Comments on the Integrated Resource Plan 2016 Draft

South African Integrated Resource Plan 2016 public hearing

CSIR Energy Centre

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Jarrad Wright	+27 79 527 6002	JWright@csir.co.za
Dr Tobias Bischof-Niemz	+27 83 403 1108	TBischofNiemz@csir.co.za
Robbie van Heerden	+27 82 803 0961	RPvHeerden@csir.co.za
Crescent Mushwana	+27 82 310 2142	CMushwana@csir.co.za

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Agenda

Expertise of Commentators

Comments on IRP Assumptions

IRP Results and Least-cost Scenario

Proposal / Next Steps

Commentators have significant expertise to give feedback on IRP & its implementation, from planning, system operation and grid perspective

Dr Tobias Bischof-Niemz

- Head of CSIR's Energy Centre
- Member of Ministerial Advisory Council on Energy (MACE)
- Member of IRP2010/IRP2013 teams at Eskom, energy planning in Europe for large utilities

Robbie van Heerden

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

Crescent Mushwana

- Research Group Leader: Energy Systems at the CSIR's Energy Centre
- Former Chief Engineer at Eskom strategic transmission grid planning

Jarrad Wright

- Principal Engineer: Energy Planning at the CSIR's Energy Centre
- Energy Commissioner in the National Planning Commission
- Former Africa manager of PLEXOS (software package used for the IRP)

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Same software package as per the IRP was used to determine the least-cost expansion path of the South African power system to 2050

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

The IRP 2016 has a significant self-imposed limitation: The amount of wind and solar PV capacity that the model is allowed to build per year is limited, which is not technically/economically justified in the plan

The CSIR has therefore conducted a study to re-optimise the South African power mix until 2050

- First and most important deviation from IRP2016: no new-build limits on renewables (wind/solar PV)
- Additional deviation: relative costing for solar PV and wind aligned with latest relative IPP tariff results

Two scenarios from the draft IRP 2016 are compared with the re-optimisation

- "Draft IRP 2016 Base Case" – new coal, new nuclear
- "Draft IRP 2016 Carbon Budget" – significant new nuclear
- "CSIR Re-Optimised" – least-cost without constraints

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

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Sources: CSIR analysis

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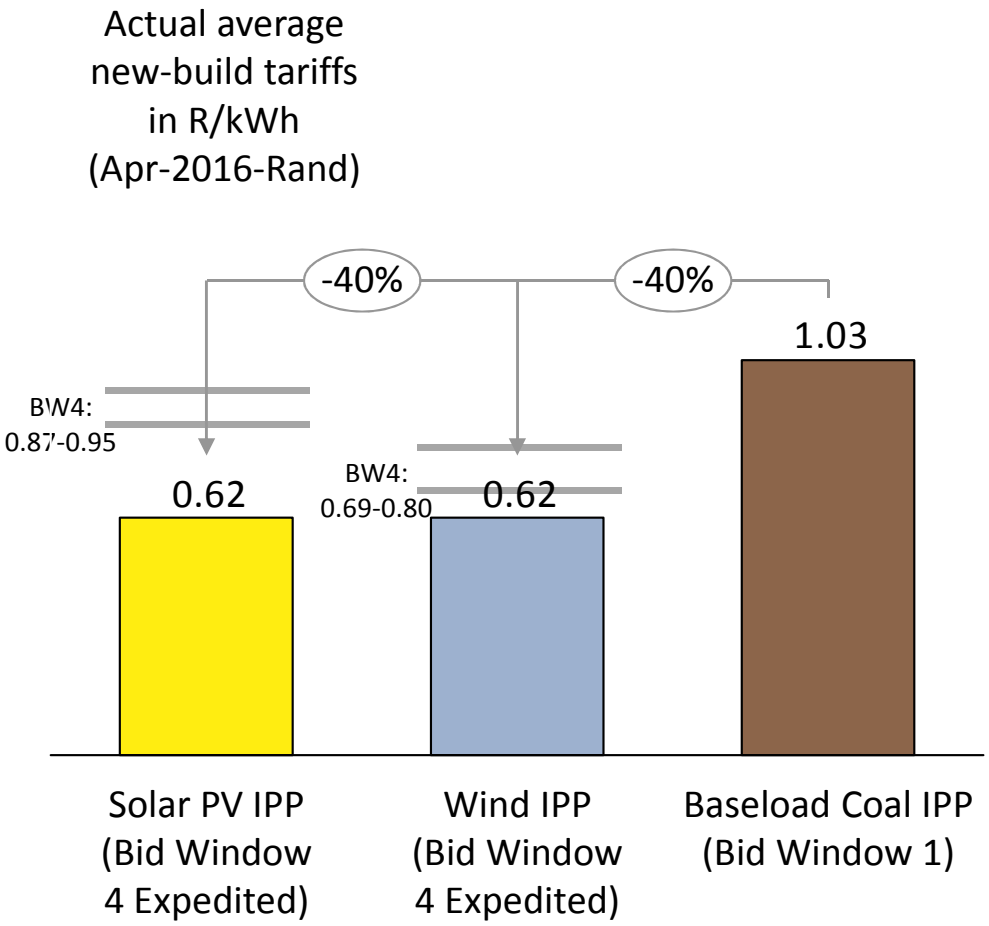
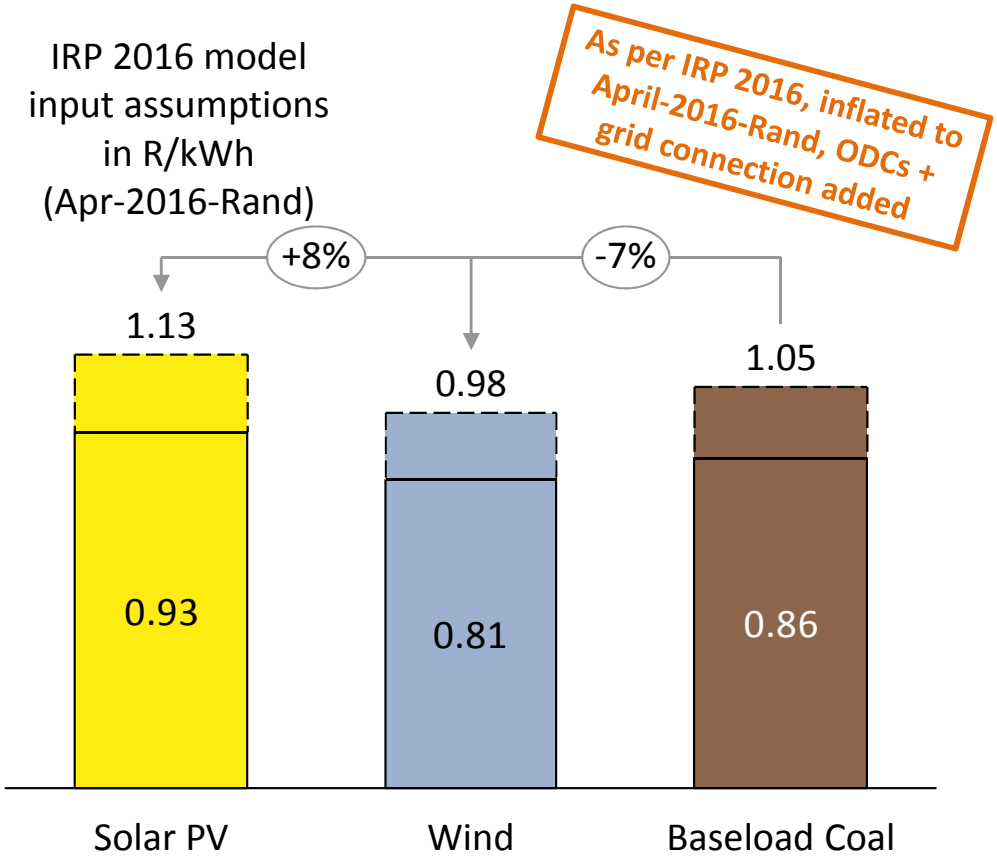
Actual tariffs for new solar PV and wind are 40% cheaper than new baseload coal, whereas IRP 2016 assumes similar LCOE for all three

