Renewable Resources in SA

Smart Camp101 – A SAIEE Event

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Crescent Mushwana

Principal Engineer : Energy-system planning and operation

Professional Experience

- March 2015 – today: Principal Engineer: Energy-system planning and integration. Responsible for a team doing energy planning, grid planning, and system modelling & optimisation
- 2008– Feb 2015: Chief Engineer, Eskom Grid Planning (Strategic). Responsible for research, strategic planning studies, specialised studies/projects and planning database management
- 2005– 2008: Wires Executive, Eskom Key Sales and Customer Service. Responsible for technical input into contracts; technical investigations and audits; part of Distribution Code Industry Expert Team
- 2002 – 2004: Senior planner, Eskom Transmission System Planning. Responsible for power system planning studies (steady-state and dynamic); Business case development and technical/financial/ economic/environmental evaluation of grid projects.

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Education

- M Eng. (Electrical), 2012, University of the Witwatersrand
- BSc Hons (Applied Science), 2004, University of Pretoria
- B Tech (Elec. Eng.), 1999, University of Johannesburg

Agenda

Resources for electricity generation

Renewables

- Renewables; what are they and myths arounds them
- International context
- Renewables in South Africa

Future South African economy with high shares of renewables

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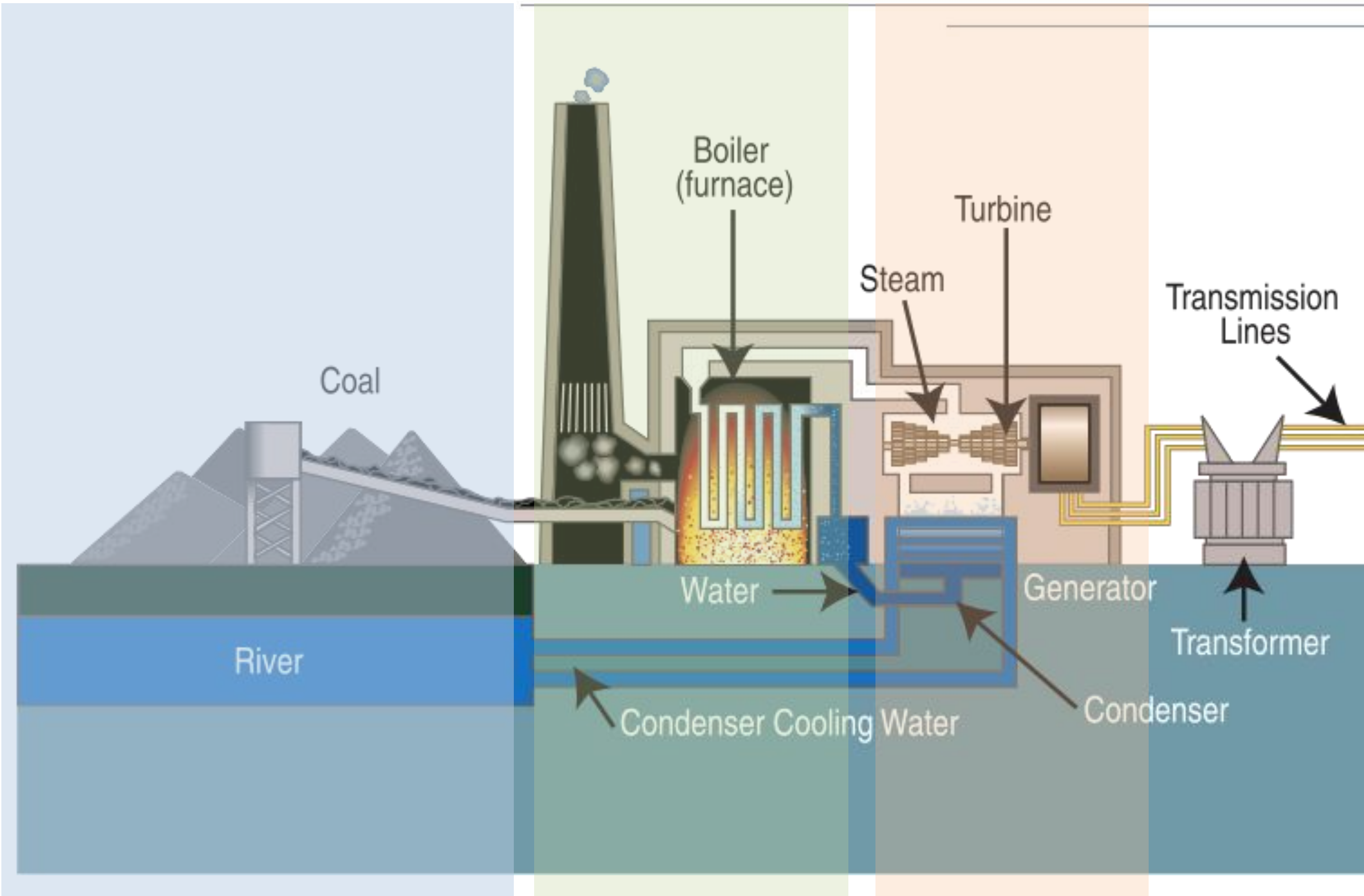
Conventional generation – a coal plant



