Setting up for the 2020s
Addressing South Africa’s electricity crisis and getting ready for the next decade

CSIR Energy Centre
Pretoria. January 2020
v1.1

DR JARRAD WRIGHT
JOANNE CALITZ

CSIR
our future through science
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As announced by the President of South Africa (March 2019), crises are (a) sources of uncertainty, disruption, and change, (b) harmful/threatening for organisations and stakeholders, (c) behavioural phenomena (socially constructed by actors involved) (d) parts of larger processes (rather than discrete events). As an individual household, as a business, as a regulator, as a policymaker/decision-maker; it is not intended to address other topics in the electricity industry in South Africa e.g. financial sustainability & operational efficiency of institutions, political economy of stakeholders interacting on the basis of relevant interests.

Sources: Bundy.

<table>
<thead>
<tr>
<th>What is happening now and what will happen in the next 3-5 years?</th>
<th>What is CSIR addressing?</th>
</tr>
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<tbody>
<tr>
<td>Is South Africa in an electricity crisis(^1,2)?</td>
<td>Assessing whether this is an electricity crisis (and the extent thereof)</td>
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<td>How long will loadshedding last?</td>
<td>Present two scenarios to understand the expected intensity &amp; duration of loadshedding</td>
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<td>What options are available to solve the electricity crisis(^3)?</td>
<td>Proposing feasible options/solutions to alleviate the crisis and testing their impact</td>
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**Focus is to analyse, interpret and present an evidence-base that can assist in supporting custodians & stakeholders to ensure short-term system adequacy**\(^3\)

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\(^1\) As announced by the President of South Africa (March 2019); \(^2\) Crises are (a) sources of uncertainty, disruption, and change, (b) harmful/threatening for organisations and stakeholders, (c) behavioural phenomena (socially constructed by actors involved) (d) parts of larger processes (rather than discrete events); \(^3\) As an individual household, as a business, as a regulator, as a policymaker/decision-maker; It is not intended to address other topics in the electricity industry in South Africa e.g. financial sustainability & operational efficiency of institutions, political economy of stakeholders interacting on the basis of relevant interests.

Sources: Bundy.
## Why is CSIR making this contribution?

| Independence | • CSIR is an independent scientific research institution with no vested interests in outcomes |
| Transparency | • CSIR has (over the years) developed & collated necessary data, analytics and modelling frameworks\(^1\)  
• CSIR publish all analysis in this domain and intend to continue (public interest)\(^2\)  
• Providing an evidence-base to inform and aid planning for all custodians/stakeholders |
| Experience/expertise | • CSIR is highly proficient/competent in this domain with well respected capabilities  
• CSIR is well positioned to undertake this suite of analysis as a publicly trusted independent institution |
| Expedience | • South Africa is in an electricity crisis\(^3\)  
• CSIR is already engaging with key custodians/stakeholders & intends to formally engage further to assist in driving expedited responses/actions by various custodians/stakeholders\(^4\) |

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1. Public domain information;  
2. As with previous analyses in this domain e.g. Draft IRP 2016, Draft IRP 2018, IRP 2019 (amongst others);  
3. As announced by the President of South Africa ([March 2019](#));  
4. DMRE RMPPP RfI is in the public domain (closing date 31 January 2020) with RfP to follow (publication for all custodians/stakeholders will inform responses, reduce risk and allow for more informed procurement)
The burning platform & need for an urgent response requires a widely understood evidence-base for all custodians/stakeholders to take action

South Africa had the worst year of loadshedding on record in 2019 (1352 GWh, 530 hours) with up to Stage 6 load shedding being implemented having significant impacts on the economy (≈R 60-120 bln)

Loadshedding is expected to continue for 2-3 years depending on key decisions/actions

An urgent response is necessary to ensure short-term adequacy and set South Africa on a path towards long-term adequacy in the 2020s

Systemic changes in Eskom fleet performance (EAF) expectation and demand forecast requires an updated understanding of capacity & energy gap relative to IRP 2019 assumptions¹ (as will be shown)

¹ Even if Medupi, Kusile, REIPPPP capacity under construction comes online as expected; EAF – Energy Availability Factor
2019 was the most intensive year of loadshedding to date in South Africa with Stage 6 being implemented in December 2019

![Graph showing load shedding GWh by year]

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration of outages (hours)</th>
<th>Energy shed (GWh)</th>
<th>Est. econ. Impact (ZAR-bln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>-</td>
<td>176</td>
<td>8-15</td>
</tr>
<tr>
<td>2008</td>
<td>-</td>
<td>476</td>
<td>21-42</td>
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<td>....</td>
<td>....</td>
<td>....</td>
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</tr>
<tr>
<td>2014</td>
<td>121</td>
<td>203</td>
<td>9-18</td>
</tr>
<tr>
<td>2015</td>
<td>852</td>
<td>1325</td>
<td>58-116</td>
</tr>
<tr>
<td>2016</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2017</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>2018</td>
<td>127</td>
<td>192</td>
<td>8-17</td>
</tr>
<tr>
<td>2019</td>
<td>530</td>
<td>1352</td>
<td>59-118</td>
</tr>
<tr>
<td>2020 (YTD)</td>
<td>80</td>
<td>143</td>
<td>6-12</td>
</tr>
</tbody>
</table>

