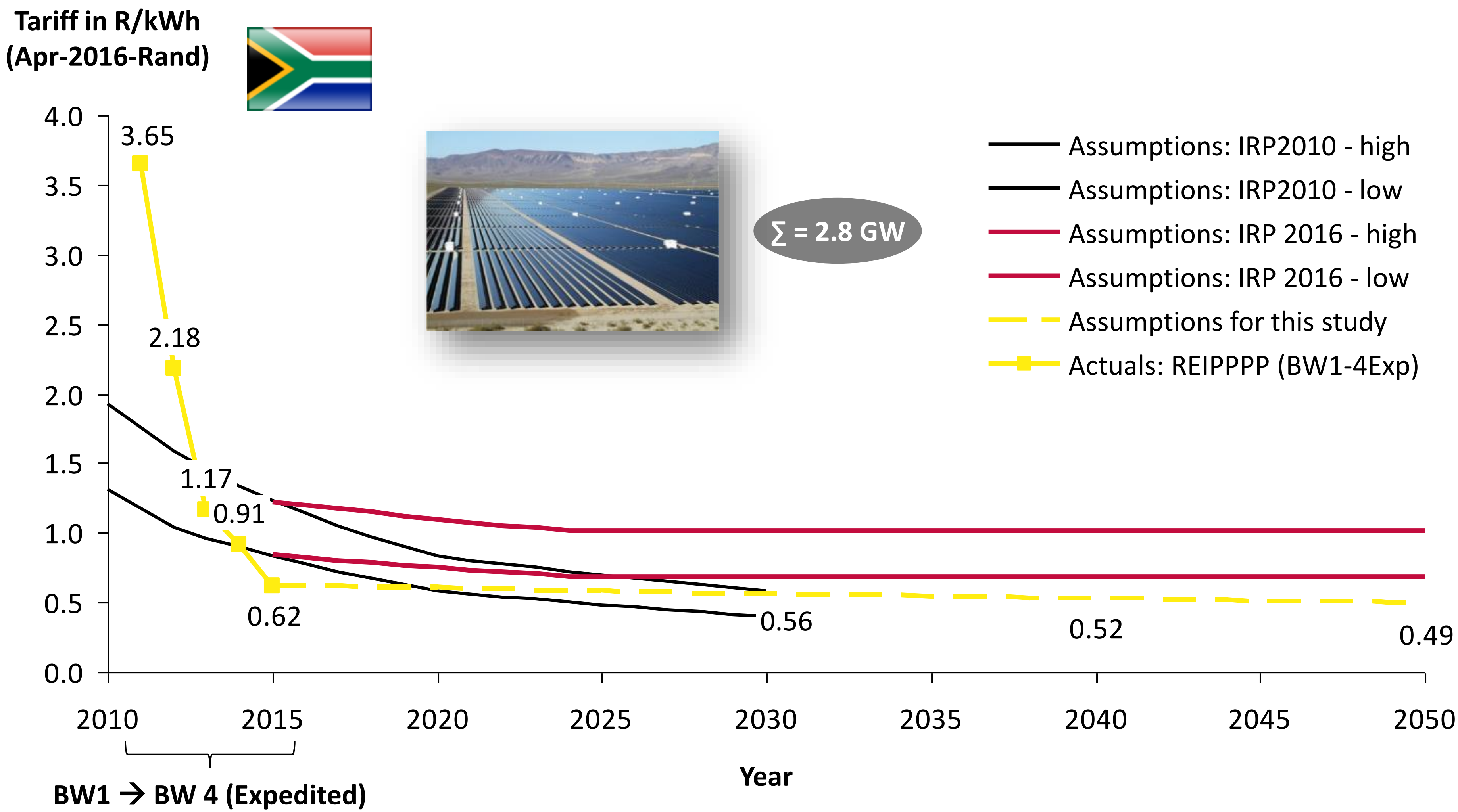
[1] Lifetime cost per energy unit is only presented for brevity. The model inherently includes the specific cost structures of each technology i.e. capex, Fixed O&M, variable O&M, fuel costs etc.
[2] Changing full-load hours for new-build options drastically changes the fixed cost components per kWh (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

IRP 2016 increases cost assumptions for solar PV compared to 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 Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis

CSIR study cost input assumptions for solar PV:
Future cost assumptions for solar PV aligned with IRP 2010



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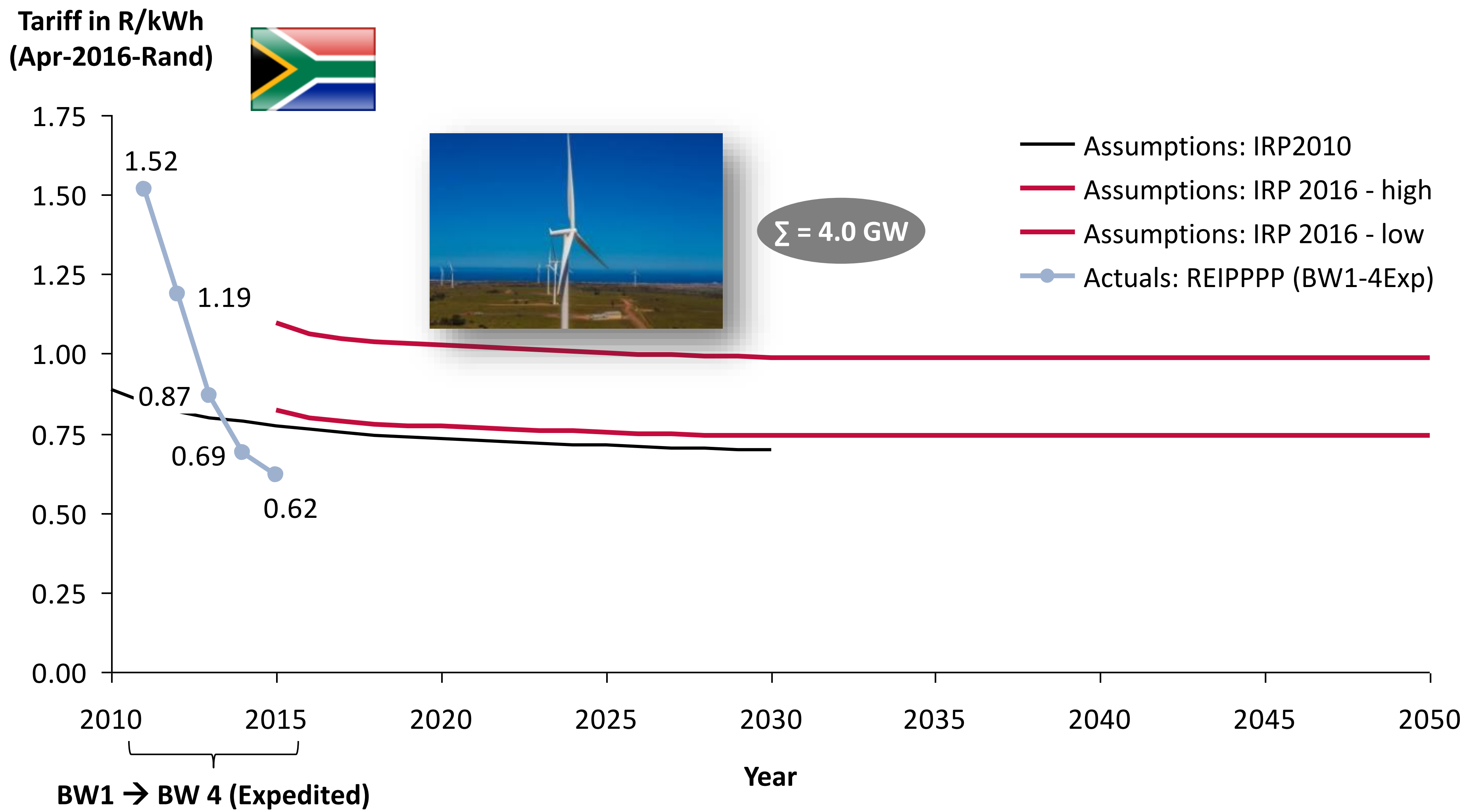
IRP 2016 increases cost assumptions for wind compared to IRP 2010



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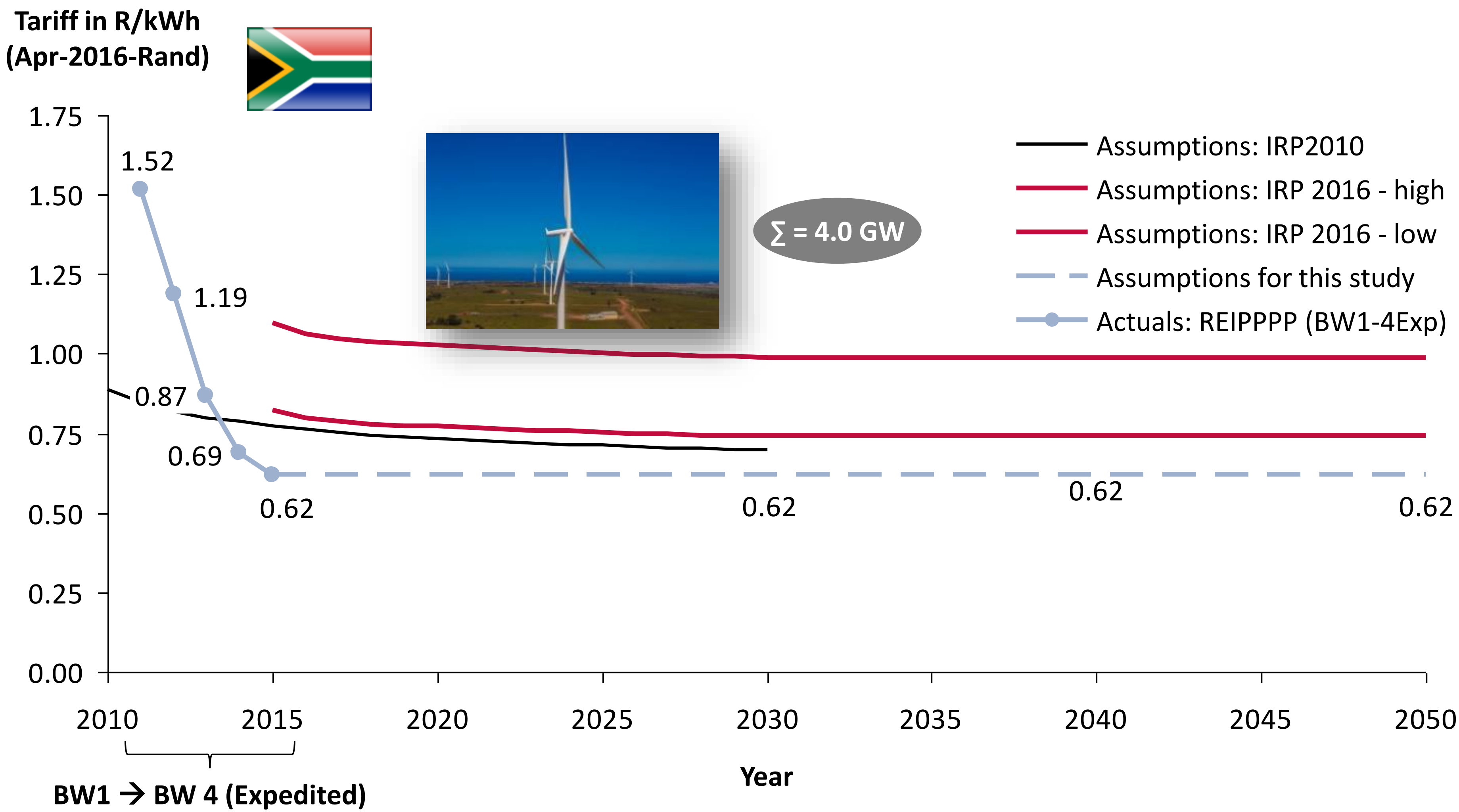
CSIR study cost input assumptions for wind:
Future cost assumptions for wind aligned with results of Bid Window 4



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

The CSIR conducted a Wind and Solar PV Resource Aggregation Study

CSIR, SANEDI, Eskom and Fraunhofer IWES conducted a joint study to holistically quantify

- the wind-power potential in South Africa and
- the portfolio effects of widespread spatial wind and solar power aggregation in South Africa

Wind Atlas South Africa (WASA) data was used to simulate wind power across South Africa

Solar Radiation Data (SoDa) was used to simulate solar PV power across South Africa

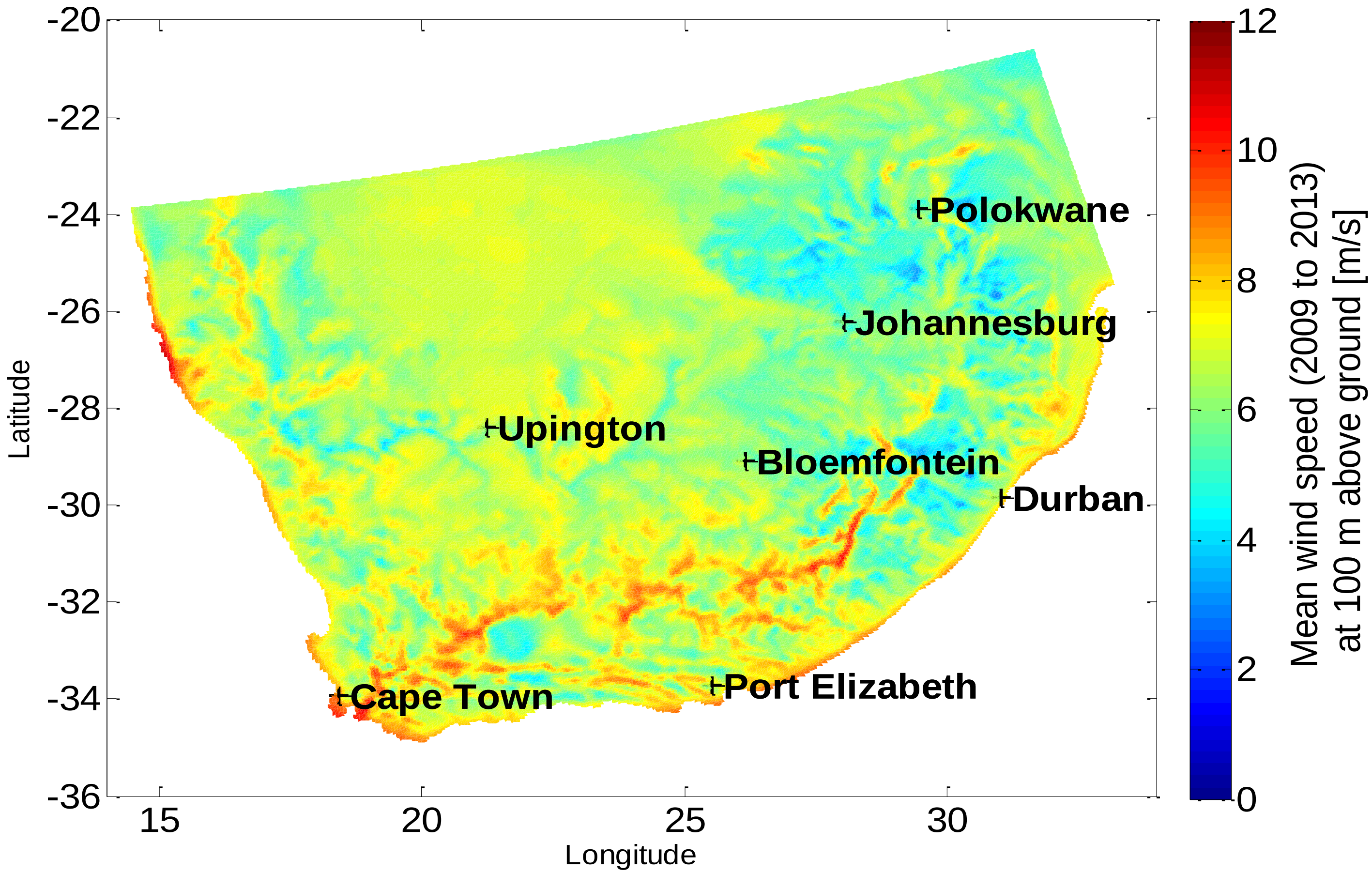
Output: Simulated time-synchronous solar PV and wind power production time-series

- 5 km x 5 km spatial resolution
- Almost 50,000 pixels covering entire South Africa
- 15-minute temporal resolution
- 5 years temporal coverage (2009-2013)

Sources: https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf; https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf

South Africa has wide areas with > 6 m/s average wind speed @ 100 m

Average wind speed at 100 meter above ground for the years from 2009-2013 for South Africa



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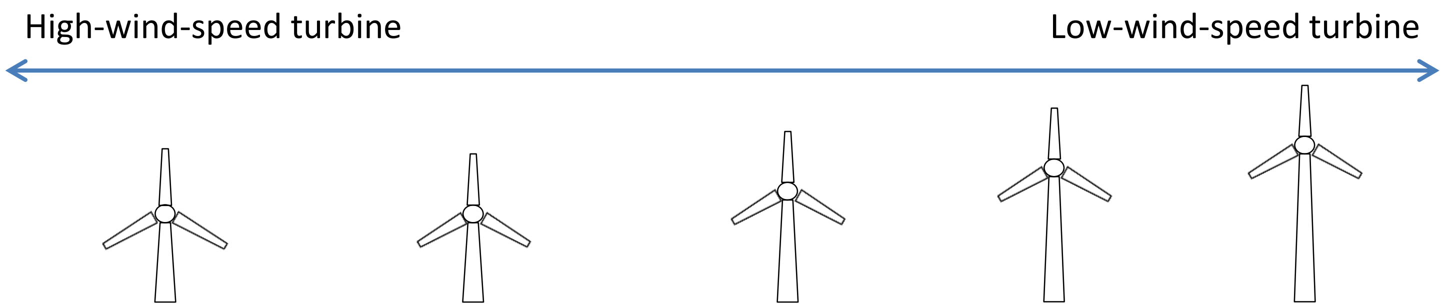
Sources: https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf; https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf

Five different generic wind turbine types defined for simulation of wind power output per 5x5 km pixel in South Africa (~50 000 pixels)



Turbine type no.	1	2	3	4	5
Nominal power [MW]	3	2.2	2.4	2.4	2.4
Selection criterion	$\bar{v}_{80m} > 8.5\frac{m}{s}$	$\bar{v}_{80m} < 8.5\frac{m}{s}$ and $\bar{v}_{100m} > 7.5\frac{m}{s}$	$\bar{v}_{100m} < 7.5\frac{m}{s}$	$\bar{v}_{120m} < 7.5\frac{m}{s}$	$\bar{v}_{140m} < 7.5\frac{m}{s}$
Blade diameter [m]	90	95	117	117	117
Hub height [m]	80	80	100	120	140