Fuel source

Process: steam generation & emissions

Conversion: Mech. to Elec. power

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Sources: Wikipedia; CSIR Analysis

Resources for electricity generation

Resource	Technology	Environmental impact	Infinite resource
Coal	Thermal	Very High	No
Nuclear	Thermal	Medium	No
Gas	Thermal	High	No
Biomass	Thermal	Low	Yes
Wind	Kinetic - wind	Negligible	Yes
Solar Thermal (CSP)	Thermal	Low	Yes
Solar PV	Solar	Low	Yes
Hydro	Kinetic - water	Low	Yes
Geothermal	Thermal	Low	Yes

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- **Renewables; what are they and myths arounds them**
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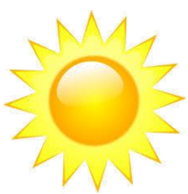
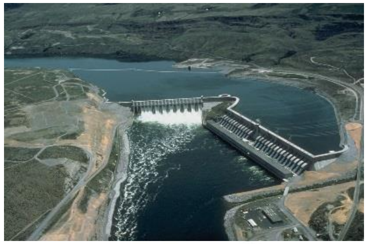
What is Renewable Energy?

Energy derived from natural resources that are replenished at a faster rate than they are consumed, and thus cannot be depleted. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy.







Myths about renewable energy

1. Renewables are too expensive

- Unsubsidised renewable (wind and PV) is now cheaper than new build convectional plants in South Africa (REBID Window 4). The same is true for other countries around the world; European Countries, Australia, India, etc

2. Renewable energy is a nice to have but not big enough

- International Energy Agency: Any country can reach high shares (approx. 60-80%) of wind, solar power cost-effectively.
- Germany, Europe's biggest economy, already gets 35% of it's electricity from renewables, and is aiming for 80% by 2050.
- Renewables supplied 42% of mainland Spain's electricity in 2013.
- By 2050 almost all of global energy needs can be met with renewables.

3. Renewable energy can't supply electricity 24/7

- When a mix of sources spread over a wide area: solar and wind power, biogas, biomass and geothermal sources, the variability of renewables is greatly reduces and renewables can supply "base load".
- With high shares of renewables, smart grids and virtual power plants will be key of a reliable supply

4. The electricity grid can't handle renewable energy

- The electricity grid must be designed for the purpose of handling high shares of renewables; smart grid, prosumers. Even with the existing grids built for centralised conventional plants, up to 30% shares of renewables can be accommodated without major changes

5. Renewable energy is bad for the environment

- Environmental Impact Assessments ensure that impact (birds & bats; noise; land use); land on wind farms is still available for farming and grazing.

