Least-Cost Energy Paths for South Africa: Technology Options

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Southern Africa – Towards Inclusive Economic Development

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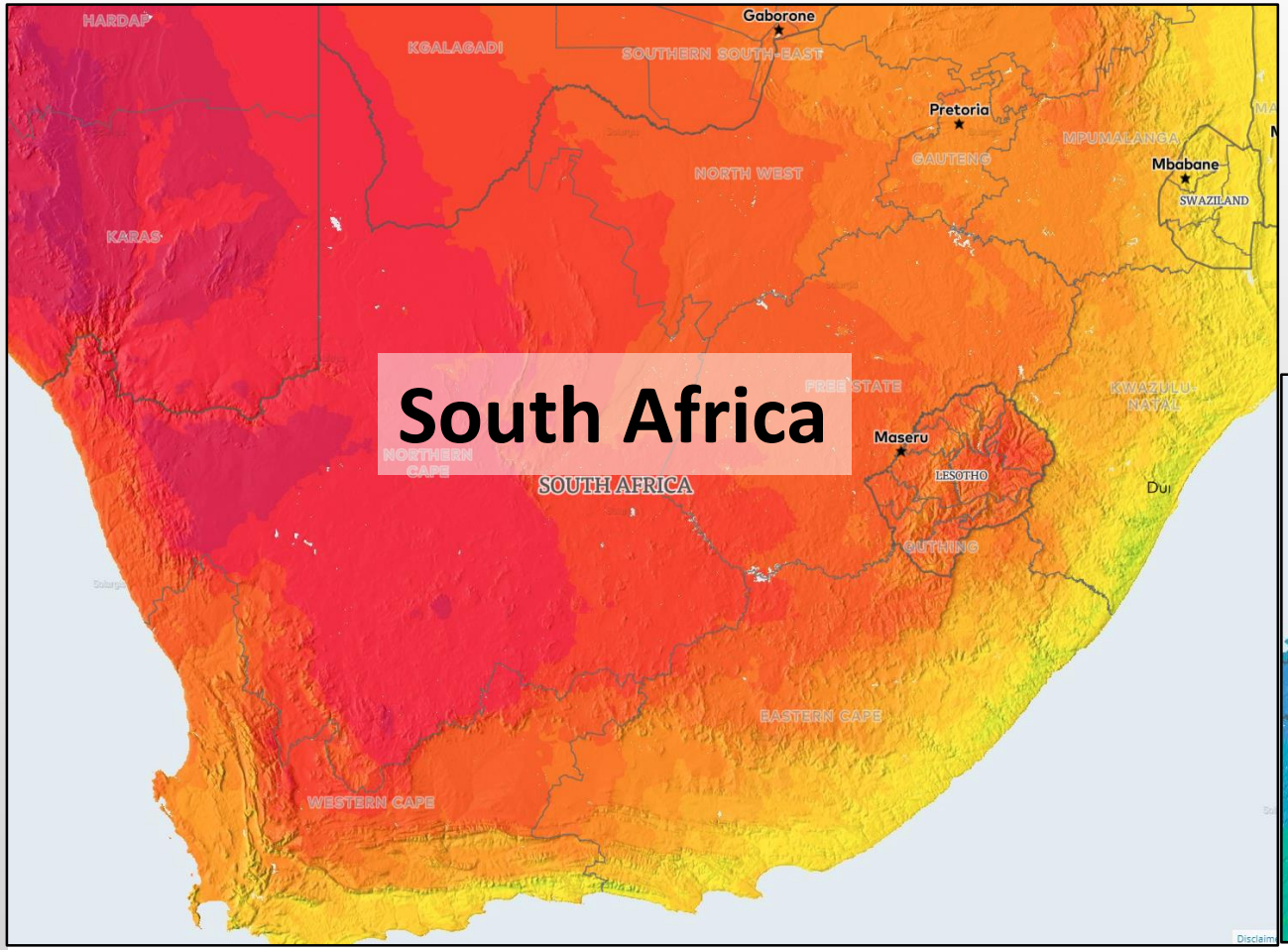
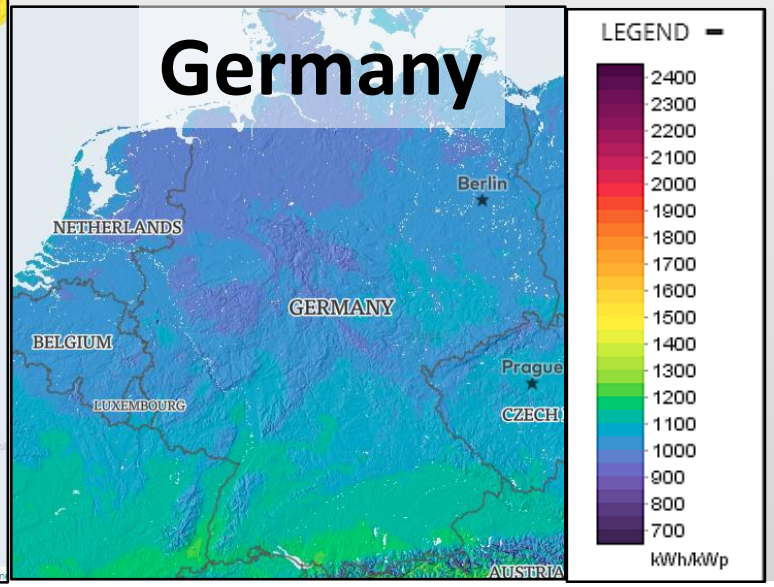
Presentation Outline:

- South Africa's renewable energy and mineral resources
- Global cost's of solar and wind RE technologies
- Performance and optimisation of a high penetration of renewable energy in South Africa
- Opportunities for spatial distribution of RE in South Africa
- Conclusions and future work

A different resource endowment…?



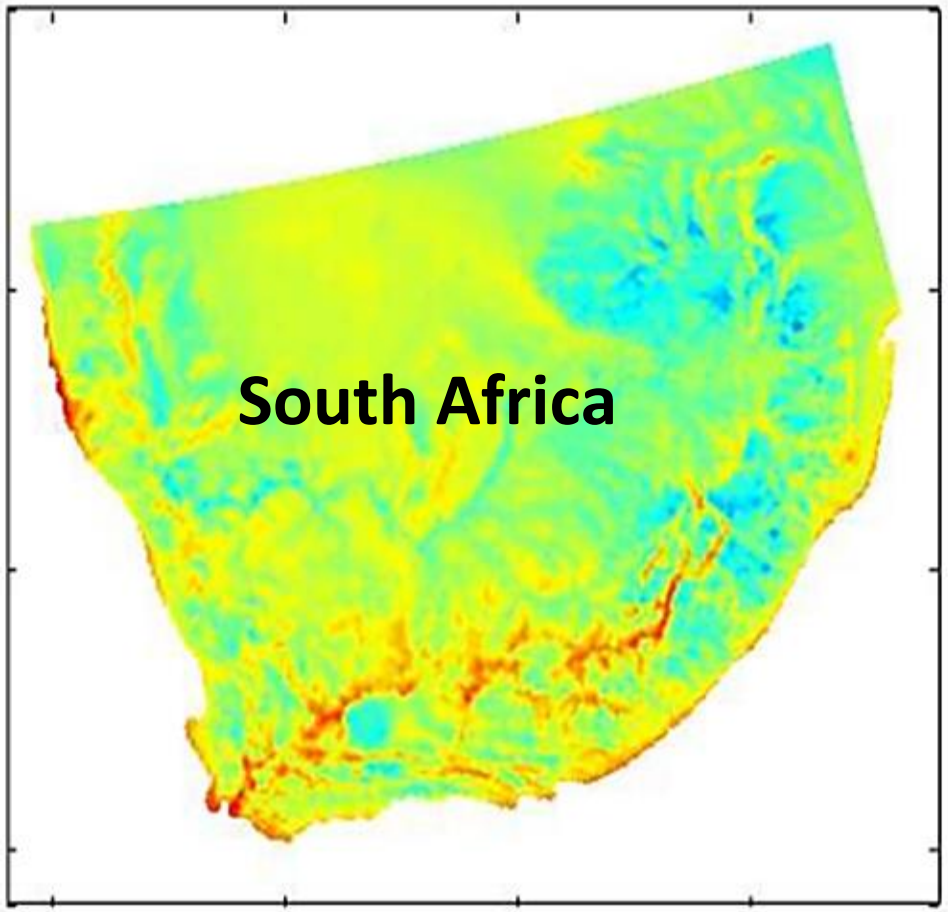
- South Africa = 4 times larger than Germany
- Worst possible solar site in RSA = better than best possible site in Germany
- Significantly less solar seasonality in RSA



Solar PV Production Potential *Comparison of a typical solar PV project in South Africa (left) compared to the same project in Germany (right) Source: SolarGIS 2017*

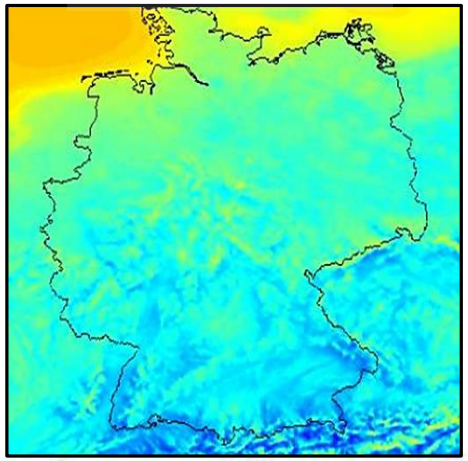
Roughly 40GW of both PV and Wind in Germany:
almost equal to South African peak generating capacity and 1 third of entire African continent!

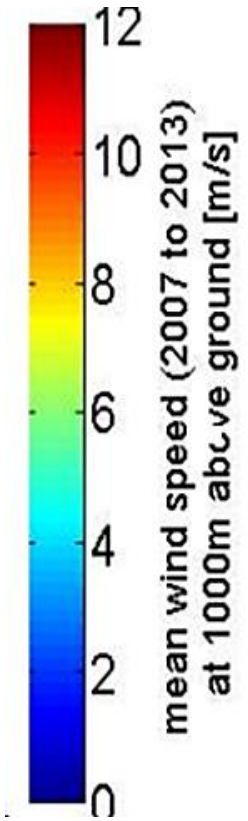
…and for wind as well



- **Previously thought good wind only along the coast**
- **Vast areas of Northern Cape have good wind that complements solar output**

Germany





Wind Speed Averages *Comparison across South Africa (left) compared to Germany (right).*

Source: WASA 2015; CSIR & Fraunhofer 2016

Roughly 40GW of both PV and Wind in Germany:
almost equal to entire South African peak generating capacity and 1 third of entire African continent!

But Also other "Conventional" Mineral Resources…

- South Africa has many critical minerals and elements for low carbon technologies: storage, wind turbines, electrolysers, and fuel cells:
  - **90%+ of global Platinum reserves**
  - Ranked 1st , 2nd , or 3rd in total global resources for:
    - Manganese, chromium, nickel, vanadium, titanium, gold, fluorite – also have some cobalt and copper

    A more valuable future resource endowment with global potential?
- Strong opportunities for local beneficiation, manufacturing, international trade co-operation, and technology exchange
- How do we make use of these resources with minimum environmental impact and maximum equitable benefit?

A future energy resource OPEC?