Actual tariffs from RE IPP and Coal IPP Procurement Programme



IRP 2016 cost input assumptions



Sources: South African Department of Energy IPP Office's publications on results of IPP Bid Windows; IRP 2016 Draft; StatsSA on CPI; CSIR analysis

Actual coal tariff of Bid Window 1 is significantly above IRP 2010 assumptions and almost exactly on the Coal PF assumption of IRP 2016

Assumptions: CPI used for normalisation to Apr-2016-Rand; LCOE calculated for IRP 2010 and 2013 with 8% discount rate (real), 30 yrs lifetime, cost and load factor assumptions as per relevant IRP document; LCOE for IRP 2016 straight from IRP document; "IRP Tariff" then calculated assuming 90% of total tariff to be LCOE EPC costs, i.e. divide the LCOE by 0.9 to derive at the "IRP Tariff"
Sources: IRP 2010; IRP 2013; IRP 2016 draft as of November 2016; https://www.ipp-projects.co.za/Home/GetPressRelease?fileid=228bdd35-e18e-e611-9455-2c59e59ac9cd&fileName=PressRelease-Coal-based-Independent-Power-Producer-programme-announcement-10Oct2016.pdf; CSIR analysis

Nuclear cost assumptions increased slightly from IRP 2010 to IRP 2016

Assumptions: CPI used for normalisation to Apr-2016-Rand; LCOE calculated for IRP 2010 and 2013 with 8% discount rate (real), 60 yrs lifetime, cost and load factor assumptions as per relevant IRP document; LCOE for IRP 2016 straight from IRP document; "IRP Tariff" then calculated assuming 90% of total tariff to be LCOE EPC costs, i.e. divide the LCOE by 0.9 to derive at the "IRP Tariff"
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Actual solar PV tariffs quickly approached IRP 2010 assumptions in first four bid windows and are now well below cost assumption funnel

Assumptions: CPI used for normalisation to Apr-2016-Rand; LCOE calculated for IRP 2010 and 2013 with 8% discount rate (real), 25 yrs lifetime, cost and load factor assumptions as per relevant IRP document; LCOE for IRP 2016 straight from IRP document; "IRP Tariff" then calculated assuming 90% of total tariff to be LCOE EPC costs, i.e. divide the LCOE by 0.9 to derive at the "IRP Tariff"
Sources: IRP 2010; IRP 2013; IRP 2016 draft as of November 2016; http://www.energy.gov.za/files/renewable-energy-status-report/Market-Overview-and-Current-Levels-of-Renewable-Energy-Deployment-NERSA.pdf; CSIR analysis

Actual wind tariffs in bid window four were below the level that was assumed for 2030 in IRP 2010, BW 4 Expedited is significantly below

Assumptions: CPI used for normalisation to Apr-2016-Rand; LCOE calculated for IRP 2010 and 2013 with 8% discount rate (real), 20 yrs lifetime, cost and load factor assumptions as per relevant IRP document; LCOE for IRP 2016 straight from IRP document; "IRP Tariff" then calculated assuming 90% of total tariff to be LCOE EPC costs, i.e. divide the LCOE by 0.9 to derive at the "IRP Tariff"
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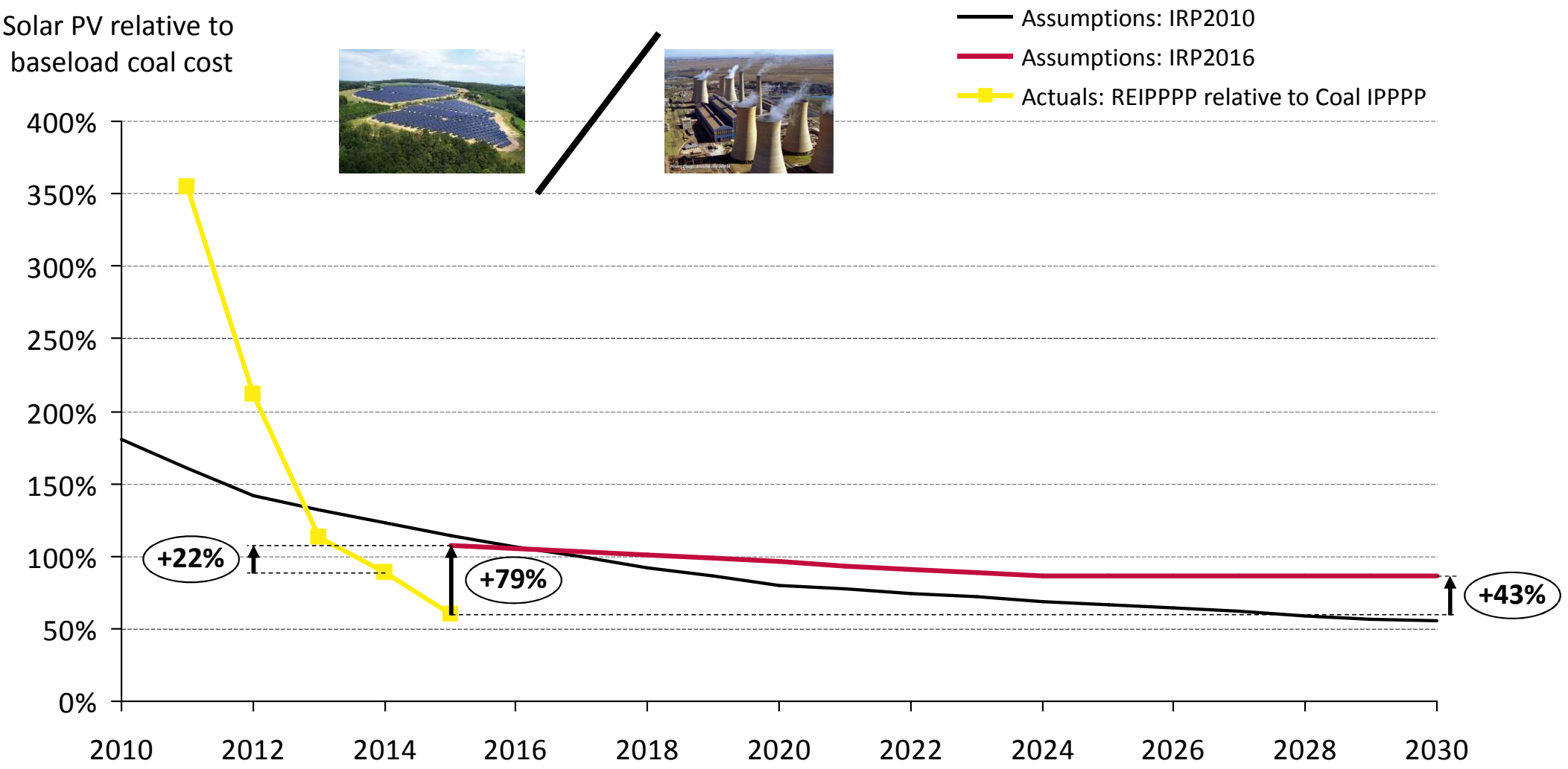
Actual CSP tariffs are declining from bid window 1 to 4 Expedited, and are now close to the upper boundary of IRP 2013 cost assumptions

