Long-term energy scenarios (LTES) for developing national energy transition plans in Africa

Webinar series

CSIR energy planning support and development in South Africa

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South Africa
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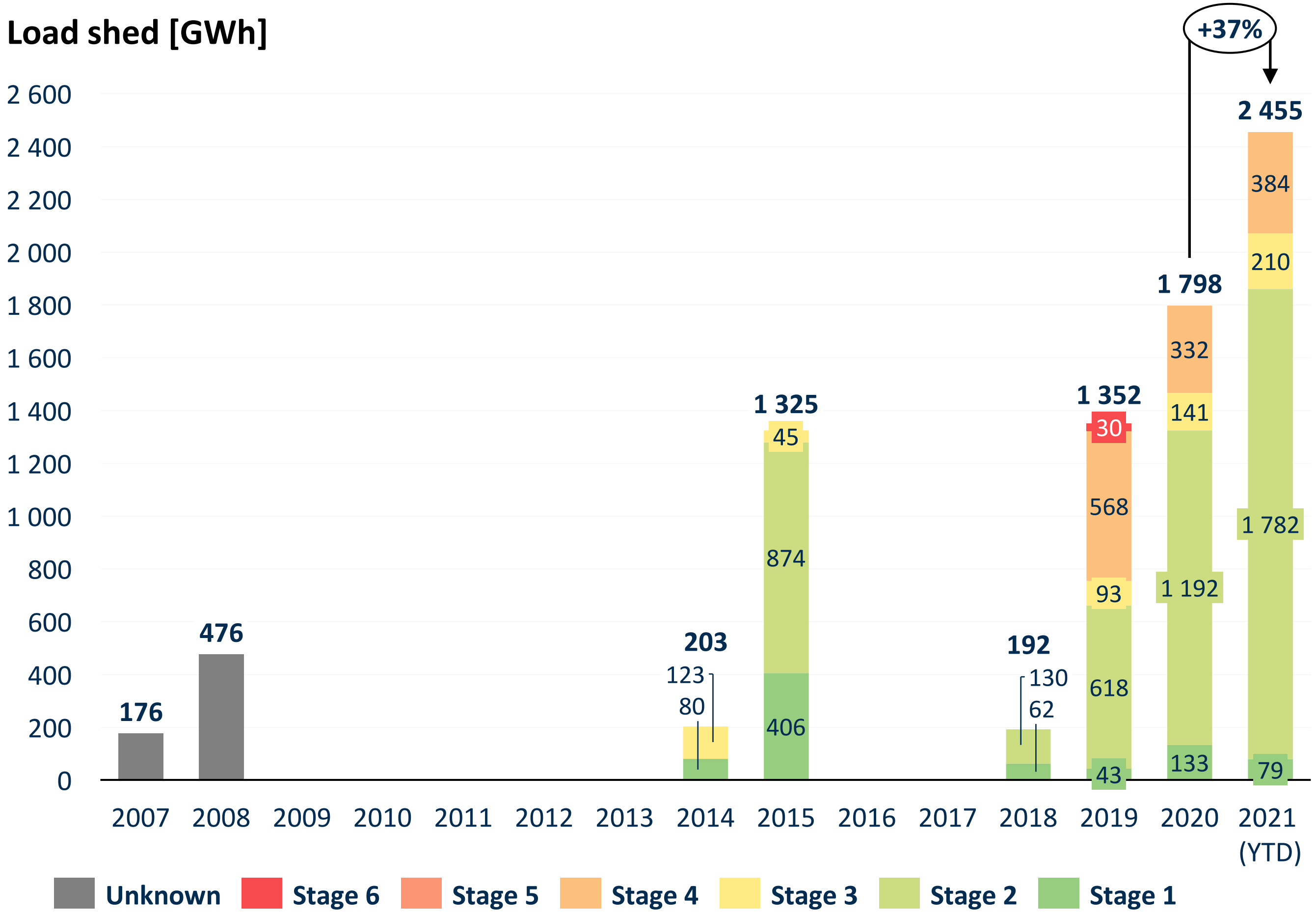
South Africa has an electricity crisis – Energy Planning is critical to guide the solutions and opportunities