(China, South Africa, DR Congo, Chile, Zimbabwe, Australia, Russia – together hold almost all of the above resources)

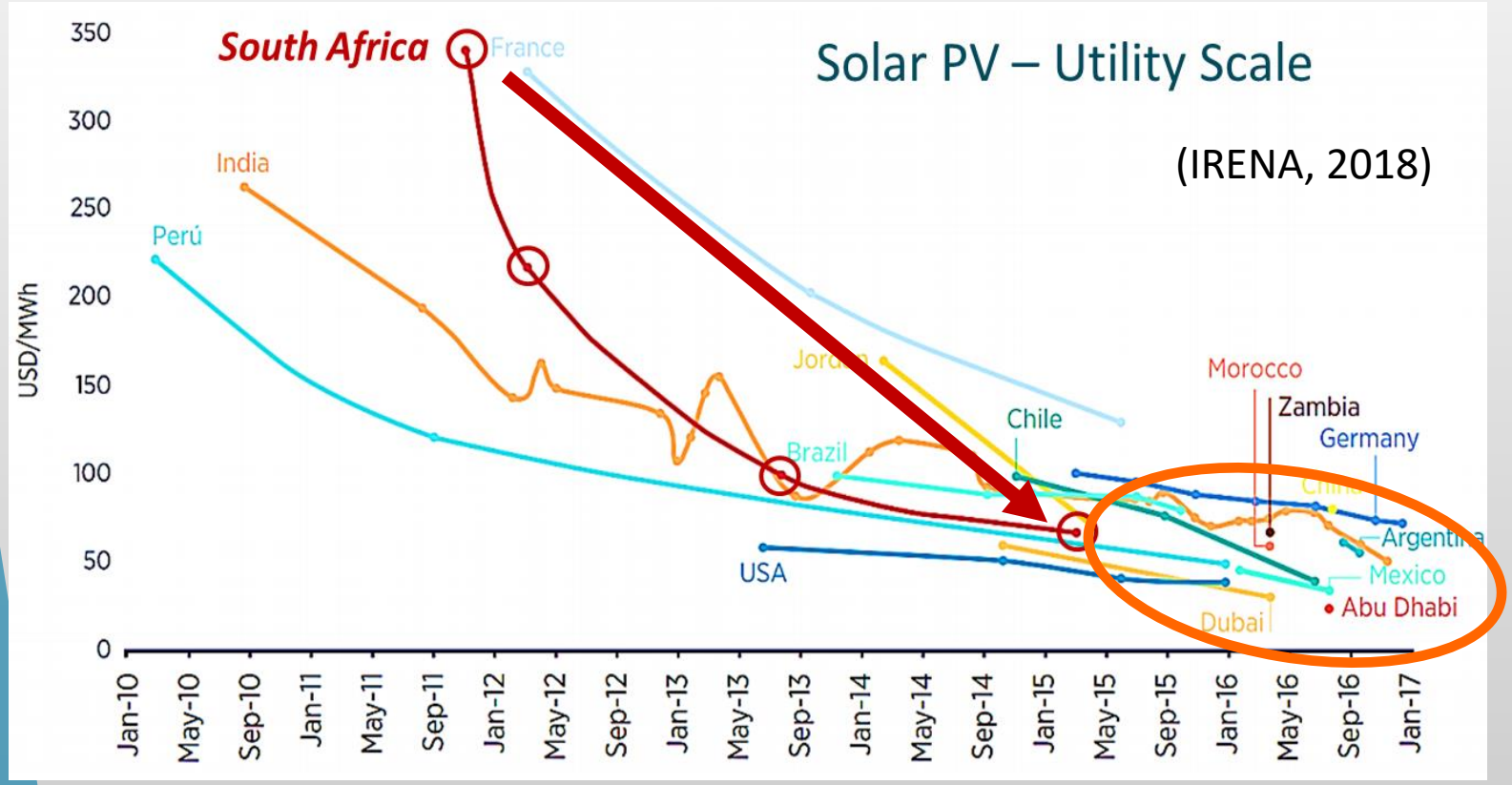
Conventional Electricity Generating Technologies

- **Coal and Nuclear are not least-cost** new electricity generation options in South Africa
- Imported Hydro power from **Inga III (DRC) is not a least-cost option**
  - Numerous other issues beyond cost: Non-transparent procurement, extensive HVDC transmission line through multiple countries over unelectrified populations, planned 60 year operation in rapidly changing world and inconsistent political situation
- Nearly all centralised complex megaprojects have a **tendency for time and cost overruns**

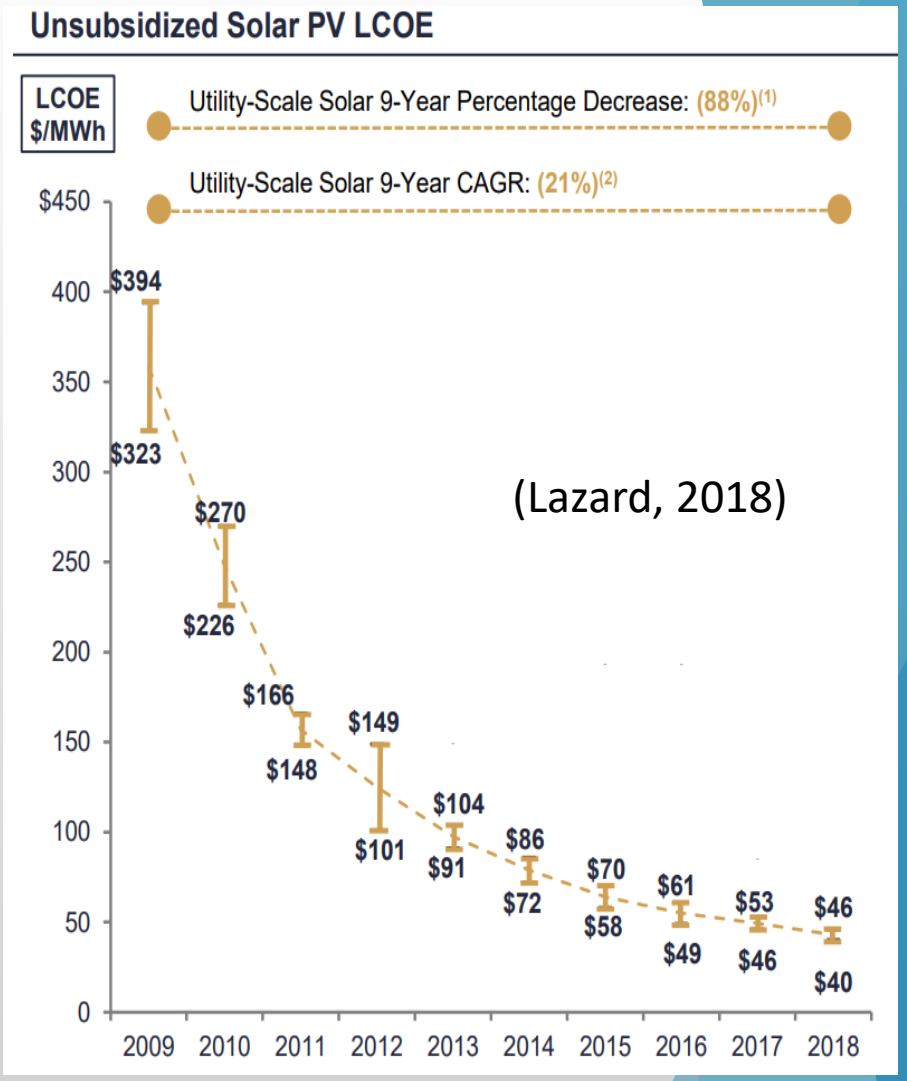
Global Cost of Solar PV:

2015 - South Africa is a world leader…

2018 – The world already moves on…

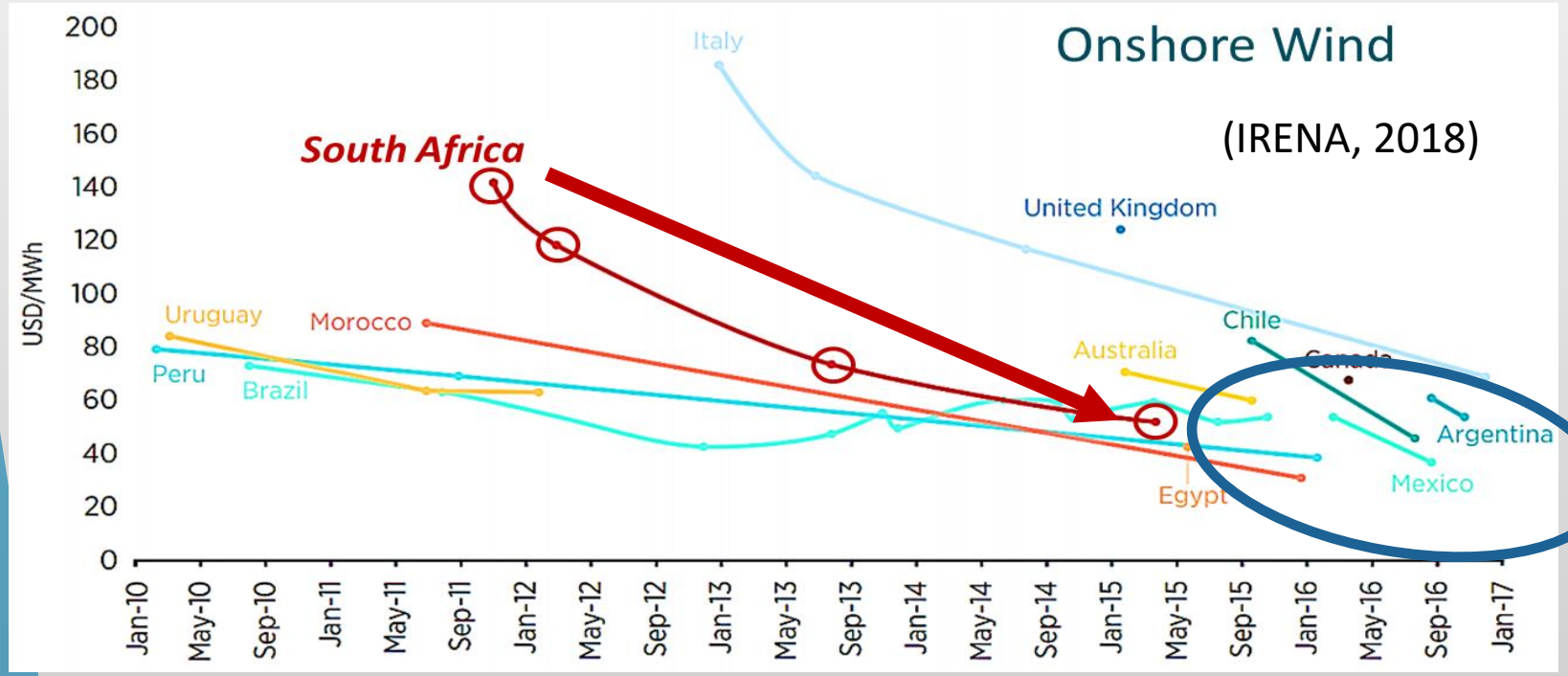


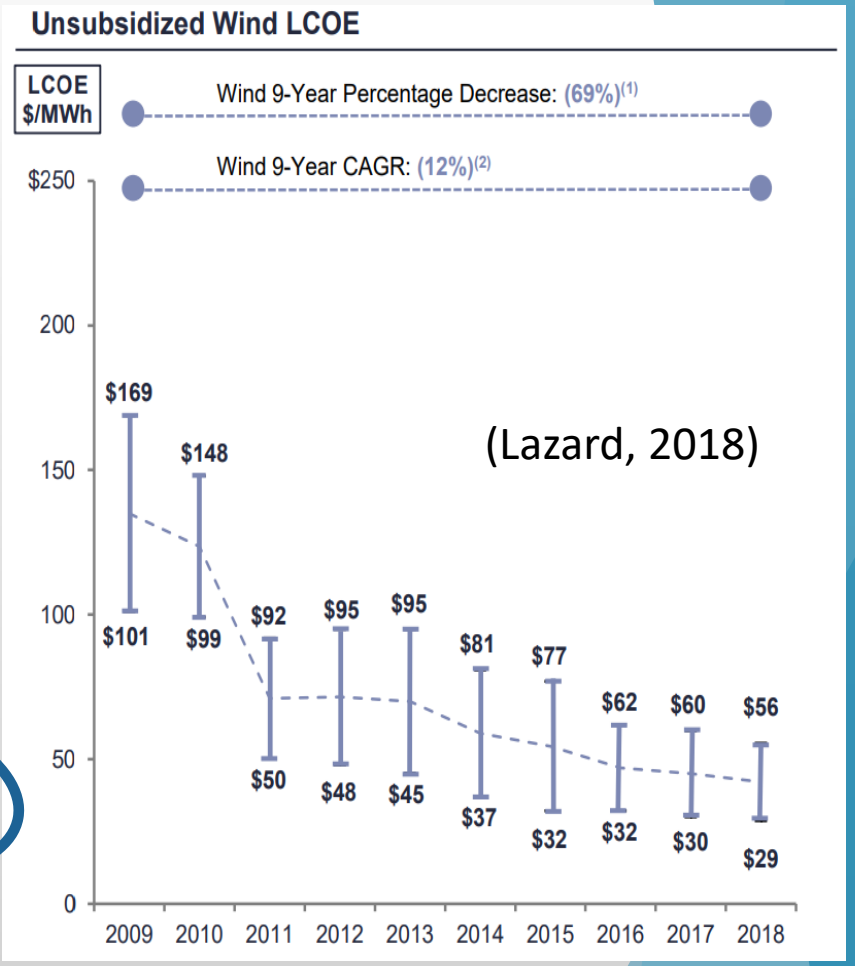
(IRENA, 2018)



(Lazard, 2018)

Similar, but less drastic for wind…





Challenges and Solutions for Modern Variable Wind and Solar Renewable Energy Options

“Diluteness” Challenge…

- Wind and solar are abundant, but spread over large areas

“Variability” Challenge…

- They are “non-dispatchable” in isolation, and dependent on weather patterns

Several Solutions:

Combine multiple complimentary energy resources and technologies into an optimized energy mix…