Assumptions: CPI used for normalisation to Apr-2016-Rand; LCOE calculated for IRP 2010 and 2013 with 8% discount rate (real), 30 yrs lifetime, cost and load factor assumptions as per relevant IRP document; LCOE for IRP 2016 straight from IRP document; "IRP Tariff" then calculated assuming 90% of total tariff to be LCOE EPC costs, i.e. divide the LCOE by 0.9 to derive at the "IRP Tariff"
Sources: IRP 2010; IRP 2013; IRP 2016 draft as of November 2016; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR analysis

IRP 2016 Solar PV cost assumptions relative to baseload coal much higher than in IRP 2010 – despite actual PV/coal ratio is much lower



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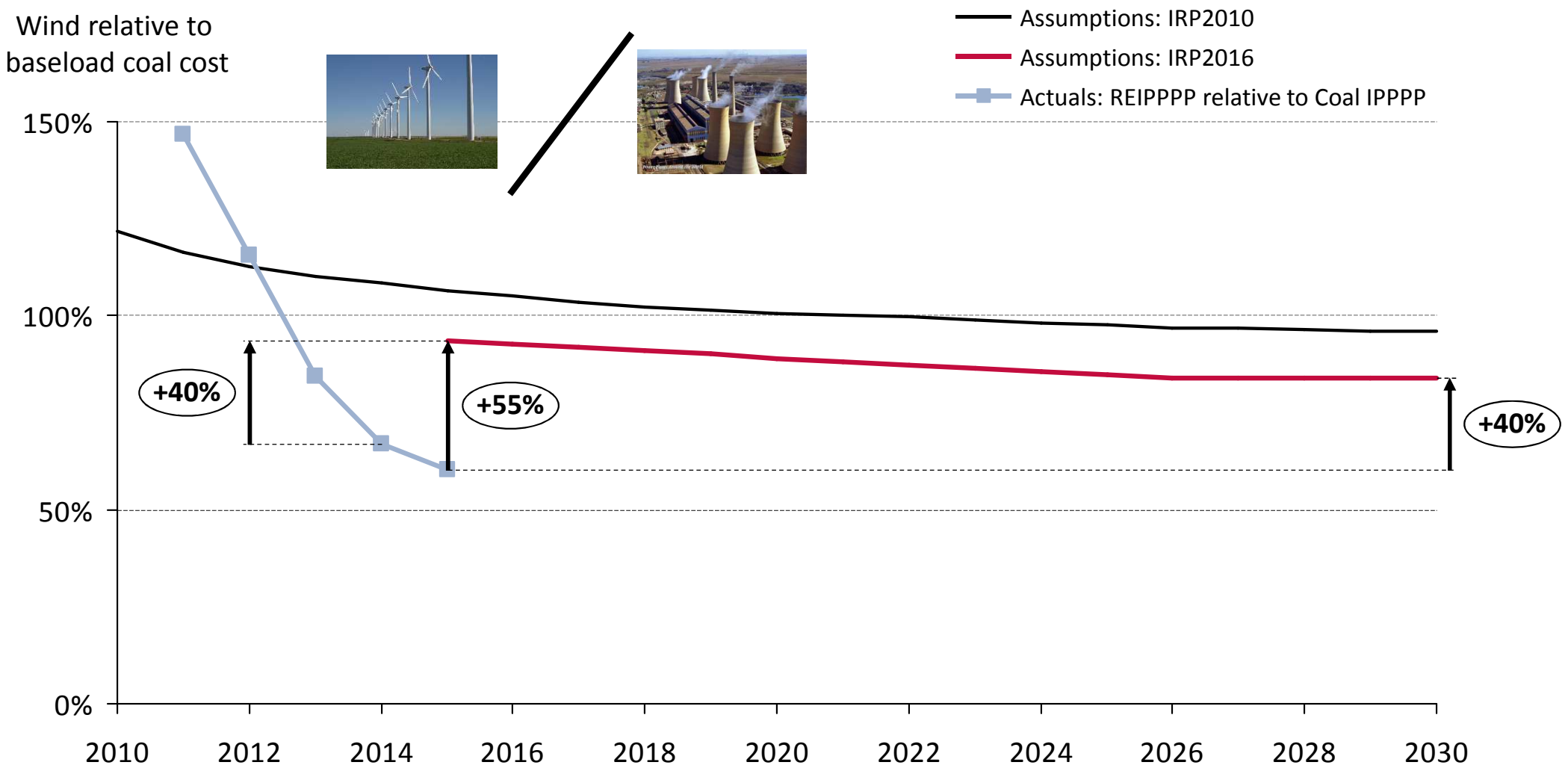
IRP 2016 wind cost assumptions relative to baseload coal lower than in IRP 2010 – but actual ratios from IPP Programmes being even lower



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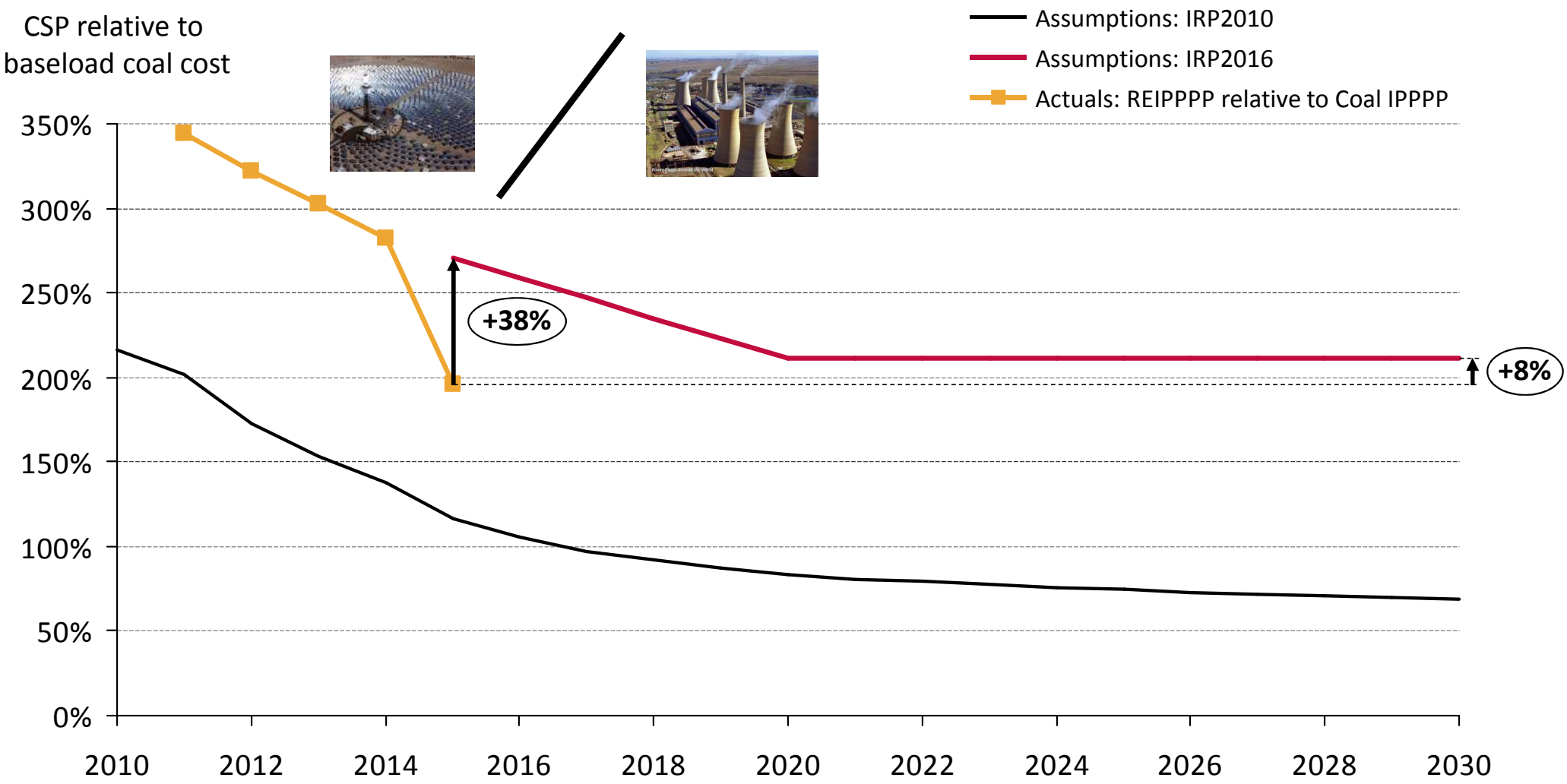
IRP 2016 CSP cost assumptions relative to baseload coal higher than in IRP 2010 – actual ratios from IPP Programmes lie between IRP2010/16