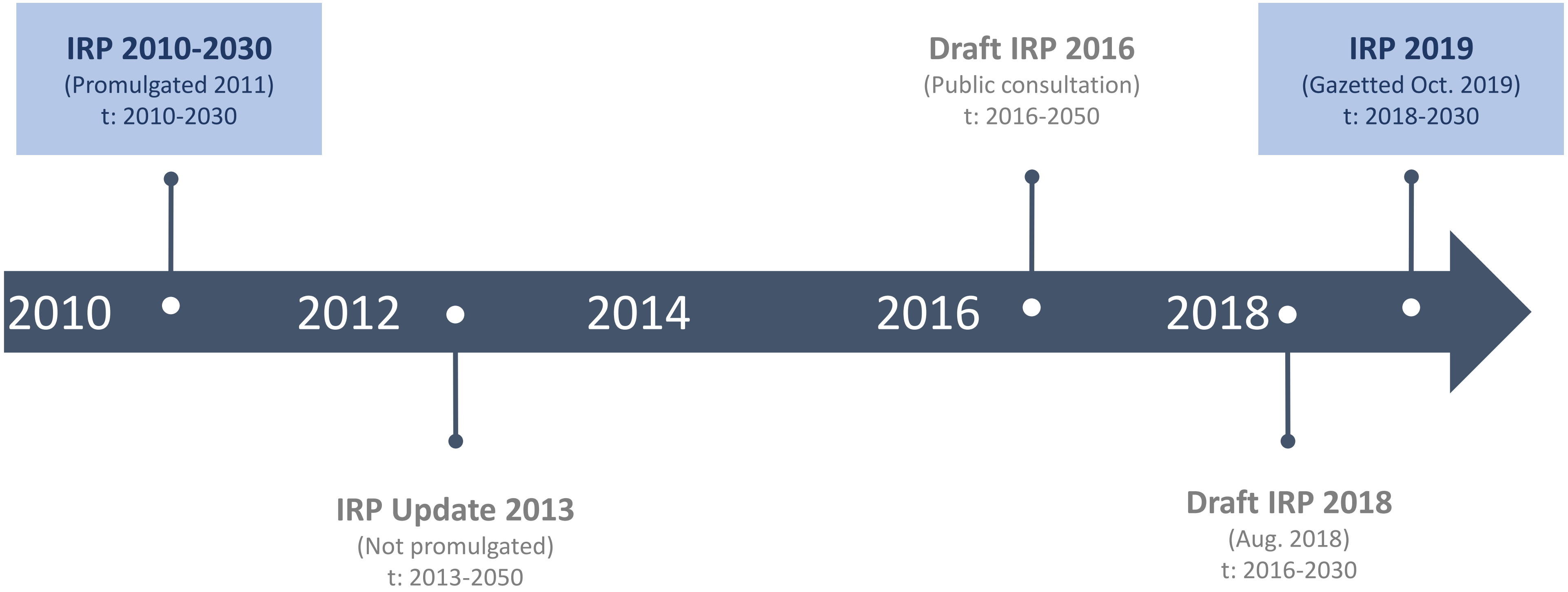
LTES LONG-TERM ENERGY SCENARIOS



Year	Duration of outages (hours)	Energy shed (GWh)
2007	-	176
2008	-	476
....	....	....
2014	121	203
2015	852	1325
2016	-	-
2017	-	-
2018	127	192
2019	530	1352
2020	859	1798
2021 (YTD)	1136	2455

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented. Practically, load shedding (and the Stage) may occassionally 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 Hld SOC Ltd FaceBook page; Eskom se Push (mobile app); Nersa; CSIR analysis

South Africa has been on a 10+ year iteration of the national electricity plan (IRP)



Sources: CSIR Energy Centre analysis

A learning and iterative process that requires extensive public consultation and feedback loops

LTES
LONG-TERM ENERGY SCENARIOS

Planning/ simulation world

Inputs

Demand forecast(s)

Existing supply:

- Plants under construction
- Preferred bidders
- Decommissioning
- Plant performance