Space requirement 0.1km²/MW
→ max. 250 MW per pixel

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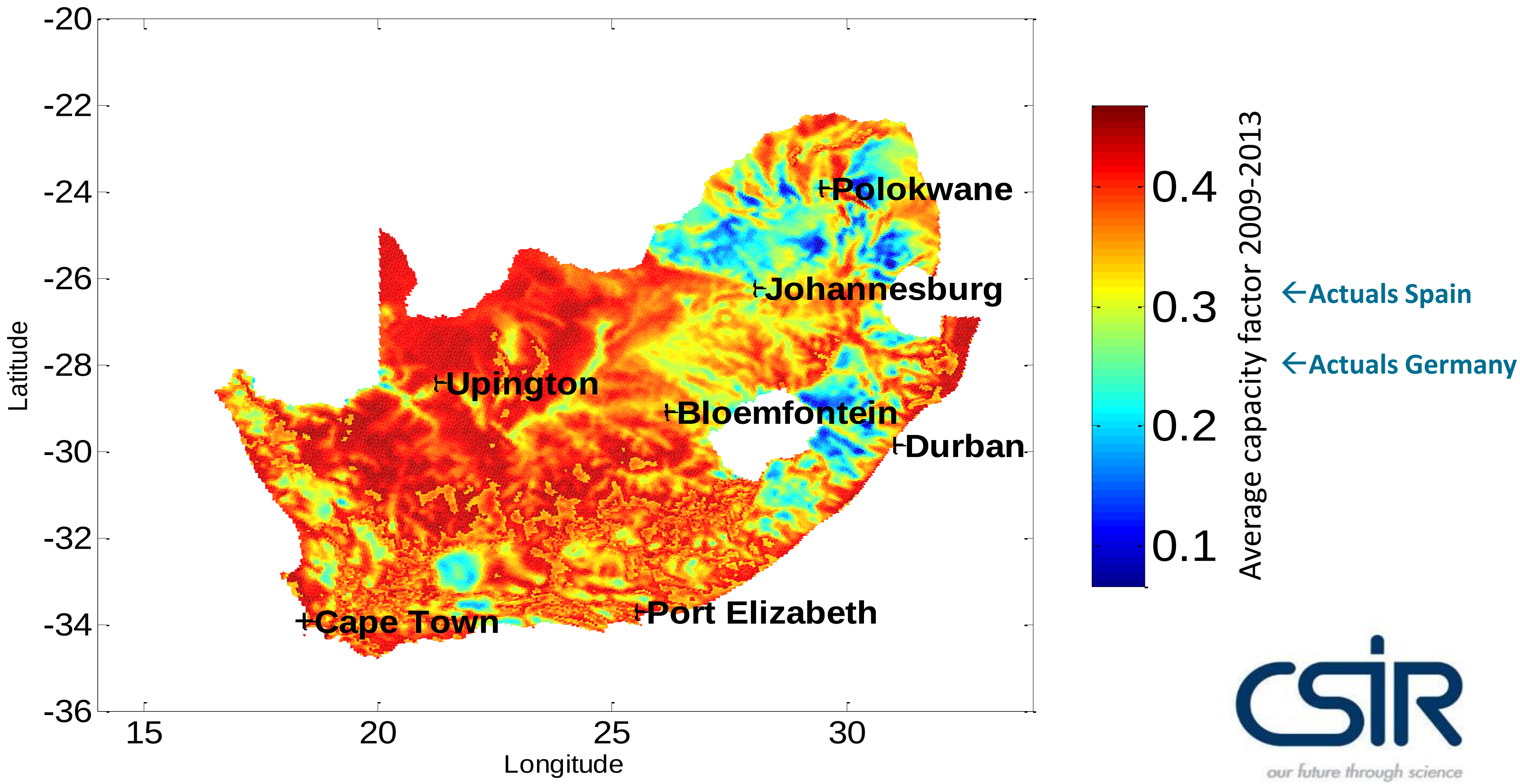
Sources: https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf; https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf

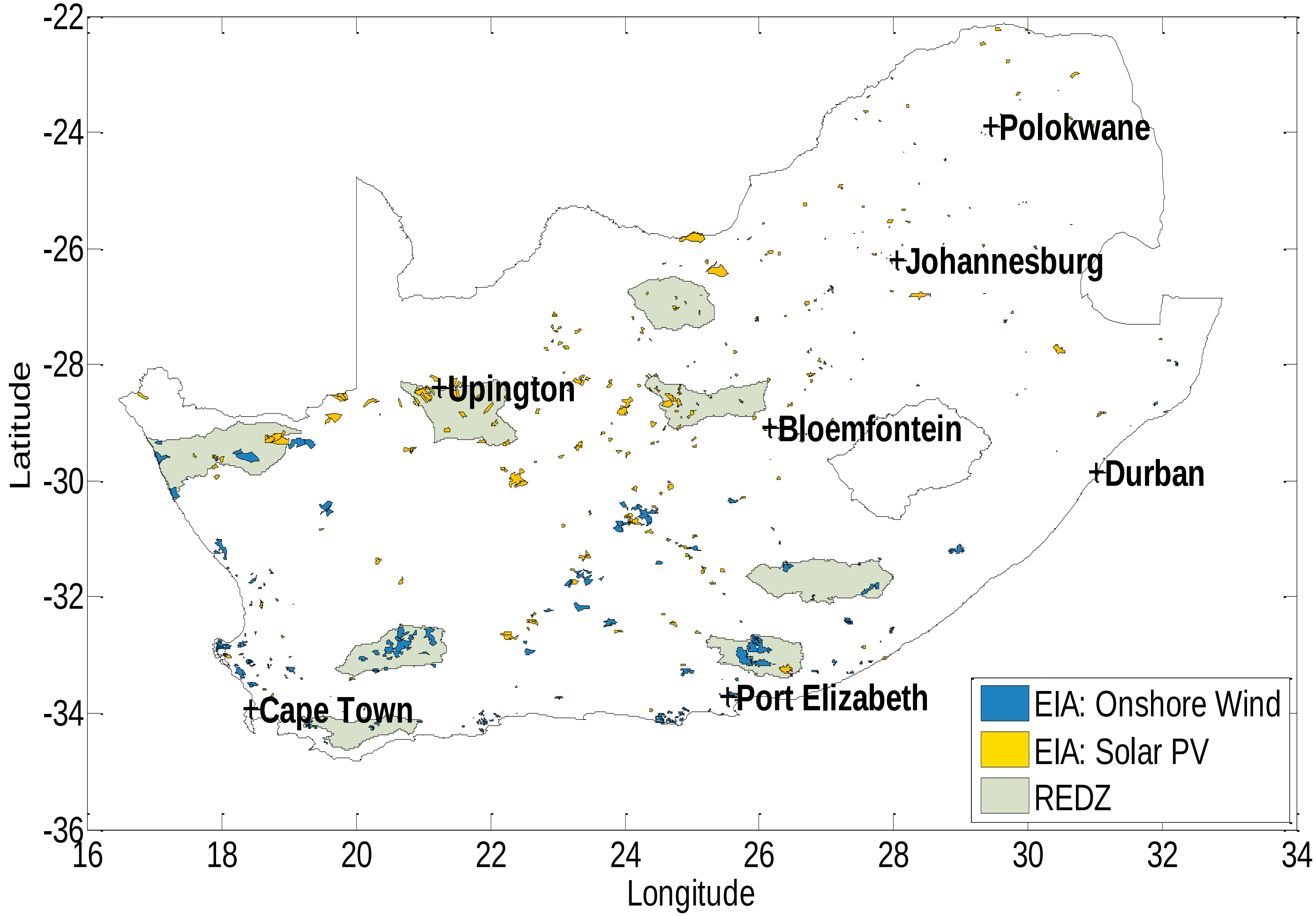
One outcome of the study:
More than 30% capacity factor achievable almost everywhere in RSA

Achievable average wind capacity factors for 2009-2013 for turbine types 1-5



Sources: https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf;
https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf

Areas already applied for Environmental Impact Assessments can cater for 90 / 330 wind / solar PV capacity



All EIAs
(status early 2016)

Wind: 90 GW
Solar PV: 330 GW

All REDZ
(phase 1)

Wind: 535 GW
Solar PV: 1 782 GW

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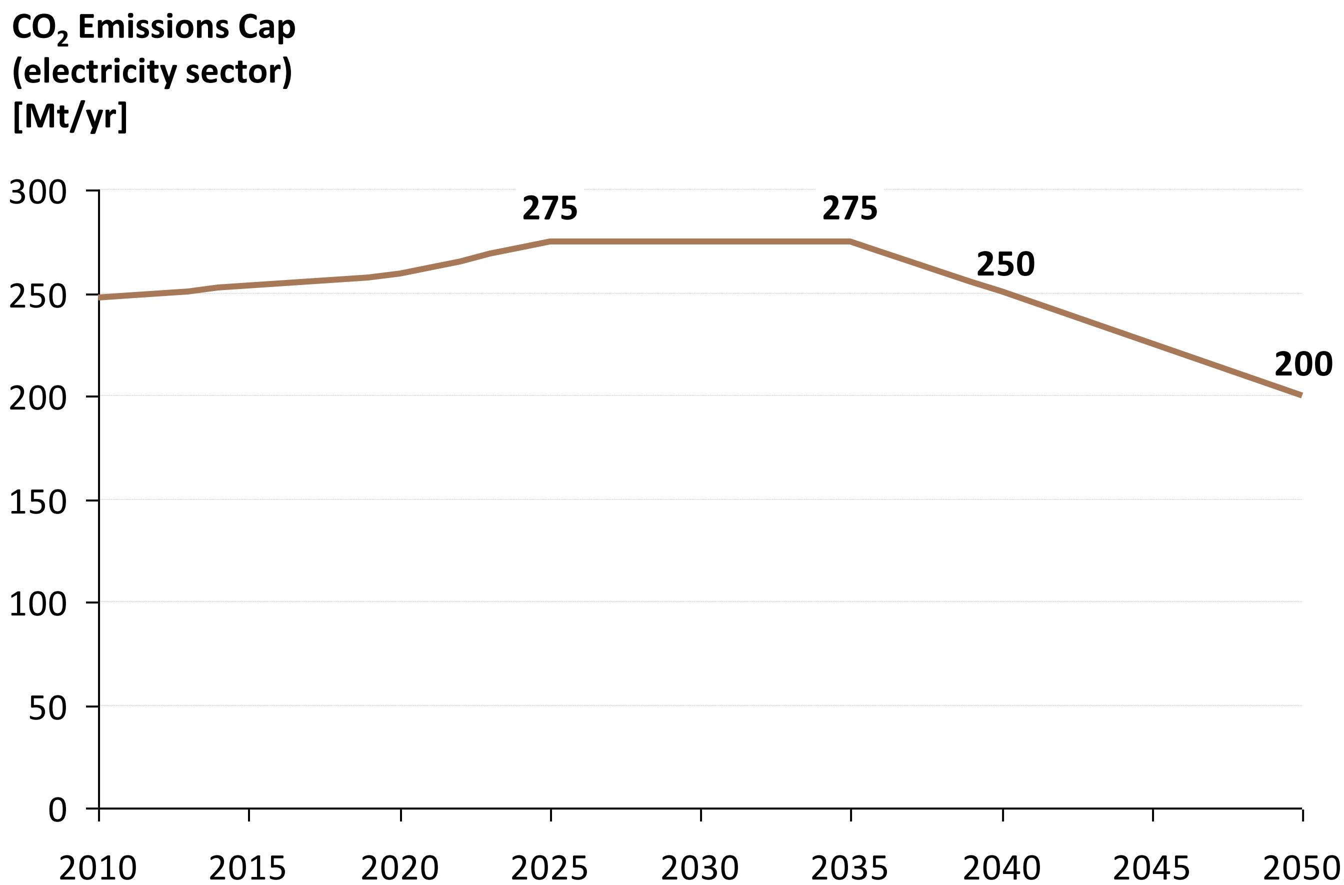
Sources: https://www.csir.co.za/sites/default/files/Documents/Wind_and_PV_Aggregation_study_final_presentation_REV1.pdf;
https://www.csir.co.za/sites/default/files/Documents/Wind%20and%20Solar%20PV%20Resource%20Aggregation%20Study%20for%20South%20Africa_Final%20report.pdf

CO_2 emissions constrained by RSA's Peak-Plateau-Decline objective

PPD that constrains CO_2 emission from electricity sector



PPD = Peak Plateau Decline

Sources: DoE IRP 2016; StatsSA; CSIR analysis

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- Input Assumptions
- Results

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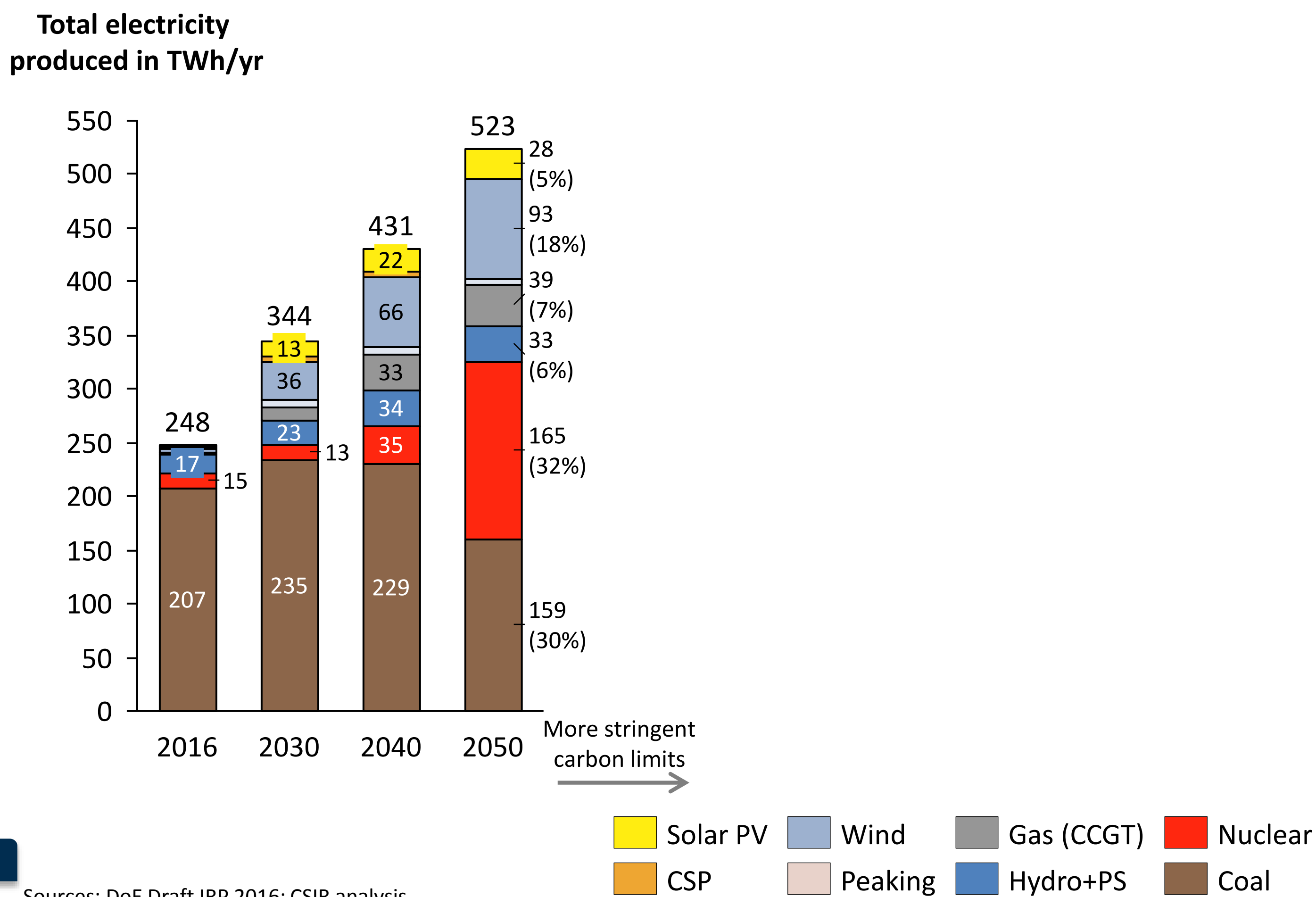
Draft IRP 2016 Base Case is a mix of roughly 1/3 coal, nuclear, RE each