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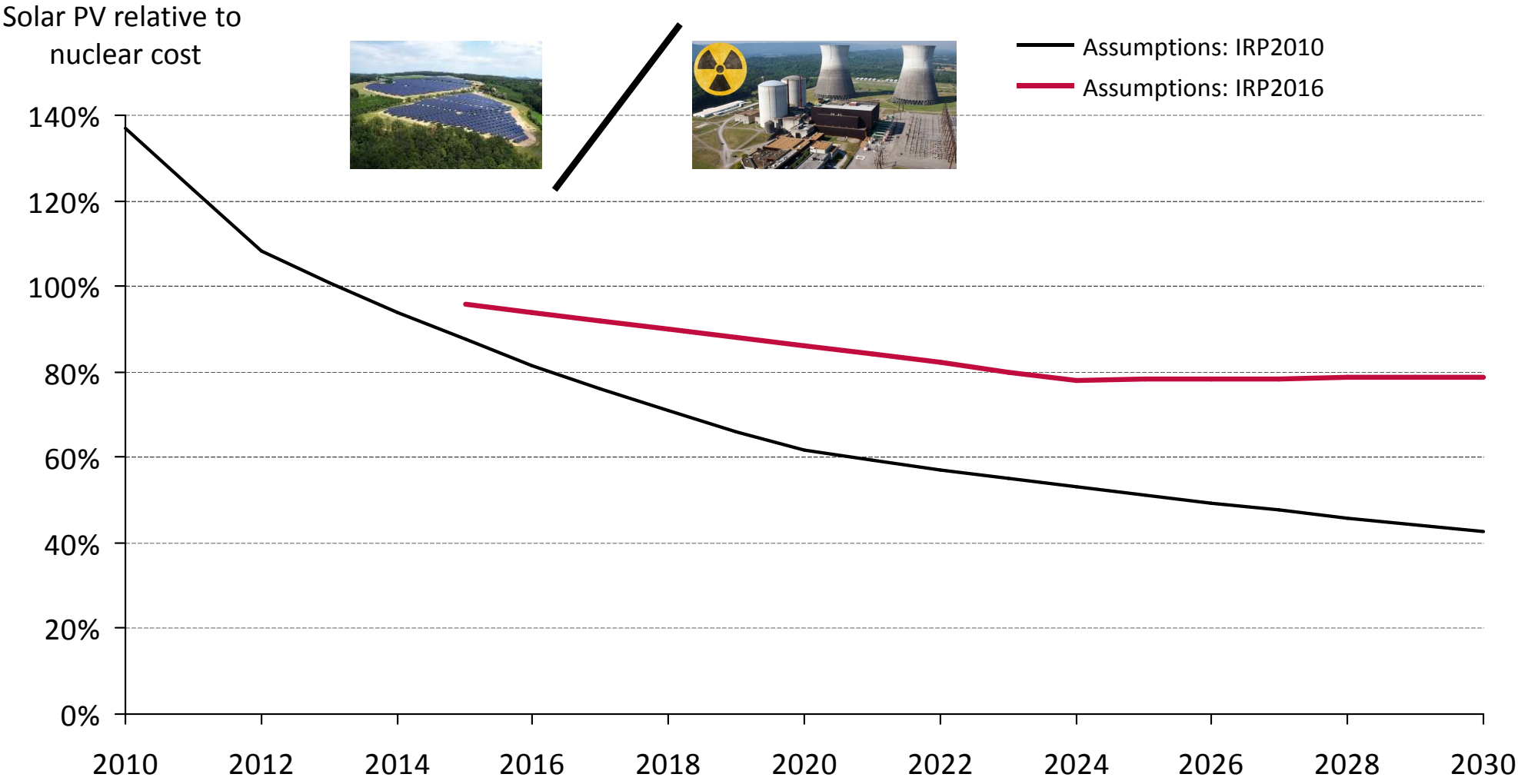
IRP 2016 Solar PV cost assumptions relative to nuclear much higher than in IRP 2010