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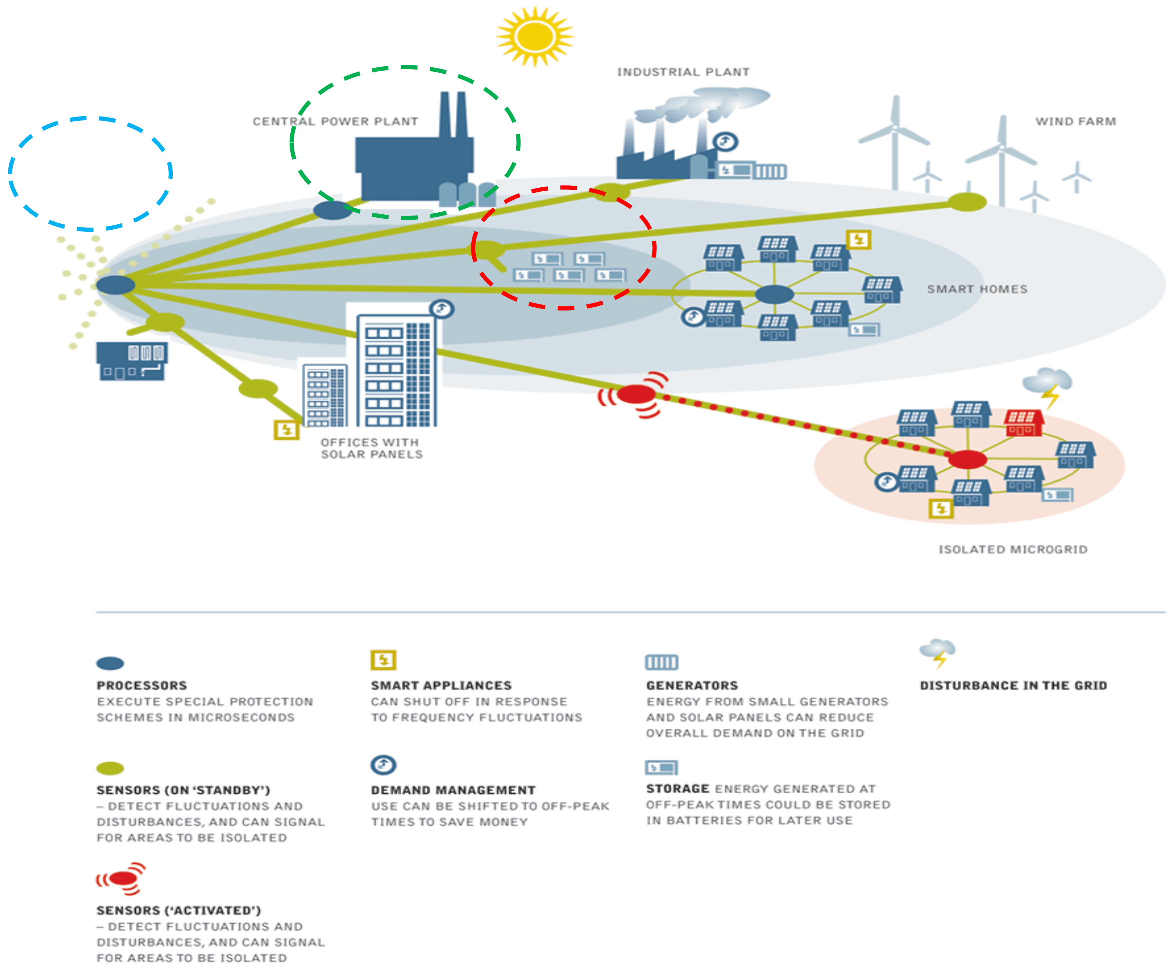
Sources: GreenCape; CSIR Analysis

A future energy system with high share of renewables



1. Storage includes battery, Hydrogen, and EV's Charging and discharging
2. Central Power plants could be supplied by fossil-fuels or synthetic fuels produced by renewable energy
3. Transportation driven by synthetic fuels or hydrogen will be a key part of the integrated energy system

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Sources: GreenCape; CSIR Analysis