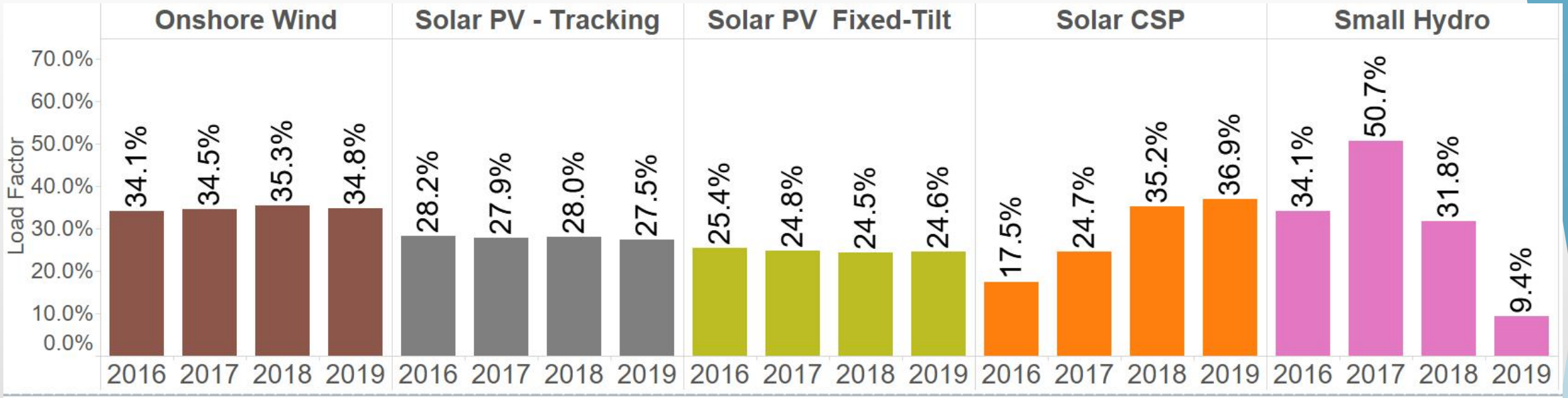
- Solar, wind and hydro, with favourable daily and seasonal patterns and geographic distribution
- Backup “firm” flexible thermal generation (fossil or renewable)
- Flexible demand, fuel switching, regional transmission links
- Energy Storage:
  - Batteries: ideal for short term daily storage
  - Pumped Hydro (“and power-to-X”/hydrogen): Weekly/Seasonal Storage
  - Thermal energy storage

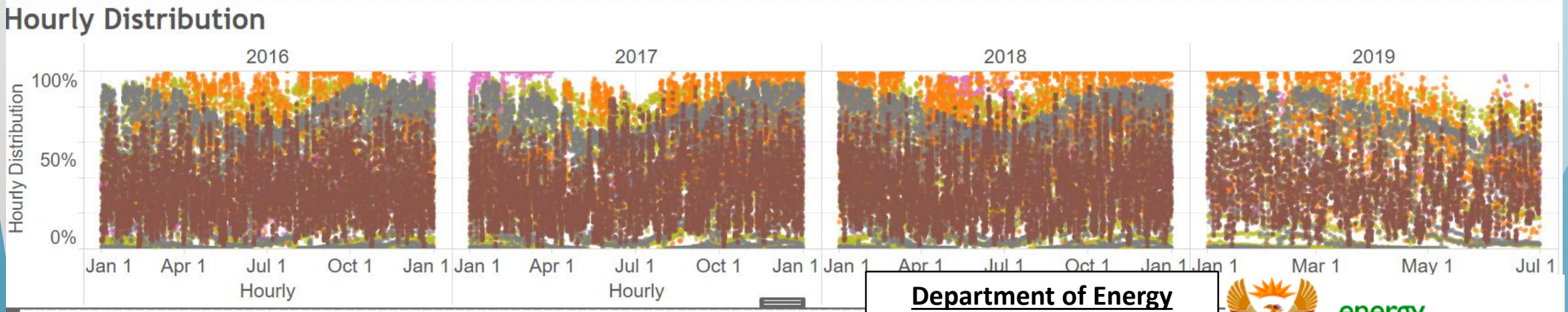
An optimal mix of new electricity generation sources in South Africa in 2050 using:

- High resolution hourly optimisation model with future very high penetration of variable renewables (2050 – no coal, imports, or nuclear)
- Existing RE generation profiles in SA (not spatially optimal)
- Using worst generation/demand match since start of REI4P in RSA (2016)
- Renewable and storage technology cost projections for 2050
- Imported LNG price: 13* USD/mBtu
- All other technology costs: as in the draft IRP2018
- Conservative 15% dispatchable reserve margin

**Japan currently pays 10 USD/mBtu (highest in the world)*

Performance of Renewable Energy Plants in South Africa





Department of Energy

Renewable Energy Data and Information Service

www.redis.energy.gov.za

energy

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Energy
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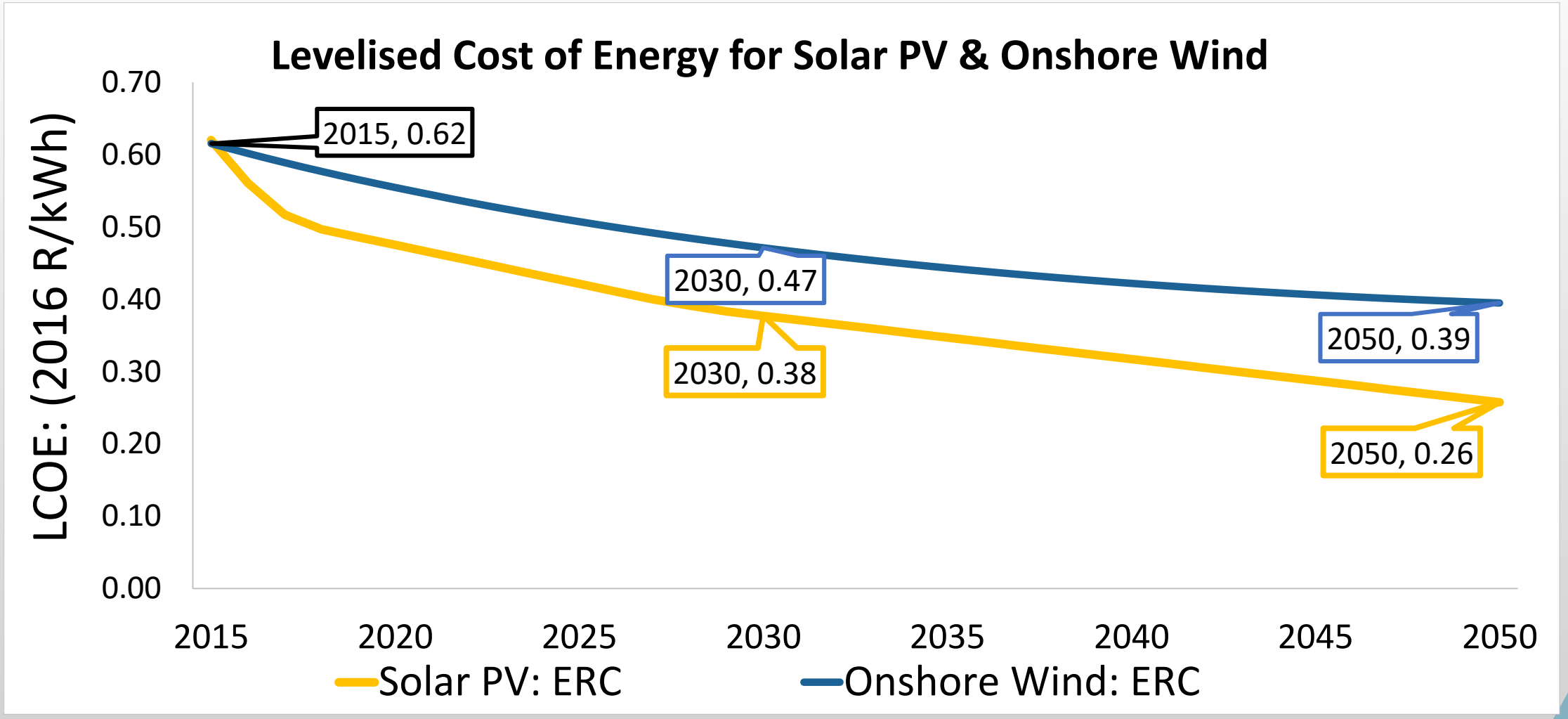
Renewable Energy Data and Information Service