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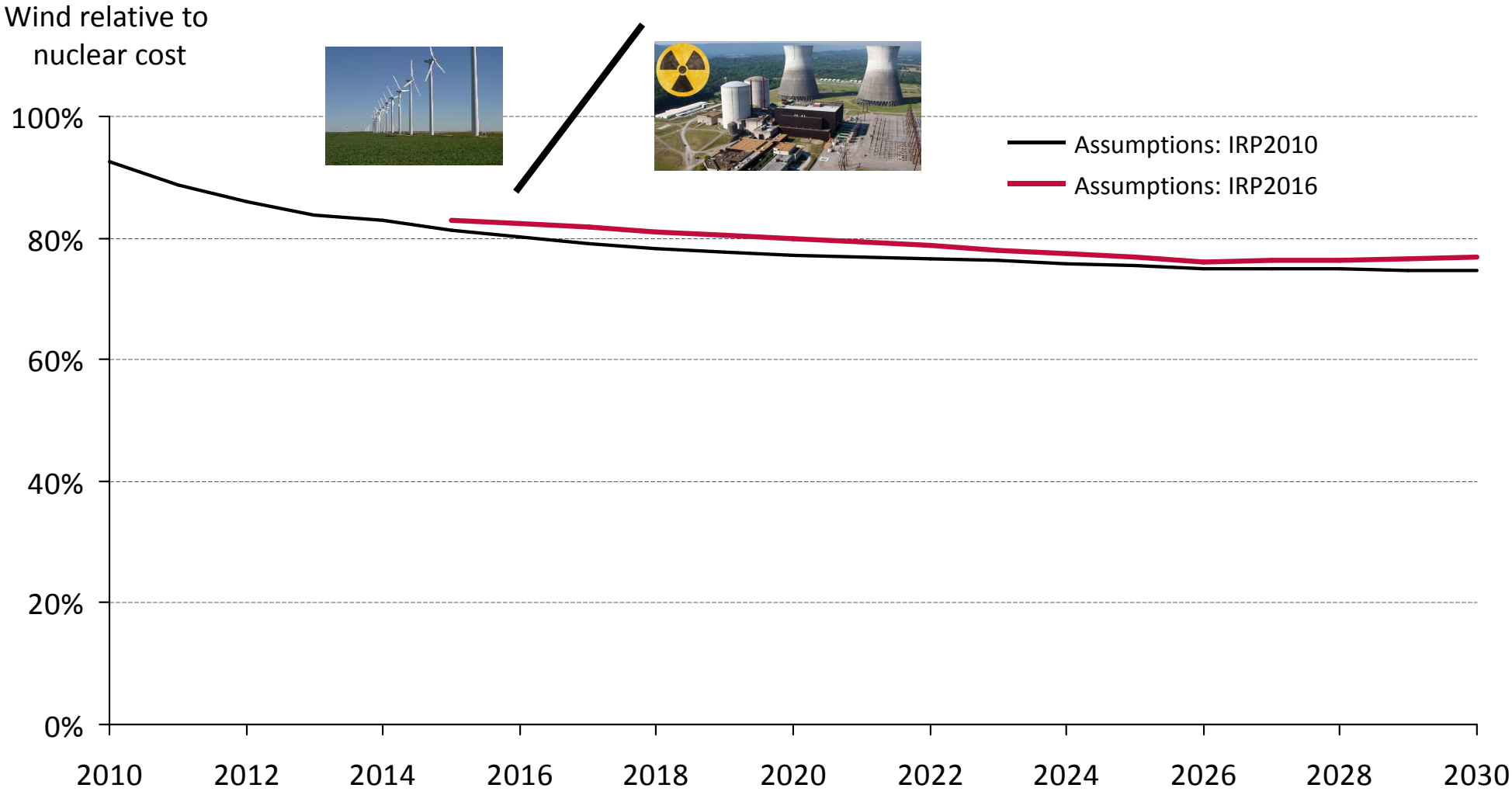
IRP 2016 wind cost assumptions relative to nuclear kept constant compared to IRP 2010



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IRP 2016 CSP cost assumptions relative to nuclear significantly higher than in IRP 2010

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Logic to derive “IRP Tariff” curves

Calculate the IRP LCOE path for each technology based on

- Cost development path for CAPEX in R/kW and for O&M in R/kW/yr as per IRP 2010 / IRP 2013
- Discount rate of 8%
- Lifetime of 25/20/30 years for PV/wind/CSP
- Load factors as per the profiles used in IRP 2010 / IRP 2013
- For IRP 2016, use straight the reported LCOE (i.e. without own LCOE calculation)

Adjust all resulting IRP LCOE numbers to Apr 2016 via CPI table

- http://www.statssa.gov.za/keyindicators/CPI/CPIHistory.pdf

Translate all Apr-2016-based IRP LCOE numbers into an “IRP Tariff”

- The IRP-assumed costs (CAPEX and O&M) reflect only the costs within the battery limit of the EPC contract. Owner’s development costs (ODCs) and grid connection costs are not considered
- Assume that for an IPP the pure EPC CAPEX plus O&M stands for 90% of the total costs that lead to the tariff
- Therefore, divide “IRP LCOE” numbers by 90% to derive at the “IRP Tariff”
- This tariff is logically comparable to the tariffs that IPPs bid for in the REIPPPP

Sources: CSIR analysis

IRP 2016: Annual new-build limits for solar PV and wind are constant in absolute terms but decrease relative to the size of the power system

Draft IRP 2016 Base Case

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 technical justification is provided for these limits. No explanation is given why these limits are constant over a 30-year period while the power system grows.

Year	System Peak Load in MW	New-build limit Solar PV in MW/yr	Relative new-build limit Solar PV	New-build imit Wind in MW/yr	Relative new-build limit Wind
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 install much more new solar PV capacity per year than what South Africa's limit is in 2030

Annual new solar PV capacity relative to system peak load

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

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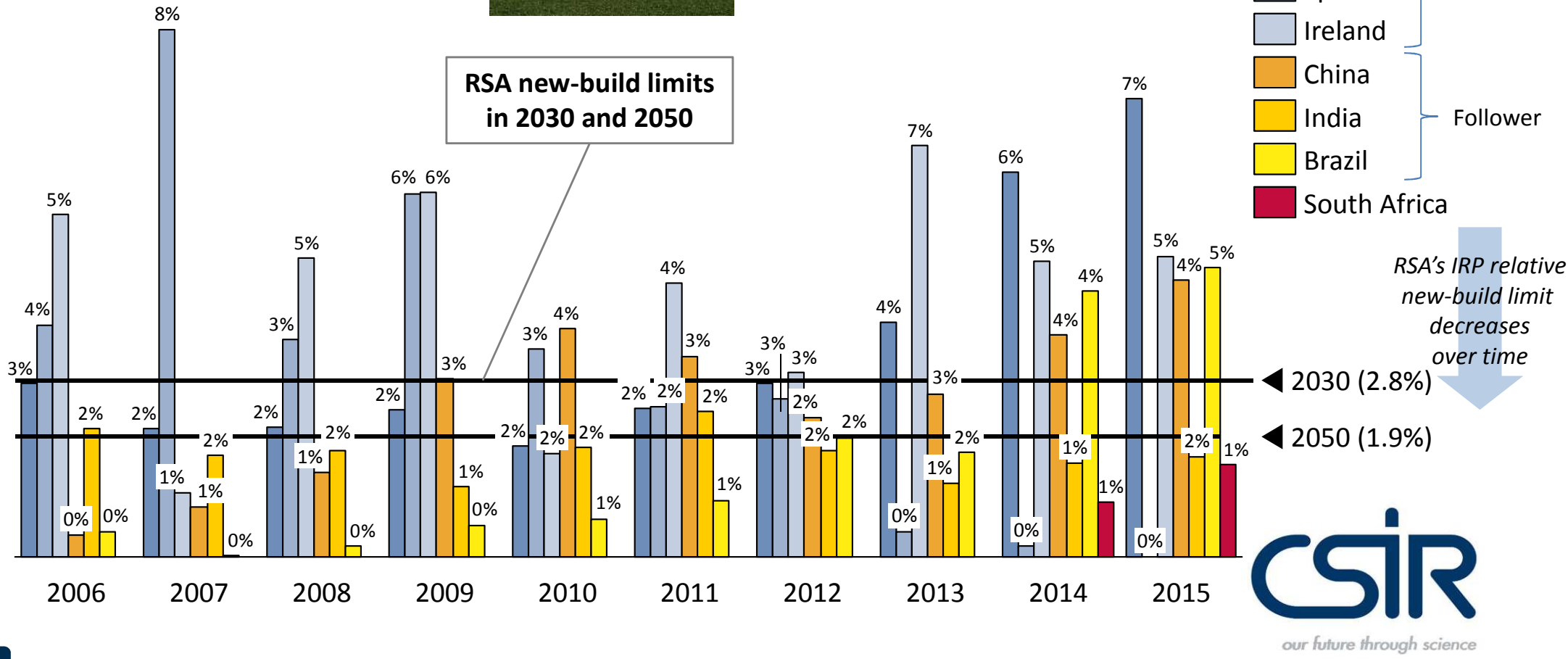
Today: Both leading and follower countries install much more new wind capacity per year than what South Africa's limit is in 2050