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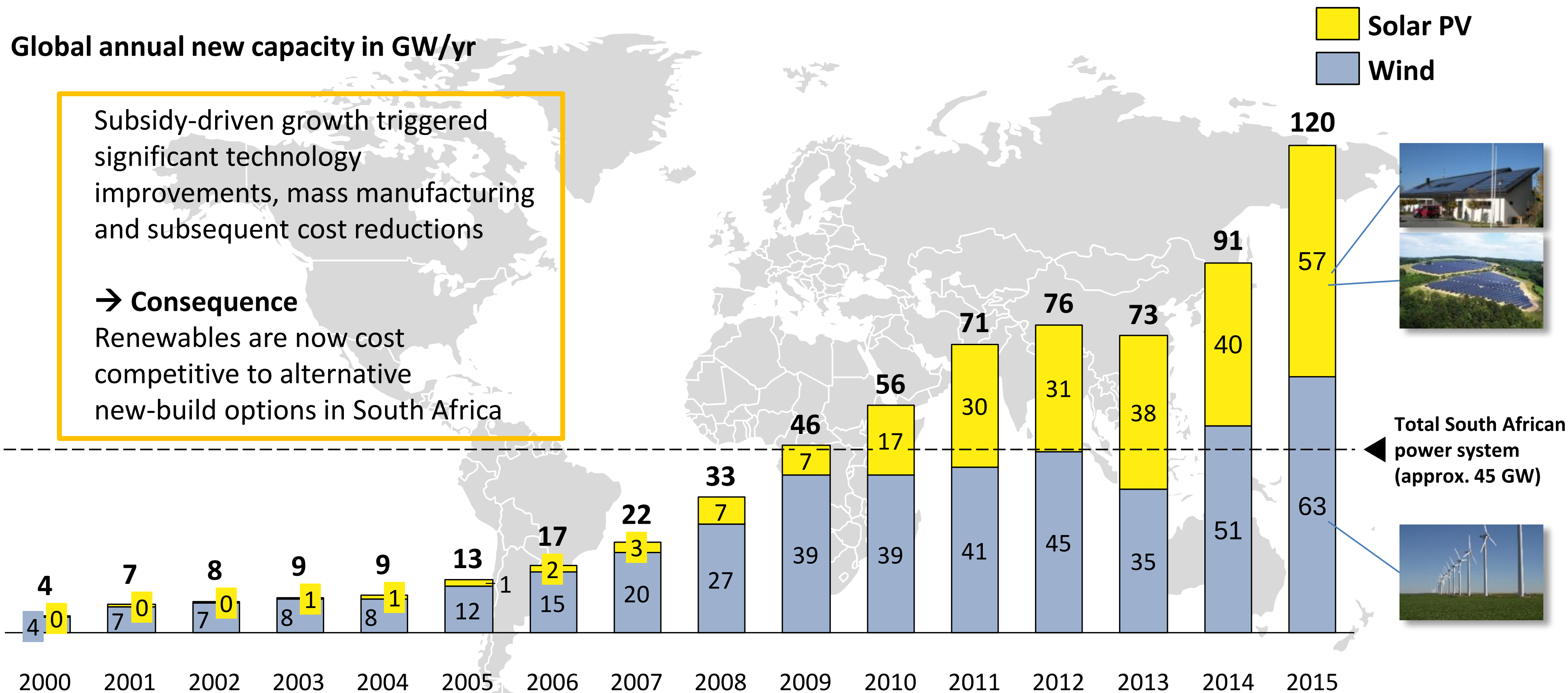
In 2015, 120 GW of wind and solar PV newly installed globally

Subsidy-driven growth triggered significant technology improvements, mass manufacturing and subsequent cost reductions

→ **Consequence**
Renewables are now cost competitive to alternative new-build options in South Africa