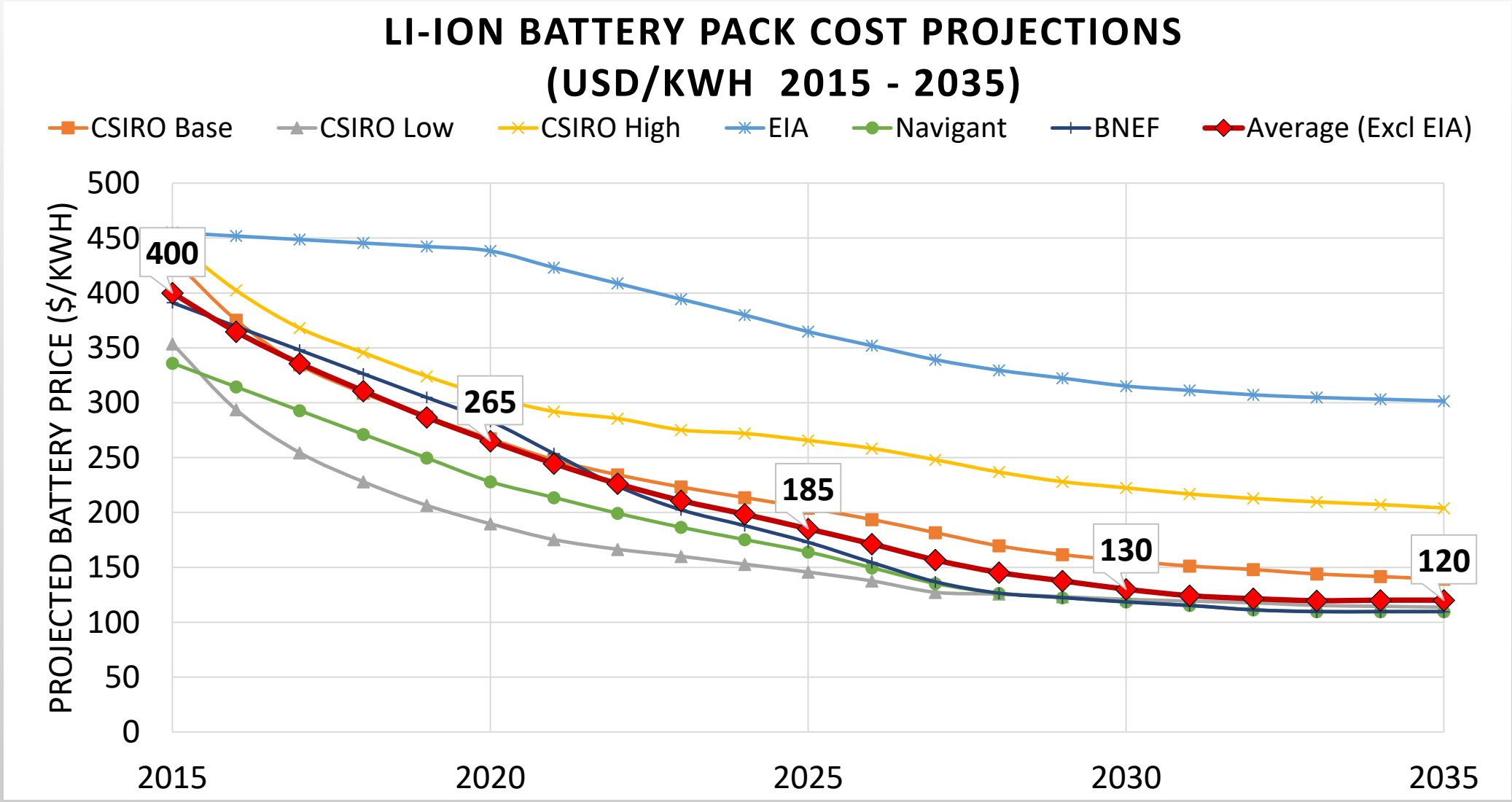
Wind and Solar PV Cost Curves



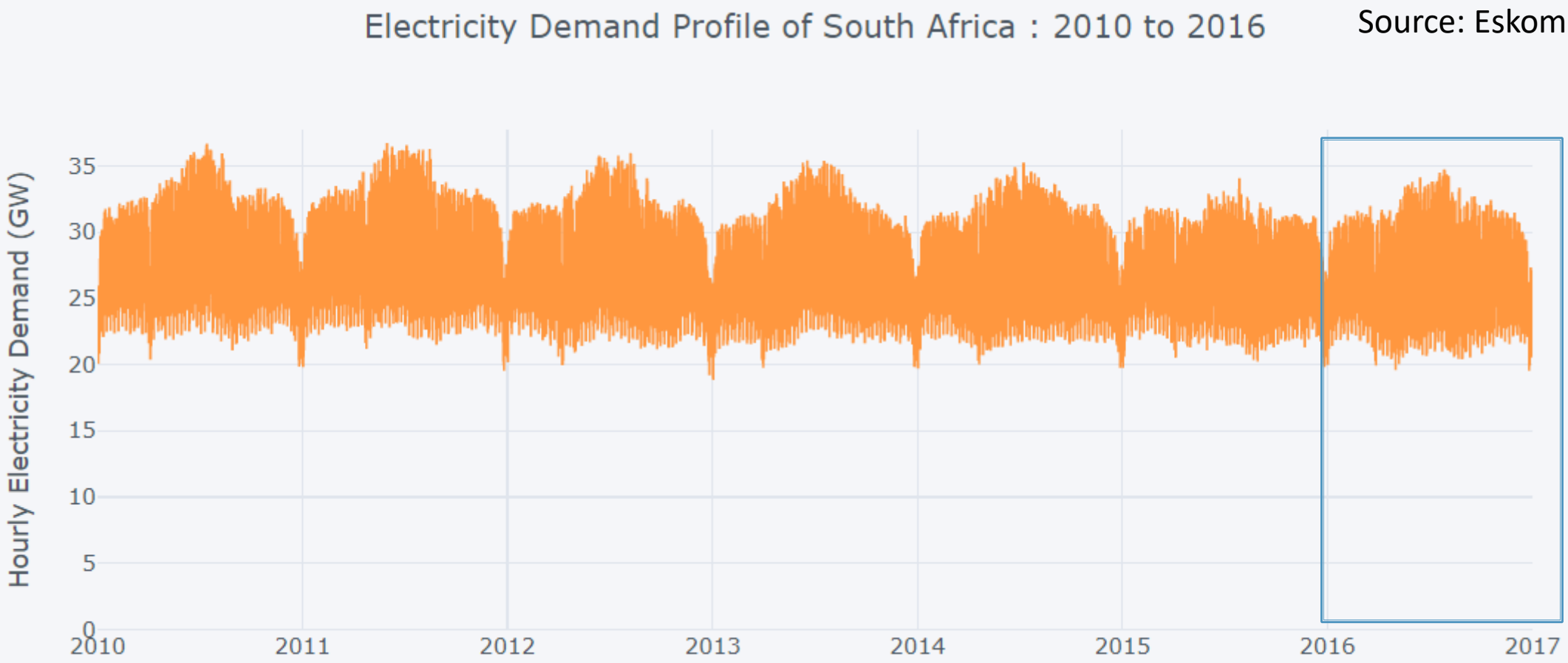
Based on: REI4P for starting point – Learning based on (NREL, 2017, IEA-Wind, 2017, Agora 2017, Fraunhofer 2015)
Levelised costs are not used in the model - show above for indicative comparison

Storage Modelled as Lithium-Ion Batteries:

Energy and Power sized independently (GW/GWh)

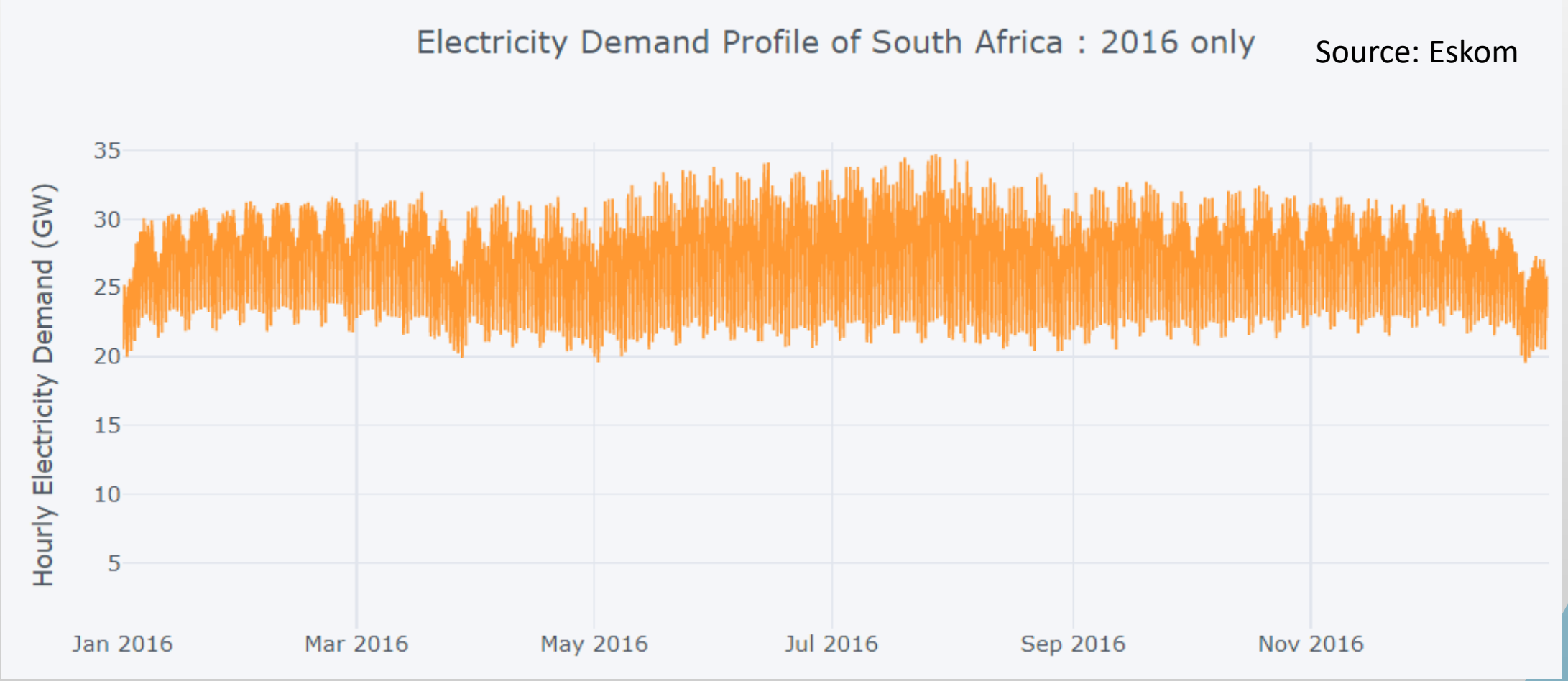


Electricity Demand in South Africa:
(2010 to 2017)

