Least Cost Electricity Mix for South Africa
Optimisation of the South African power sector until 2050

CSIR Energy Centre

Status: 16 January 2017
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)
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. The same software platform as IRP was used to determine the least-cost expansion path of the South African power system to 2050.

Sources: CSIR analysis
Agenda

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IRP Results and Least-cost Scenario

Proposal / Next Steps
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**

- Solar PV IPP (Bid Window 4 Expedited): 0.62 R/kWh (Apr-2016-Rand) -40% → 0.62 R/kWh (Apr-2016-Rand)
- Wind IPP (Bid Window 4 Expedited): 0.87-0.95 R/kWh → 0.62 R/kWh (Apr-2016-Rand)
- Baseload Coal IPP (Bid Window 1): 1.03 R/kWh

**IRP 2016 cost input assumptions**

- Solar PV: 1.13 R/kWh (Apr-2016-Rand)→ 0.93 R/kWh (Apr-2016-Rand) +8%
- Wind: 0.98 R/kWh (Apr-2016-Rand) -7%
- Baseload Coal: 1.05 R/kWh (Apr-2016-Rand)

As per IRP 2016, inflated to April-2016-Rand, ODCs + grid connection added

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 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**

- Solar PV IPP (Bid Window 4 Expedited): 0.62
- Wind IPP (Bid Window 4 Expedited): 0.62
- Baseload Coal IPP (Bid Window 1): 1.03
- CSP IPP (Bid Window 4 Expedited): 2.02

**IRP 2016 cost input assumptions**

- Solar PV: 0.93
- Wind: 0.81
- Baseload Coal: 0.86
- CSP: 2.34

Sources: South African Department of Energy IPP Office’s publications on results of IPP Bid Windows; IPP Office on Bid Window 4 expedited; 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.

Tariff in R/kWh (Apr-2016-Rand)


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”

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”

Actual solar PV tariffs quickly approached IRP 2010 assumptions in first four bid windows and are now well below cost assumption funnel.
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Assumptions: IRP2010</th>
<th>Assumptions: IRP2016</th>
<th>Actuals: REIPPPP (BW1-4 Expedited)</th>
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<tbody>
<tr>
<td>2010</td>
<td>1.75</td>
<td>1.51</td>
<td>0.00</td>
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<td>2012</td>
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<td>1.19</td>
<td>0.62</td>
</tr>
<tr>
<td>2014</td>
<td>1.19</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>0.87</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>0.75</td>
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<td>2020</td>
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<td>2026</td>
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<td>2028</td>
<td>1.51</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>1.75</td>
<td>1.90</td>
<td></td>
</tr>
</tbody>
</table>

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”

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

**Solar PV relative to baseload coal cost**

- Assumptions: IRP2010
- Assumptions: IRP2016
- Actuals: REIPPPP relative to Coal IPPPP

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

Wind relative to baseload coal cost

- Assumptions: IRP2010
- Assumptions: IRP2016
- Actuals: REIPPPP relative to Coal IPPPP

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

Actuals: REIPPPP relative to Coal IPPPP.

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

Solar PV relative to nuclear cost

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

Wind relative to nuclear cost

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

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


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
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.

### Table: New-build limits for solar PV and wind

<table>
<thead>
<tr>
<th>Year</th>
<th>System Peak Load in MW</th>
<th>New-build limit Solar PV in MW/yr</th>
<th>Relative new-build limit Solar PV</th>
<th>New-build limit Wind in MW/yr</th>
<th>Relative new-build limit Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>44 916</td>
<td>1 000</td>
<td>2.2%</td>
<td>1 600</td>
<td>3.6%</td>
</tr>
<tr>
<td>2025</td>
<td>51 015</td>
<td>1 000</td>
<td>2.0%</td>
<td>1 600</td>
<td>3.1%</td>
</tr>
<tr>
<td>2030</td>
<td>57 274</td>
<td>1 000</td>
<td>1.7%</td>
<td>1 600</td>
<td>2.8%</td>
</tr>
<tr>
<td>2035</td>
<td>64 169</td>
<td>1 000</td>
<td>1.6%</td>
<td>1 600</td>
<td>2.5%</td>
</tr>
<tr>
<td>2040</td>
<td>70 777</td>
<td>1 000</td>
<td>1.4%</td>
<td>1 600</td>
<td>2.3%</td>
</tr>
<tr>
<td>2045</td>
<td>78 263</td>
<td>1 000</td>
<td>1.3%</td>
<td>1 600</td>
<td>2.0%</td>
</tr>
<tr>
<td>2050</td>
<td>85 804</td>
<td>1 000</td>
<td>1.2%</td>
<td>1 600</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

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

Expertise of Commentators

Comments on IRP Assumptions

IRP Results and Least-cost Scenario

Proposal / Next Steps
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: www.csir.co.za/Energy_Centre/wind_solarpv.html
A single wind farm changes its power output quickly
Simulated wind-speed profile and wind power output for 14 January 2012
Aggregating 100 wind farms: 15-min gradients almost zero
Simulated wind-speed profile and wind power output for 14 January 2012