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented. Practically, load shedding (and the Stage) may occasionally change/ end during a particular hour; Total GWh calculated assuming Stage 1 = 1 000 MW, Stage 2 = 2 000 MW, Stage 3 = 3 000 MW, Stage 4 = 4 000 MW, Stage 5 = 5 000 MW, Stage 6 = 6 000 MW; Cost to the economy of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh; Sources: Eskom Twitter account; Eskom se Push (mobile app); Nersa; CSIR analysis
System inadequacy has been highlighted recently by DMRE and Eskom – but no specific solutions/interventions provided (yet)

**Integrated Resource Plan 2019 (IRP 2019)**
- Released: October 2019
- Primarily due to lead-time of first new-build capacity in 2023

**Medium-Term System Adequacy Outlook 2019 (MTSAO 2019)**
- Released: November 2019
- Also highlighted lack of system adequacy if Eskom fleet EAF is below 72% for time horizon 2019-2024
- No new investments made in time-horizon

NOTE: Different assumptions made in a few dimensions for IRP 2019 and MTSAO 2019 (demand forecast, EAF, supply) but same conclusions reached. Sources: DMRE; Eskom
Historical fleet EAF decline seems irreversible, IRP 2018 EAF has not materialised... risk of IRP 2019 or MTSAO 2019 EAF (High) not materialising?

EAF – Energy Availability Factor; MTSAO – Medium-term System Adequacy Outlook
NOTE: 2019 EAF actual is YTD
Sources: Draft IRP 2018; IRP 2019; Eskom; CSIR Energy Centre analysis
What if the demand forecast is lower than in IRP 2019 (very likely) and what if the Eskom fleet EAF is lower than in IRP 2019 (also very likely)?

Sources: CSIR Energy Centre analysis
Would an updated EAF expectation and demand forecast make any difference to capacity and energy shortages?

NOTE: “Updated” scenario is a test scenario developed by CSIR; Demand forecast is based on Eskom MTSAO demand forecast (until 2024) and IRP 2019 growth rates thereafter; Updated EAF based on MTSAO MES 1 (Low); EAF – Energy Availability Factor
Sources: IRP 2019; MTSAO; CSIR
Shortage from IRP 2019 indicating a dominant short-term capacity gap & small energy gap until planned new-build capacity comes online

Capacity (shortage)

Energy (shortage)

IRP 2019 EAF & IRP 2019 demand forecast
(EAF recovery from ≈67% in 2019 to 75.5% by 2024) (Demand forecast immediately growing to 284 TWh by 2025)

* Estimated Eskom Demand Response (DR) capability (mostly industrial & energy limited); NOTES: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported; All IRP 2019 capacity is assumed to come online as planned (Step 3 is always considered implemented); Cost of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh; Sources: CSIR Energy Centre analysis
Updated EAF & demand forecast indicates further shortage relative to IRP 2019 requiring capacity and significantly more energy

* Estimated Eskom Demand Response (DR) capability (mostly industrial & energy limited); NOTES: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported; All IRP 2019 capacity is assumed to come online as planned (Step 3 is always considered implemented); Cost of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh; Sources: CSIR Energy Centre analysis

Updated EAF & Updated demand forecast
(EAF from ≈67% in 2019 to ≈64% by 2024) (Demand forecast initially flat & growth to 267 TWh by 2025)
Criteria to decide on options to meet the short-term gap should be informed and applied consistently to ensure reasonable cost & timeous delivery.

Criteria for choice of short-term options available can ensure a portfolio of options:

1. Can be supply-side, demand-side and/or storage
2. Can be delivered in 1-2 years
3. Will not require extensive procurement process (lead-time)
4. Can meet capacity (MW) and/or energy needs (MWh)
5. Can be contracted for 1-3 years (or more if aligned with long-term energy mix)
6. Ease of implementation (does not require extensive regulatory reform/change)
7. Aligned with long-term energy mix pathways (technology choices)
8. Does not require extensive network expansion or augmentation for interconnection

Sources: CSIR Energy Centre analysis
Critical decisions/actions needed now along with accelerated processes to ensure timeous implementation allowing RSA to ramp into 2020s successfully

### Customer response at scale

- **Step 1**
  - **Capacity**: 1.2 GW (supply/storage)
  - **Decision/action**: Comms/incentives (SSEG)
  - **Stakeholders**: IPPO/DBSA, DMRE, NERSA, Eskom (DPE), NT
  - **Custodians**: IPPO/DBSA, DMRE, NERSA, Eskom (DPE), NT

### DMRE RMPPP

- **Step 2**
  - **Capacity**: 1.3-2.8 GW (supply)
  - **Decision/action**: RFI (response), RIP (response)
  - **Stakeholders**: Customers (businesses, households), municipalities, IPPs, financial institutions

### Implement IRP 2019

- **Step 3**
  - **Capacity**: 1.6 GW (wind), 1.0 GW (PV), 0.5 GW (storage)
  - **Decision/action**: IPPPPP (response), IPPPPP (FC)
  - **Stakeholders**: Customers (businesses, households), municipalities, IPPs