As per Draft IRP 2016

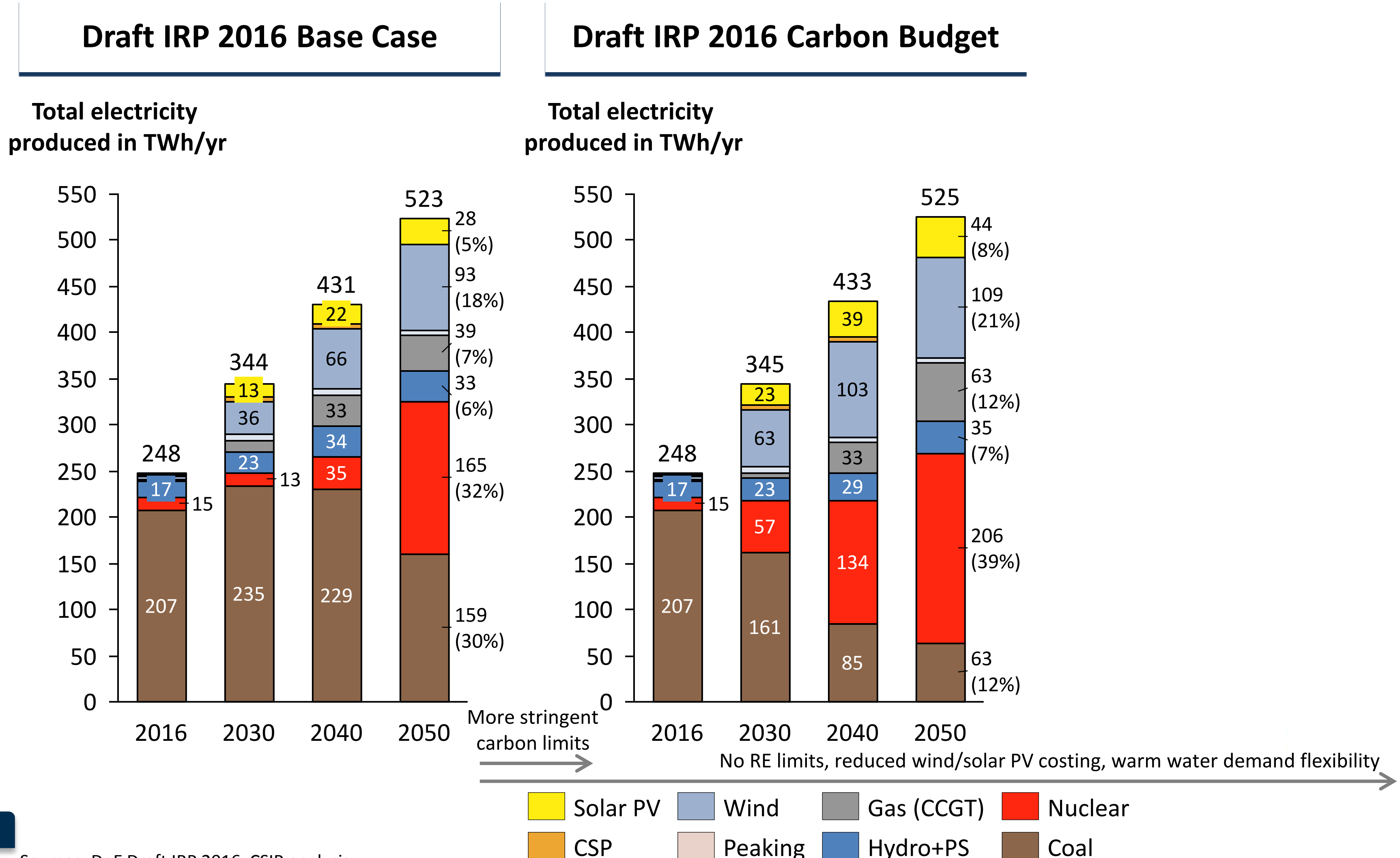
Draft IRP 2016 Base Case



Sources: DoE Draft IRP 2016; CSIR analysis

Draft IRP 2016 Carbon Budget case: 40% nuclear energy share by 2050

As per Draft IRP 2016



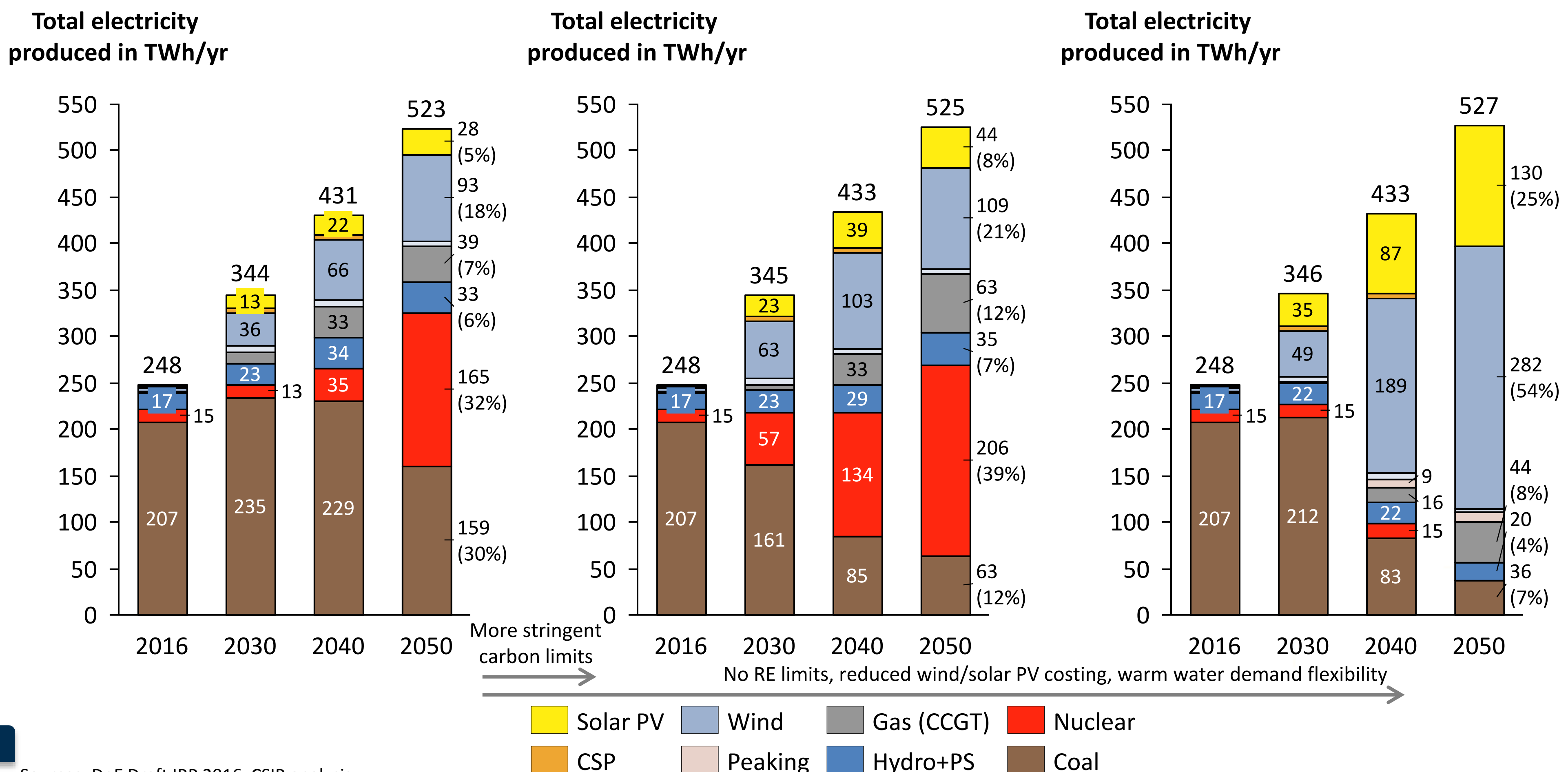
Sources: DoE Draft IRP 2016; CSIR analysis

Least Cost case is largely based on wind and solar PV

Preliminary results

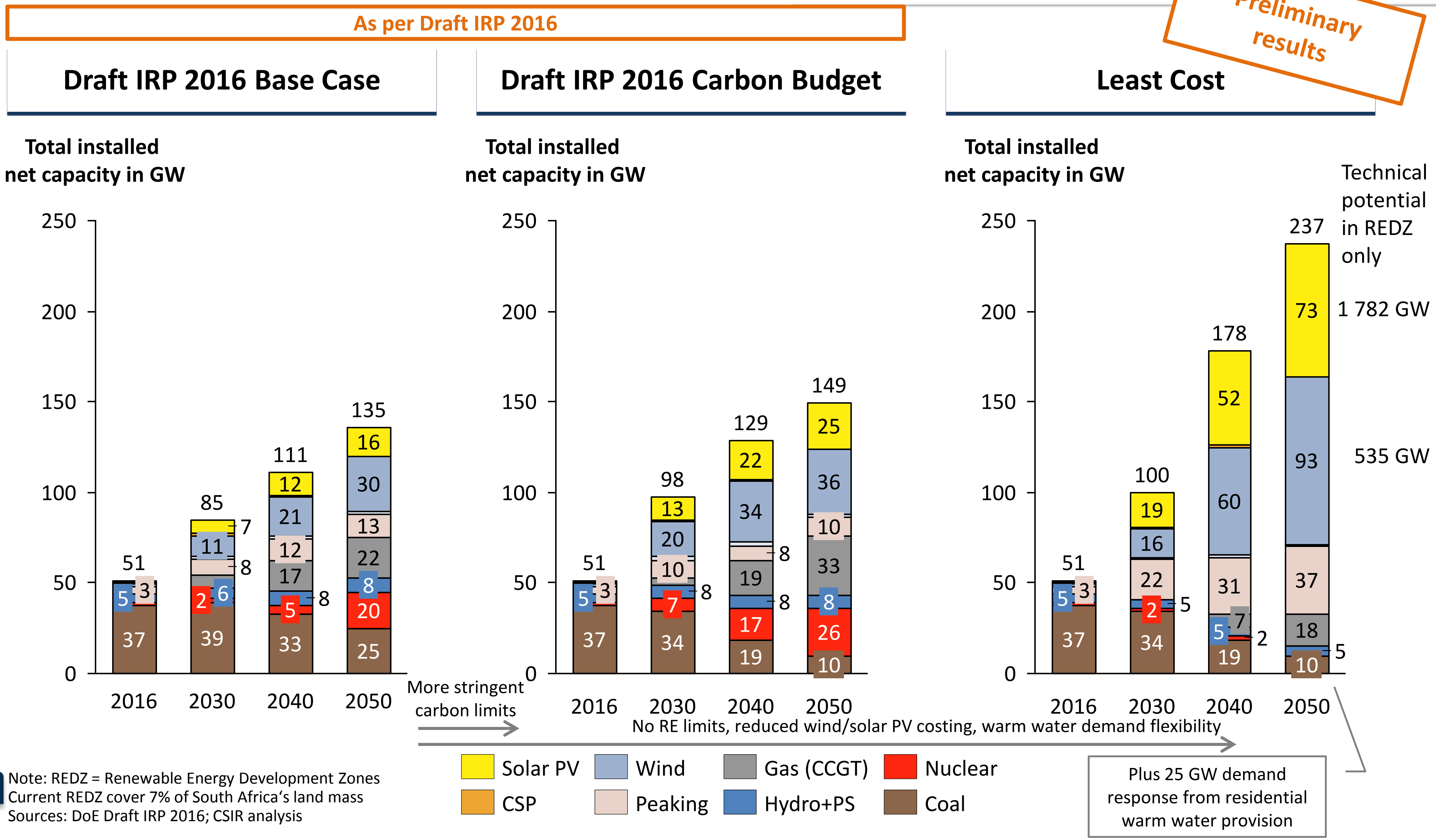
As per Draft IRP 2016

Draft IRP 2016 Base Case	Draft IRP 2016 Carbon Budget	Least Cost



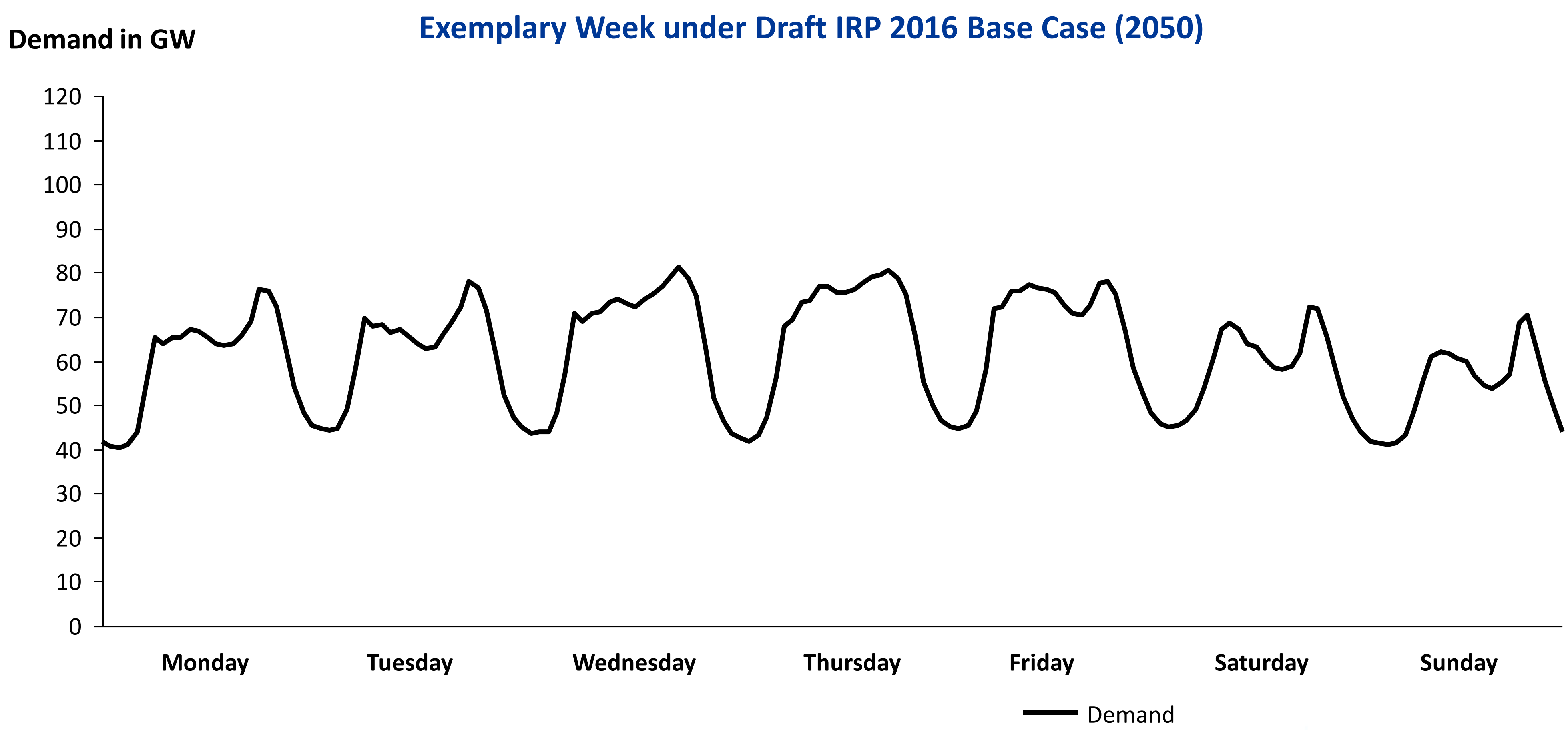
Sources: DoE Draft IRP 2016; CSIR analysis

Least Cost means no new coal and no new nuclear until 2050, instead 90 GW of wind and 70 GW of solar PV plus flexible capacities



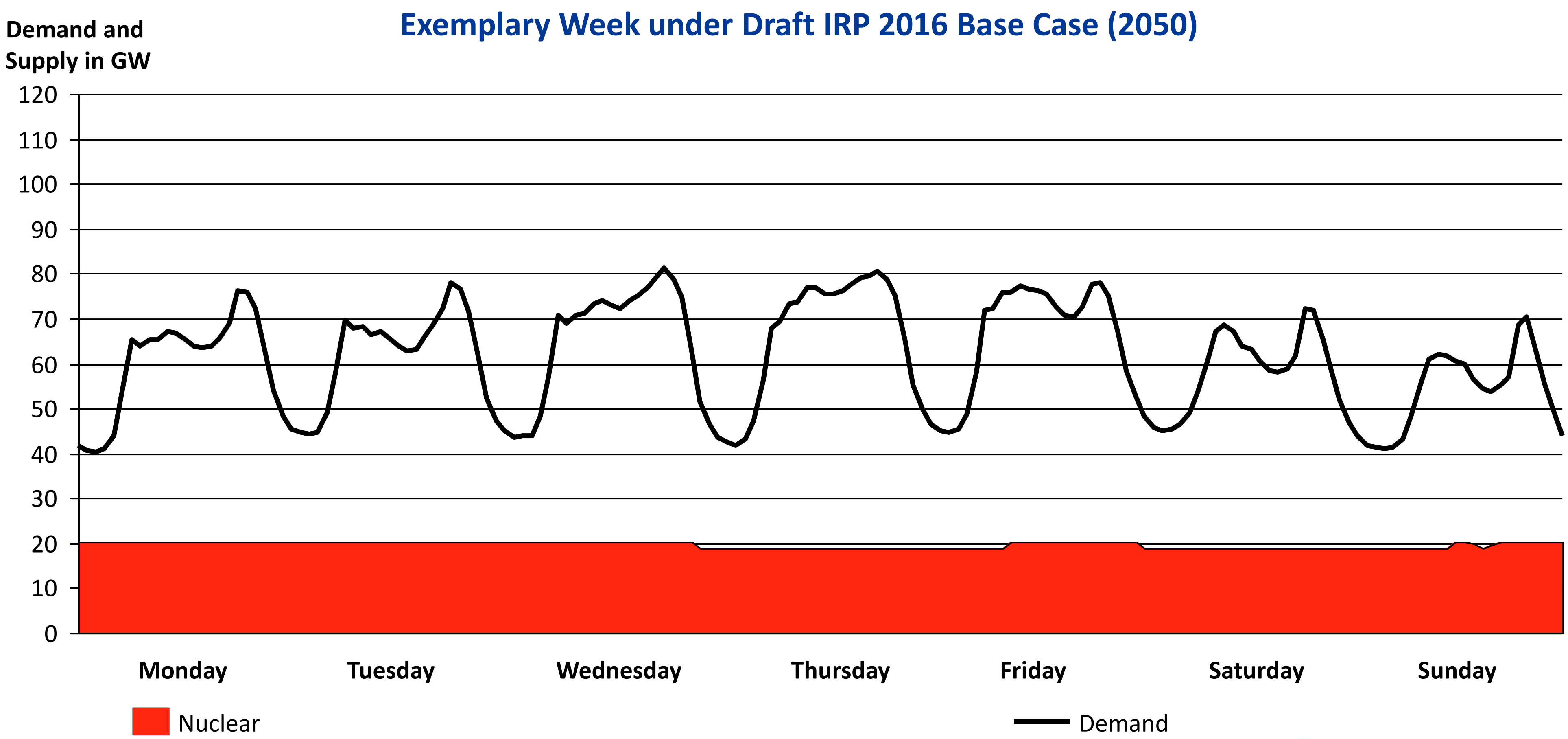
Note: REDZ = Renewable Energy Development Zones
Current REDZ cover 7% of South Africa's land mass
Sources: DoE Draft IRP 2016; CSIR analysis

Draft IRP 2016 Base Case:
Weekly electricity demand profile in 2050



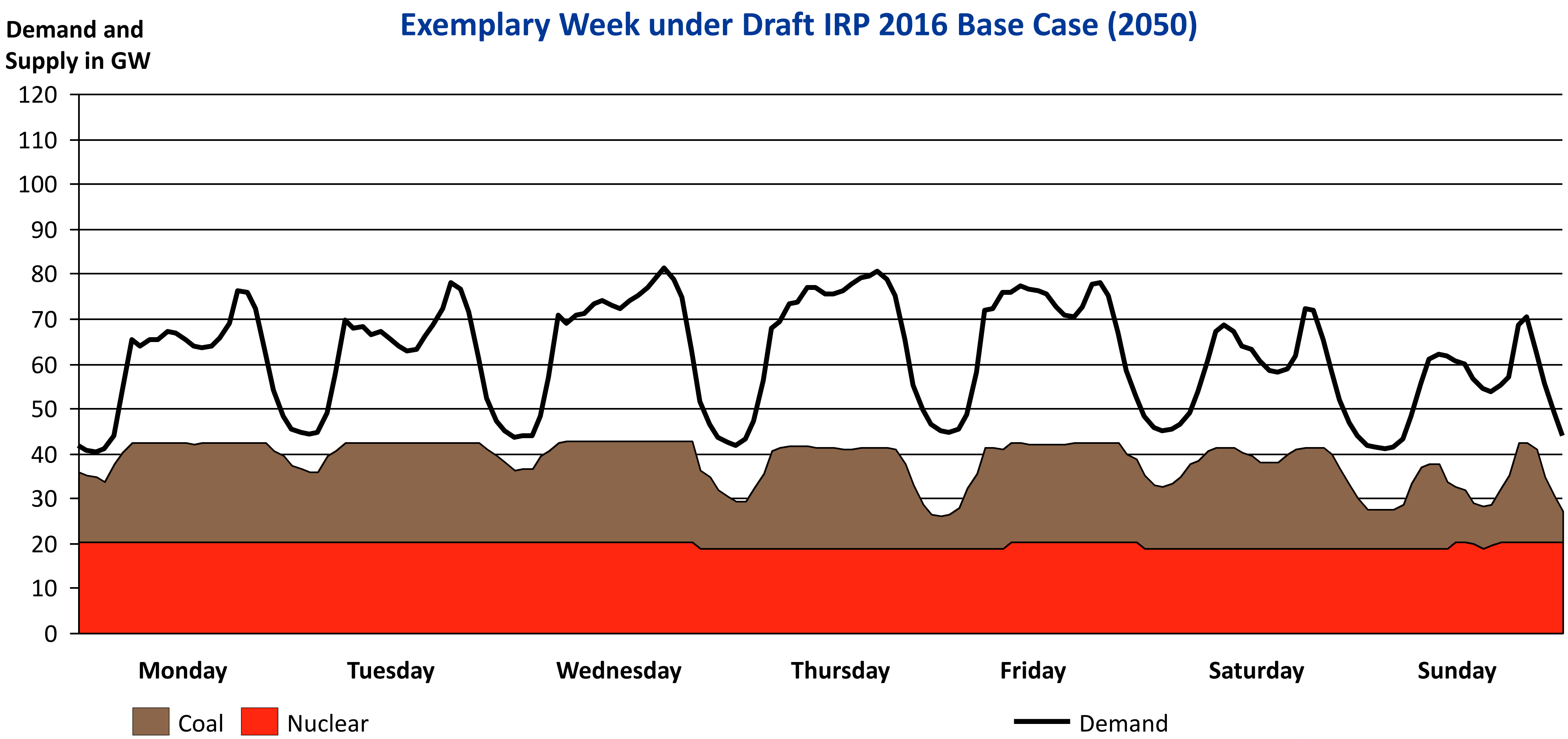
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Draft IRP 2016 Base Case:
Nuclear and coal dominate the supply mix in 2050