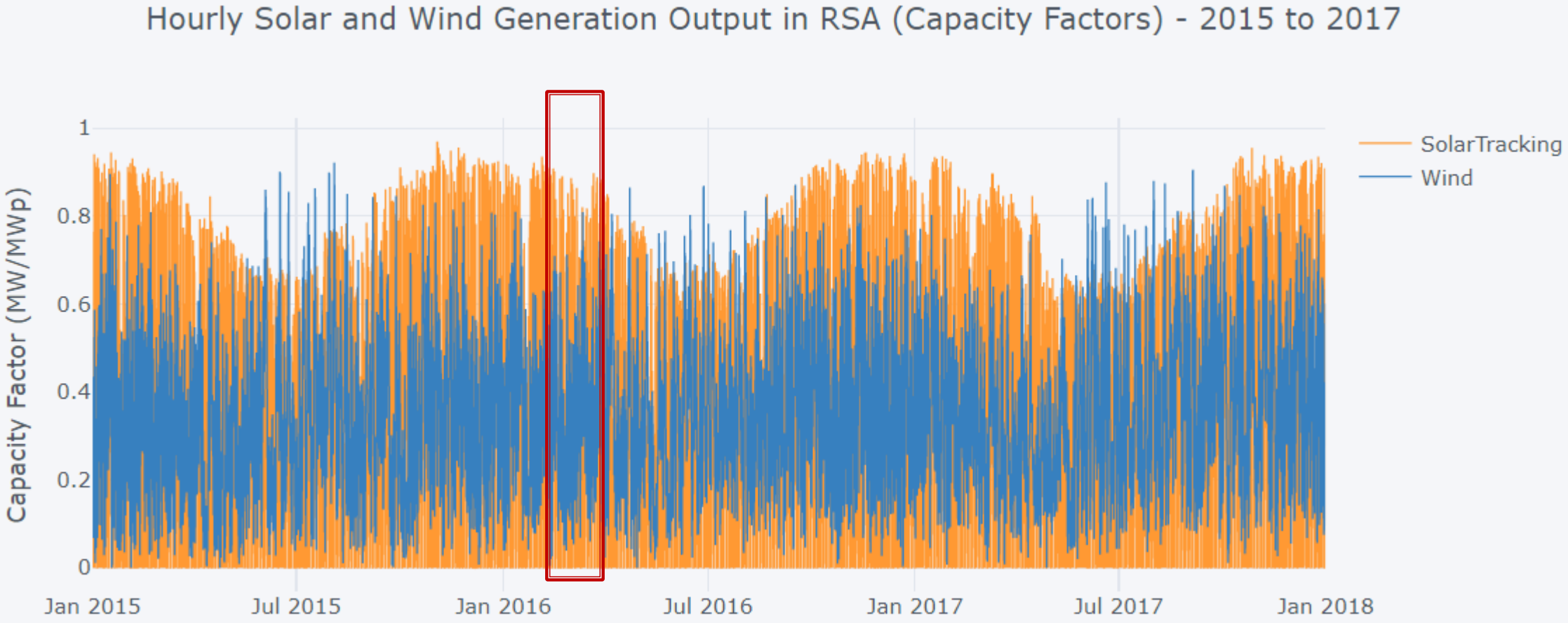


Source: Eskom

Looking at 2016 only…

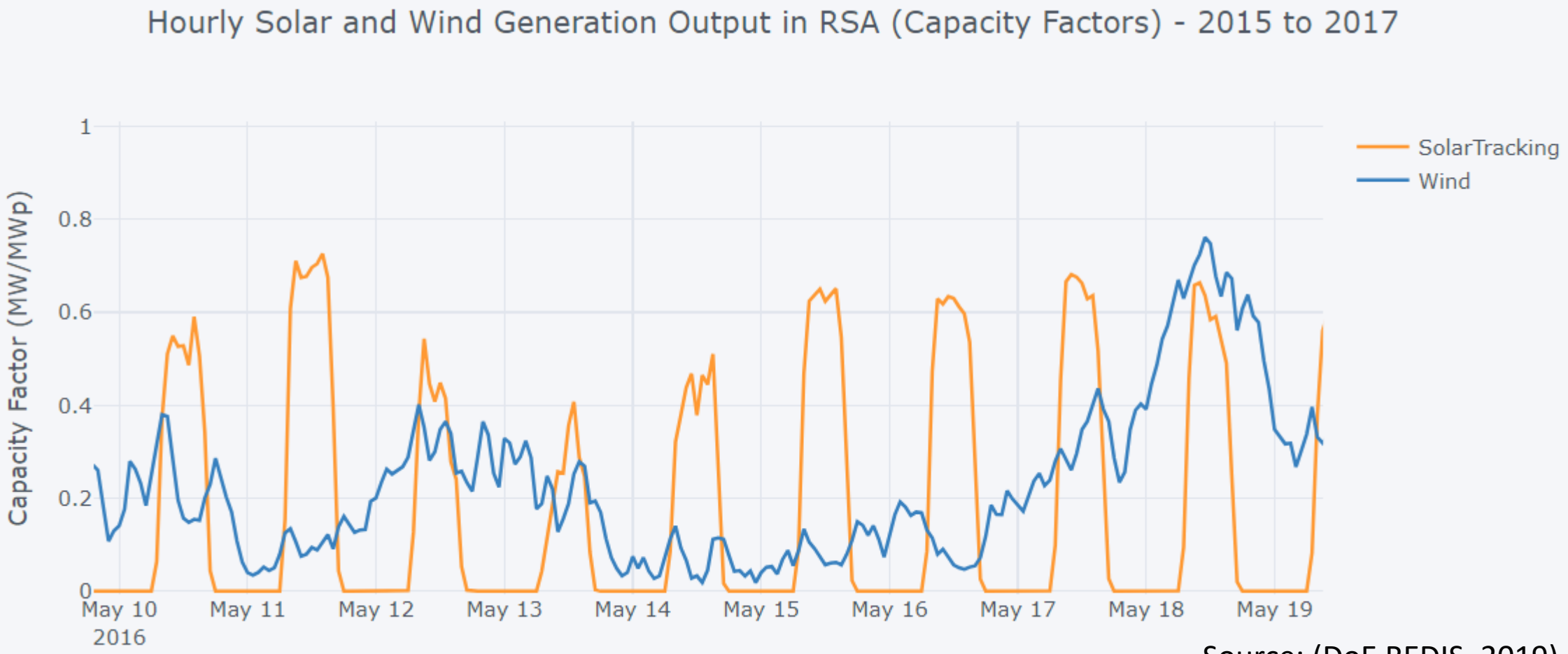


Wind and Solar PV generation in RSA: 2015 to 2018



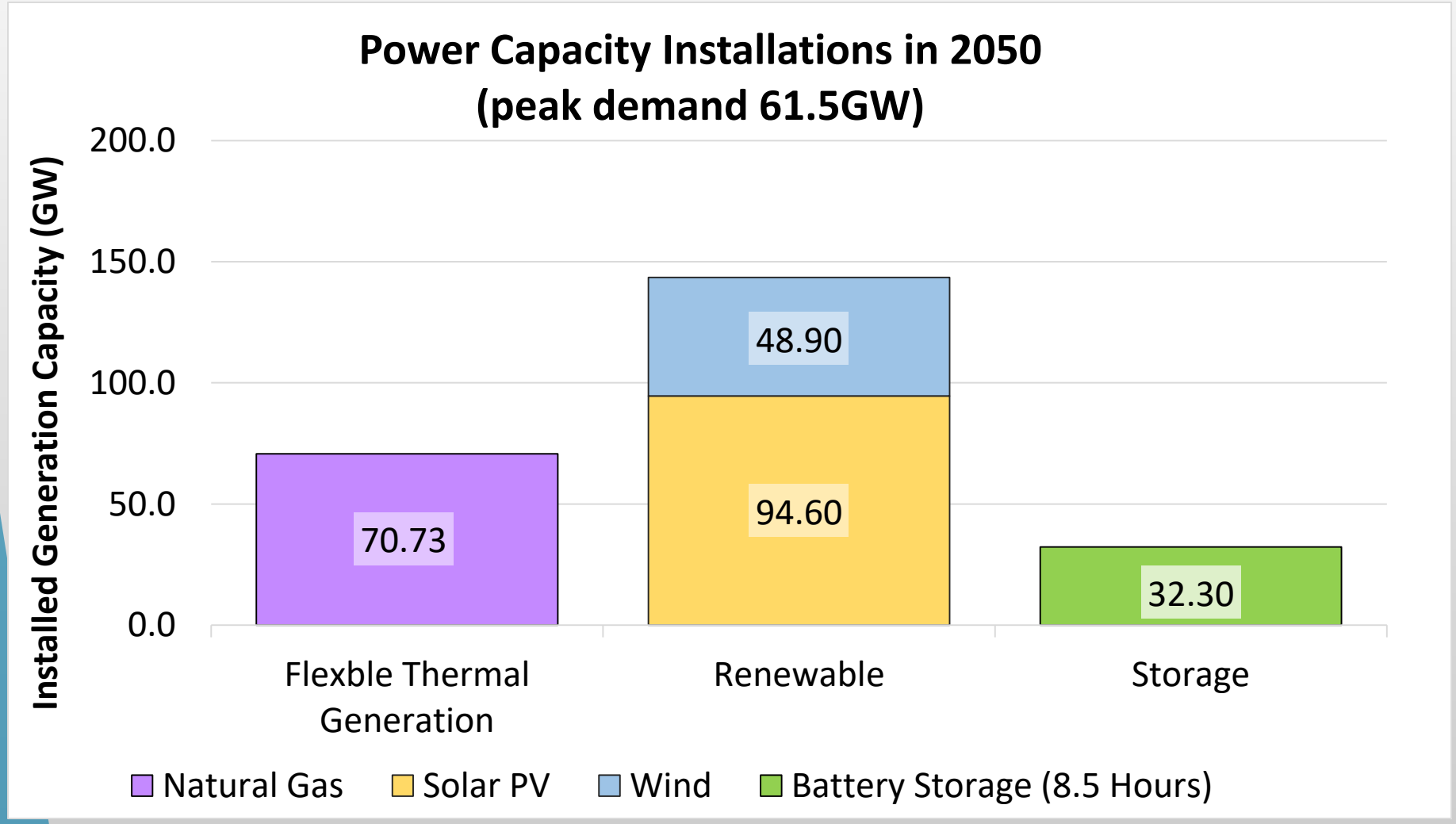
Closer look at 2 weeks in May 2016…

Worst combination of wind, solar, and demand



Source: (DoE REDIS, 2019)

Optimal Installed Capacity in 2050 - if no Coal, Hydro, or Nuclear



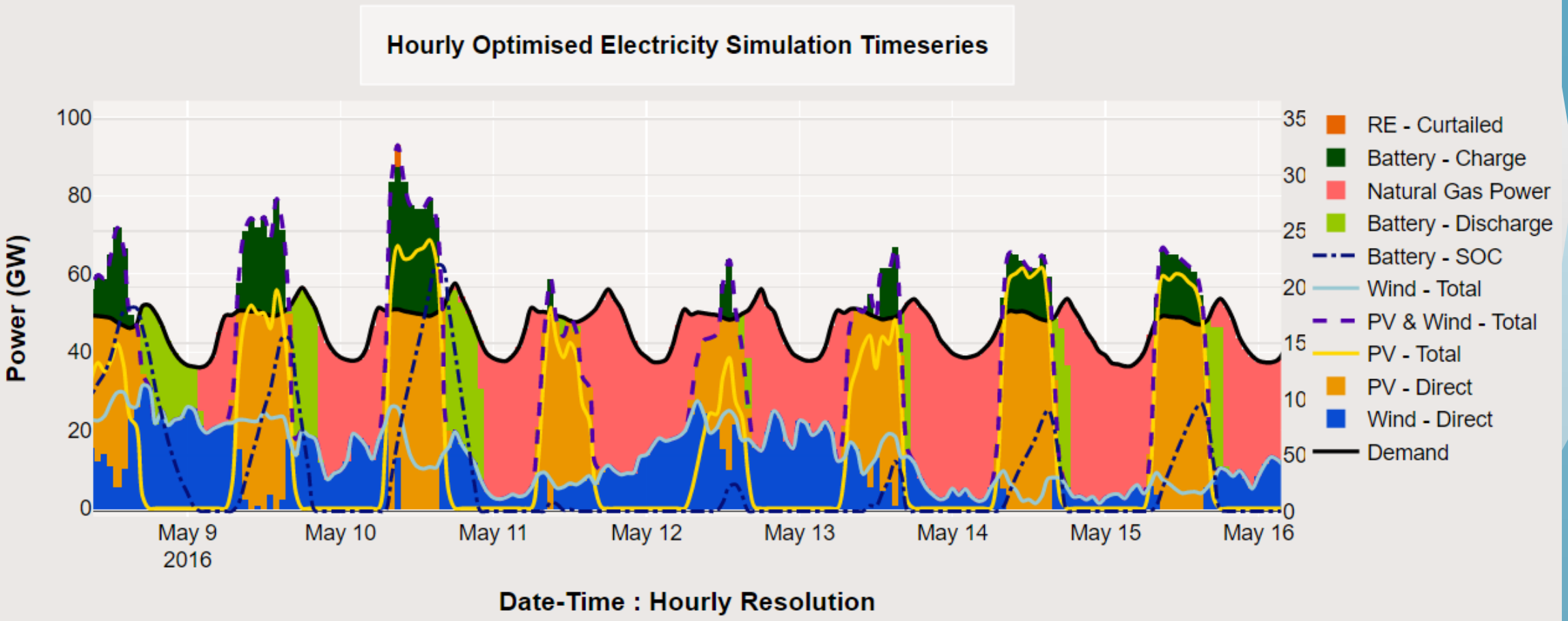
- **Renewables Share:**

  91%

- **Renewable Energy Curtailed:**

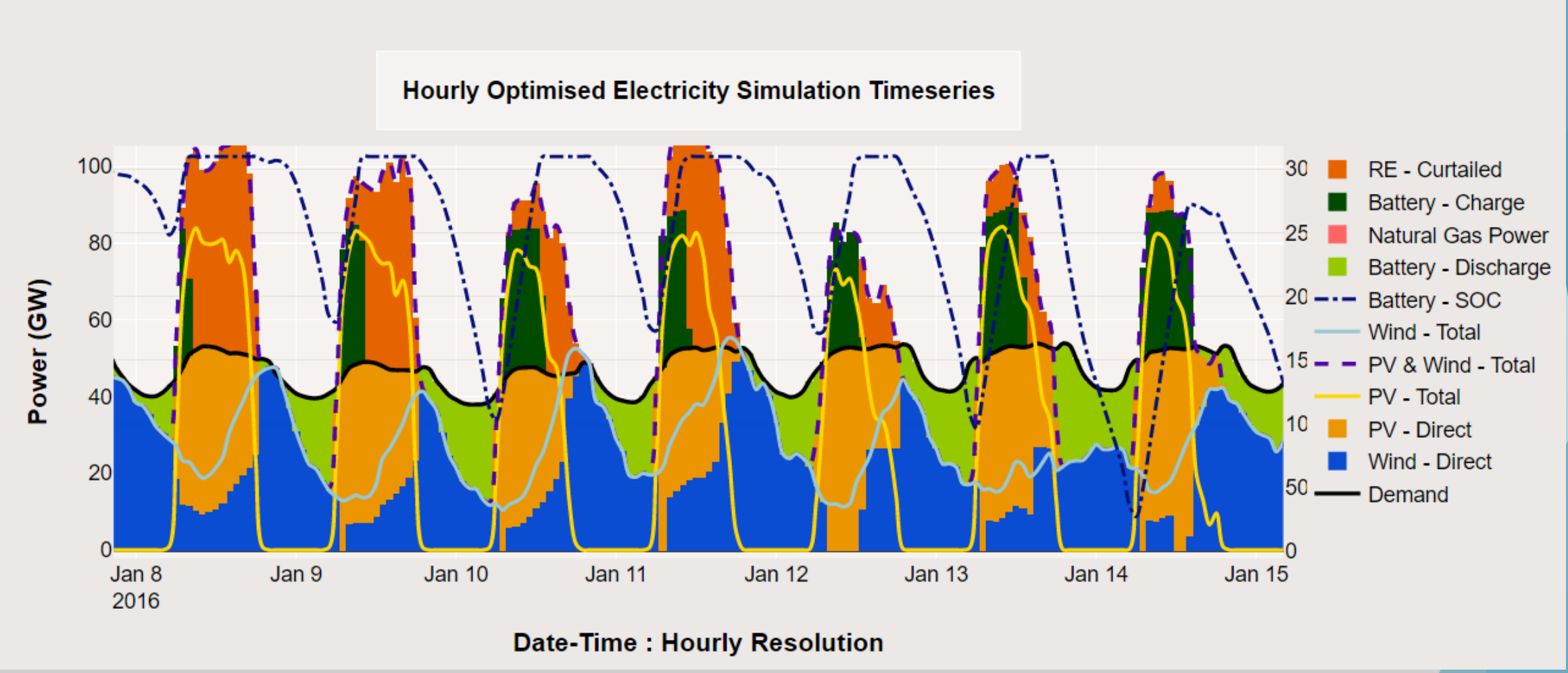
  10%

Worst Week in May 2050…
Dispatchable generation is used

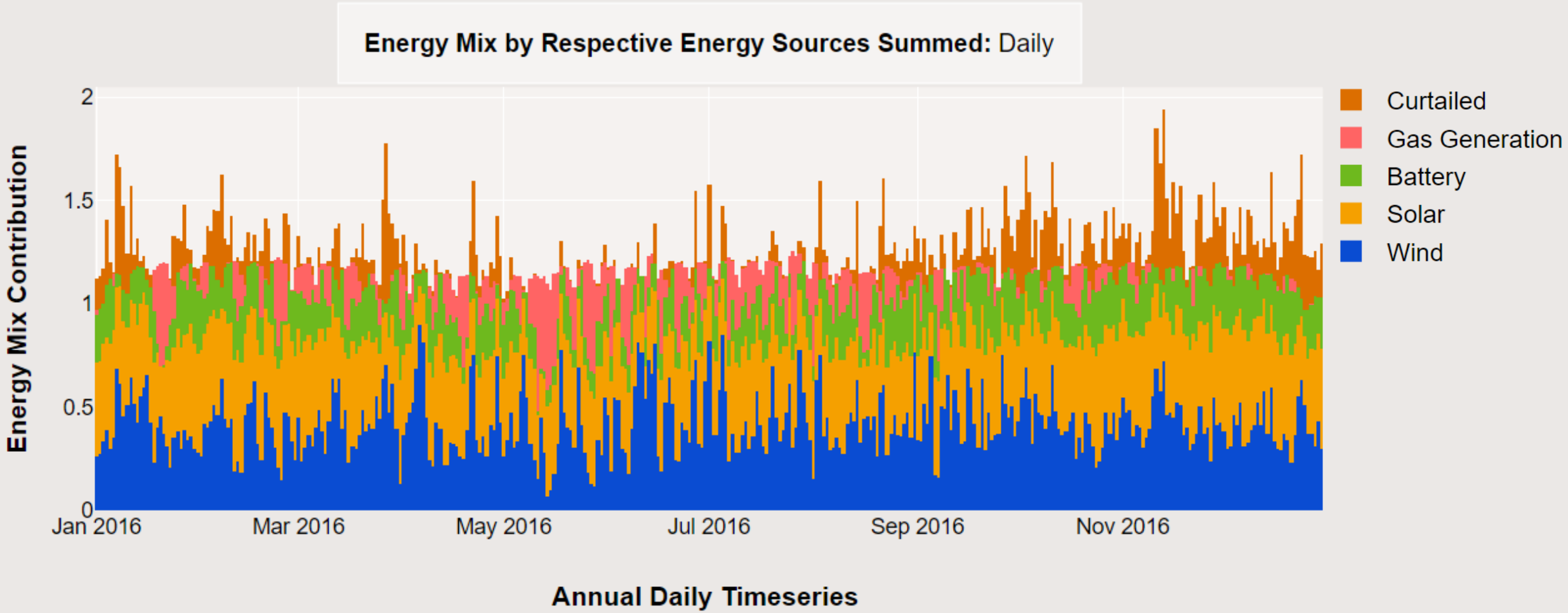


Good week in January 2050:

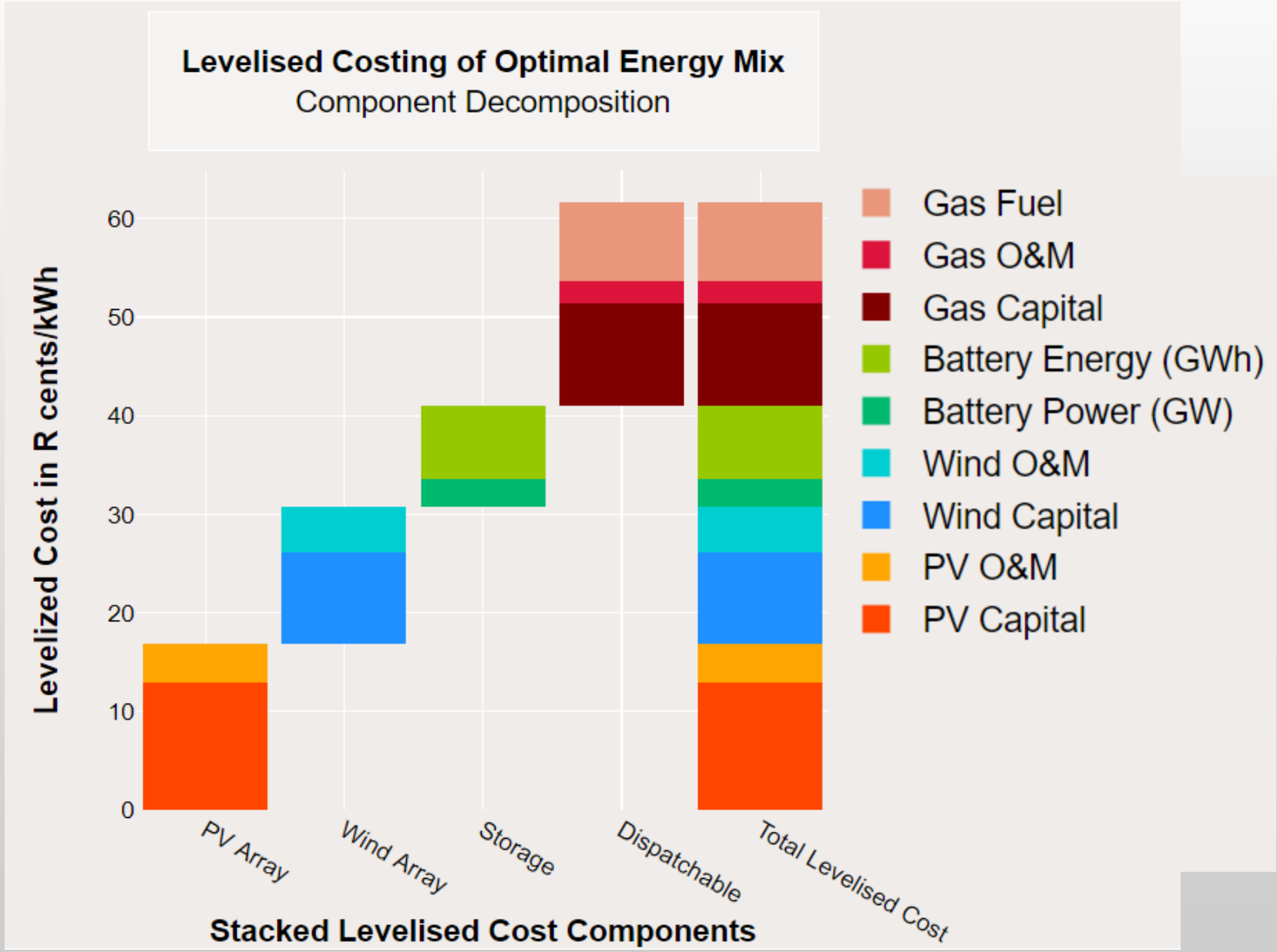
100% Renewable – however excess is curtailed…



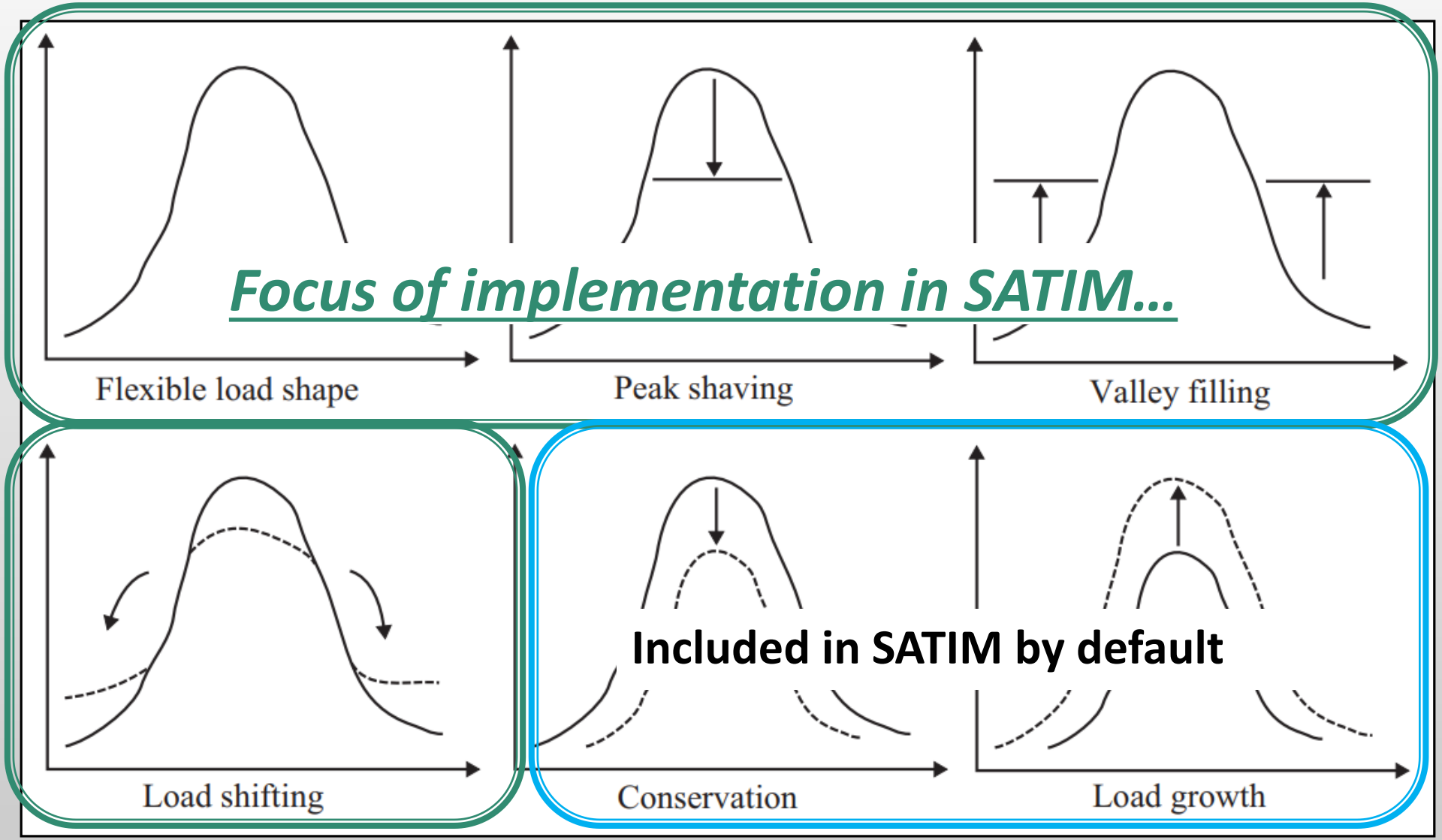
Full year: Daily energy mix contributions



Total Blended Levelised Cost of Energy (2050)



Demand-Side Management: Flexible Demand and Demand Response in Electricity Systems



Flexible Demand System Definitions

- All SATIM model equations and technology functional specifications are implemented as in the standard TIMES modelling framework and can be found in the official IEA-ETSAP documentation (IEA-ETSAP, 2018).
- Flexible demands are modelled here as **centrally controllable standard TIMES electrical storage devices**
- Energy storage is “discharged” by reducing demand, and “charged” by increasing demand
- Given associated availability profiles to specify **maximum up and down regulating power capacities (“negawatts”)**, and a **total allowable time delay duration.**

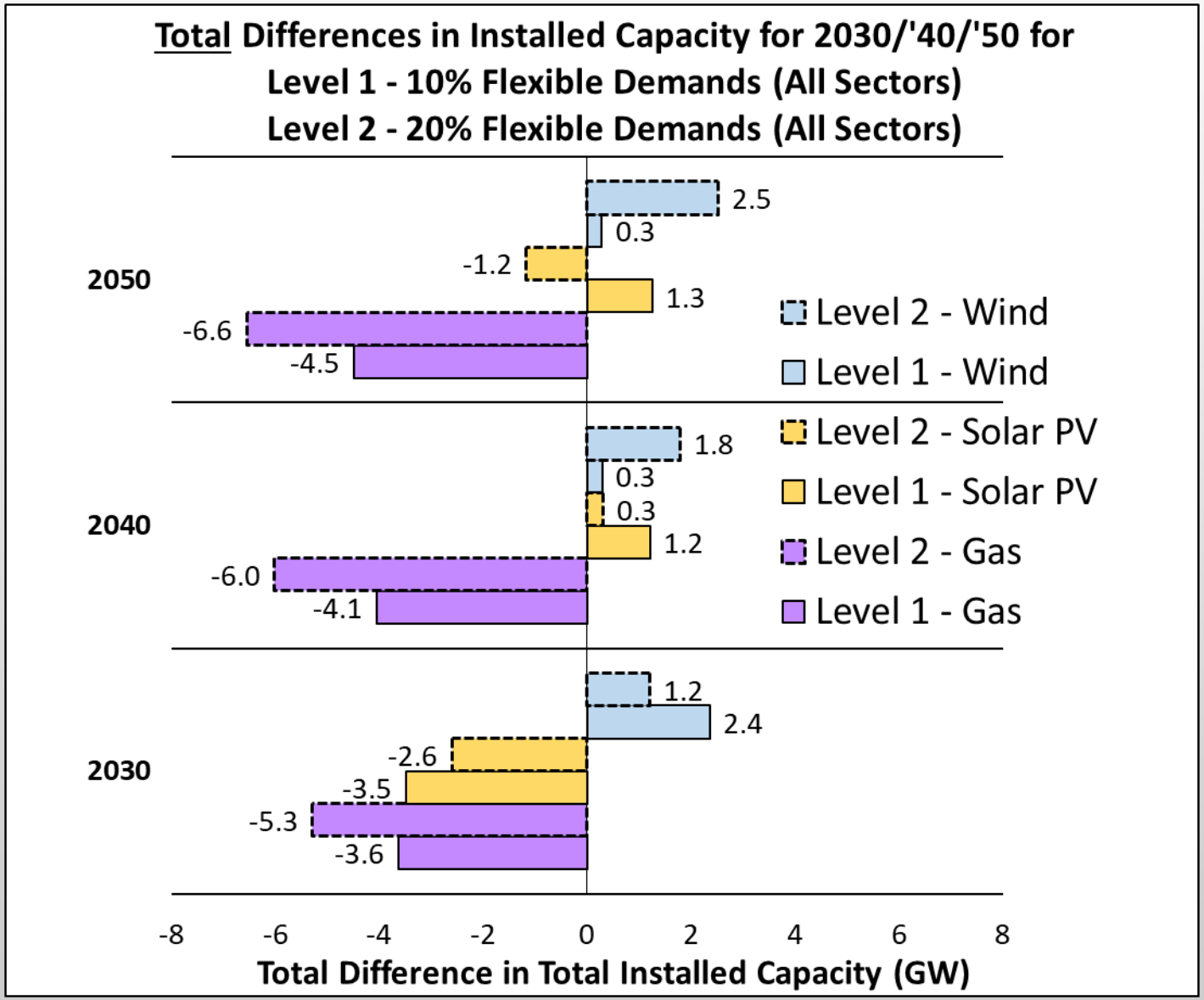
Scenarios Modelled in previous SATIM study

Three levels of electrical flexible demand penetration are modelled in this study: **Residential, Commercial, and Industrial** sectors are modelled

- **0% flexibility** – All electrical demands must provide the exact defined energy service demand profile. **(Reference)**
- **10% flexibility** – 10% of the peak electrical demand per sector are considered fully controllable and flexible including a **maximum 4-hour delay – all total service demands must balance and be served within a day.**
- **20% flexibility** –as above but with 20% of electrical demand per sector.