### Timelines

- **01/2020**
  - 1.2 GW (supply/storage)
  - 1.3-2.8 GW (supply)
  - 1.6 GW (wind), 1.0 GW (PV), 0.5 GW (storage)

- **01/2021**
  - 2.6 GW (supply/storage)
  - 0.1-1.9 GW (supply)
  - 2.0 GW (wind), 0.5 GW (storage), 0.75 GW (cool)

- **01/2022**
  - 4.9 GW (supply/storage)
  - 0.1-1.6 GW (supply)
  - 0.5 GW (DG/EG), 0.75 GW (cool)

- **01/2023**
  - 4.9 GW (supply/storage)
  - 0.1-1.6 GW (supply)
  - 0.5 GW (DG/EG), 0.75 GW (cool)

- **01/2024**
  - 4.9 GW (supply/storage)
  - 1.2-3.9 GW (supply)
  - 4.8 GW (wind), 2.0 GW (PV), 0.5 GW (storage), 0.75 GW (cool)

- **01/2025**
  - 4.9 GW (supply/storage)
  - 6.4 GW (wind), 3.0 GW (PV), 0.5 GW (storage), 0.75 GW (cool)

**NOTES:**

- Timelines are estimated and in no way prescriptive; PBs – Preferred bidders, PPA – Power Purchase Agreement; RFI – Request for Information; RIP – Request for Proposal; FC – Financial Close, COD – Commercial Operations Date;
- Total additional installed capacity;
- Requires adjusted SSEG regulations (proposed lifting licensing requirement for SSEG & only requiring registration with NERSA - from 1 MW to 10 MW (or more));
- SSEG (res.) does not require regulatory changes (just communications rollout but could be further incentivised by Eskom/municipalities);
- Will require Ministerial Determination - generators expected >10 MW (technologies aligned with IRP 2019);
- Unlikely to get capacity online before 2023-2024 (risk of misalignment with IRP 2019).
Step 1 is the only immediate feasible response as Step 2 & 3 are expected from 2022/2023 only (best case) but still critical to ensure system adequacy

Key recommendations

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<tr>
<th>Customer response at scale</th>
<th>DMRE RMPPP</th>
<th>Implement IRP 20194</th>
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</table>
| **Step 1** Immediate focus on customer response at scale (self-supply) in all customer segments via **enabling regulations** (easy to implement)  
*Driven by SSEG (residential), EG (commercial/agricultural), EG/DG (industrial/mining), municipalities & storage, REIPPPP ‘power-up’* | **Step 2** Accelerate DMRE RMPPP process to address remaining capacity & energy gap and ensure capacity can come online timeously  
*An accelerated process necessary due to immediate shortages & should be based on estimated required capacity (complementing Step 1)* | **Step 3** Immediate focus on **Ministerial Determinations** for all technologies in IRP 2019 followed by **procurement process** to ensure timeous implementation  
*Due to procurement processes & technology specific lead-times this action/decision is required now* |

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<th>IMPACT</th>
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| Immediate focus on customer response at scale (self-supply) in all customer segments via enabling regulations (easy to implement)  
*Driven by SSEG (residential), EG (commercial/agricultural), EG/DG (industrial/mining), municipalities & storage, REIPPPP ‘power-up’* | **Immediate** reduced load shedding as capacity can come online in **2020 already**  
**Further assistance from 2021 onwards** as more capacity comes online |
| Accelerate DMRE RMPPP process to address remaining capacity & energy gap and ensure capacity can come online timeously  
*An accelerated process necessary due to immediate shortages & should be based on estimated required capacity (complementing Step 1)* | **Capacity online from 2022 only** (mid-2021 with accelerated DMRE RMPPP process)  
**Further reduction in load shedding** once capacity comes online |
| Immediate focus on Ministerial Determinations for all technologies in IRP 2019 followed by procurement process to ensure timeous implementation  
*Due to procurement processes & technology specific lead-times this action/decision is required now* | **First capacity online from 2023 only** (best case) but **required in 2022** (as per IRP 2019)  
**Adequate** power system into mid-2020s as existing capacity is decommissioned if IRP 2019 planned new-build capacity comes online |

**NOTE:** Even with short-term interventions, if EAF does not recover to IRP 2019 levels, shortage is expected in 2020-2021 depending on capacity that can feasibly come online, structural load shedding may still need to be considered for 2-3 years (shortages exaggerated in Updated scenario)

SSEG – Small-Scale Embedded Generation; DG – Distributed Generation; EG – Embedded Generation; RMPPP – Risk Mitigation Power Purchase Procurement Programme
This is a crisis - get capacity under construction online, recover Eskom plant performance AND implement all steps with urgency

Key recommendations

Ensure capacity under construction is delivered as planned (Medupi/Kusile, REIPPPP)

Recover Eskom fleet EAF to realistic levels whilst ensuring value for money relative to alternatives

Implement/enable 3 steps concurrently and with urgency:

- **Step 1**: Intentionally drive a customer response at scale (with enabling regulations) driven by SSEG (residential), EG (commercial/agricultural), EG/DG (industrial/mining) & storage\(^1\)
- **Step 2**: Address remaining capacity/energy gap via an accelerated DMRE RMPPPP process to ensure capacity is online when required
- **Step 3**: Continued implementation of IRP 2019 as an immediate focus to ensure sufficient lead-time for procurement processes and technology specific construction lead-times