New Supply Options:

- Technology costs
- Technology technical characteristics

Constraints:

- CO_2 limits
- Security/adequacy of supply level

IRP modelling framework[1] (PLEXOS)

LT[2] techno-economic least-cost optimisation

MT/ST[3] production cost testing system adequacy (security of supply)

Outputs

Output (per scenario):

- Total system costs
- Capex & Opex over time
- Capacity expansion (GW)
- Energy share (TWh)
- CO_2 emissions
- Water usage
- Employment

After policy adjustment:

- Final promulgated "IRP"
- What to build (MW)?
- When to build it (timing)?

Actuals/ real world

Inputs

Determinations/pathways for preferred new technologies and capacity (supply, demand, storage)

Procurement/ deployment

Competitive bidding, FITs, net-metering etc.

e.g. REIPPPP, coal, nuclear, gas, storage etc.

Outcomes

- 'Winning' technologies
- Capacity allocated/deployed
- Actual technology costs

[1] Could include various other commercaially available and/or other open-source tools (South Africa currently opts for PLEXOS)

[2] LT = Long-term

[3] MT/ST = Medium-term/Short-term

Key considerations have shifted in some dimensions but remained largely unchanged in others

	IRP 2010-2030 (Promulgated 2011) t: 2010-2030	**IRP Update 2013** (Not promulgated) t: 2013-2050	**Draft IRP 2016** (Public consultation) t: 2016-2050	**Draft IRP 2018** (Aug. 2018) t: 2016-2030	**IRP 2019** (Gazetted Oct. 2019) t: 2018-2030
Expected energy mix	Scenario-based; **Big**: Coal, nuclear **Medium**: VRE, gas **Small**: imports (hydro)	Decision trees; **Big**: Coal, nuclear **Medium**: VRE, gas, CSP **Small**: Imports (hydro, coal), others	Scenario-based **Big**: Coal **Medium**: Nuclear, Gas, VRE **Small**: Imports (hydro), others	Scenario-based **Big**: Coal, VRE **Medium**: Gas **Small**: Nuclear, DG/EG imports (hydro), others	Scenario-based; **Big**: Coal, VRE **Medium**: Gas, DG/EG **Small**: Nuclear, Imports (hydro), Storage, others
Demand	454 TWh (2030)	409 TWh (2030) 522 TWh (2050)	350 TWh (2030) 527 TWh (2050)	313 TWh (2030) 392 TWh (2050)	307 TWh (2030) 382 TWh (2050)
Emissions (CO_2-eq)	Peak only, EM1 (275 Mt from 2025)	PPD (Moderate)	PPD (Moderate)	PPD (Moderate)	PPD (Moderate)
Nuclear options	Commit to 9.6 GW	Delay option (2025-2035)	No new nuclear pre-2030; 1st units (2037)	No new nuclear pre-2030; (pace/scale/affordability) 1st units (2036-2037)	No new nuclear pre-2030; (pace/scale/affordability) 2.5 GW (≥2030)
Import options	Coal, hydro/PS, gas (fuel)	Coal, hydro/PS, gas (fuel)	Hydro, gas (fuel)	Hydro, gas (fuel)	Hydro, gas (fuel)

[1] Performance (energy production & cost level/certainty); [2] For each technology option; EM1 – Emissions Limit 1 (whilst other scenarios EM2/EM3/CT (carbon-tax) with increasingly stricter CO_2 emissions limits were explored non were adopted); PPD - Peak-plateau-decline; EAF – Energy Availability Factor; Sources: LC – least-cost; MES – minimum emissions standards; LT – long-term; ST – short-term; Tx – transmission networks; Dx – distribution networks; DG – distributed generation; EG – embedded generation;
Sources: DoE/DMRE; CSIR Energy Centre analysis