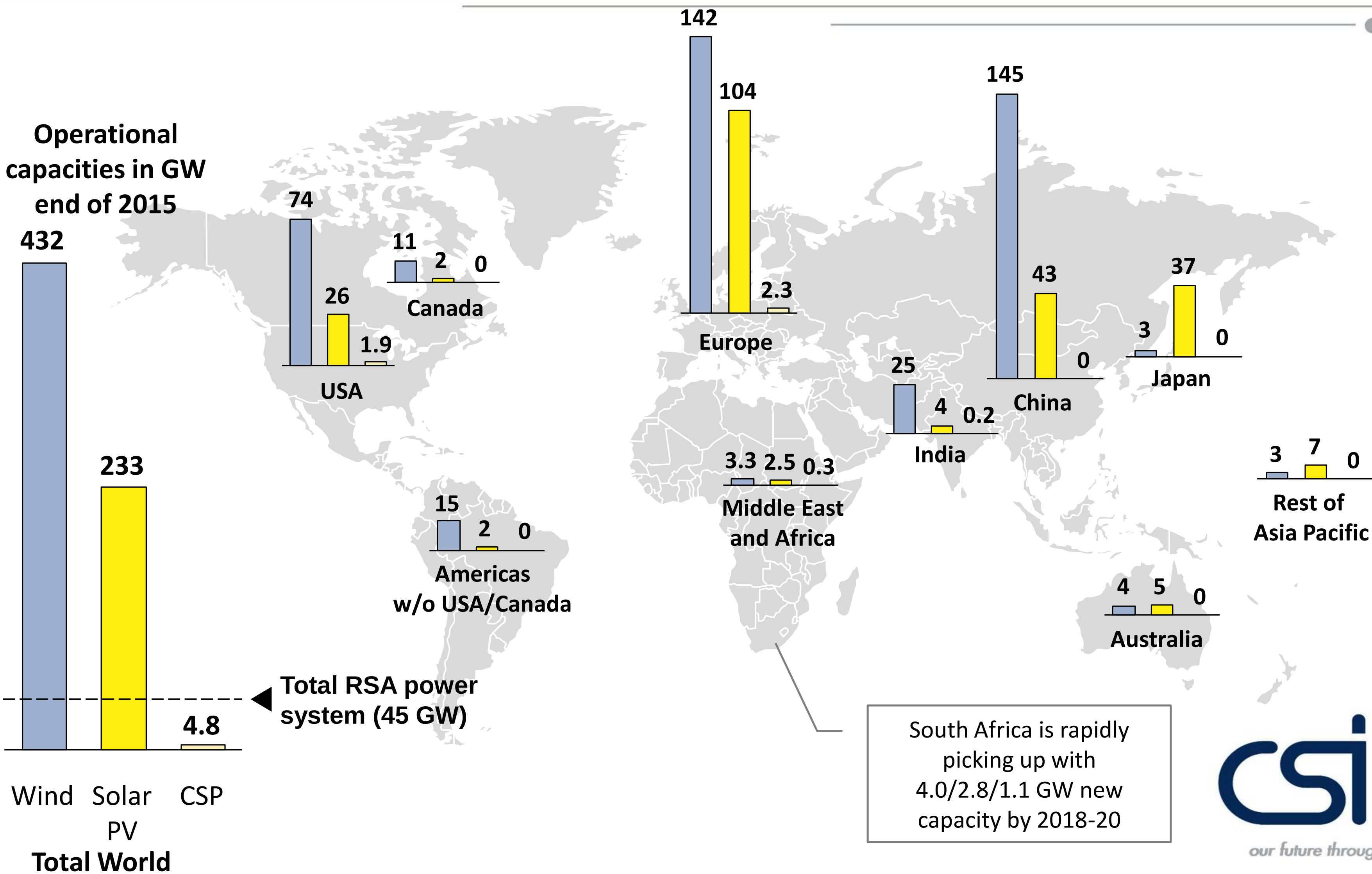


This is all very new: Almost 90% of the globally existing PV capacity was installed during the last five years alone!

Sources: GWEC; EPIA; BNEF; CSIR analysis

Renewables until today mainly driven by US, Europe, China and Japan

Globally installed capacities for three major renewables wind, solar PV and CSP end of 2015



Sources: GWEC; EPIA; CSPToday; CSIR analysis

Phasing out of fossil fuels by 2100 – "greeny" or business sense?

G7 announcement on 8 June 2015

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G7 leaders agree to phase out fossil fuel use by end of century

German chancellor Angela Merkel announces commitment to 'decarbonise global economy' and end extreme poverty and hunger

G7 leaders, including Angela Merkel (in pink jacket), and invitees line up for the traditional group photo at the end of the summit. Photograph: Sven Hoppe/dpa/Corbis

The G7 leading industrial nations have agreed to cut greenhouse gases by phasing out the use of fossil fuels by the end of the century, the German chancellor, Angela Merkel, has announced, in a move hailed as historic by some environmental campaigners.