14 Jan 2012 23:45 SAST
wind speed at 100m above ground

Aggregation level: 2
Number of wind pixel: 100

normalised wind power

% of nominal power

Hour

Aggregation level: 1
Number of wind pixel: 10

normalised wind power

% of nominal power

Hour

normalised wind power 15-min gradient

% of nominal power

Hour

normalised wind power 15-min gradient

% of nominal power

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

Space requirement 0.1km²/MW à max. 250 MW per pixel
On almost 70% of suitable land area in South Africa a 35% capacity factor or higher can be achieved (>50% for turbines 1-3). Share of South African land mass less exclusion zones with capacity factors to be reached accordingly.

Installing turbine type 4 and 5 will cause higher costs but also increase capacity factors and electricity yield whilst consuming the same area.
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

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  
3. 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

   - 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

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
Source: DoE (IRP 2010); DoE (IRP 2013); Eskom MTSAO 2016-2021; StatsSA; World Bank; CSIR analysis
Actual tariffs: new renewables projects much cheaper than first ones
First four Bid Windows’ results of Department of Energy’s RE IPP Procurement Programme (REIPPPP)

Notes: For CSP Bid Window 3, 3.5 and 4 Expedited, the weighted average of base and peak tariff is indicated, assuming 64%/36% split between base and peak tariff; BW = Bid Window; Sources: Department of Energy’s publications on results of first four bidding windows http://www.energy.gov.za/files/renewable-energy-status-report/Mar%202016-Market-Overview-and-Current-Les-of-Renewable-Energy-Deployment-NERSA.pdf; IPP Office on BW4 Expedited; StatsSA on CPI; CSIR analysis
Key input cost assumptions for new supply technologies

**Lifetime cost per energy unit**

<table>
<thead>
<tr>
<th>R/kWh (Apr-2016-R)</th>
<th>Actual new-build tariffs</th>
<th>Assumptions based new-build cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bid Window 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Solar PV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Baseload</td>
<td>1.03</td>
<td>Actuals: REIPPPP BW 4 (Exp.)</td>
</tr>
<tr>
<td>Baseload</td>
<td>1.05-1.16</td>
<td>Coal IPPPP BW1</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Gas (CCGT)</td>
<td>1.24</td>
<td>High-priced gas at 150 R/GJ</td>
</tr>
<tr>
<td>Mid-merit Coal</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Gas (OCGT)</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Diesel (OCGT)</td>
<td>3.10</td>
<td></td>
</tr>
</tbody>
</table>

**Typical capacity factor**

- Solar PV: 92%
- Wind: 50%
- Baseload: 50%
- Nuclear: 10%
- Coal (IPP): 10%
- Coal (Eskom): 10%

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 à higher capital costs and fixed O&M costs per kWh);
3. 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

Assumptions: IRP2010 - high
Assumptions: IRP2010 - low
Assumptions for this study
Actuals: REIPPPP (BW1-4Exp)

∑ = 2.8 GW

Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis
Future cost assumptions for wind aligned with results of Bid Window 4

Sources: Stats SA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis
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.

For bid window 3, 3.5 and 4 Exp, weighted average tariff of base and peak tariff calculated on the assumption of 64%/36% base/peak tariff utilisation ratio.

Sources: StatsSA for CPI; IRP 2010; South African Department of Energy (DoE); DoE IPP Office; CSIR analysis
CO2 emissions constrained by RSA’s Peak-Plateau-Decline objective

PPD that constrains CO2 emission from electricity sector

CO2 emissions (electricity sector) [Mt/yr]

CO2 cap implemented as a hard constraint into the model (i.e. must not be exceeded)
Only in post-processing to calculate cost of CO2, cost of 120 R/t assumed

Sources: DoE (IRP 2010-2030 Update); StatsSA; CSIR analysis
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**
  - 2016: 248 TWh/yr
  - 2030: 344 TWh/yr
  - 2040: 431 TWh/yr
  - 2050: 523 TWh/yr

### Draft IRP 2016 Carbon Budget

- **Total electricity produced in TWh/yr**
  - 2016: 248 TWh/yr
  - 2030: 345 TWh/yr
  - 2040: 433 TWh/yr
  - 2050: 525 TWh/yr

### CSIR Re-Optimised

- **Total electricity produced in TWh/yr**
  - 2016: 248 TWh/yr
  - 2030: 346 TWh/yr
  - 2040: 433 TWh/yr
  - 2050: 527 TWh/yr