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	IRP 2010-2030 (Promulgated 2011) t: 2010-2030	IRP Update 2013 (Not promulgated) t: 2013-2050	Draft IRP 2016 (Public consultation) t: 2016-2050	Draft IRP 2018 (Aug. 2018) t: 2016-2030	IRP 2019 (Gazetted Oct. 2019) t: 2018-2030
Coal fleet performance	>85% EAF; 50 year decom.	~80% EAF; LifeEx (10 yrs)	72-80% EAF; 50 year decom. MES delay (2020/25)	72-80%; 50 year decom. MES delay (2020/25)	67-76%; 50 year decom. MES delay (2020/25)
New-build coal	1st units forced earlier 1.0 GW (2014) 6.3 GW (2030)	Displaced by LifeEx (10 yrs) 1.0 GW (2025) <3.0 GW by 2030	1st 1.5 GW (2028) 4.3 GW (2030)	0.5 GW (2023) 1.0 GW (2030)	0.75 GW (2023) 1.5 GW (2030)
New technologies[1]	Uncertain VRE cost/perf. CSP (marginal); Annual constr.: 0.3-1.0 GW/yr (PV) 1.6 GW/yr (wind)	Uncertain VRE cost/perf. CSP (notable); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Battery/CAES (option); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Batteries (option); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)	VRE cost/perf. proven CSP (minimal); Batteries (notable); Annual constr.: 1.0 GW/yr (PV) 1.6 GW/yr (wind)
Security of supply	LT (reserve margin); ST (hourly dispatch); Immediate ST need; Research: Fuel supply, base-load, backup, high VRE	LT (reserve margin); ST (hourly dispatch); Research: Fuel supply, base-load, backup, high VRE	Assumed similar Research: None highlighted	Assumed similar Research: Gas supply, high VRE, just transition	Assumed similar; Immediate ST need; Research: Gas supply, high VRE, just transition
Network requirements[2]	Not considered; Tx/Dx research need	Not a concern (Tx power corridors) Dx networks research need (DG/EG)	None	Explicit Tx needs costed (per tech.)	Explicit Tx needs costed (per tech.)

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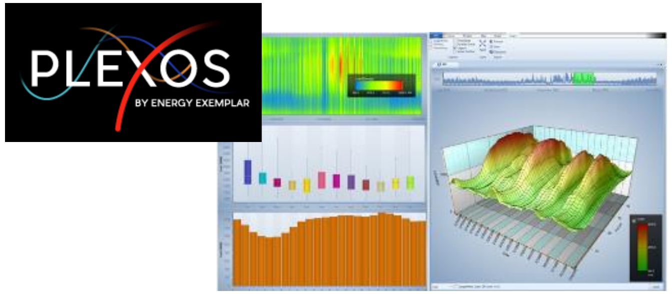
CSIR has applied an industry standard software package for the modelling of the RSA power system

Commercial software – PLEXOS ®

Co-optimisation of long-term investment & operations in hourly time resolution to 2050 (focus to 2030)

- What mix to build?
- How to operate the mix once built?
- Objective function: Least Cost, subject to an adequate power system and constraints