On the final day of talks in a Bavarian castle, Merkel said the leaders had committed themselves to the need to "decarbonise the global economy in the

Most popular

Black children are not even safe from police violence at a pool party | Steven W Thrasher

Is Richard Dawkins destroying his reputation? | Sophie Elmhirst

'You think you're

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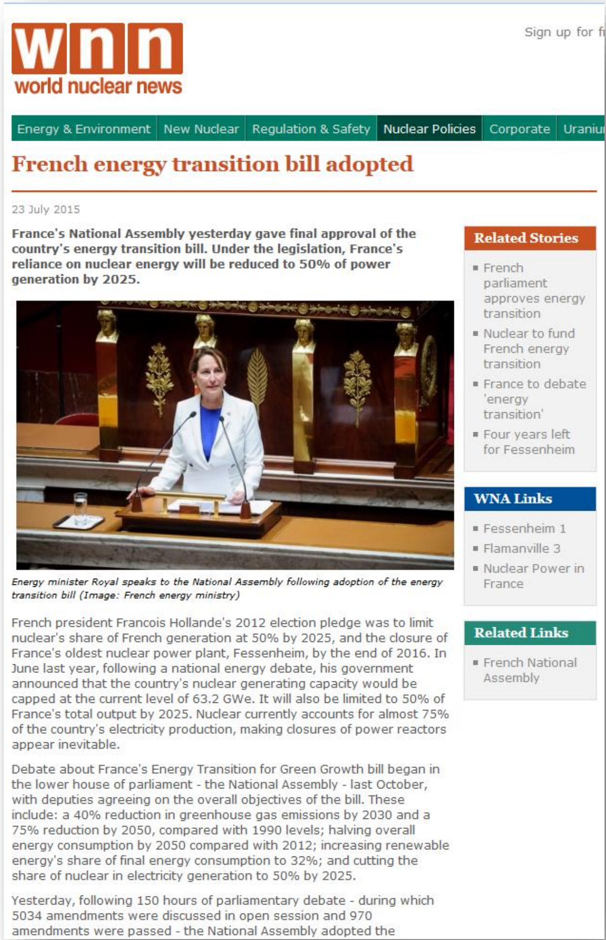
France will phase out "10 Koebergs" by 2025 – replaced by renewables



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French energy transition bill adopted

23 July 2015

France's National Assembly yesterday gave final approval of the country's energy transition bill. Under the legislation, France's reliance on nuclear energy will be reduced to 50% of power generation by 2025.

Energy minister Royal speaks to the National Assembly following adoption of the energy transition bill (Image: French energy ministry)

French president Francois Hollande's 2012 election pledge was to limit nuclear's share of French generation at 50% by 2025, and the closure of France's oldest nuclear power plant, Fessenheim, by the end of 2016. In June last year, following a national energy debate, his government announced that the country's nuclear generating capacity would be capped at the current level of 63.2 GWe. It will also be limited to 50% of France's total output by 2025. Nuclear currently accounts for almost 75% of the country's electricity production, making closures of power reactors appear inevitable.

Debate about France's Energy Transition for Green Growth bill began in the lower house of parliament - the National Assembly - last October, with deputies agreeing on the overall objectives of the bill. These include: a 40% reduction in greenhouse gas emissions by 2030 and a 75% reduction by 2050, compared with 1990 levels; halving overall energy consumption by 2050 compared with 2012; increasing renewable energy's share of final energy consumption to 32%; and cutting the share of nuclear in electricity generation to 50% by 2025.

Yesterday, following 150 hours of parliamentary debate - during which 5034 amendments were discussed in open session and 970 amendments were passed - the National Assembly adopted the

Related Stories

- French parliament approves energy transition
- Nuclear to fund French energy transition
- France to debate 'energy transition'
- Four years left for Fessenheim

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- Nuclear Power in France

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- French National Assembly

http://www.world-nuclear-news.org/NP-French-energy-transition-bill-adopted-2307155.html

France has by far the highest nuclear penetration of any country in the world, with 75% of its electricity coming from nuclear

France has passed a bill on 23 July 2015: mandates a reduction of the share of nuclear in the electricity mix to 50% by 2025

That's a reduction by 140 TWh/yr of nuclear power generation, which is the same amount of energy produced by 10 Koebergs