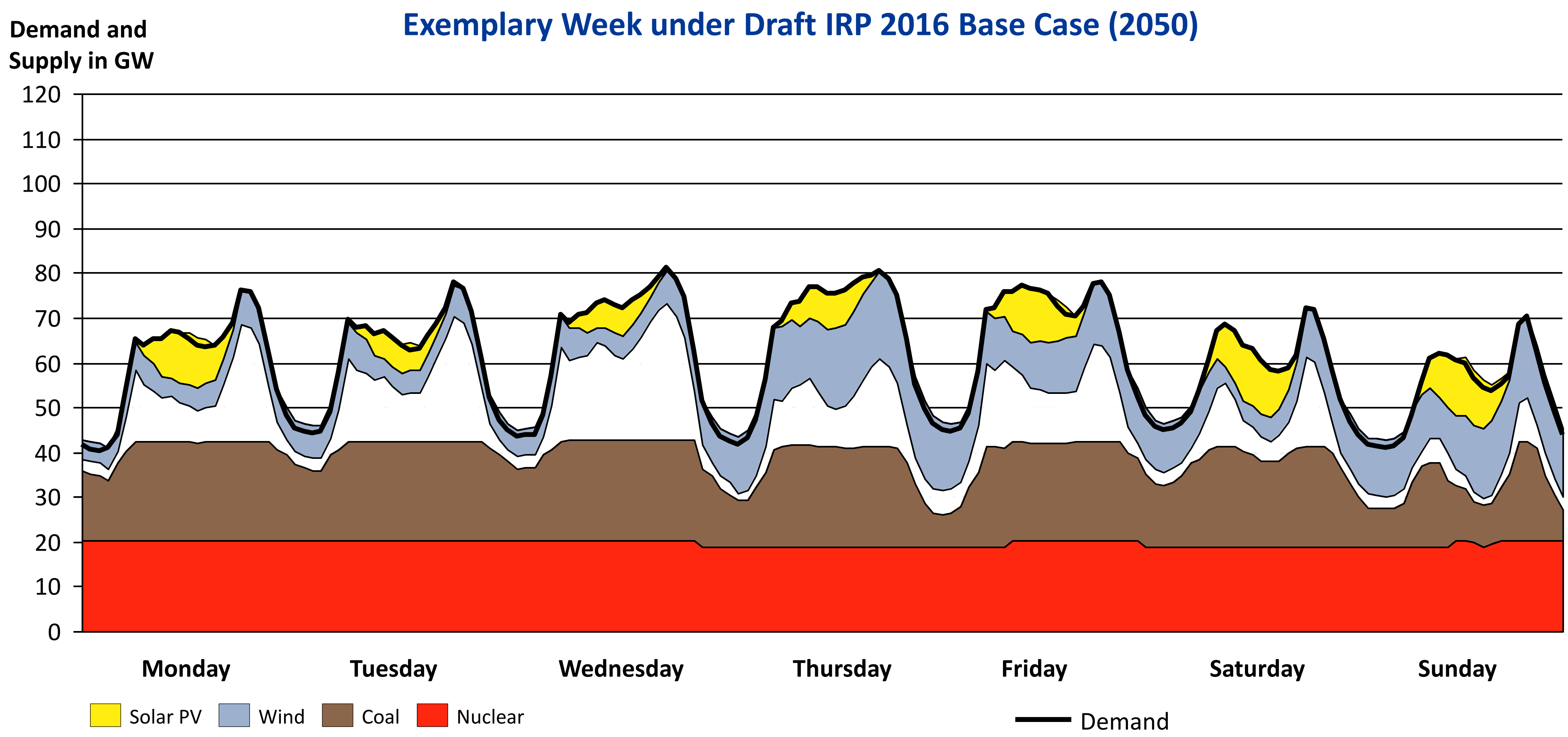
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Draft IRP 2016 Base Case: Nuclear and coal dominate the supply mix in 2050



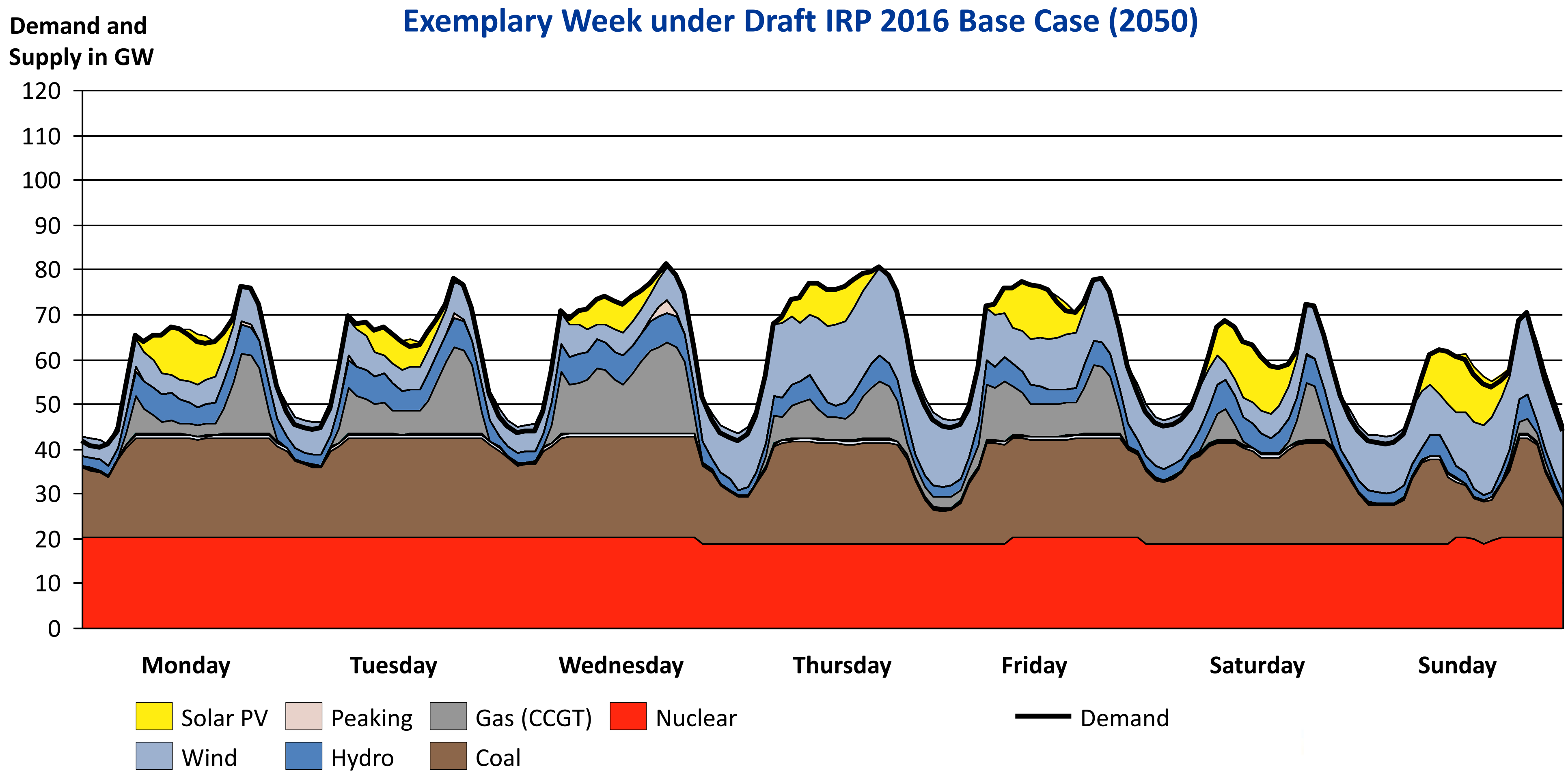
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Draft IRP 2016 Base Case:
Nuclear and coal dominate the supply mix in 2050



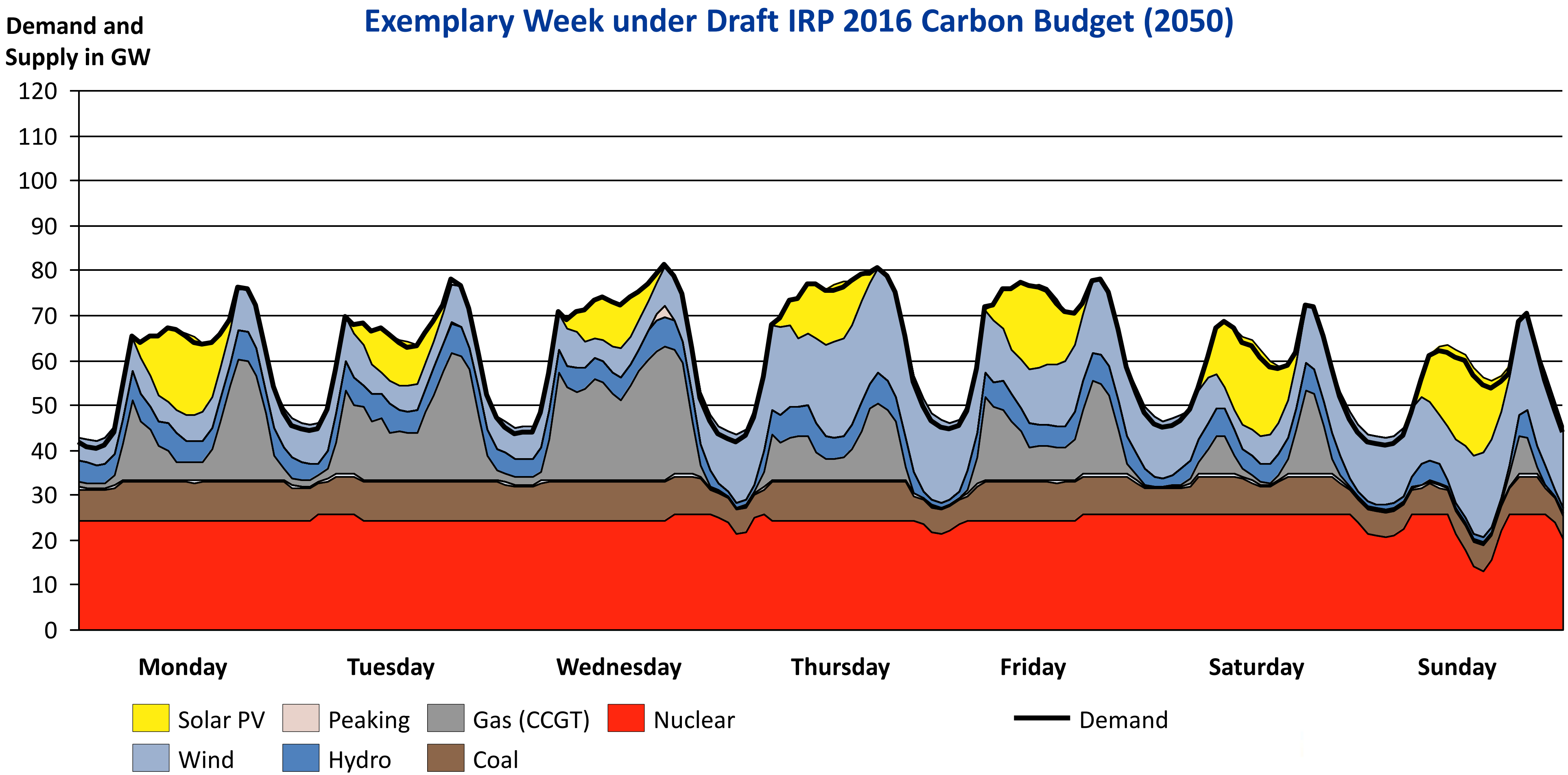
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Draft IRP 2016 Base Case:
Nuclear and coal dominate the supply mix in 2050



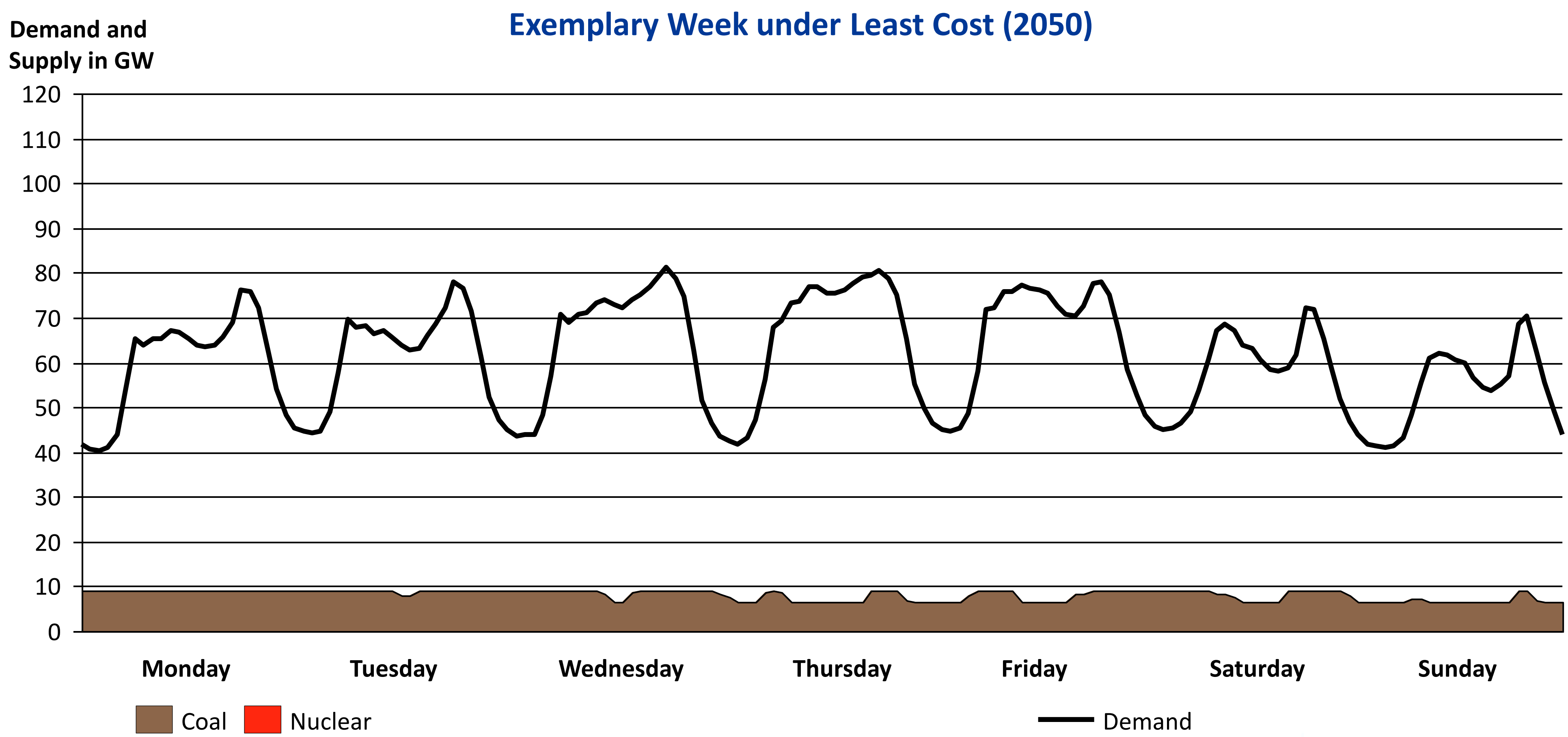
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Draft IRP 2016 Carbon Budget:
Nuclear dominates the supply mix in 2050, gas required for balancing



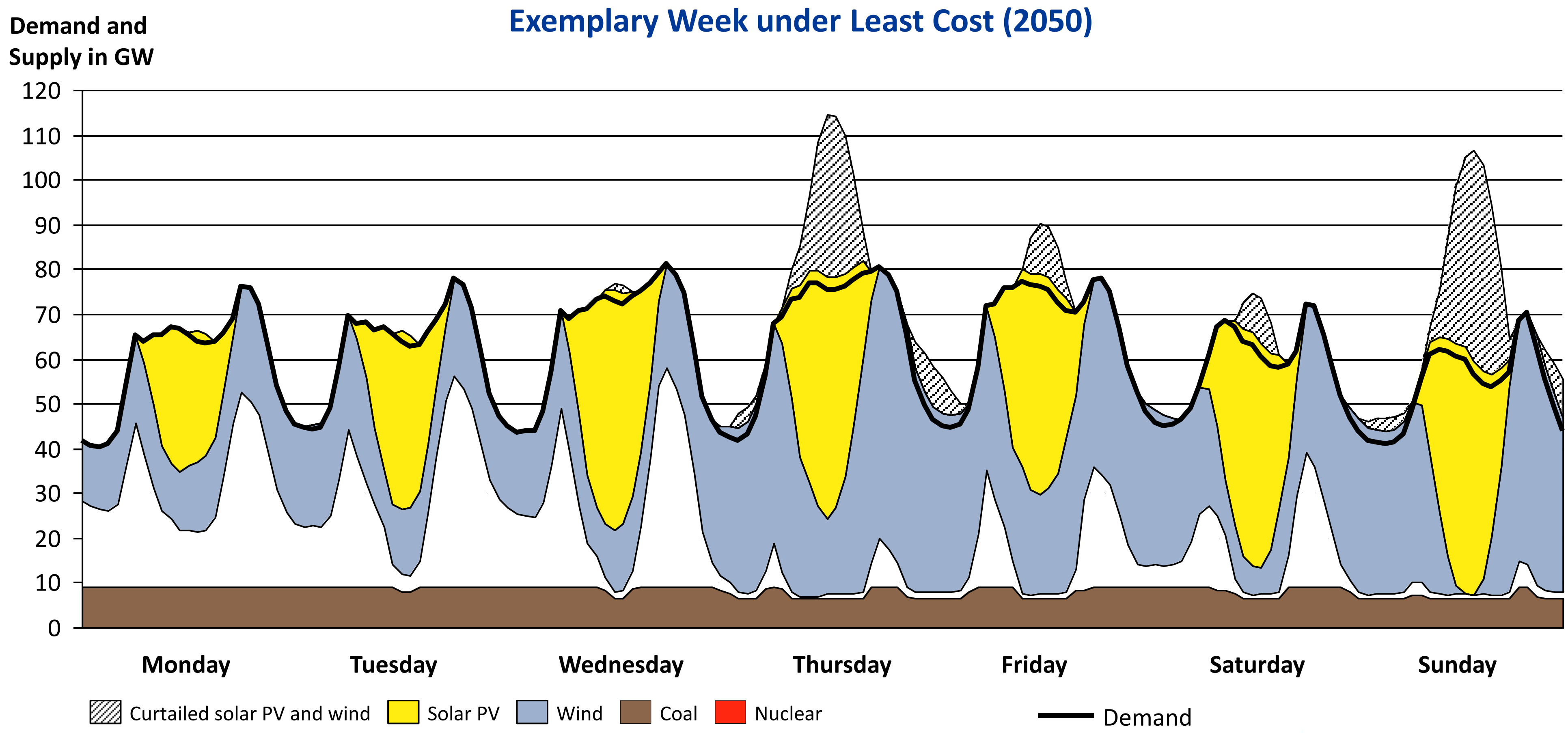
Sources: CSIR analysis, based on DoE's Draft IRP 2016