The total impacts and value are determined by the <u>difference in total system costs between scenarios.</u>

Differences in Installed Capacity per Technology

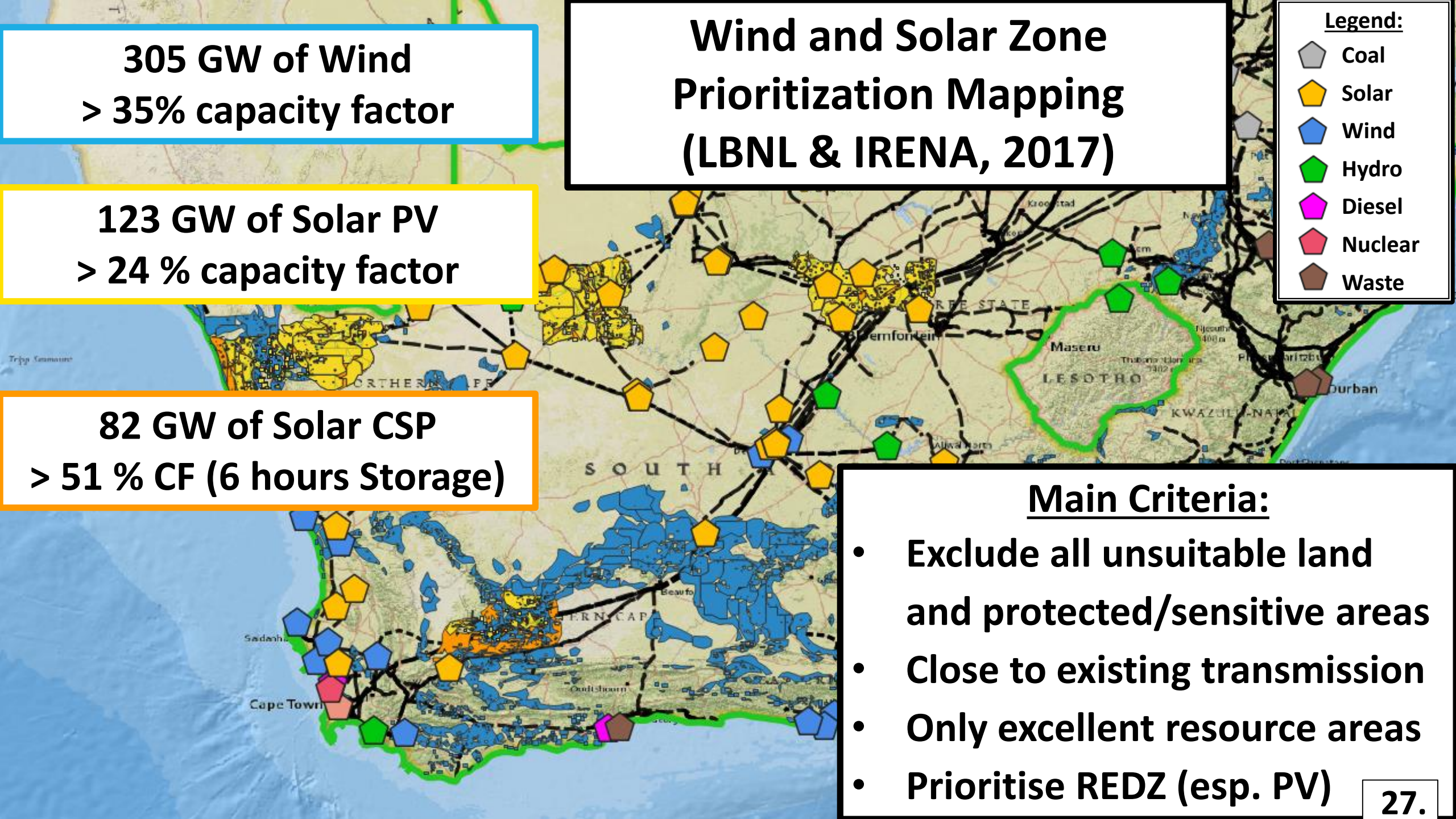


Wind and Solar Zone Prioritization Mapping (LBNL & IRENA, 2017)

305 GW of Wind
> 35% capacity factor

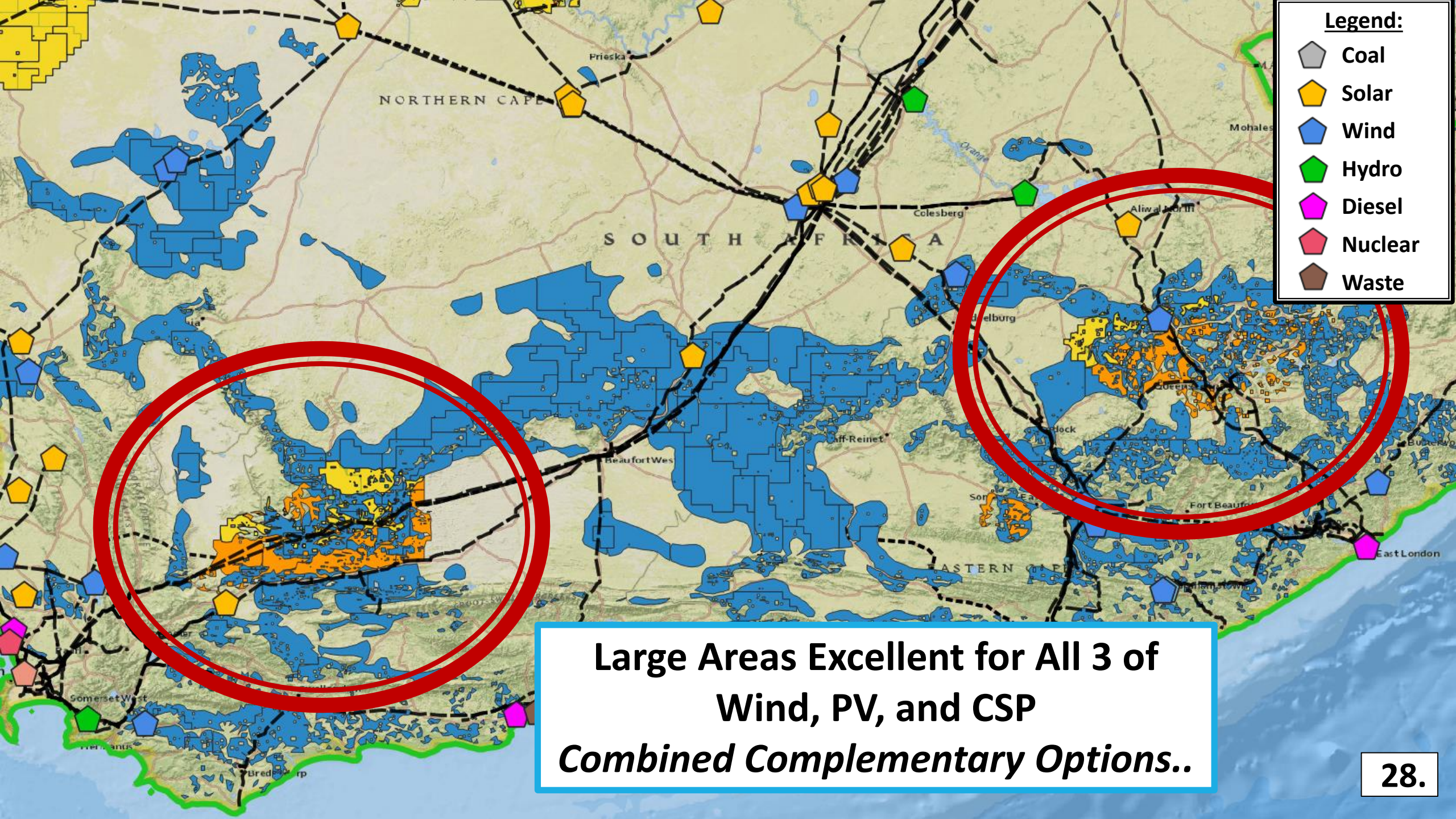
123 GW of Solar PV
> 24 % capacity factor

82 GW of Solar CSP
> 51 % CF (6 hours Storage)



Main Criteria:

- Exclude all unsuitable land and protected/sensitive areas
- Close to existing transmission
- Only excellent resource areas
- Prioritise REDZ (esp. PV)



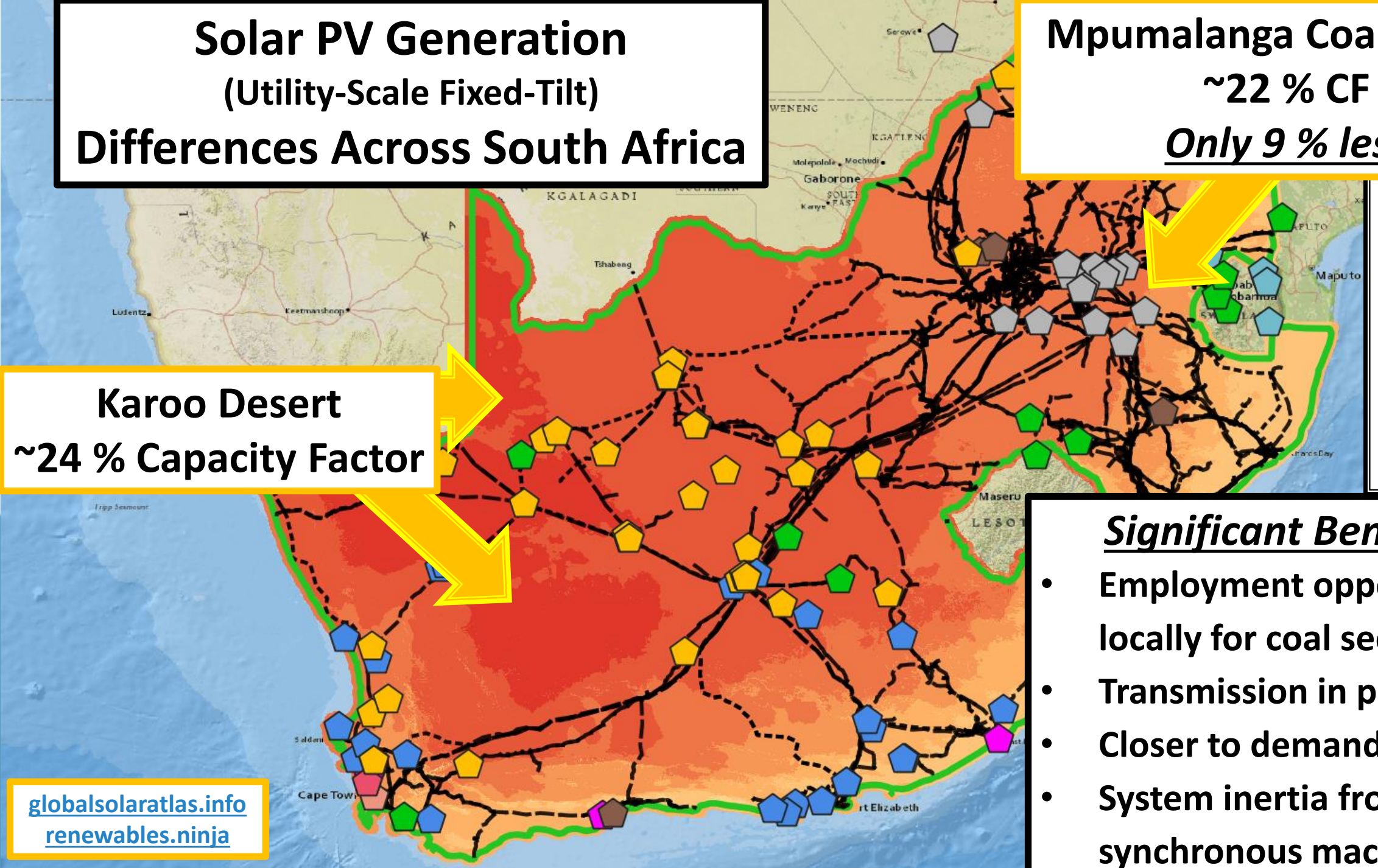
Large Areas Excellent for All 3 of Wind, PV, and CSP

Combined Complementary Options..