Annual new wind capacity relative to system peak load



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

Today: Solar PV penetration in leading countries 2.5 times RSA's plan for 2050 – follower countries already today almost at RSA's 2050 level

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

Today: Wind penetration in leading countries almost twice RSA's plan for 2050 – follower countries already today at 60% of RSA's 2050 level

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

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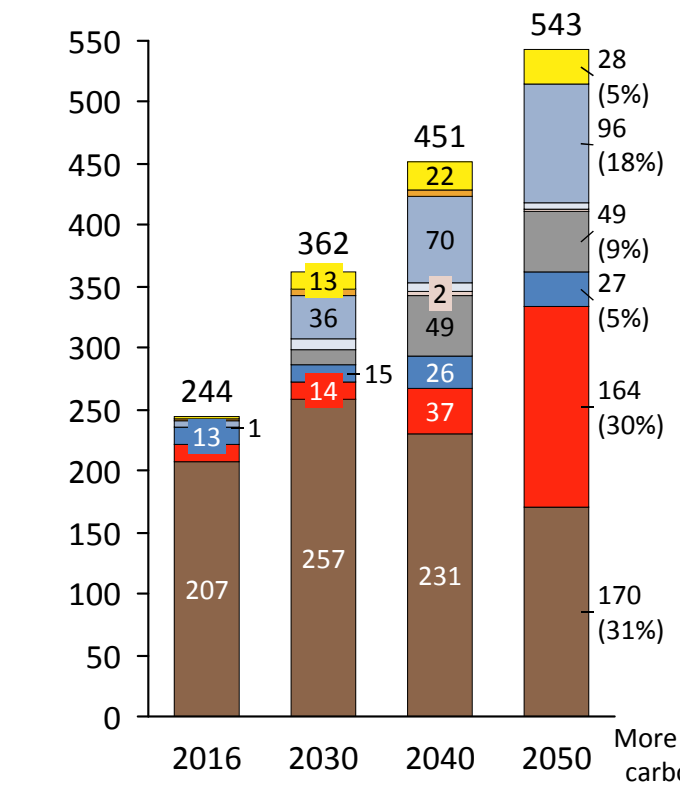
Proposal / Next Steps