Least Cost:
Medupi, Kusile and Coal IPPs will still produce constant power by 2050



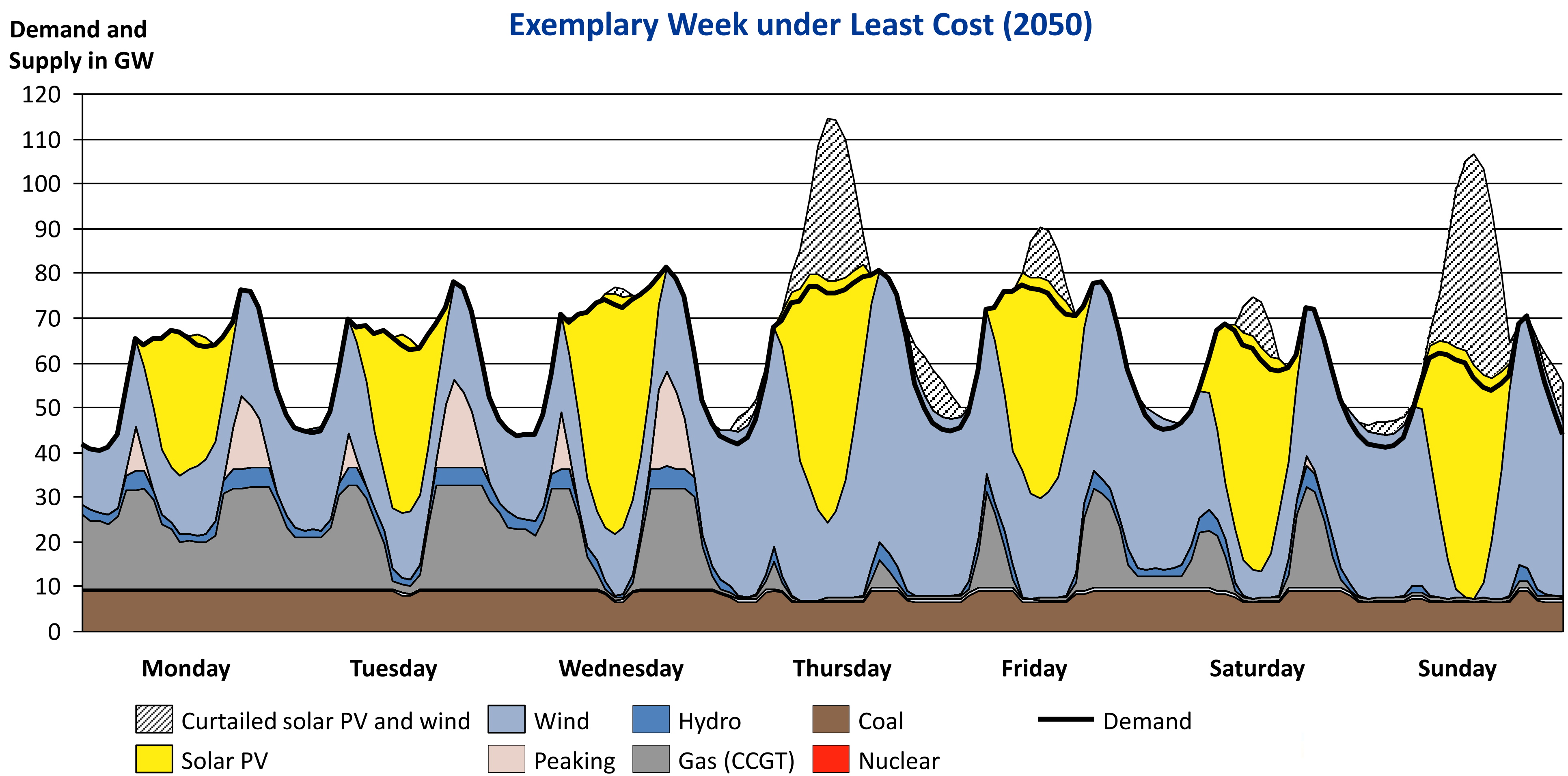
Sources: CSIR analysis

Least Cost:
Solar PV and wind dominate supply mix in 2050, with excess at times



Sources: CSIR analysis

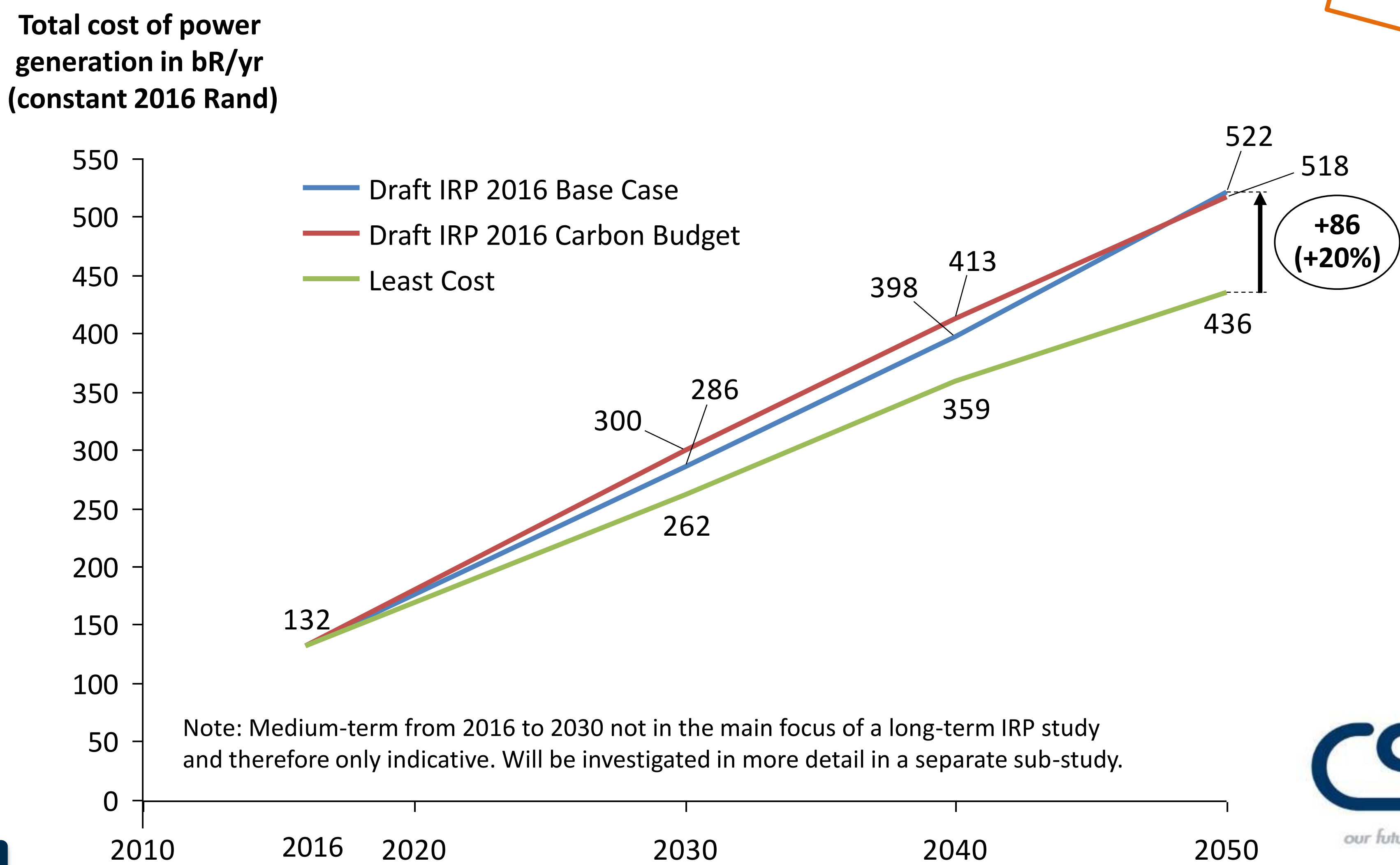
Least Cost:
Solar PV and wind dominate supply mix in 2050, with excess at times



Sources: CSIR analysis

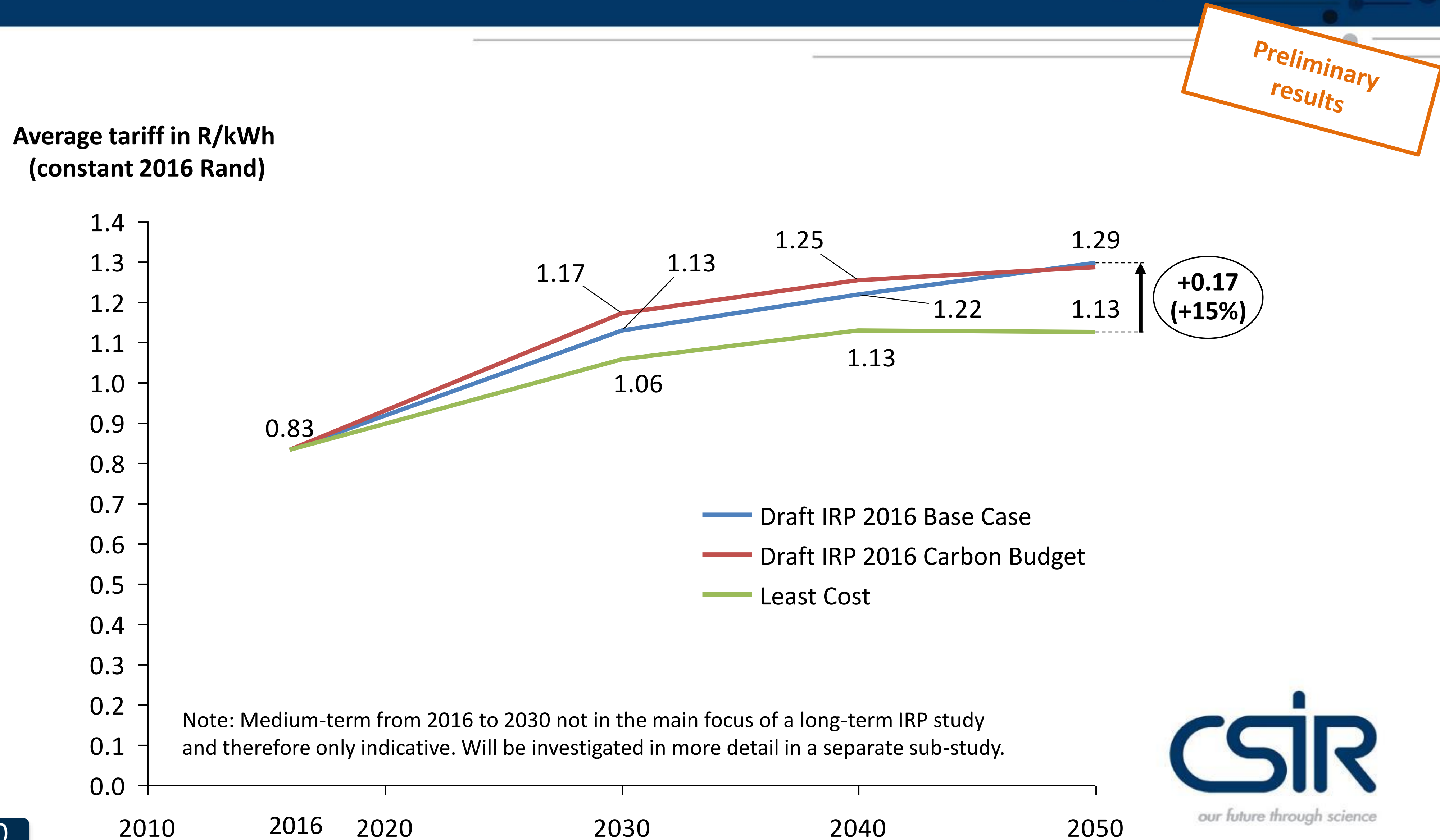
Total cost of power generation: Draft IRP 2016 Base Case R86 bn/year more expensive by 2050 than Least Cost (without cost of CO_2)

Preliminary results



Sources: CSIR analysis

Average tariff (<u>without</u> cost of CO_2): Draft IRP Base Case tariff 17 cents/kWh higher than Least Cost by 2050



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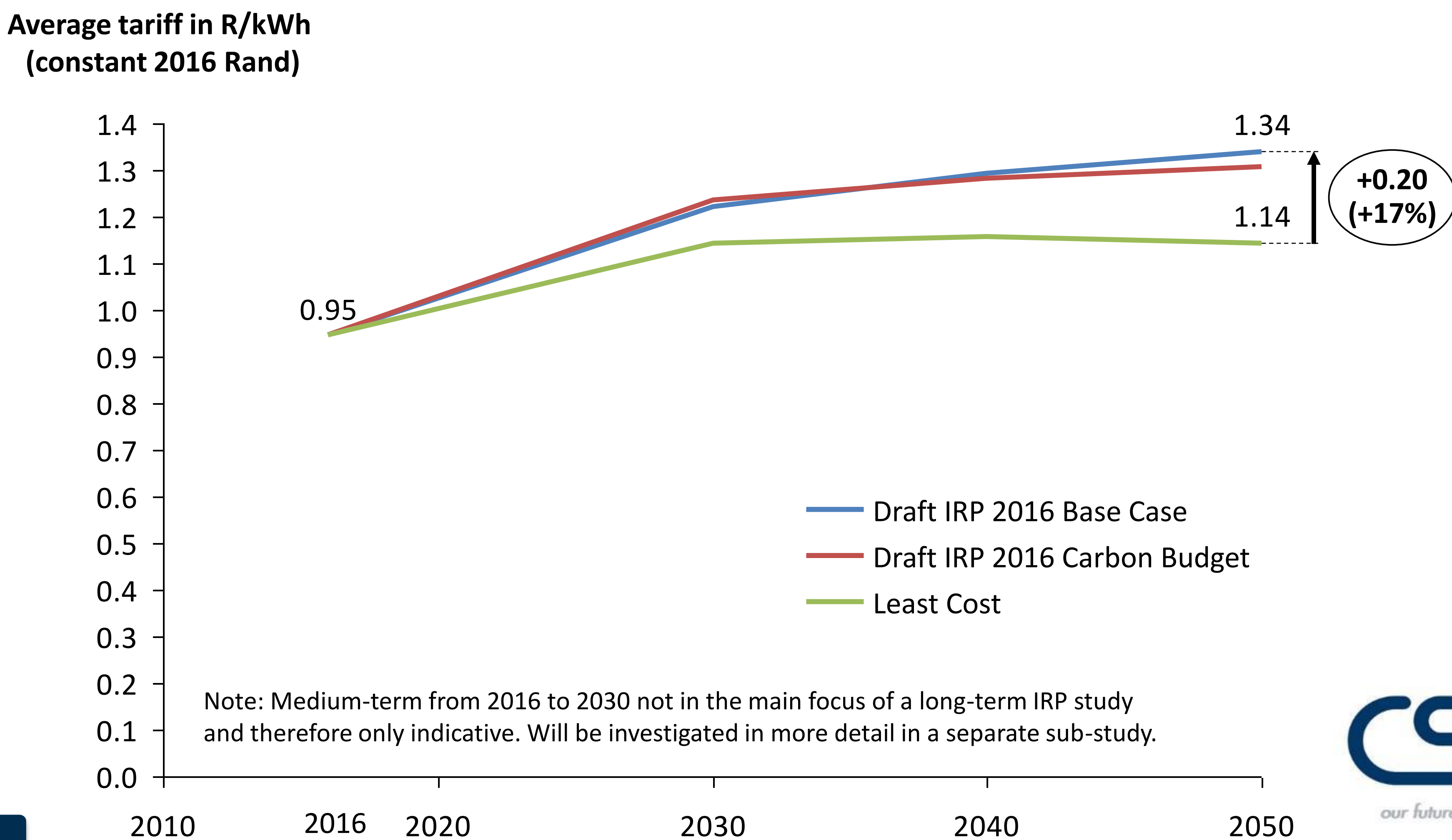
Note: Average tariff projections include 0.30 R/kWh for transmission, distribution and customer service (today's average cost for these items) Sources: Eskom on Tx, Dx cost; CSIR analysis

Average tariff (<u>with</u> cost of CO_2): Draft IRP Base Case tariff 20 cents/kWh higher than Least Cost by 2050

Preliminary results



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Note: Average tariff projections include 0.30 R/kWh for transmission, distribution and customer service (today's average cost for these items) Sources: Eskom on Tx, Dx cost; CSIR analysis

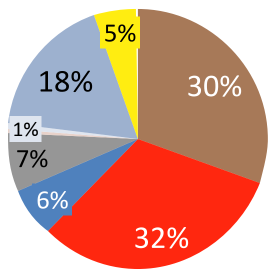
Least Cost without renewables limits is R82-86 billion/yr cheaper by 2050 than IRP 2016 Base Case and IRP 2016 Carbon Budget case