\(^1\) As shown, these are the only options/solutions that would assist in mitigating load shedding in the next 2-3 years (other options/solutions would take further time to implement). SSEG – Small-Scale Embedded Generation; DG – Distributed Generation; EG – Embedded Generation; RMPPPP – Risk Mitigation Power Purchase Procurement Programme; NOTE: For further details – please refer to the remainder of this presentation; SSEG could include a range of technologies but would be dominated by solar PV.
In order to enable and implement recommended steps, first immediate decisions/actions are needed:

- **DMRE/Nersa** to update regulations to enable streamlined & expedited self-supply options\(^1\)
- **DMRE/Nersa** to publish Ministerial Determinations and/or update EG/DG regulations to enable DMRE RMPPPP additional capacity
- **DMRE/Nersa** to publish Ministerial Determinations aligned with IRP 2019
- **IPPO** engage & implement feasible existing REIPPPP PPA negotiations (REIPPPP ‘power-up’)
- **Various stakeholders** to drive intentional communications program and/or incentives for SSEG deployment (res./com./agri. focus)\(^2\)
- **IPPO** to run bid windows for new-build procurement (technologies aligned with IRP 2019) and undertake annually going forward

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\(^1\) Adjusted/updated SSEG regulations (proposed lifting licensing requirement for SSEG & only requiring registration with NERSA - from 1 MW to 10 MW (or more)); \(^2\) SSEG (res./com.) does not require regulatory changes (just communications rollout but could be further incentivised by Eskom/municipalities with appropriate tariffs).
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2019 has been the most intensive year of load shedding to date with Stage 6 being implemented in December 2019.

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented. Practically, load shedding (and the Stage) may occasionally change/ end during a particular hour; Total GWh calculated assuming Stage 1 = 1 000 MW, Stage 2 = 2 000 MW, Stage 3 = 3 000 MW, Stage 4 = 4 000 MW, Stage 5 = 5 000 MW, Stage 6 = 6 000 MW.

Cost to the economy of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh.

Sources: Eskom Twitter account; Eskom se Push (mobile app); Nersa; CSIR analysis.
Hourly distribution of actual load shedding January to June 2019

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented. Practically, load shedding (and the Stage) may occasionally change/end during a particular hour; Total GWh calculated assuming Stage 1 = 1 000 MW, Stage 2 = 2 000 MW, Stage 3 = 3 000 MW, Stage 4 = 4 000 MW, Stage 5 = 5 000 MW, Stage 6 = 6 000 MW

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Hourly distribution of actual load shedding July to December 2019

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Sources: Eskom Twitter account; Eskom se Push (mobile app); CSIR analysis
Severely constrained system from 4 December 2019, compounded by further breakdowns up to 9 December 2019 resulting in Stage 6 loadshedding

Actual hourly production from all power supply sources in RSA for December 2019

NOTES: Pumping load excluded; UCLF – Unplanned Capacity Loss Factor; OCGTs – Open-Cycle Gas Turbines
Sources: Eskom; CSIR Energy Centre analysis
South African supply-demand balance is maintained by the System Operator (Eskom) with some supply/demand responsive customers.
Historical fleet EAF decline since 2001 with apparent recovery in 2016-2017 but trend continued thereafter and is at ≈67% for 2019

EAF (annual)
[?] 100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
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20
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10
8
6
4
2
0

Actual
Planned

EAF – Energy Availability Factor
NOTE: 2019 EAF actual is YTD
Sources: IRP2019; Eskom; CSIR Energy Centre analysis
Recent Eskom weekly fleet EAF has been declining with unfortunate consequences of a highly constrained power system.
Historical fleet EAF decline seems irreversible... IRP 2018 EAF has also not materialised, risk of IRP 2019 or MTSAO 2019 EAF (High) not materialising?

EAF (annual) [%]

EAF – Energy Availability Factor; MTSAO – Medium-term System Adequacy Outlook

NOTE: 2019 EAF actual is YTD

Sources: Draft IRP 2018; IRP2019; Eskom; CSIR Energy Centre analysis
The supply-demand balance must be maintained for every hour of every day utilising available supply/demand options (dispatchable & self-dispatched).
Example – Lower EAF (lower coal fleet availability) would mean a more constrained power system and high-risk of loadshedding
Example – Higher EAF (higher coal fleet availability) would mean a less constrained power system and low-risk of loadshedding.
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- No new investments made in time-horizon

NOTE: Different assumptions made in a few dimensions for IRP 2019 and MTSAO 2019 (demand forecast, EAF, supply) but same conclusions reached.
Sources: DMRE; Eskom
CSIR simulated South African power system model benchmarked against actuals shows good alignment (2018 as a reference - annual)

PS – Pumped Storage; HVDC – High Voltage Direct Current;
NOTES: Includes generation for pumping load; Simulation in PLEXOS: production cost model with hourly temporal resolution and public input data; “Imports, Other” includes mostly imported hydro generation (via HVDC imports from Mozambique);
Sources: Eskom; CSIR Energy Centre analysis
CSIR simulated South African power system model benchmarked against actuals shows good alignment – coal focus (2018 as a reference - monthly)

NOTES: Simulation in PLEXOS: production cost model with hourly temporal resolution and public input data; Sources: Eskom; CSIR Energy Centre analysis
IRP 2019 has been gazetted indicating an immediately inclining demand forecast, decommissioning coal fleet but with improving EAF. Installed capacity and electricity supplied from 2018 to 2050.