Least-cost "CSIR Re-Optimised" case is largely based on wind and PV

As per Draft IRP 2016

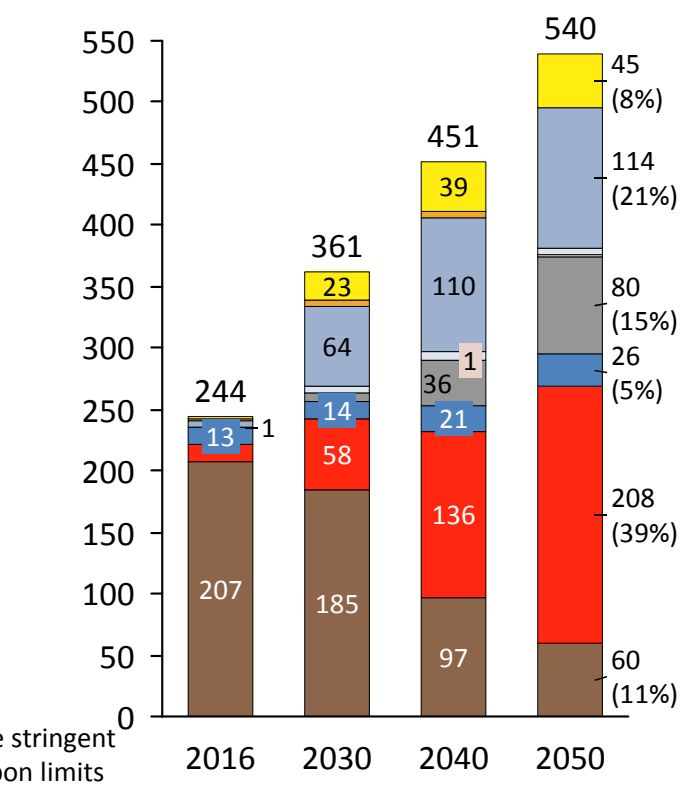
Draft IRP 2016 Base Case

Total electricity produced in TWh/yr



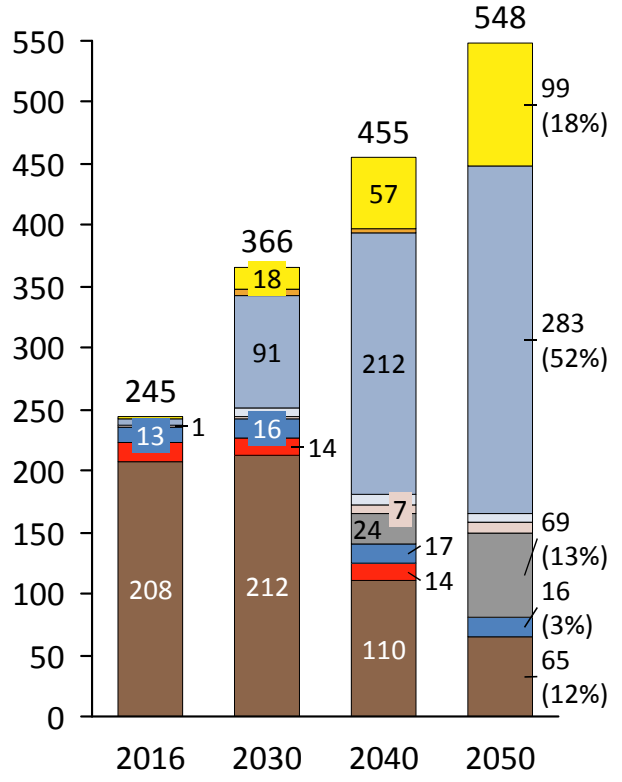
Draft IRP 2016 Carbon Budget

Total electricity produced in TWh/yr



CSIR Re-Optimised

Total electricity produced in TWh/yr



More stringent carbon limits →

No RE limits →

Solar PV | Wind | Gas (CCGT) | Nuclear
CSP | Peaking | Hydro+PS | Coal

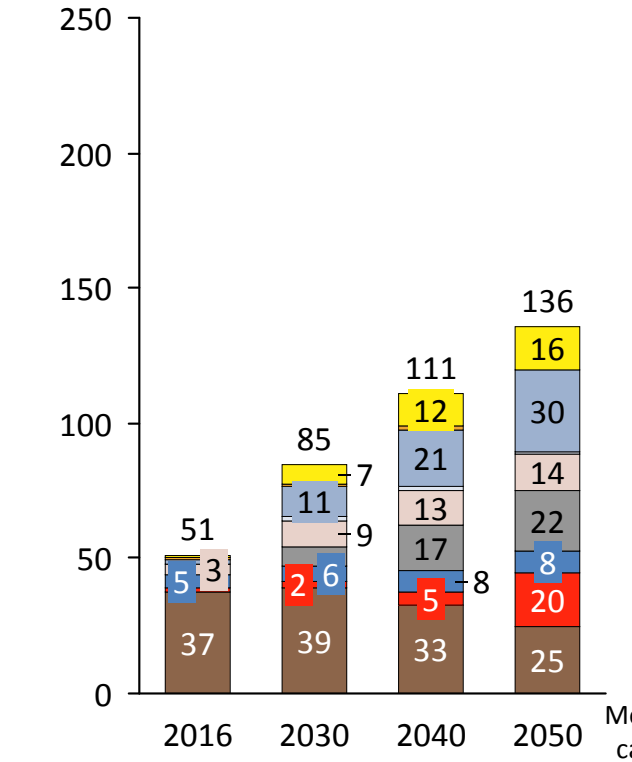
Sources: CSIR analysis

In the CSIR Re-Optimised case, 100 GW of wind & 60 GW of PV by 2050

As per Draft IRP 2016

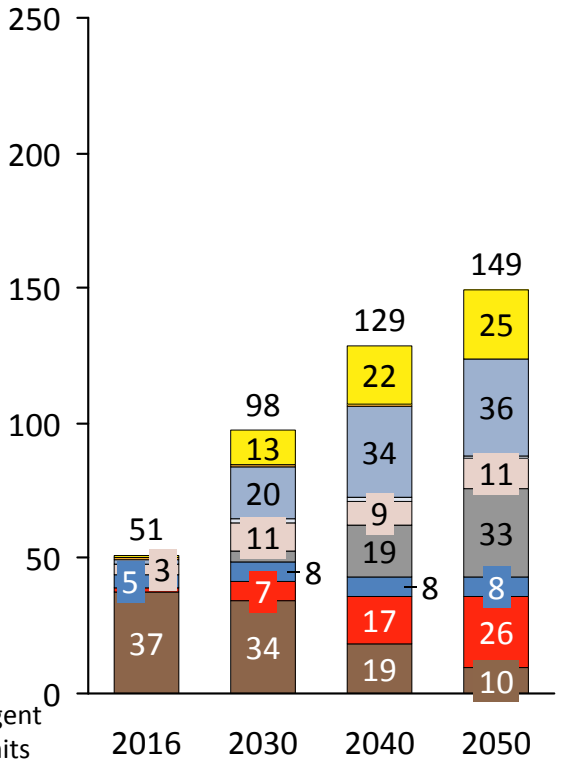
Draft IRP 2016 Base Case

Total installed net capacity in GW



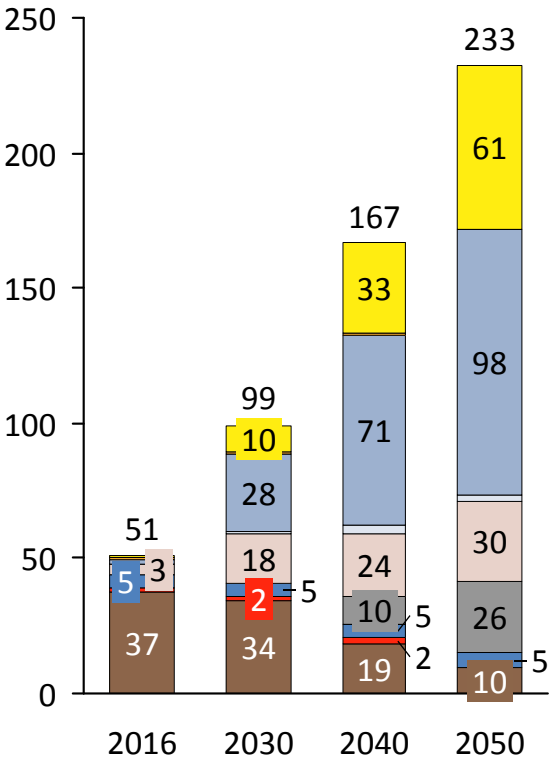
Draft IRP 2016 Carbon Budget

Total installed net capacity in GW



CSIR Re-Optimised

Total installed net capacity in GW



More stringent carbon limits

No RE limits

Solar PV
Wind
Gas (CCGT)
Nuclear
CSP
Peaking
Hydro+PS
Coal

Sources: CSIR analysis

CSIR Re-Optimised case without renewables limits is R90 billion/yr cheaper than both IRP 2016 Base Case & IRP 2016 Carbon Budget case

Year 2050

Draft IRP 2016 Base Case	Draft IRP 2016 Carbon Budget	CSIR Re-Optimised
 27%	 34%	 72%
 R580 billion/yr	 R580 billion/yr	 R490 billion/yr
 200 Mt/yr	 90 Mt/yr	 90 Mt/yr
 40 bn l/yr	 16 bn l/yr	 16 bn l/yr

Sources: CSIR analysis

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Recommendation:
The IRP Base Case should be least-cost, free of any artificial constraints

Solar PV, wind and flexibility is the cheapest new-build mix for the South African power system and it is the cost-optimal expansion to aim for a >70% renewable energy share by 2050

This "CSIR Re-Optimised" mix is R90 billion per year cheaper by 2050 than current Draft IRP Base Case

Also, CSIR Re-Optimised mix reduces CO2 emissions by 65% (-130 Mt/yr) compared to Draft IRP Base Case

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

Recommendation: The IRP Base Case should be least-cost, free of any artificial constraints

- New-build limits for renewables should be lifted, relative costs of wind/PV updated, and the unconstrained re-run should form the Base Case of the IRP 2016
- Any cost increase due to deviations from the least-cost Base Case should be reported on

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Note: Wind and solar PV would have to be 60% more expensive than assumed before the IRP Base Case and the CSIR Re-Optimised case break even
Sources: CSIR analysis