Preliminary results for the year 2050

As per Draft IRP 2016

Draft IRP 2016 Base Case

~525 TWh/yr



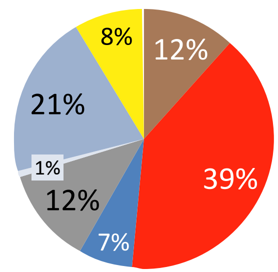
R522 billion/yr
Ø tariff = 1.29 R/kWh

CO_2 200 Mt/yr

38 bn l/yr

Draft IRP 2016 Carbon Budget

~525 TWh/yr



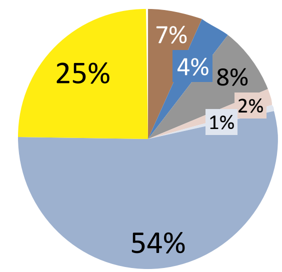
R518 billion/yr
Ø tariff = 1.29 R/kWh

CO_2 100 Mt/yr

16 bn l/yr

Least Cost

~525 TWh/yr



R436 billion/yr
Ø tariff = 1.13 R/kWh

CO_2 70 Mt/yr

9 bn l/yr

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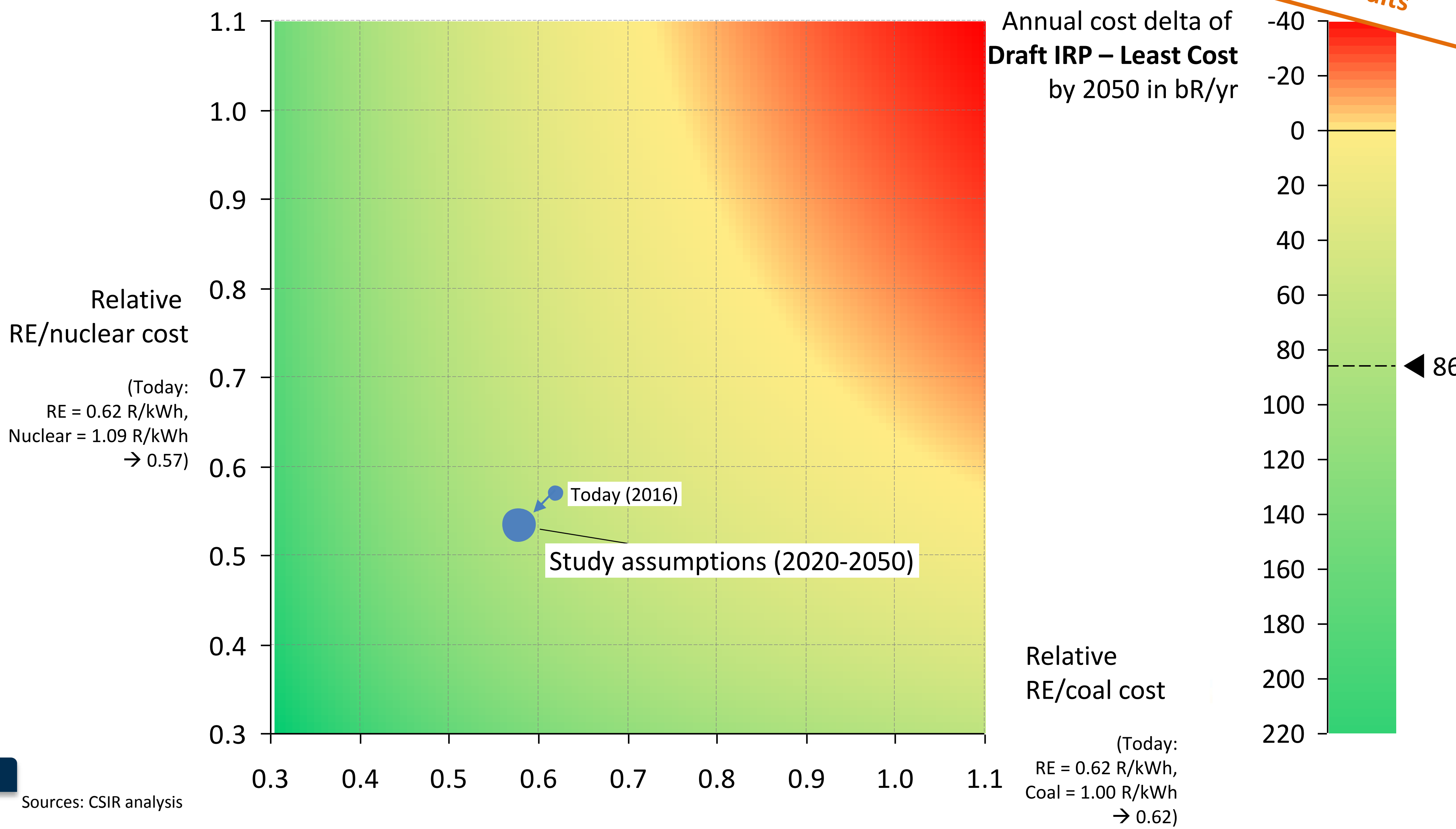
Coal | Nuclear | Hydro + Pumped Storage | Gas (CCGT) | Peaking | Other | Wind | CSP | Solar PV

Note: Average tariff projections include 0.30 R/kWh for transmission, distribution and customer service (today's average cost for these items)   Sources: Eskom on Tx, Dx cost; CSIR analysis

Sensitivity on cost difference: Even if RE were 50% more expensive than assumed, Least Cost is still cheaper than Draft IRP 2016 Base Case

Preliminary results



Sources: CSIR analysis

Agenda

Background

CSIR's Approach and Project Team

Comments on IRP Assumptions

IRP Results and Least-cost Scenario

Summary

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Summary:
A mix of solar PV, wind and flexible power generators is least cost

It is cost-optimal to aim for >70% renewable energy share by 2050

- Solar PV, wind and flexible power generators (e.g. gas, CSP, hydro, biogas, demand response) are the cheapest new-build mix for the South African power system
- There is no technical limitation to solar PV and wind penetration over the planning horizon until 2050

"Clean" and "least-cost" is not a trade-off anymore: South Africa can de-carbonise its electricity sector at <u>negative</u> carbon-avoidance cost

- The "Least Cost" mix is ><u>R80 billion per year</u> cheaper by 2050 than the current Draft IRP 2016 Base Case
- Additionally, Least Cost mix reduces CO_2 emissions by 65% (-130 Mt/yr) over Draft IRP 2016 Base Case

The IRP and this analysis factor in all first-order cost drivers <u>within</u> the boundaries of the electricity system, but not external costs and benefits of certain electricity mixes that occur <u>outside</u> of the electricity system

Deviations from the Least Cost electricity mix can be quantified to inform policy adjustments
(e.g. forcing in of certain technologies not selected by the least-cost mix like coal, nuclear, pumped storage, CSP, biogas, biomass, etc.)

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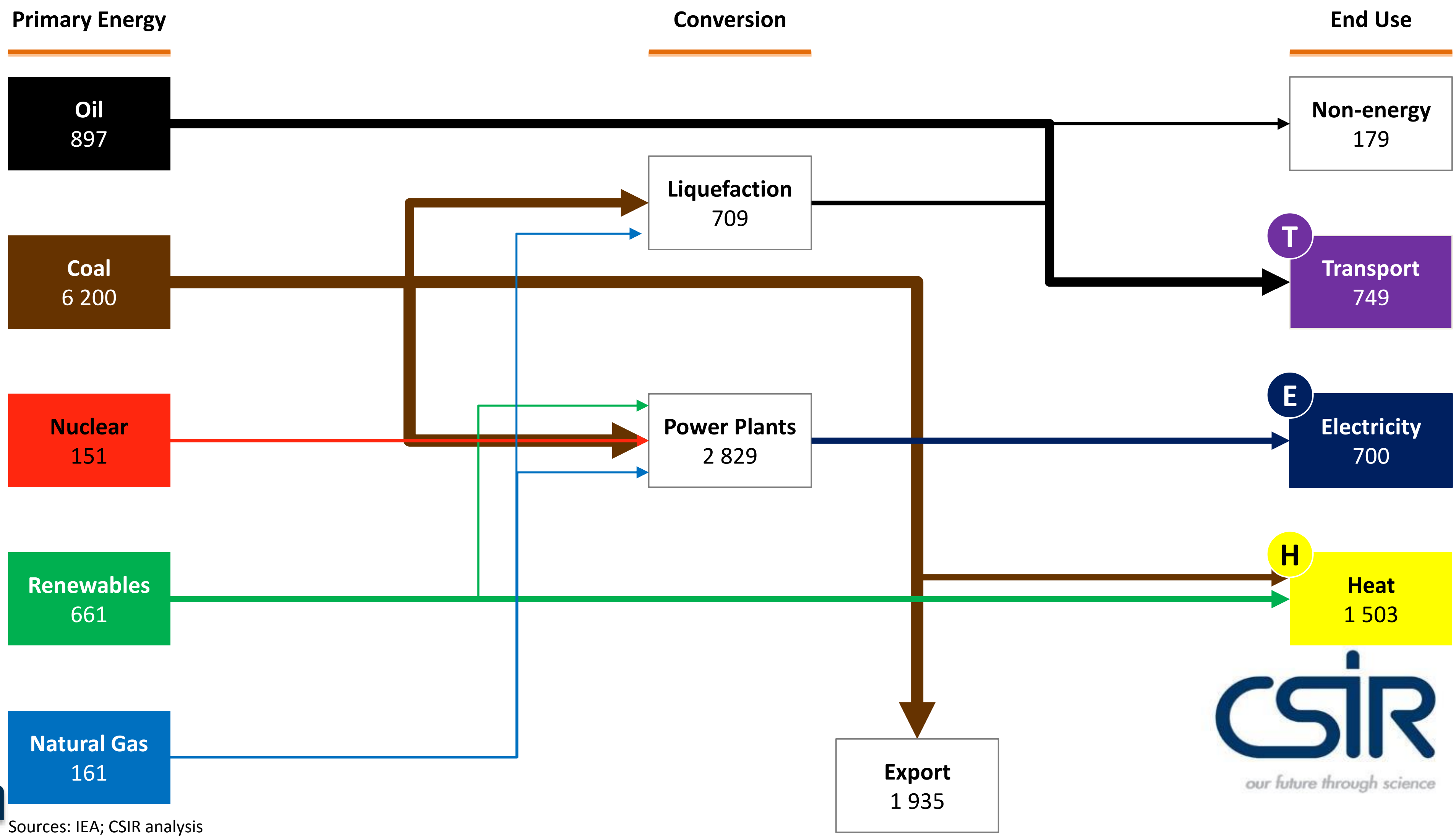
Note: Wind and solar PV would have to be 50% more expensive than assumed before the IRP Base Case and the Least Cost case break even
Sources: CSIR analysis

South Africa's energy system relies on domestic coal and imported oil

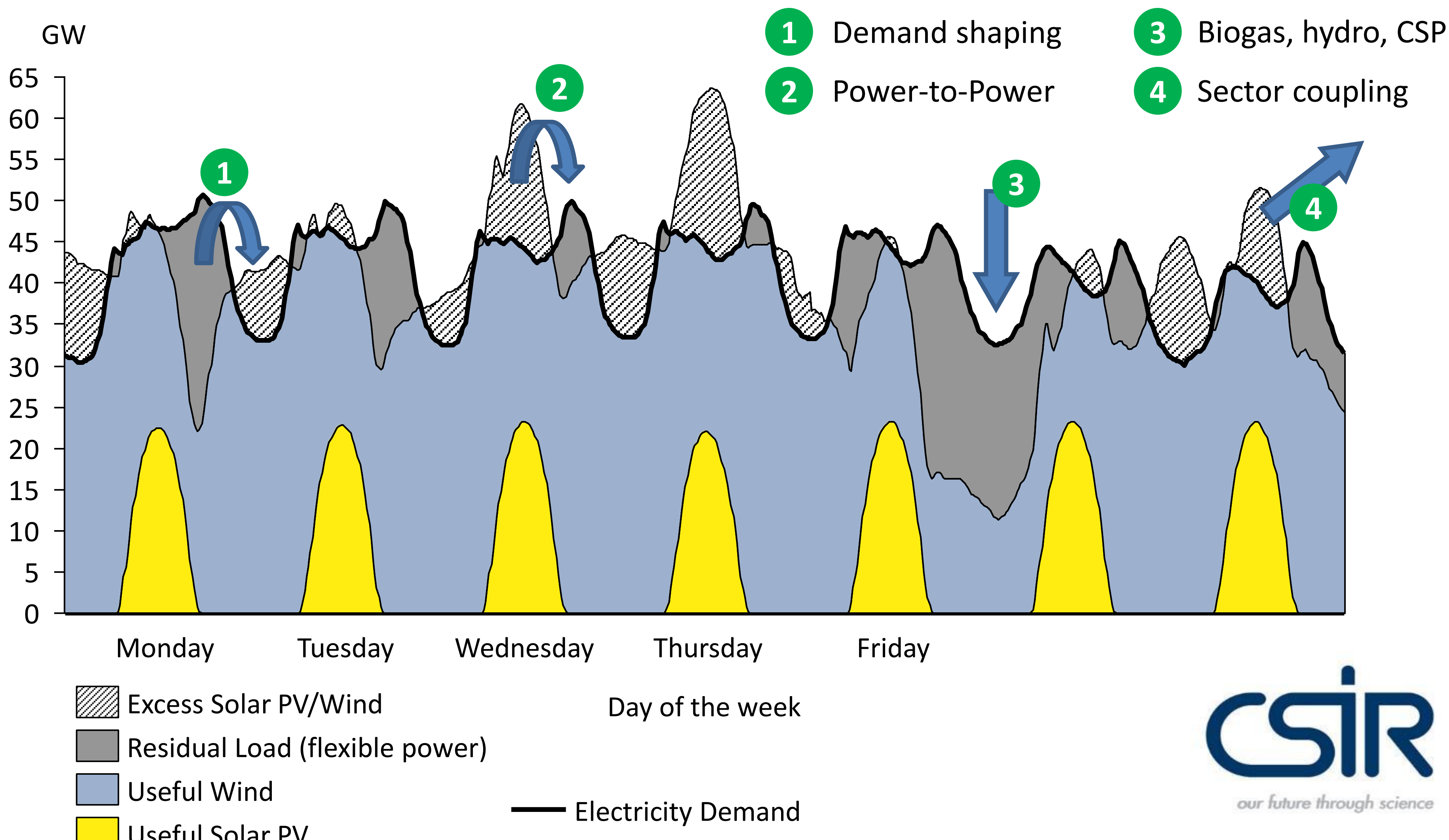
Simplified energy-flow diagram (Sankey diagram) for South Africa in 2014 in PJ



Sources: IEA; CSIR analysis

Future energy system will be built around variability of solar PV & wind

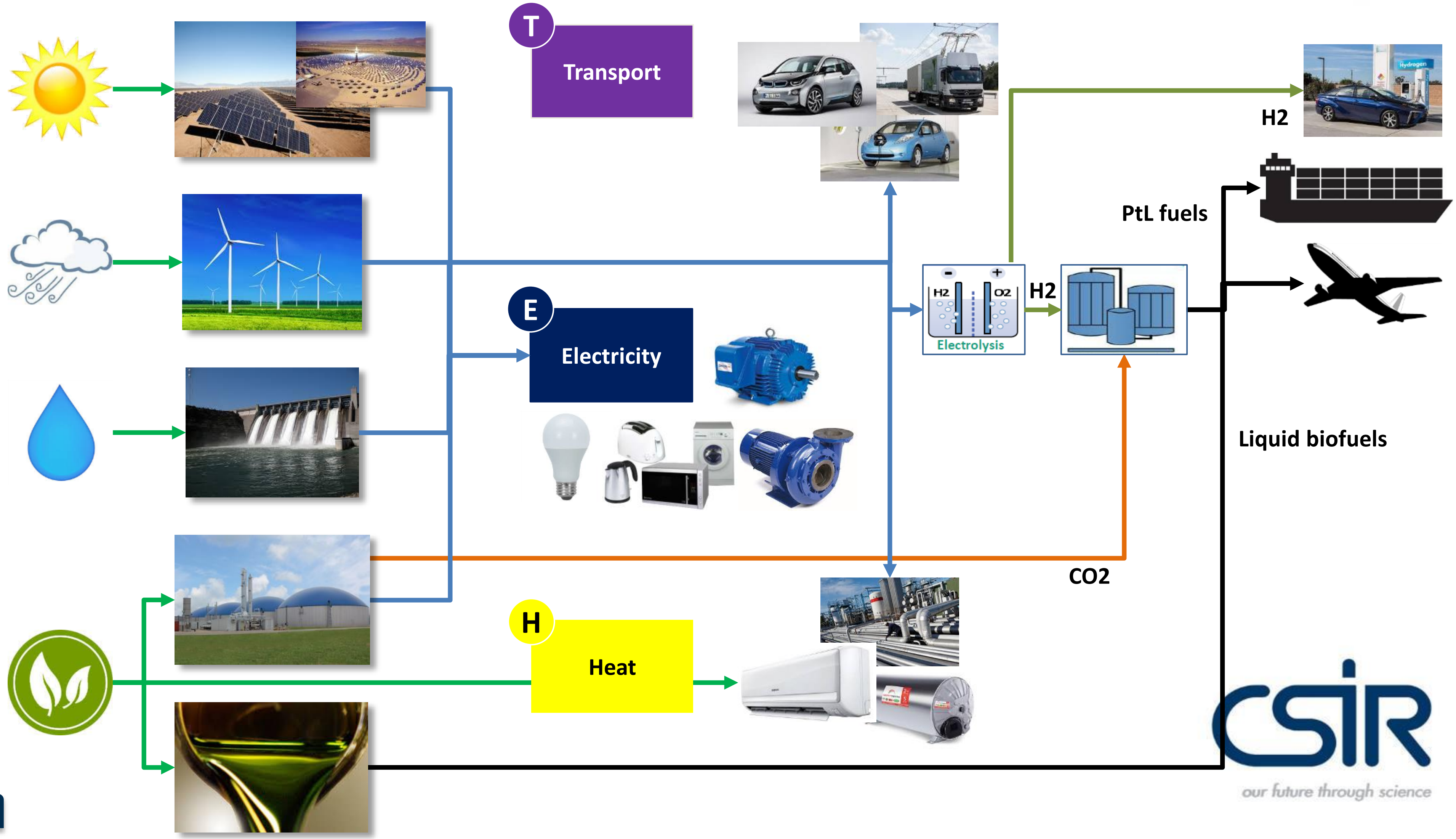
Actual scaled RSA demand & simulated 15-minute solar PV/wind power supply for week from 15-21 Aug '11



Sources: CSIR analysis

High Renewables: energy in RSA mostly from domestic renewables

Hypothetical energy-flow diagram (Sankey diagram) for South Africa in the year 20??