**Installed capacity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total installed capacity (net) [GW]</th>
</tr>
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<tbody>
<tr>
<td>2018</td>
<td>53.5</td>
</tr>
<tr>
<td>2020</td>
<td>82.2</td>
</tr>
<tr>
<td>2022</td>
<td>108.8</td>
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**Energy mix**

<table>
<thead>
<tr>
<th>Year</th>
<th>Gazetted IRP 2019</th>
<th>Projection¹</th>
</tr>
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<tbody>
<tr>
<td>2018</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
</tr>
<tr>
<td>2022</td>
<td>Gazetted IRP 2019</td>
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</tr>
<tr>
<td>2024</td>
<td>Gazetted IRP 2019</td>
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<tr>
<td>2026</td>
<td>Gazetted IRP 2019</td>
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<tr>
<td>2028</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
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<tr>
<td>2030</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
</tr>
<tr>
<td>2032</td>
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**Electricity production**

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<tr>
<th>Year</th>
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<tr>
<td>2024</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
</tr>
<tr>
<td>2026</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
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<tr>
<td>2028</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
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<tr>
<td>2030</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
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<tr>
<td>2032</td>
<td>Gazetted IRP 2019</td>
<td>Projection¹</td>
</tr>
</tbody>
</table>

**First new-builds:**

- **Wind (2022)**: 1.6 GW
- **PV (2022)**: 1.0 GW
- **Storage (2022)**: 0.5 GW
- **Coal (2023)**: 0.75 GW
- **Gas (2024)**: 1.0 GW

1. Projection based on optimisation of 2030-2050 energy mix utilising input assumptions from DMRE IRP 2019 (not unconstrained least-cost); DSR – Demand Side Response; DG = Distributed Generation; VRE – variable renewable energy; NOTE: Energy share is a best estimate based on available data. Sources: IRP 2019. CSIR Energy Centre analysis.
IRP 2019 has also indicated an expected gap between 2018-2022 following which expected new-build options can come online (lead time dependant)

Installed capacity and electricity supplied from 2018 to 2050

---

**Installed capacity**

**Total installed capacity (net) [GW]**

- **Gazetted IRP 2019**
  - Supply gap: 82.2 GW
- **Projection**
  - Total installed capacity: 108.8 GW

**Energy mix**

**Electricity production [TWh/yr]**

- **Gazetted IRP 2019**
  - **Supply gap**: 202.8 TWh
- **Projection**
  - **Supply gap**: 311.3 TWh

---

1. **Projection based on optimisation of 2030-2050 energy mix utilising input assumptions from DMRE IRP 2019 (not unconstrained least-cost);**
2. **DSR – Demand Side Response; DG = Distributed Generation; VRE – variable renewable energy;**
3. **NOTE: Energy share is a best estimate based on available data.**
4. **Sources: IRP 2019. CSIR Energy Centre analysis**
Shortage from IRP 2019 indicating a dominant short-term capacity gap & small energy gap until planned new-build capacity comes online

* Estimated Eskom Demand Response (DR) capability (mostly industrial & energy limited); NOTES: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported; All IRP 2019 capacity is assumed to come online as planned (Step 3 is always considered implemented); Cost of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh; Sources: CSIR Energy Centre analysis

IRP 2019 EAF & IRP 2019 demand forecast
(EAF recovery from ≈67% in 2019 to 75.5% by 2024) (Demand forecast immediately growing to 284 TWh by 2025)

Loadshedding (actual)
2019: 1352 GWh
(R60-120bln cost to the economy)
NOTE: Understatement of energy shortages in simulation (conservative estimates)
IRP 2019 daily shortage profile shows capacity need in the morning/evening peak combined with daytime energy needs.

NOTE: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported.

Sources: CSIR Energy Centre analysis
Representative 2 weeks - constrained/unconstrained showing capacity needs along with daytime energy needs during some weekdays
Simulated hourly generation stack of the total power supply in RSA for 2 weeks in 2021

![Graph showing energy shortage and capacity shortage](image)

Energy shortage (daytime)
Capacity shortage (morning/evening)
Pumped storage (pumping mode)

**Eskom fleet EAF (week) = 64%**
**Eskom fleet EAF (week) = 79%**

NOTE: Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; one nuclear unit on planned outage from day 2.
Sources: CSIR Energy Centre analysis
<table>
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<th>Agenda</th>
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<td>Executive Summary</td>
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<td>The burning platform</td>
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<td>Current plans (IRP 2019)</td>
<td>30</td>
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<td>4</td>
<td>What if?</td>
<td>39</td>
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<tr>
<td>5</td>
<td>Mitigation options/solutions</td>
<td>45</td>
</tr>
</tbody>
</table>
What if the demand forecast is lower than in IRP 2019 (very likely) and what if the Eskom fleet EAF is lower than in IRP 2019 (also very likely)?

Sources: CSIR Energy Centre analysis
Would an updated EAF expectation and demand forecast make any difference to capacity and energy shortages?