**More stringent carbon limits**

- 2016: 248 TWh/yr
- 2030: 344 TWh/yr
- 2040: 431 TWh/yr
- 2050: 523 TWh/yr

**No RE limits**

- 2016: 248 TWh/yr
- 2030: 346 TWh/yr
- 2040: 433 TWh/yr
- 2050: 527 TWh/yr

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

### Draft IRP 2016 Base Case

<table>
<thead>
<tr>
<th>Year</th>
<th>Total installed net capacity in GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>51</td>
</tr>
<tr>
<td>2030</td>
<td>85</td>
</tr>
<tr>
<td>2040</td>
<td>131</td>
</tr>
<tr>
<td>2050</td>
<td>161</td>
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</table>

### Draft IRP 2016 Carbon Budget

<table>
<thead>
<tr>
<th>Year</th>
<th>Total installed net capacity in GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>51</td>
</tr>
<tr>
<td>2030</td>
<td>98</td>
</tr>
<tr>
<td>2040</td>
<td>129</td>
</tr>
<tr>
<td>2050</td>
<td>149</td>
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</tbody>
</table>

### CSIR Re-Optimised

<table>
<thead>
<tr>
<th>Year</th>
<th>Total installed net capacity in GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>51</td>
</tr>
<tr>
<td>2030</td>
<td>103</td>
</tr>
<tr>
<td>2040</td>
<td>178</td>
</tr>
<tr>
<td>2050</td>
<td>237</td>
</tr>
</tbody>
</table>

**Sources:** CSIR analysis
CSP sensitivity: CSP < 1.4 R/kWh and at 20% CF is cost competitive

Comparison of energy supply for Re-Optimised base scenario and Re-Optimised with low CSP cost

Sources: CSIR analysis
CSP sensitivity: CSP < 1.4 R/kWh and at 20% CF is cost competitive
Comparison of energy supply for Re-Optimised base scenario and Re-Optimised with low CSP cost

Sources: CSIR analysis
CSP sensitivity: CSP < 0.9 R/kWh and at 60% CF is cost competitive
Comparison of energy supply for Re-Optimised base scenario and Re-Optimised with low CSP cost

Sources: CSIR analysis
CSP sensitivity: CSP < 0.9 R/kWh and at 60% CF is cost competitive
Comparison of energy supply for Re-Optimised base scenario and Re-Optimised with low CSP cost

CSIR Re-Optimised (base)

Re-Optimised, CSP Sensitivity

Sources: CSIR analysis
CSP sensitivity: CSP cost below 1.4 R/kWh makes it a gas fuel saver

Two pre-conditions for CSP to be a cost-efficient contributor in the energy mix in 2050

- 1) CSP cost below 1.4 R/kWh @ 20% CF à today RSA: 2.0 R/kWh @ 50-60% CF, or
- 2) CSP cost below 0.9 R/kWh @ 60% CF à today RSA: 2.0 R/kWh @ 50-60% CF

- CSP fully dispatchable within a certain daily energy budget (i.e. CSP energy budget can be distributed by the System Operator as required into the 24 hours of the day, within the maximum of installed capacity)

If these two conditions are met, then CSP can play the role of a gas fuel saver and displaces wind in 2050
IRP 2016 (DRAFT): CSIR Re-Optimised in 2050
CSP 20% CF

Example Week under CSIR Re-Optimised 2050

Sources: CSIR analysis
Example Week under CSIR Re-Optimised 2050

Sources: CSIR analysis
Example Week under CSIR Re-Optimised 2050

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

<table>
<thead>
<tr>
<th>Draft IRP 2016 Base Case</th>
<th>Draft IRP 2016 Carbon Budget</th>
<th>CSIR Re-Optimised</th>
</tr>
</thead>
<tbody>
<tr>
<td>27%</td>
<td>33%</td>
<td>80%</td>
</tr>
<tr>
<td>R580 billion/yr</td>
<td>R580 billion/yr</td>
<td>R490 billion/yr</td>
</tr>
<tr>
<td>200 Mt/yr</td>
<td>100 Mt/yr</td>
<td>70 Mt/yr</td>
</tr>
<tr>
<td>40 bn l/yr</td>
<td>16 bn l/yr</td>
<td>11 bn l/yr</td>
</tr>
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</table>

Sources: CSIR analysis
Tipping point cost for CSP depends on annual average CF
Expertise of Commentators

Comments on IRP Assumptions

IRP Results and Least-cost Scenario

Proposal / Next Steps
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.

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.
Thank you

Ha Khensa

Siyathokoza

Siyabonga

Re a leboha

Enkosi

Re a leboga

Ro livhuha

Dankie

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

27 Supply areas' generation integration capacity = 85 000 MW by year 2022 based on GCCA 2022 - using the grid designed for according to the 2014 TDP grid models.

Additional studies (stability etc.) to quantify 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:
- CSIR analyses
Lack of location-based incentives for IPPs leads to interest in substations that are already constrained (e.g. RE Bid 4 Expedited).

Proactive planning (location-based IPP programme) can derisk projects and lead to early grid connection and higher allocations.

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

Low risk:
Capacity available

Medium risk:
Minimal grid infrastructure required

High risk:
Extensive grid infrastructure required at Tx level
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