Re a leboha

Ha Khensa

Enkosi

Siyathokoza

Thank you

Re a leboga

Ro livhuha

Dankie

Siyabonga

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Note: „Thank you“ in all official languages of the Republic of South Africa

BACKUP

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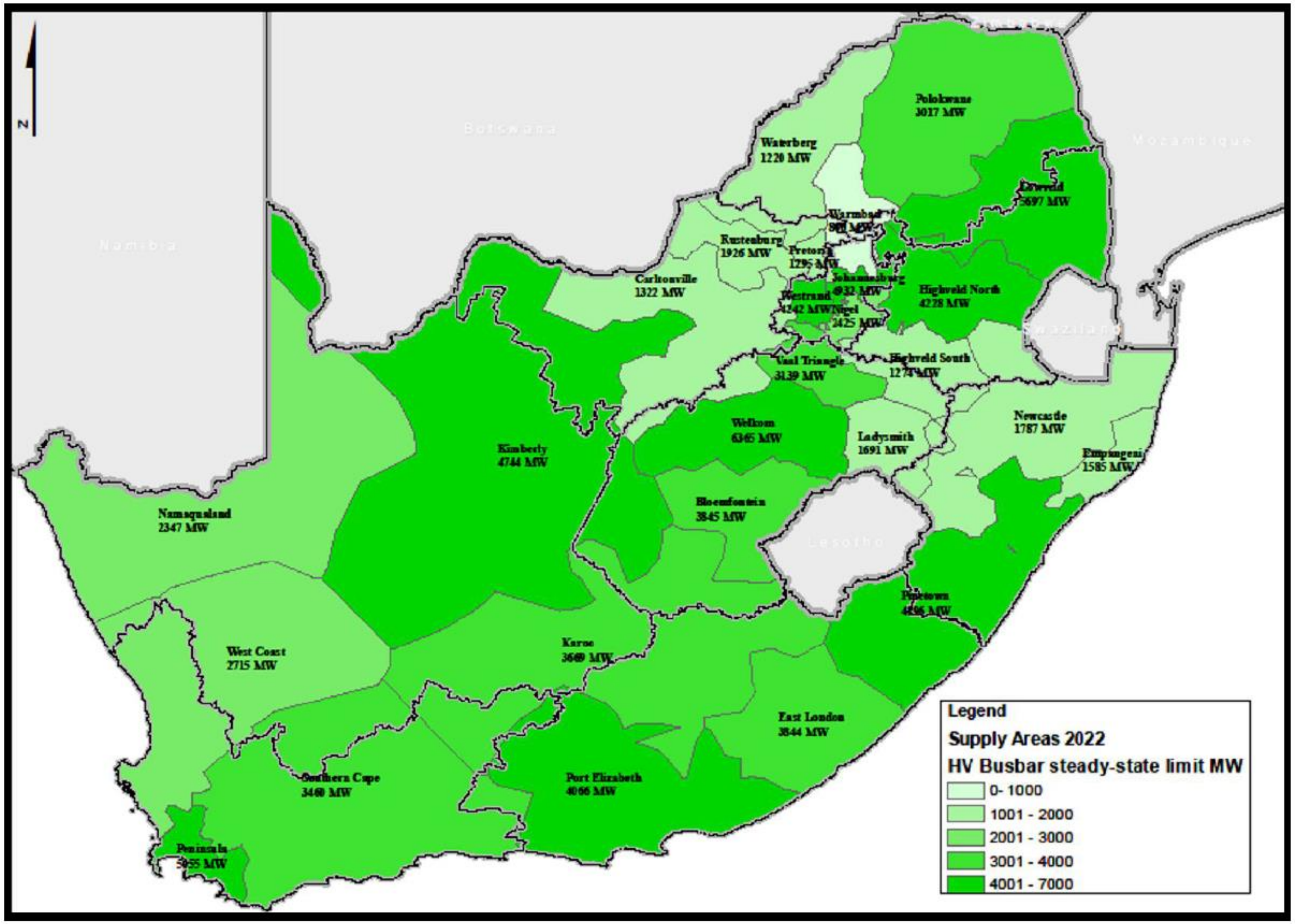
Transmission supply area generation connection capacity for simultaneous generation sources in an area



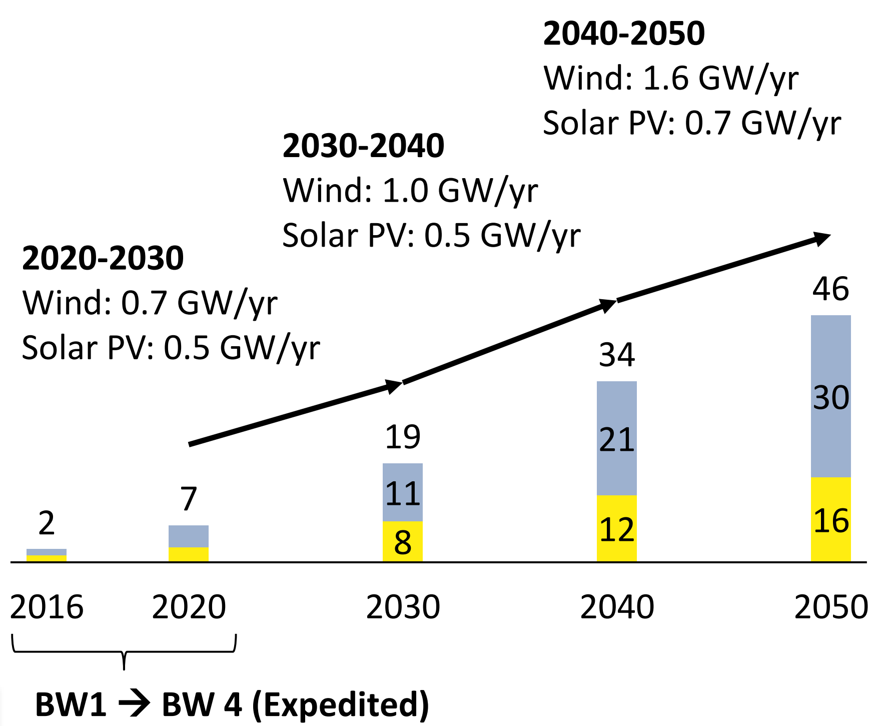
Grid capacity is available all over the country, therefore wind and PV projects should be incentivised to go where there is grid capacity in order to expedite time to connect to the grid. *Focusing only on the Northern Cape for Wind and PV will result in unnecessary delay to connect new plants since wind and PV resource is good all over the country*

Source:
- GCCA 2022: http://www.eskom.co.za/Whatweredoing/GCCAReport/Pages/Default.aspx

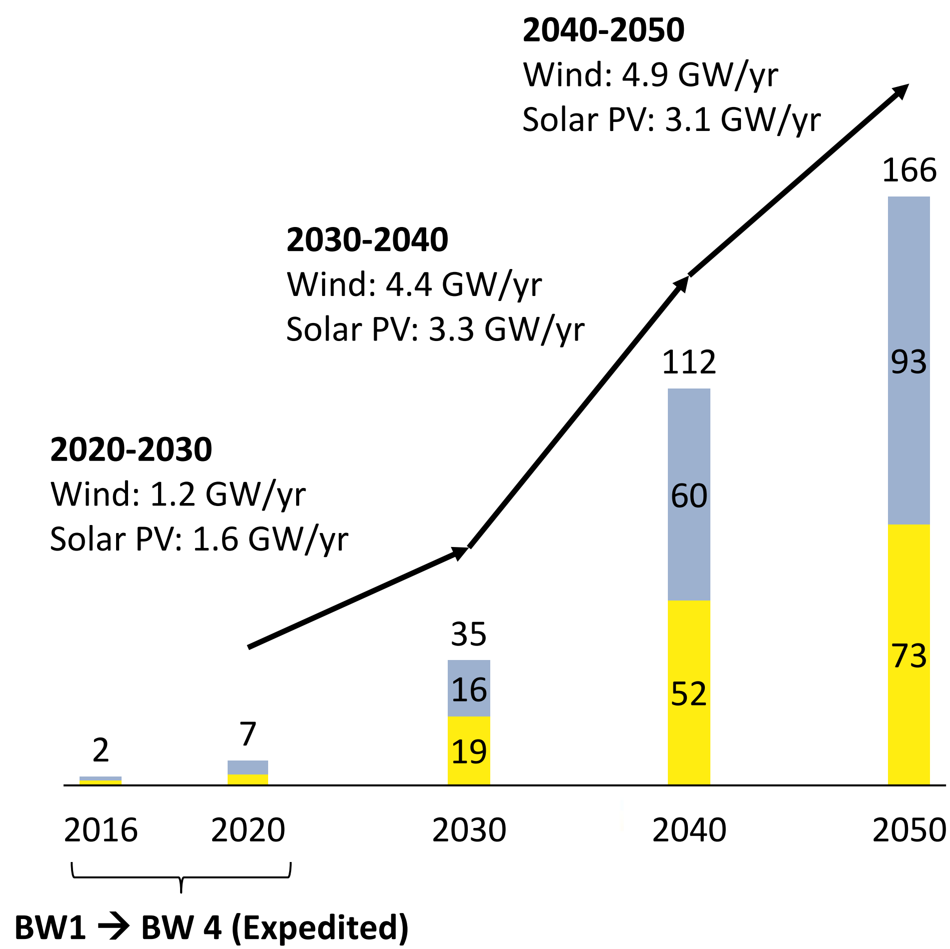
Least Cost scenario creates a steady, significant and increasing market

Roadmap of investment for wind and solar PV to 2050

Draft IRP 2016 Base Case

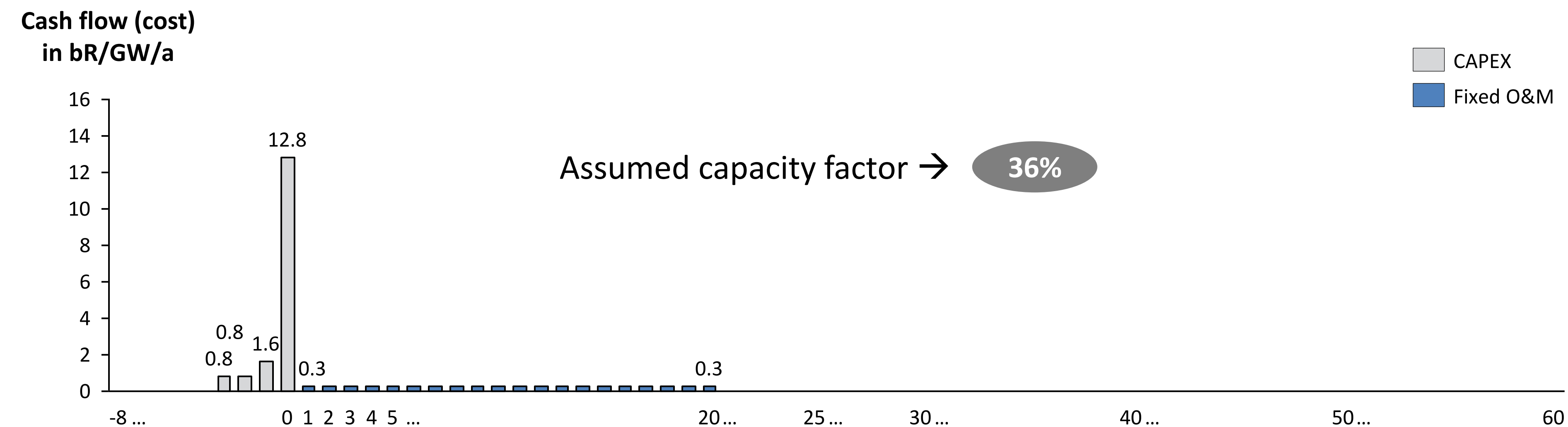


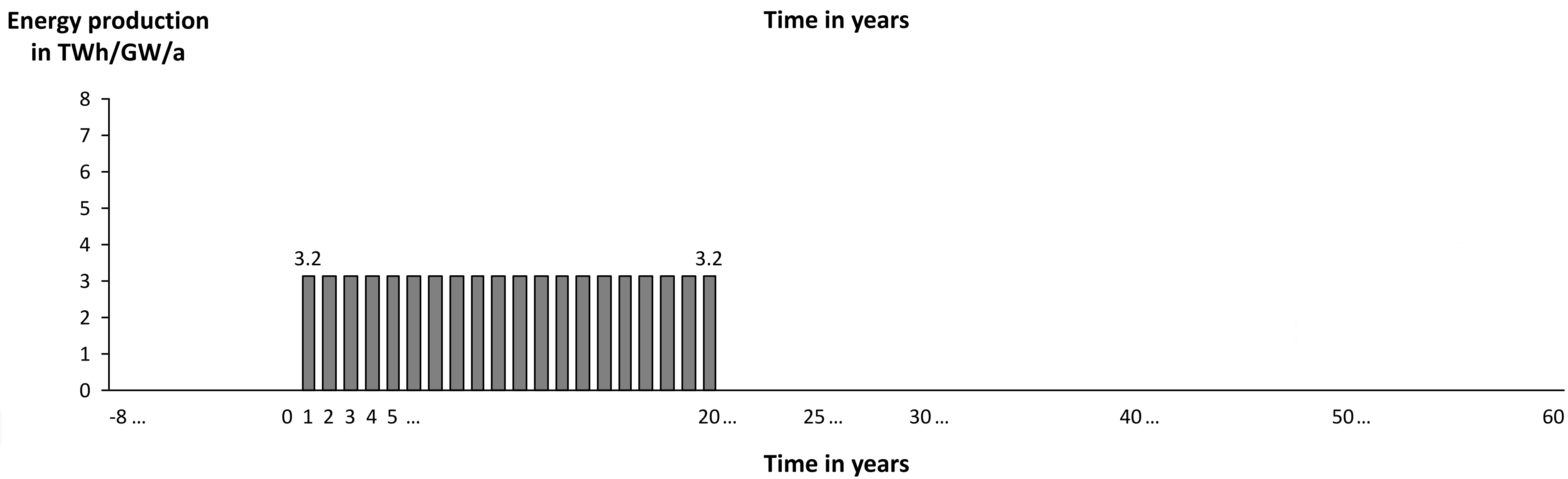
Least Cost



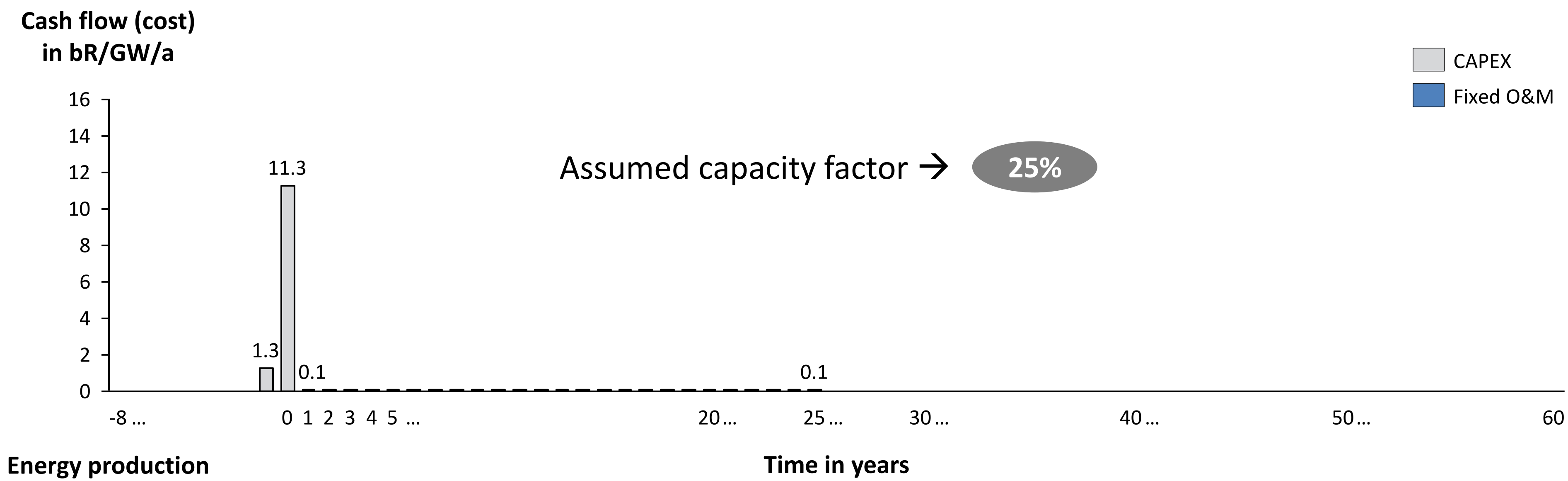
Note: Annual new-build capacity between 2040 and 2050 includes replacement of decommissioned wind and solar PV plants Sources: CSIR analysis

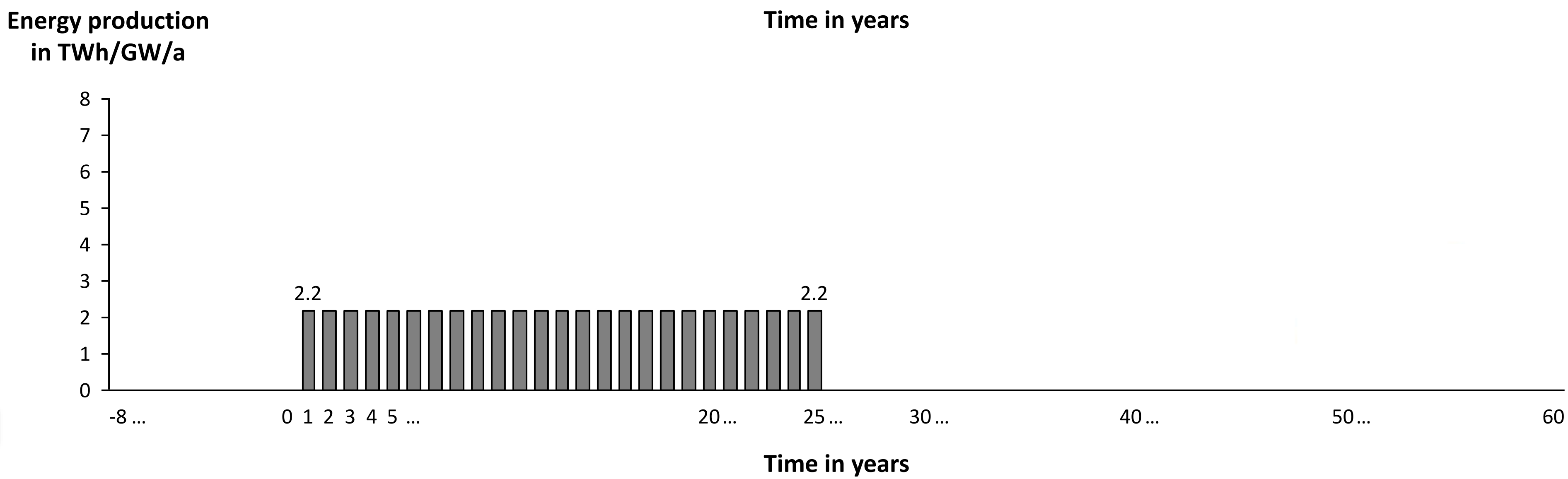
Wind:
Lifetime annual cash flow and annual energy production



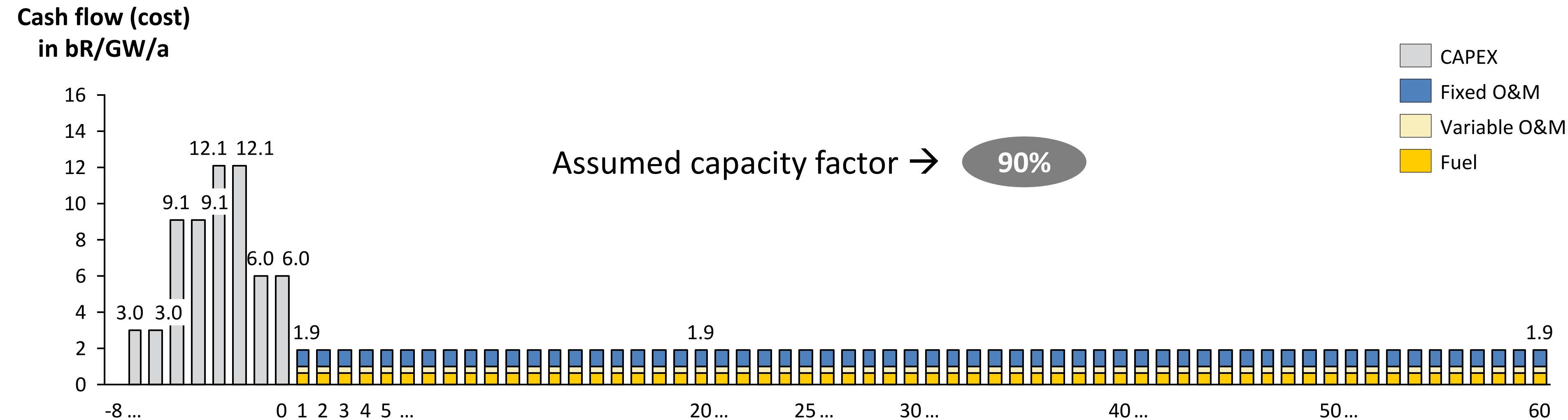


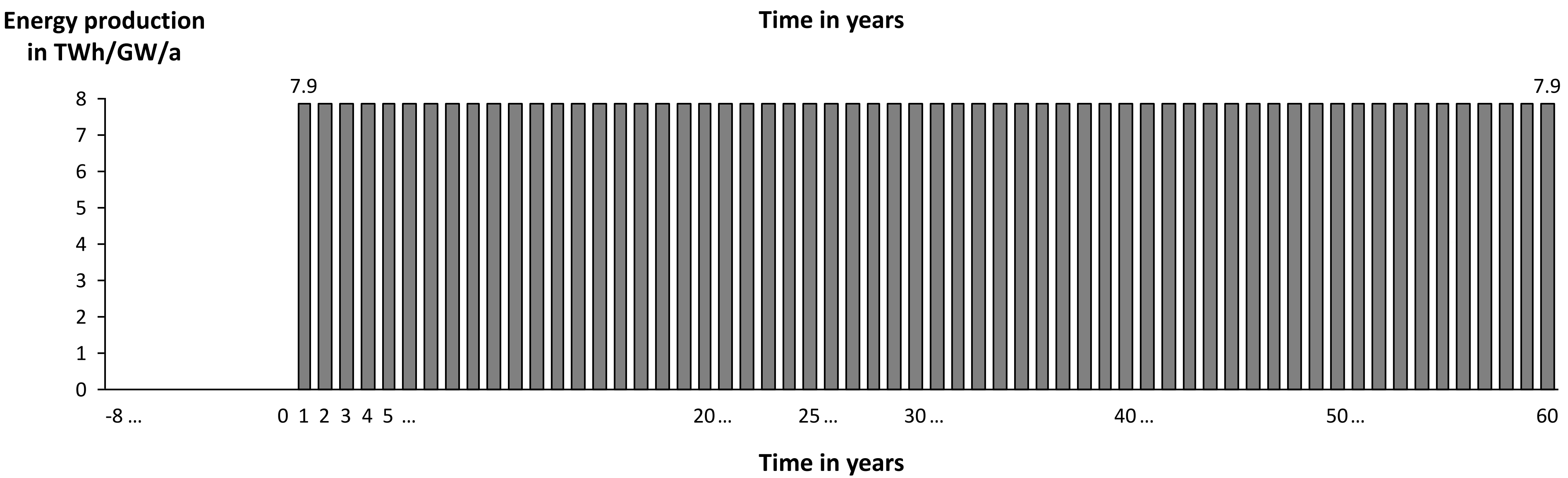
Solar PV:
Lifetime annual cash flow and annual energy production