Re a leboha

Ha Khensa

Enkosi

Siyathokoza

Thank you

Re a leboga

Ro livhuha

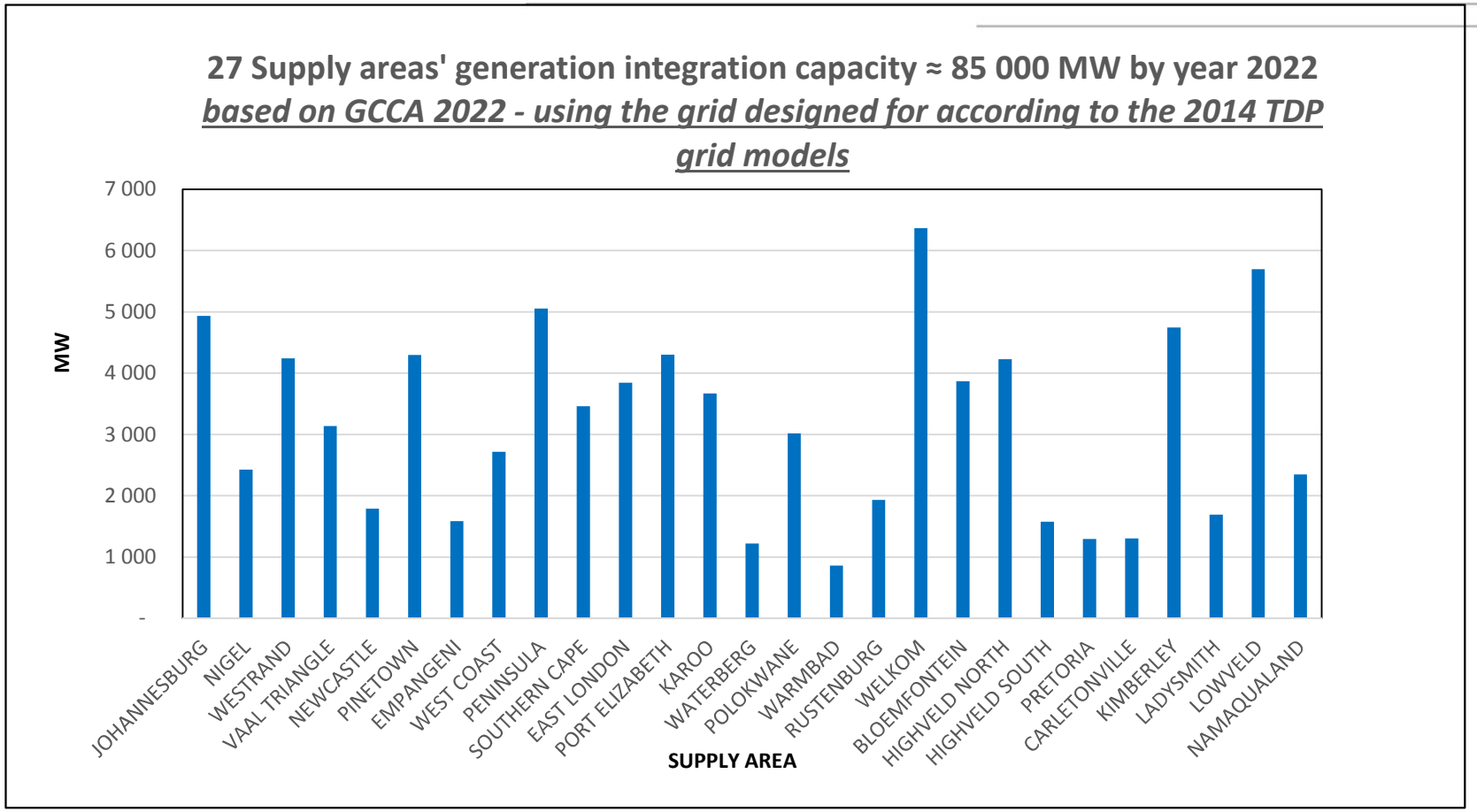
Dankie

Siyabonga

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

BACKUP

REBID 1-4 amounts to only 6.8 GW of Wind and PV, the grid has more than enough capacity (≈85 GW) by year 2022



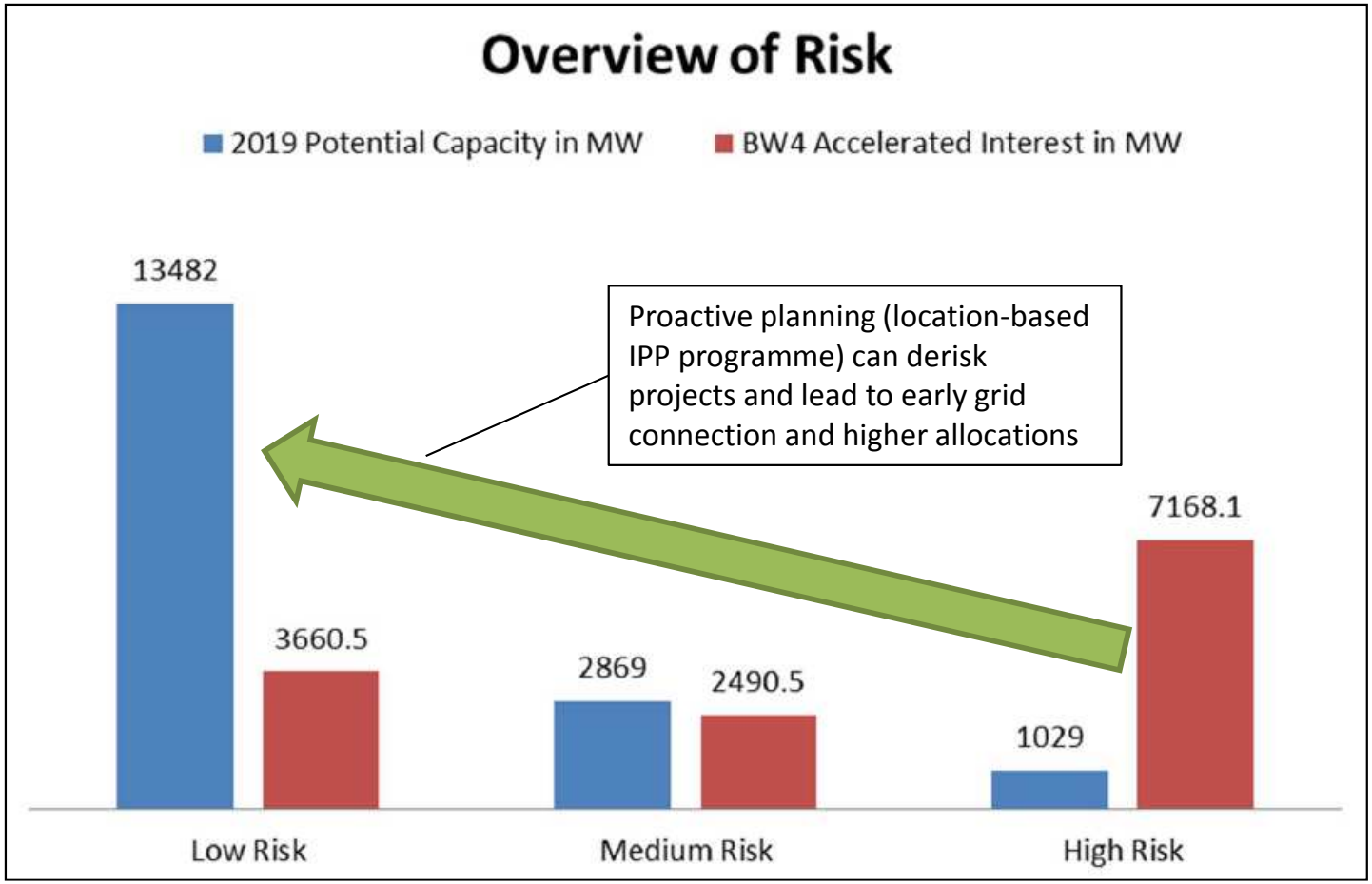
Additional studies (stability etc.) to quantity how much of the 85 GW can be comprised of wind and PV (with flexible generators) are warranted for managing the rollout plan

GCCA – Generation Connection Capacity Assessment

Sources:

- Transmission development plan 2016-2025: http://www.eskom.co.za/Whatweredoing/TransmissionDevelopmentPlan/Pages/Transmission_Development_Plans.aspx
- GCCA 2022: http://www.eskom.co.za/Whatweredoing/GCCAReport/Pages/Default.aspx
- CSIR analyses

Lack of location-based incentives for IPPs leads to interest in substations that are already constrained (e.g. RE Bid 4 Expedited)



Low risk:
Capacity available

Medium risk:
Minimal grid infrastructure required

High risk:
Extensive grid infrastructure required at Tx level

For Bid Window 4 Expedited, only 1170 MW was allocated for wind (650 MW) and PV (520 MW); more could have been allocated

Sources:
- Eskom Transmission Grid Planning - Expedited Bid Window Programme Access Risk Assessment
- CSIR analysis

Grid assessment/information to accompany the formal submission – all to be based publicly available information and data sets

- Grid capacity available at all busbars (66/88/132/275/400 kV) in transmission substations after RE Bid Windows 1-4
- Wind and solar PV correlation/aggregation impact on grid capacity assessment
- Location of wind and PV plants for the least-cost optimised electricity generation mix by 2050
- The estimated grid cost for the integration of new generation capacity for each scenario studies
- High-level assessment of the variable RE penetration levels for South Africa that will necessitate detailed stability and other studies associated with a South African system with low inertia

Actual experience from power systems globally indicate that > 50% instantaneous penetration of variable RE is possible before stability issues are a cause for concern