Key technical limitations of power generators covered

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

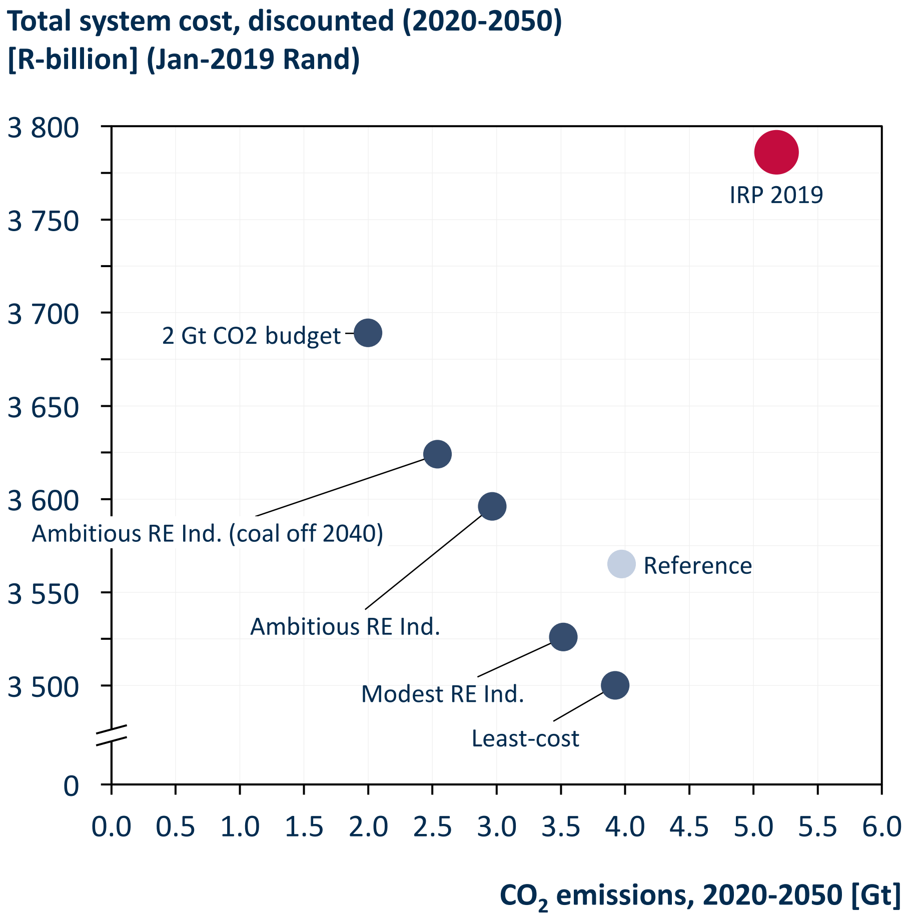
… covers all key cost drivers of a power system

- **Costs covered in the model include**
  - All capacity-related costs of all power generators
    - CAPEX of new power plants (R/kW)
    - Fixed Operation and Maintenance (FOM) cost (R/kW/yr)
  - All energy-related costs of all power generators
    - Variable Operation and Maintenance (VOM) cost (R/kWh)
    - Fuel cost (R/GJ)
  - Efficiency losses due to more flexible operation
  - Reserves provision (included in capacity costs)
  - Start-up and shut-down costs

- **Costs not covered in the model currently used are:**
  - Any grid-related costs (note: transmission-level grid costs typically ~10-15% of generation costs)
  - Costs related to add. system services (e.g. inertia requirements, black-start and reactive power)