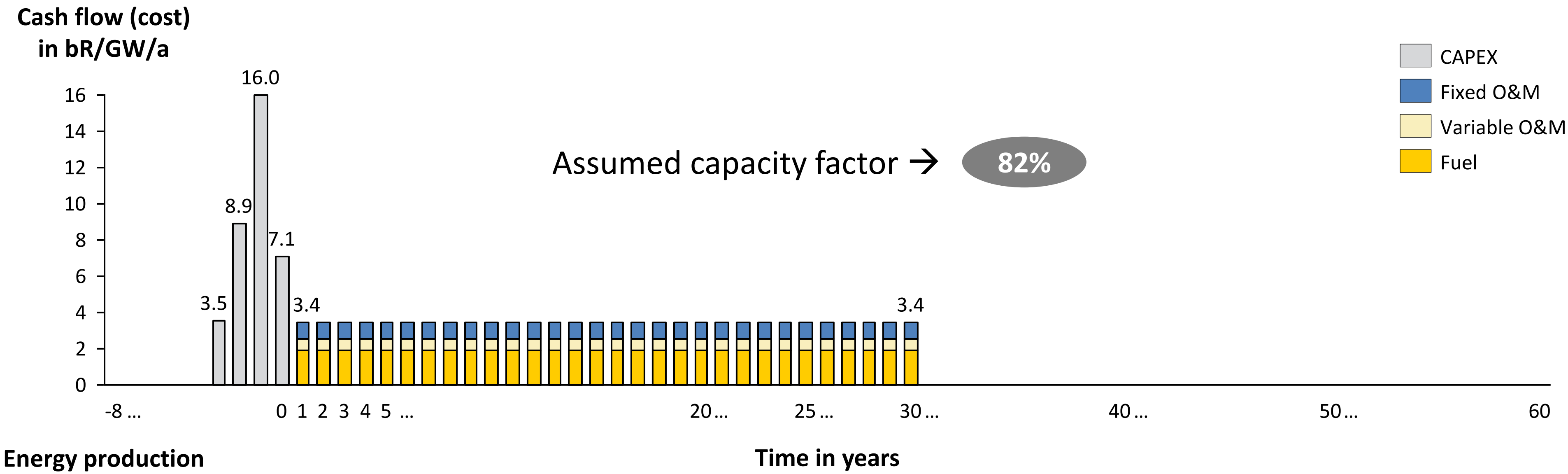


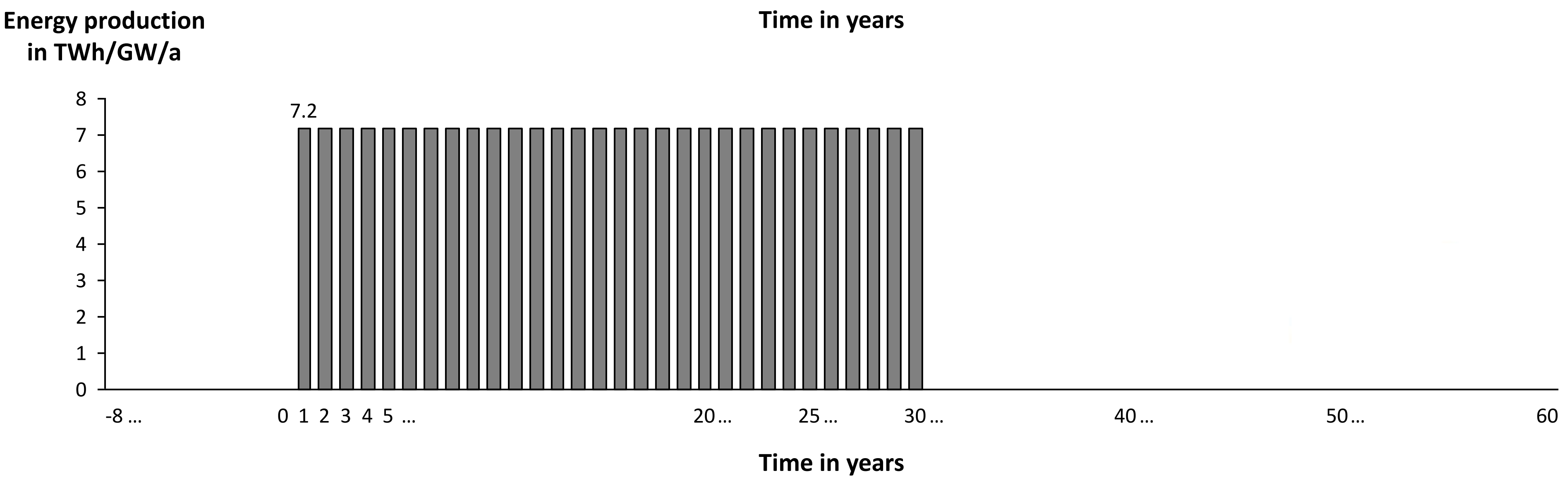
Nuclear:
Lifetime annual cash flow and annual energy production



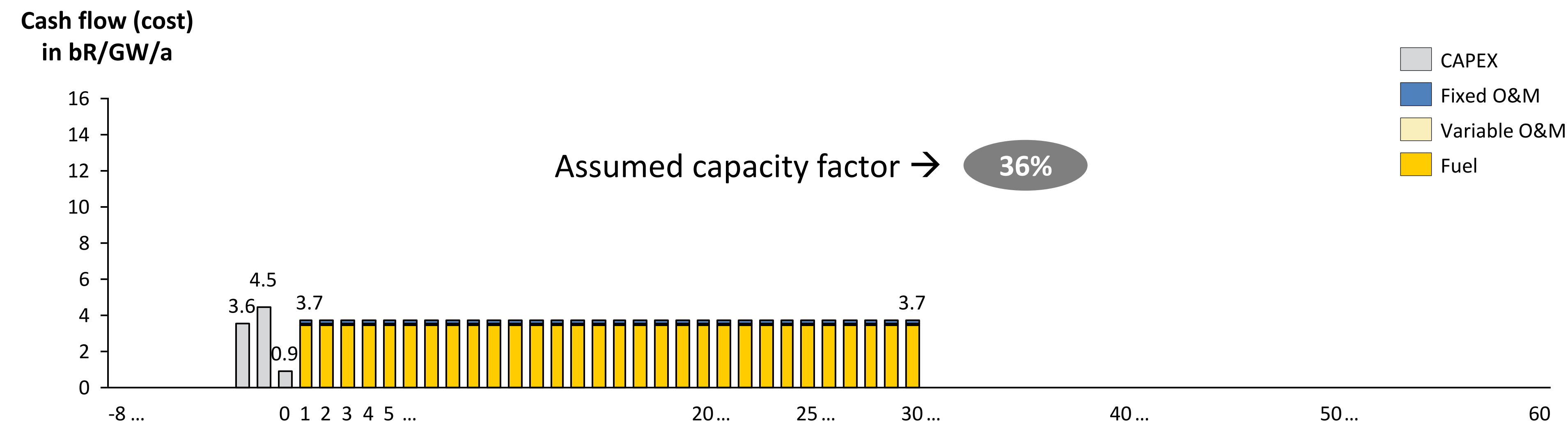


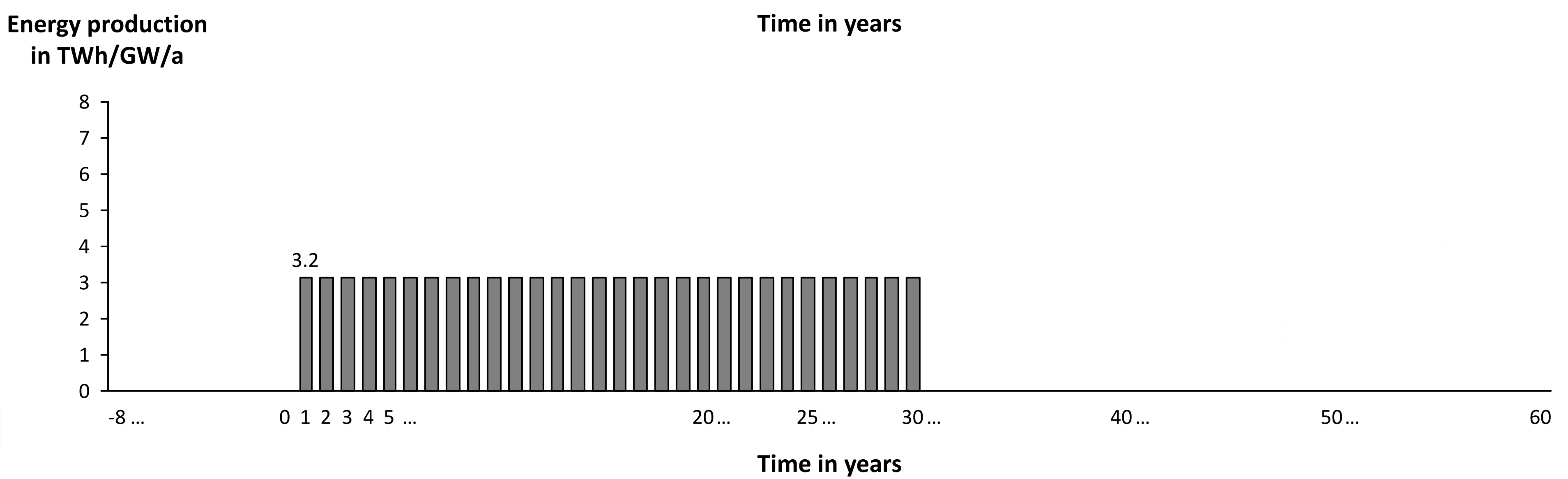
Coal:
Lifetime annual cash flow and annual energy production



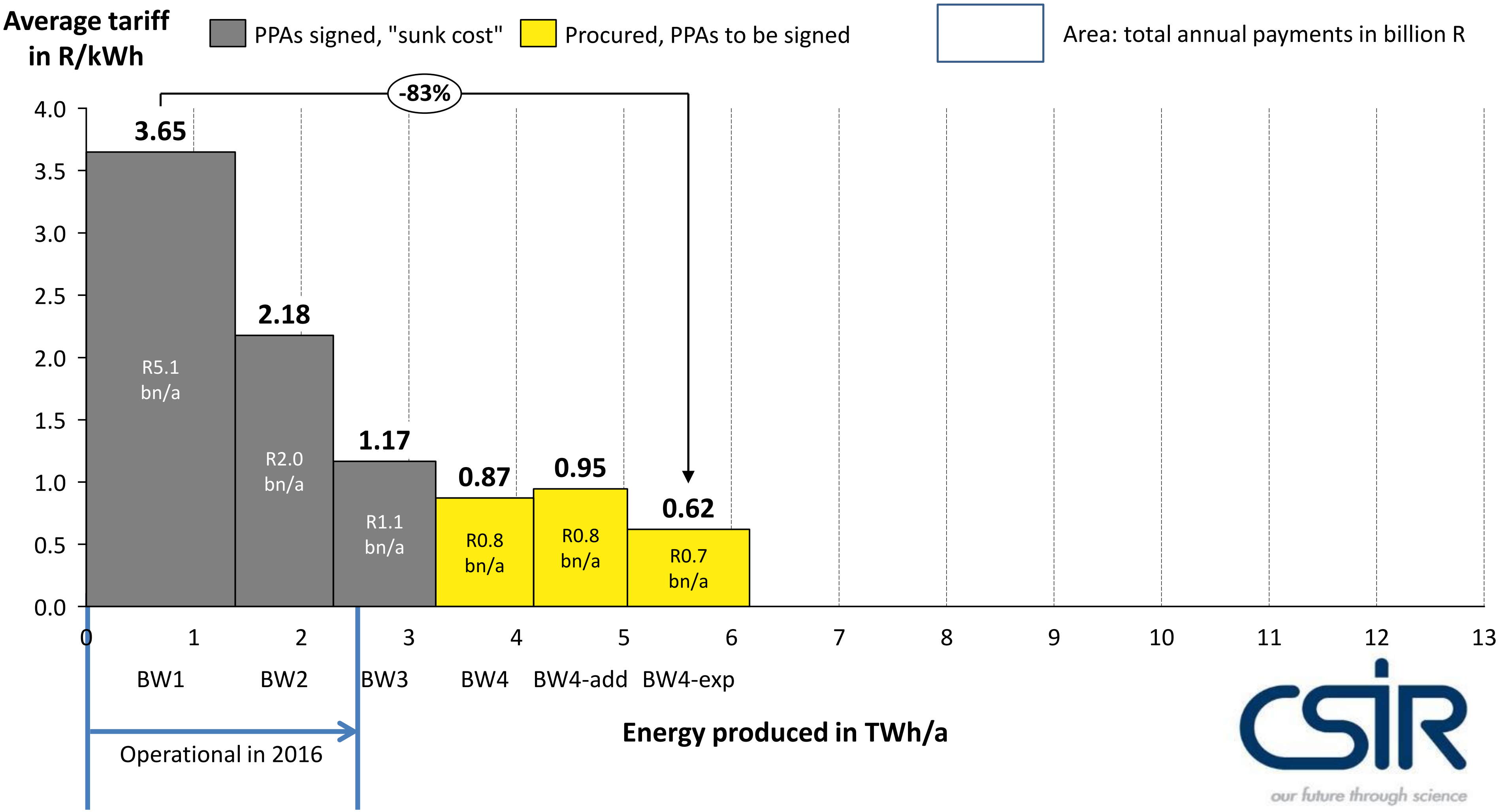


Gas (CCGT):
Lifetime annual cash flow and annual energy production





New solar PV projects are >80% cheaper than BW1 and reduce the average solar PV tariff as they come online



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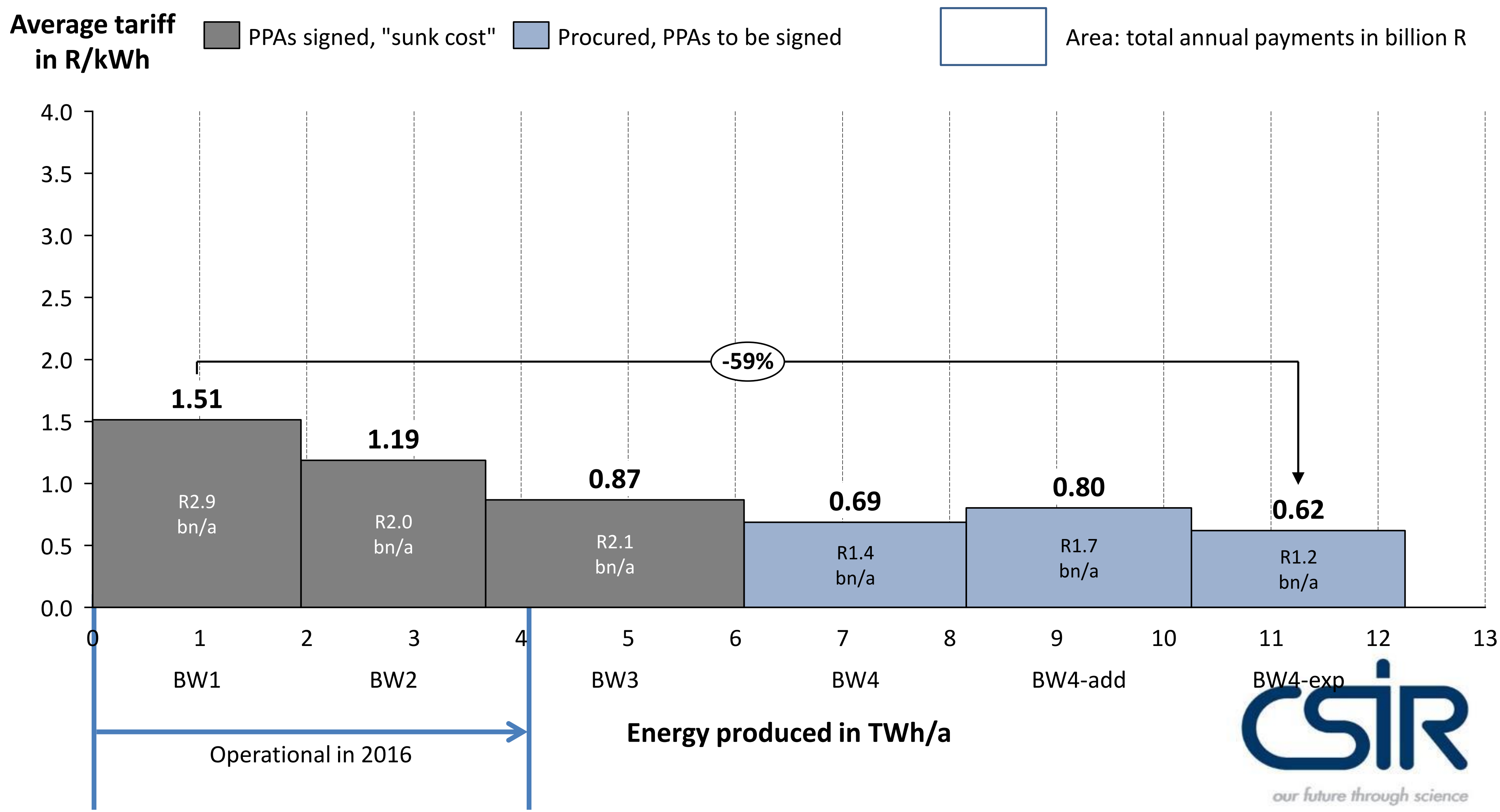
New wind projects are 60% cheaper than BW1 and reduce the average wind tariff as they come online



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CSP costs come down – new CSP is still quite expensive