Solar PV Generation
(Utility-Scale Fixed-Tilt)
Differences Across South Africa

Mpumalanga Coal Region
~22 % CF
Only 9 % less

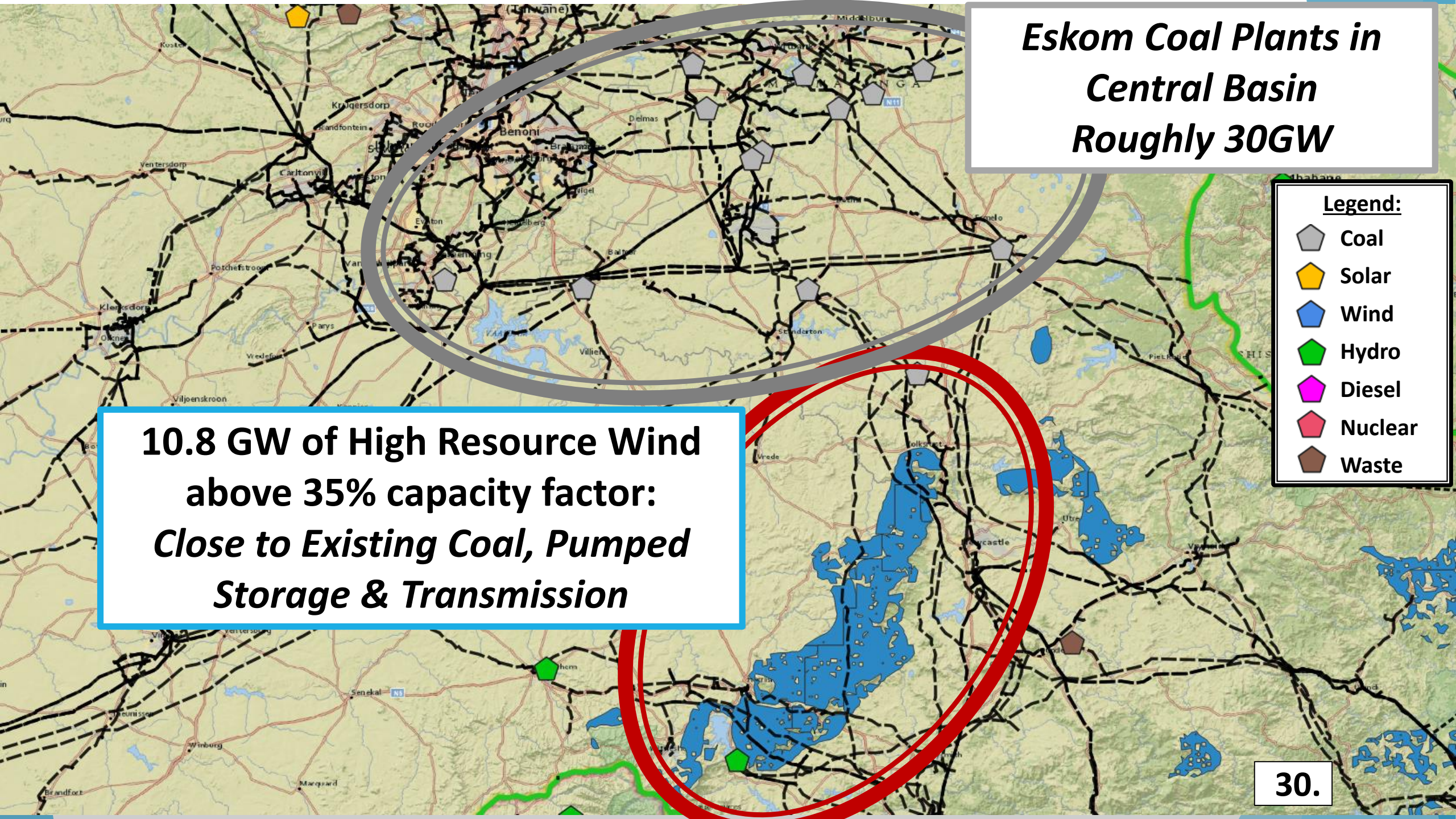
Karoo Desert
~24 % Capacity Factor



globalsolaratlas.info
renewables.ninja

Significant Benefits:

- Employment opportunities locally for coal sector
- Transmission in place
- Closer to demand
- System inertia from old synchronous machines


Eskom Coal Plants in Central Basin Roughly 30GW
Legend:
Coal
Solar
Wind
Hydro
Diesel
Nuclear
Waste
10.8 GW of High Resource Wind above 35% capacity factor:
Close to Existing Coal, Pumped Storage & Transmission
30.

Conclusions and future work…

- South Africa has an abundant resource endowment
  - Renewable AND “conventional”…
- Very high shares of variable renewable energy can be integrated into the South African electricity system
- Understanding the long-term variability of wind and solar in South Africa is key for planning an optimal electricity system
- The spatial distribution of new energy investments in South Africa is a critical area of ongoing work

Emerging solutions to investigate further for South Africa….

- Significantly more sector coupling
- Smart-grids and demand side management
- Concentrating Solar Power
- Hydrogen - “Power-to-X”
  - Energy storage
  - “Green” liquid-fuels
  - Iron and Steel

Thank you!

We are open for collaboration and contributions for future work…

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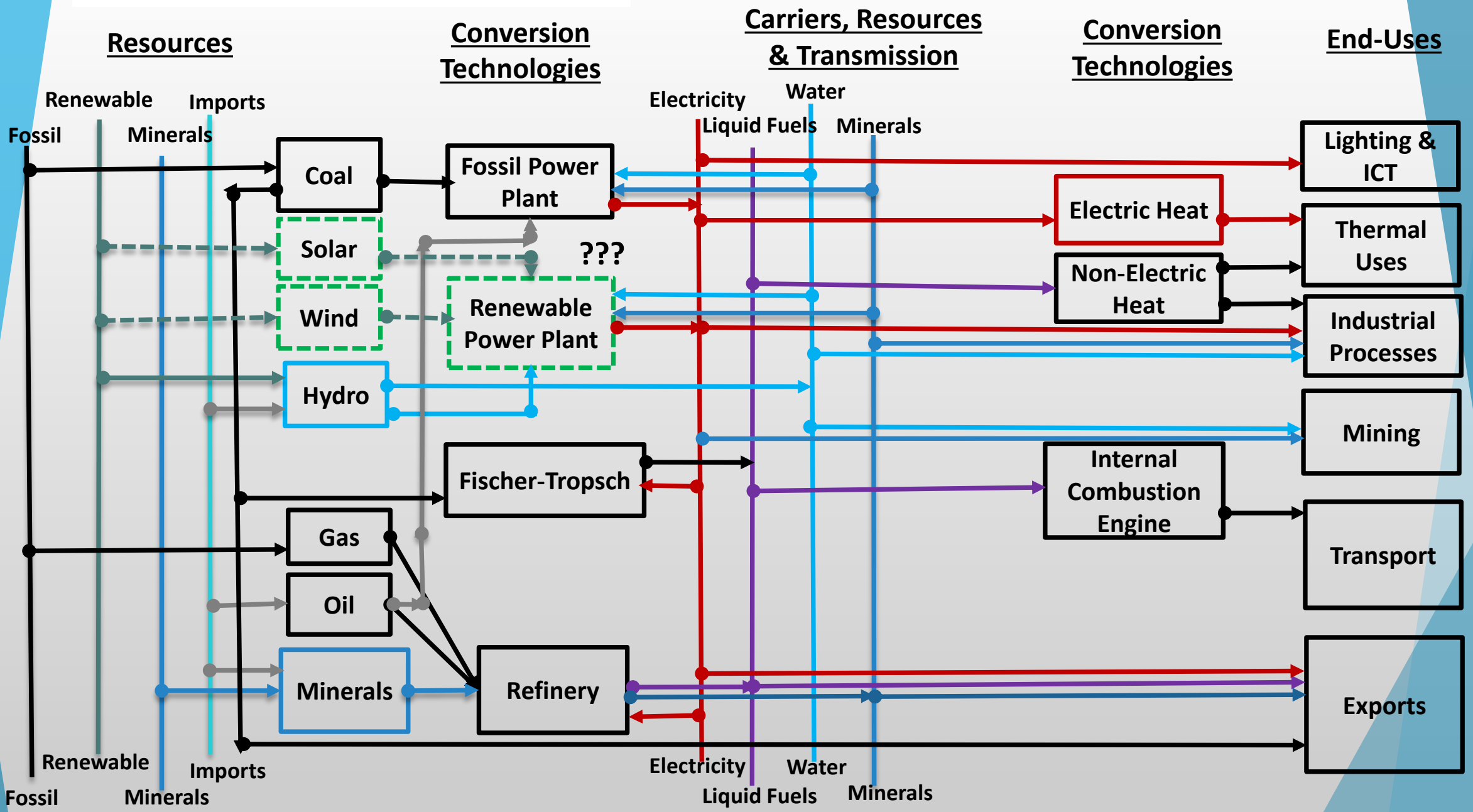
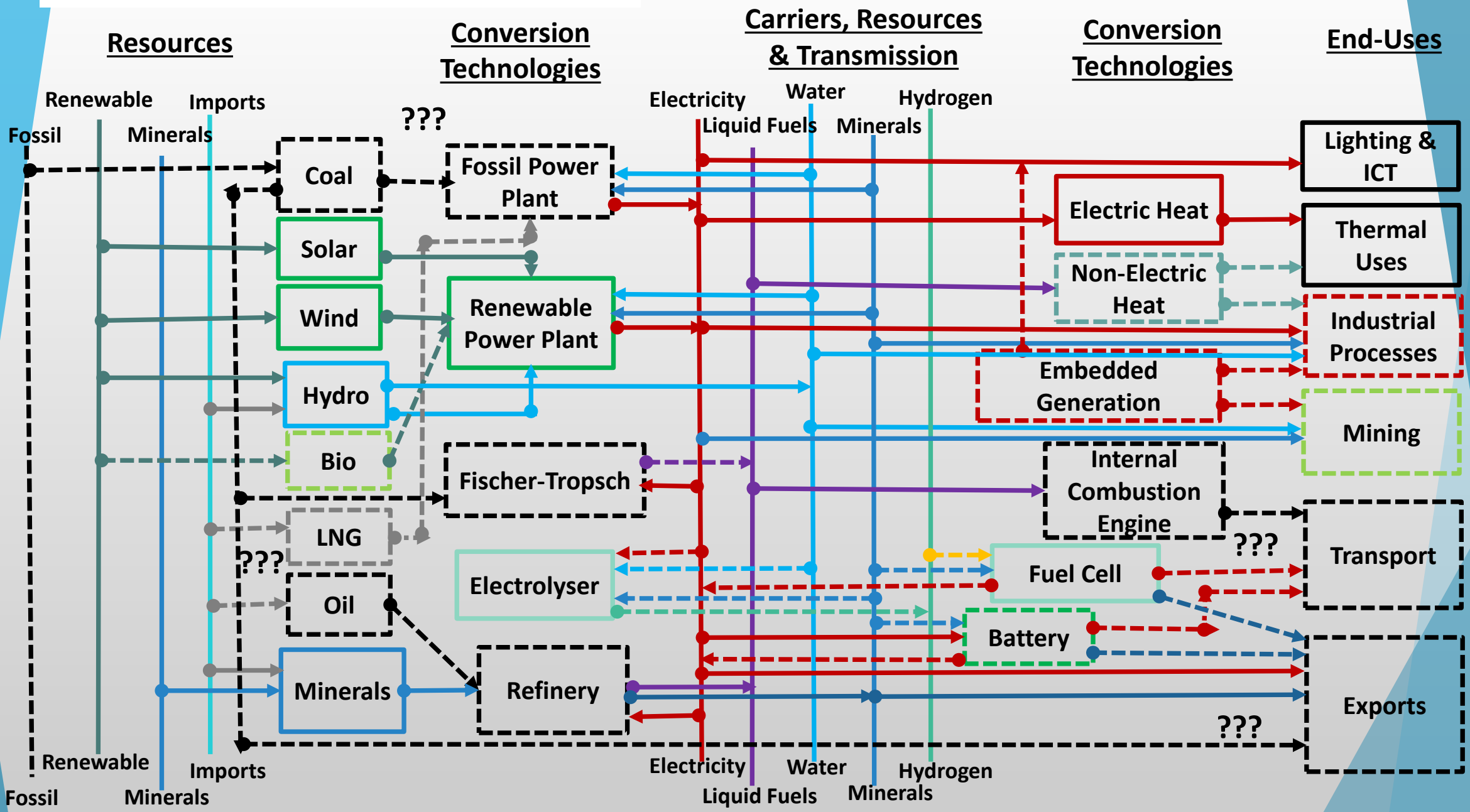
Today in South Africa → *Coal and emissions intensive*



Medium-Term… in RSA ⟶ *Transition Period*



The Future in South Africa ⟶ *Decarbonised & modernised*