NOTE: “Updated” scenario is a test scenario developed by CSIR; Demand forecast is based on Eskom MTSAO demand forecast (until 2024) and IRP 2019 growth rates thereafter; Updated EAF based on MTSAO MES 1 (Low); EAF – Energy Availability Factor

Sources: IRP 2019; MTSAO; CSIR
Updated EAF & demand forecast indicates further shortage relative to IRP 2019 requiring capacity and significantly more energy

* Estimated Eskom Demand Response (DR) capability (mostly industrial & energy limited); NOTES: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported; All IRP 2019 capacity is assumed to come online as planned (Step 3 is always considered implemented); Cost of load shedding is estimated using COUE (cost of unserved energy) = 87.50 R/kWh; Sources: CSIR Energy Centre analysis
Updated scenario shows initial morning/evening capacity need combined with all-day energy, shifting to morning/evening need only in later years.

NOTE: Energy & capacity shortage is demand that cannot be served due to a lack of capacity (including OCGTs, pumped storage & Eskom DR); Outcomes shown are from deterministic simulations - thus indicative; 99th percentile of capacity & energy shortage is reported.

Sources: CSIR Energy Centre analysis
Example – Updated scenario showing significant capacity & energy shortages during representative 2 weeks
Simulated hourly generation of the total power supply in RSA for 2 weeks in 2021

Eskom fleet EAF (week) = 56%
Eskom fleet EAF (week) = 67%

Extensive daily energy shortages
Minimal pumped storage generating/pumping
Capacity shortage (morning/evening)

NOTE: Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles;
One nuclear unit on planned outage from day 2.
Sources: CSIR Energy Centre analysis
## Agenda

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<th>Executive Summary</th>
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<tr>
<td>5</td>
<td>Mitigation options/solutions</td>
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</tbody>
</table>
Criteria to decide on options to meet the short-term gap should be informed and applied consistently to ensure reasonable cost and timeous delivery

Criteria for choice of short-term options available can ensure a portfolio of options:

1. Can be supply-side, demand-side and/or storage
2. Can be delivered in 1-2 years
3. Will not require extensive procurement process (lead-time)
4. Can meet capacity (MW) and/or energy needs (MWh)
5. Can be contracted for 1-3 years (or more if aligned with long-term energy mix)
6. Ease of implementation (does not require extensive regulatory reform/change)
7. Aligned with long-term energy mix pathways (technology choices)
8. Does not require extensive network expansion or augmentation for interconnection

Sources: CSIR Energy Centre analysis
Choice of the suite of solutions/interventions to fill the gap is highly dependant on lead-times and limits resulting options available

<table>
<thead>
<tr>
<th>Supply-side options</th>
<th>Technical potential</th>
<th>Short-term (2020-2022)</th>
<th>REIPPPP ‘power-up’</th>
<th>SSEG(^2) (res.)</th>
<th>Standby Gx aggregator</th>
</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td>200-500 MW (2020)</td>
<td>125-200 MW/yr</td>
<td>200-1 000 MW/yr</td>
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<td></td>
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<td></td>
<td>SSEG(^1) (com./ind./agri.)</td>
<td>400-750 MW/yr</td>
<td>DG/EG(^3) (ind./min.)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>400-750 MW/yr</td>
<td>250-750 MW/yr</td>
<td>500-2 000 MW/yr</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Solar PV: 1 000 MW (2022)</td>
<td>Solar PV: 6 000 MW</td>
<td>Solar PV: 1 500 MW</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Coal: 750 MW (2023)</td>
<td>Coal: 1 500 MW</td>
<td>DSR: 4 000 MW</td>
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<td></td>
<td>EG/DG: 500 MW (2023)</td>
<td>Gas: 3 000 MW</td>
<td>Storage (munics):</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gas: 1 000 MW (2024)</td>
<td></td>
<td>30-100 MW/yr / 90-300 MWh</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand-side options</th>
<th>Technical potential</th>
<th>Short-term (2020-2022)</th>
<th>Storage - SSEG(^2) (res.)</th>
<th>Storage - SSEG(^1) (com./ind./agri.)</th>
<th>Structural loadshedding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>30-100 MW/yr / 90-300 MWh</td>
<td>100-375 MW/yr / 300-1125 MWh</td>
<td>Stage 1: 1 000 MW</td>
</tr>
<tr>
<td></td>
<td>Prescribed in IRP 2019</td>
<td>Medium-term/Long-term (≥2023)</td>
<td>Storage - SSEG(^2) (res.)</td>
<td>Storage - SSEG(^1) (com./ind./agri.)</td>
<td>Stage 2: 2 000 MW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Storage: 513 MW (2022)</td>
<td>DSR</td>
<td>Structural loadshedding</td>
</tr>
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<td></td>
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<td>IRP 2019 (by 2030)</td>
<td>IRP 2019 (by 2030)</td>
<td>Storage: 2 088 MW</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Storage: 513 MW (2022)</td>
<td>Storage: 2 088 MW</td>
<td></td>
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</tbody>
</table>