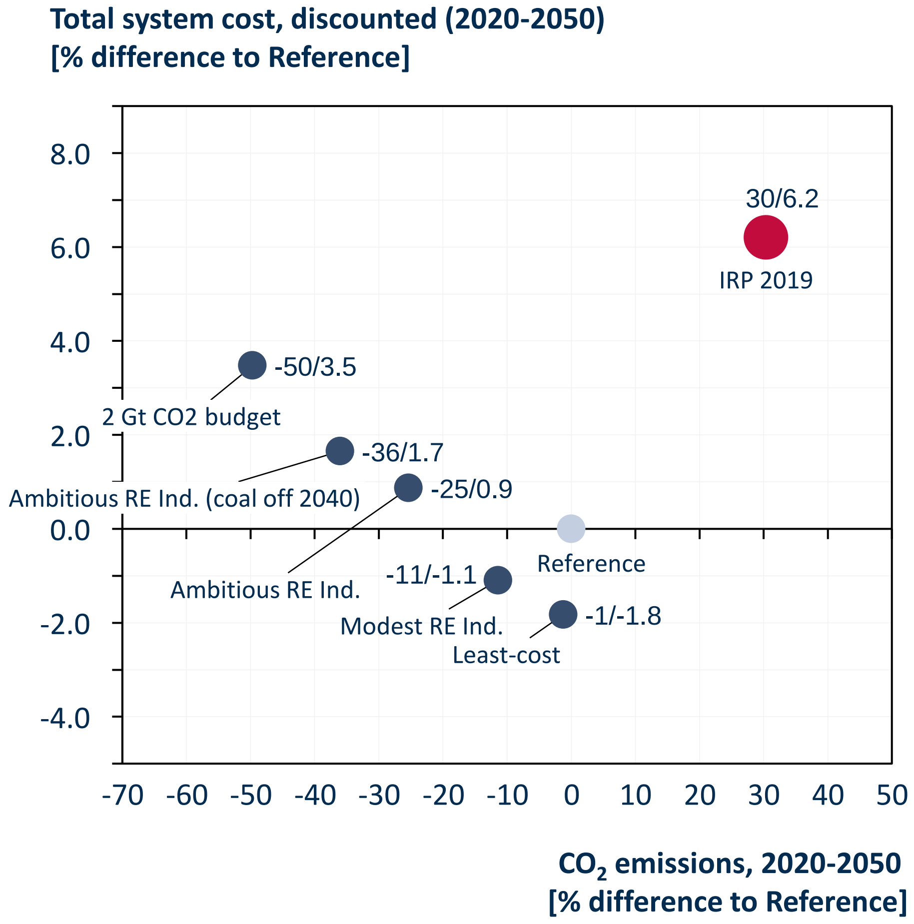
Applied at varying levels: National

Absolute



Sources: CSIR Energy Centre analysis

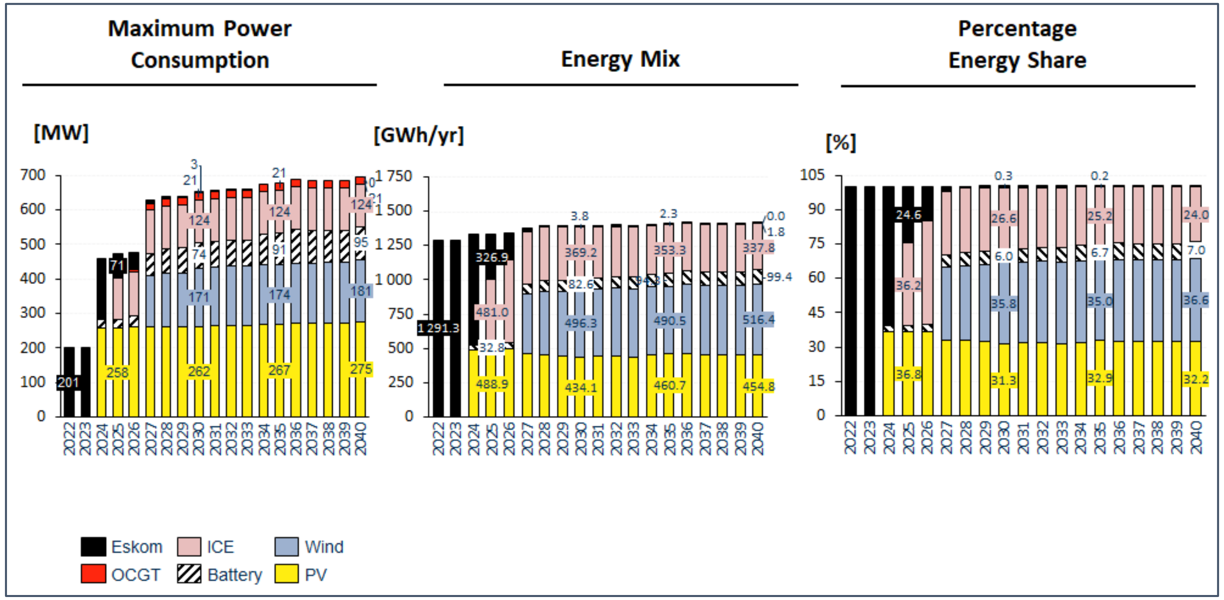
Relative

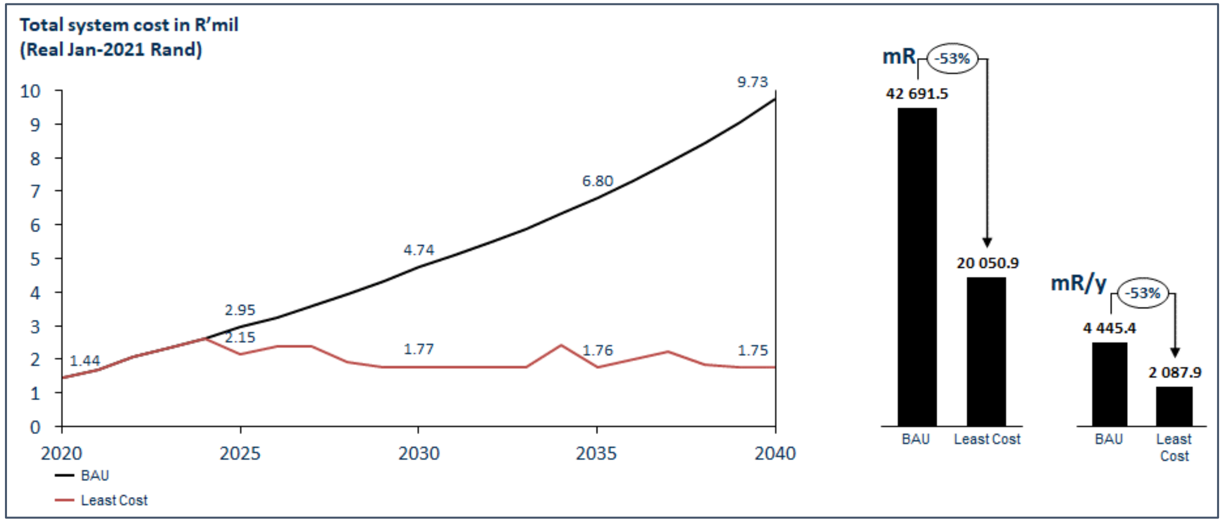


Applied at varying levels: Municipal

Garden Route District Municipality

Western Cape, South Africa





Sources: CSIR Energy Centre analysis, GIZ SAGEN-3 (Draft)

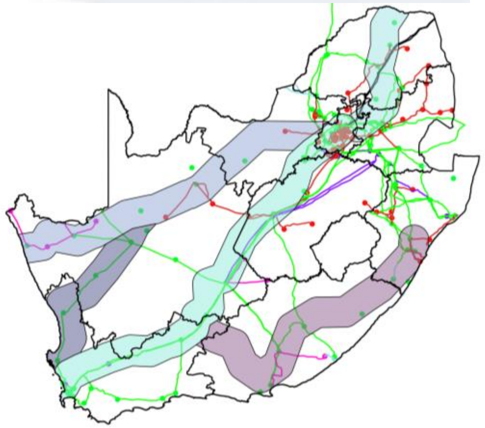
Some learnings based on our experiences

Use capabilities, build more and collaborate – cost networks

Utilities have extensive experience in planning networks (Tx/Dx)
Use this & complement with available academic and industrial partners

System operator is expert to define system services – cost them

Ancillary services (fault levels, voltage control, black-start, stability)
When relevant – detailed design and costing



Quantify, Quantify, Quantify

From defined scenarios, quantify cost differences
Positioning of policy on this basis can then be done transparently

Periodic, consistent updating with transparent governance

Update IRPs periodically and consistently (even if only small changes)
Create and maintain consistent governance structures
(reporting, sub-committees, public engagements)

Some learnings based on our experiences

Models have limitations – but they do provide insights

Common practice globally to have model-based outcomes inform policy
Not just in energy – these models and modelling frameworks are useful

Energy research/planning needs to catch-up

Globally (and more particularly in RSA)
Energy research and planning should catch up
Apply principles applied for decades in open-software

Be the Bazaar (not the Cathedral)

Some would argue RSA is not even the Cathedral yet…
When exploring long-term energy planning options – be the Bazaar!

Eliminate errors and show transparency to buy trust

Enough oversight (eyes on the prize)
Unlikely any assumption, approach or outcome will have errors

Cathedral - source is available with each release, but code developed between releases is restricted
Bazaar - source is developed openly at all times in view of the public.

Sources: Box, G. E. P. (1979); Raymond, E.S. catb.org (http://www.catb.org/~esr/writings/cathedral-bazaar/)

LTES
LONG-TERM ENERGY SCENARIOS

Thank you for your attention

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AFRICAN UNION DEVELOPMENT AGENCY

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