NOTES: Storage deployment is considered as a demand-side option for simplicity and ease of understanding (is a net user of energy); SSEG could include a range of technologies but would be dominated by solar PV; Gx – Generation; com. – Commercial; ind. – Industrial; min. – mining; agri. – Agricultural; res. – Residential; DSR – Demand Side Response; ¹ Requires adjusted SSEG regulations (proposed lifting licensing requirement for SSEG & only requiring registration with NERSA - from 1 MW to 10 MW (or more)); ² Does not require regulatory changes (just communications rollout but could be further incentivised by Eskom/municipalities); ³ Will require Ministerial Determination - generators expected to be >10 MW (technologies should be aligned with IRP 2019); ⁴ Will require fast-tracked procurement process; ⁵ In addition to capacity under construction.
Considering the options available – a customer response at scale would form the only options with fastest lead-times (likely mostly self-dispatched)

**Step 1 (customer response at scale)**

- Some solutions can be quickly implemented by customers & at scale (short lead-times)
- Immediate requirement is adjusted SSEG regulations
- Adjusted PPAs with already existing REIPPPP generation capacity
- Communications/incentives/financing for SSEG for further deployment (with requisite Eskom/municipal tariffs)
- DG/EG (ind./min.) expected to be >10 MW each, requires licensing & ministerial approval*

- Options include (from 2020 onwards):
  - REIPPPP ‘power-up’: 200-500 MW
  - SSEG (com./ind./agri.)¹: 400-750 MW/yr
  - Storage - SSEG (com./ind./agri.)¹: 100-375 MW/yr / 300-1125 MWh
  - SSEG (res.)²: 125-200 MW/yr
  - Storage - SSEG (res.)²: 30-100 MW/yr / 90-300 MWh
  - DG/EG (ind./min.)³: 250-750 MW/yr
  - Storage (munics)²,³: 30-120 MW / 90-360 MWh

- Structural loadshedding:
  - Stage 1: 1000 MW; Stage 2: 2000 MW; (or more)

**NOTES:** Gx – Generation; com. – Commercial; ind. – Industrial; min. – mining; agri. – Agricultural; res. – Residential; DSR – Demand Side Response; * Technologies should be aligned with IRP 2019; DSR (EWHs) could also contribute 50-150 MW/yr in the short-term but has not been explicitly considered as yet due to uncertainty; ¹ Requires adjusted SSEG regulations (proposed lifting licensing requirement for SSEG & only requiring registration with NERSA - from 1 MW to 10 MW (or more)); ² Does not require regulatory changes (just communications rollout but could be further incentivised by Eskom/municipalities); ³ Will require Ministerial Determination - generators expected to be >10 MW (technologies should be aligned with IRP 2019)
Manage short-term needs with the range of options from Step 1 whilst RfI process runs in Step 2 (many dispatchable options likely to be available)

### Step 2 (addressing short-term adequacy and setting up for long-term expected energy mix)

- DMRE Risk Mitigation Power Purchase Procurement Programme (RMPPPP) RfI
- RfI (and resulting RfP) should assist to fill gap following Step 1 (customer response at scale)
- Reality: Only likely to come online from 2021 onwards
- Capacity providers expected to be >10 MW - licensing & ministerial approval (technologies aligned with IRP 2019)
- Can also include some of the options in Step 1

- Options could include (from 2021 onwards):
  - Standby Gx aggregator\(^1\): 200-1000 MW/yr
  - Emergency Gx\(^2,3\): 500-2000 MW/yr
  - Structural loadshedding: Stage 3: 3000 MW; Stage 4: 4000 MW

NOTES: Gx – Generation; com. – Commercial; ind. – Industrial; min. – mining; agri. – Agricultural; res. – Residential; DSR – Demand Side Response; \(^1\) Requires adjusted SSEG regulations (proposed lifting licensing requirement for SSEG & only requiring registration with NERSA - from 1 MW to 10 MW (or more)); \(^2\) Will require Ministerial Determination - generators expected to be >10 MW (technologies should be aligned with IRP 2019 but could include temporary/permanent engines, OCGTs, cogeneration, imports etc.); \(^3\) Will require fast-tracked procurement process.
DMRE RfI is needed & important but is only part of the puzzle and a component of the supply/demand options that will be needed

DMRE Request for Information (RfI)

• Request for Risk Mitigation Power Purchase Procurement (Generation)

• Released: 13 December 2019

• Briefing Session: 8 January 2020

• Response: 31 January 2020

• Specification:
  o Quantity: 2000 – 3000 MW
  o Can include supply-side and demand-side options
  o Lead-time: 3-6 months (2000 MW), 6-12 months (3000 MW)
  o PPA tenure: 3 years, 5 years, 10 years, 15 year, 20 years
  o Type: “Baseload Energy”, “Peaking Energy”, Mid-Merit Energy”
  o Regime: “Dispatchable”, “Self-Dispatchable”

• RfP to follow once RfIs have been assessed
Step 3 to setup for the 2020s - immediately run procurement rounds aligned with IRP 2019 & consider reductions based on Step 1 & 2 deployments

**Step 3 (continued implementation of IRP 2019)**

- Immediate Ministerial Determinations aligned with IRP 2019
- Begin next procurement rounds for new capacity (lead-times necessitate this)
- Reality: Only likely to come online from 2022 onwards (more likely 2023-2024)

- Options as defined by IRP 2019 (should likely be subtracted from capacity already deployed in Step 1 and Step 2):
  - Solar PV: 1000 MW (2022)  Solar PV: 6000 MW (2030)
  - Coal: 750 MW (2023)  Coal: 1500 MW (2030)
  - EG/DG: 500 MW (2023)  EG/DG: 4000 MW (2030)
  - Gas: 1000 MW (2024)  Gas: 3000 MW (2030)
  - Storage: 513 MW (2022)  Storage: 2088 MW (2030)
IRP 2019 scenario and roll out of step 1, daytime energy shortages & diesel burn substantially reduced, but load shedding still required

IRP 2019 with customer response at scale options (Step 1) options: Simulated hourly generation for 2 weeks in 2021

NOTE: Lower end of total estimated capacity in Step 1 is considered in scenarios; Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
IRP 2019 comparison with customer response at scale options (Step 1) revealing notably less constrained power system

Simulated hourly generation of the total power supply in RSA for 1 week in 2021

Eskom fleet EAF (week) = 64%

NOTE: Lower end of total estimated capacity in Step 1 is considered in scenarios; Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
IRP 2019 scenario (where improved EAF occurs) that is supplemented by customer response (Step 1) will then require mostly capacity (less energy)

What is still needed to ensure system adequacy (utilising DMRE RMPPPP RfI/RfP process)? (Step 2)

- Capacity\(^1\): 1.3 GW (2021), 0.1-1.2 GW (2022-2025)
- Capacity factor <3%

**NOTE:**

- This scenario assumes IRP 2019 EAF & IRP 2019 demand forecast:
  - EAF recovery from \(\approx67\%\) in 2019 to 75.5\% by 2024
  - Demand forecast immediately growing to 284 TWh by 2025
- If lower customer response at scale (Step 1), additional energy will be needed (higher capacity factor)
- Structural loadshedding (Stage 3 & Stage 4) may also be necessary during 2020-2021

\(^1\) It is assumed that capacity from Step 2 will only come online in 2021 (owing to procurement process & technology lead times);
Sources: CSIR Energy Centre analysis
IRP 2019 comparison with customer response (Step 1) and DMRE RMPPPP (Step 2) revealing capacity needs met (notably less constrained system)

Simulated hourly generation of the total power supply in RSA for 1 week in 2021

IRP 2019 with customer response at scale (Step 1)

IRP 2019 with customer response (Step 1) and DMRE RMPPPP (Step 2)

Eskom fleet EAF (week) = 64%

Reduced shortages

NOTE: Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
Updated scenario - with updated EAF & demand, with customer response (Step 1) reduces daytime shortages & diesel burn, but load shedding remains

Updated scenario with customer response at scale options (Step 1): Simulated hourly generation for 2 weeks in 2021

NOTE: Lower end of total estimated capacity in Step 1 is considered in scenarios; Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
Updated scenario shows significantly less constrained system with the roll out of customer response at scale (Step 1)
Simulated hourly generation of the total power supply in RSA for 1 week in 2021

NOTE: Lower end of total estimated capacity in Step 1 is considered in scenarios; Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
Updated scenario will require significant additional capacity & energy through to 2025 in addition to customer response at scale (Step 1)

Now... What is still needed to ensure system adequacy (utilising DMRE RMPPPP RfI/RfP process)? (Step 2)

• Capacity\(^1\): 2.8 GW (2021), 1.9 GW (2022) and 1.6-3.9 GW (2023-2025)
• Capacity factor 8% (2021), 10% (2022), 1-3% (2023-2025)

NOTE:

• This scenario assumes an Updated EAF & demand forecast:
  o EAF from \(\approx 67\%\) in 2019 to \(\approx 65\%\) by 2025
  o Demand forecast initially flat & growth to 267 TWh by 2025
• If lower customer response at scale (Step 1), additional energy will be needed (higher capacity factor)
• Structural low-level loadshedding (Stage 3 & Stage 4) may also be necessary during 2020-2021

\(^1\) It is assumed that capacity from Step 2 will only come online in 2021 (owing to procurement process & technology lead times); Sources: CSIR Energy Centre analysis
Updated scenario comparison of customer response (Step 1) and additional DMRE RMPPPP (Step 2) revealing notably less constrained power system

Simulated hourly generation of the total power supply in RSA for 1 week in 2021

Updated scenario
with customer response at scale (Step 1)

Updated scenario
with customer response (Step 1) and DMRE RMPPPP (Step 2)

NOTE: Lower end of total estimated capacity in Step 1 is considered in scenarios; Representative week(s) shown but entire time horizon is simulated at hourly resolution in production cost model applying unit commitment and economic dispatch principles; One nuclear unit on planned outage from day 2. Sources: CSIR Energy Centre analysis
Thank you
Loadshedding data

- Eskom twitter account: https://twitter.com/Eskom_SA
- ESP (Twitter app): https://sepush.co.za/

COUE


Eskom fleet Energy Availability Factor (EAF)

- Eskom System Adequacy Reports: http://www.eskom.co.za/Whatweredoing/SupplyStatus
References

Capacity and energy mix to 2030 (IRP 2019)

DMRE Risk Mitigation Power Purchase Procurement Programme (RMPPPP) RfI
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