This energy will be replaced by renewables

This emphasises again the recently achieved cost-competitiveness of renewables

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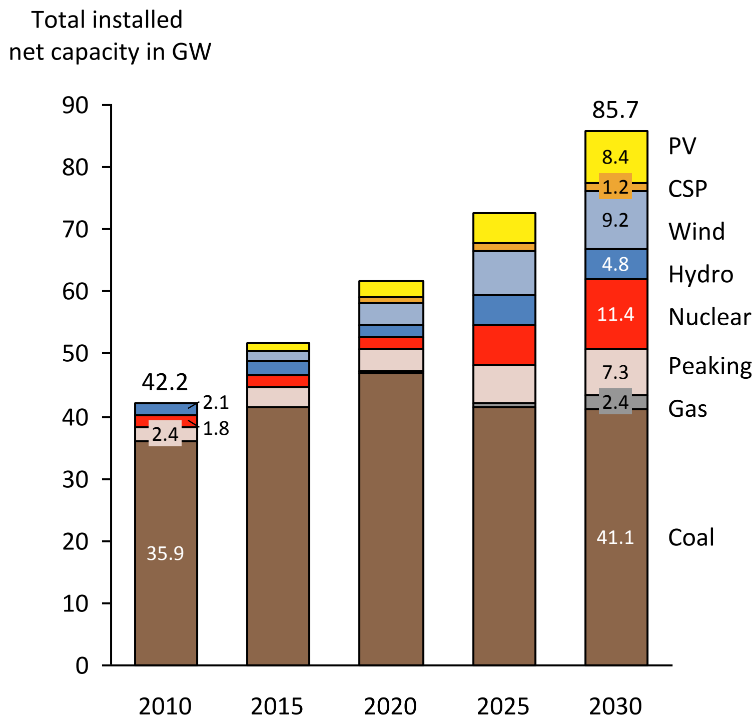
- **Renewables in South Africa**

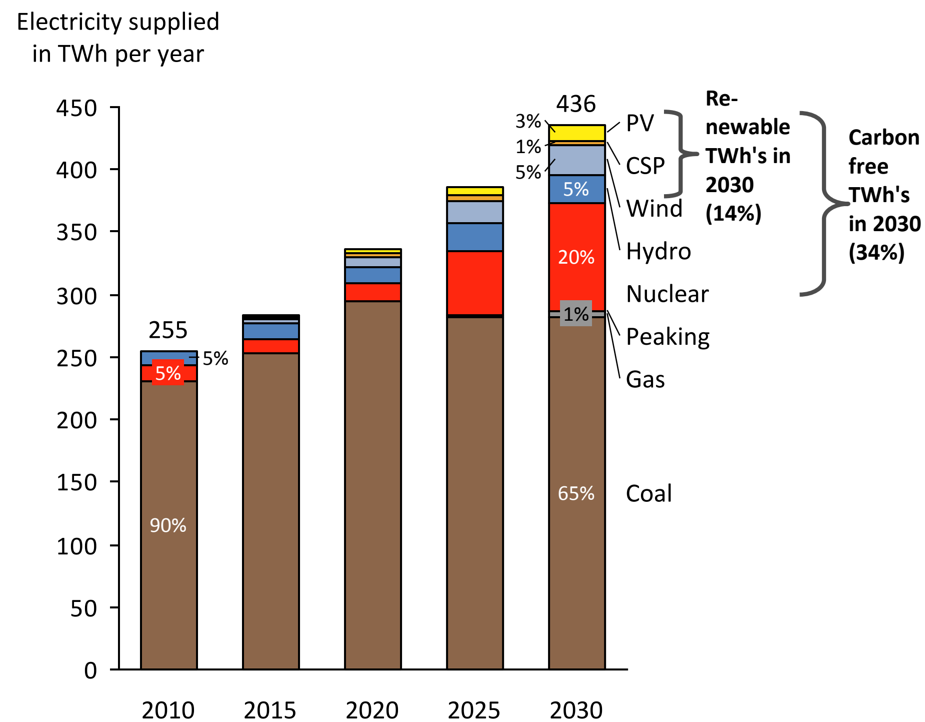
Future South African economy with renewables

Integrated Resource Plan 2010 (IRP 2010): Plan of the power generation mix for South Africa until 2030

Installed capacity



Energy mix



Share new renewables **0%** → **9%**

Implementation of the IRP is done by Department of Energy through competitive tenders ("REIPPPP" for renewables)

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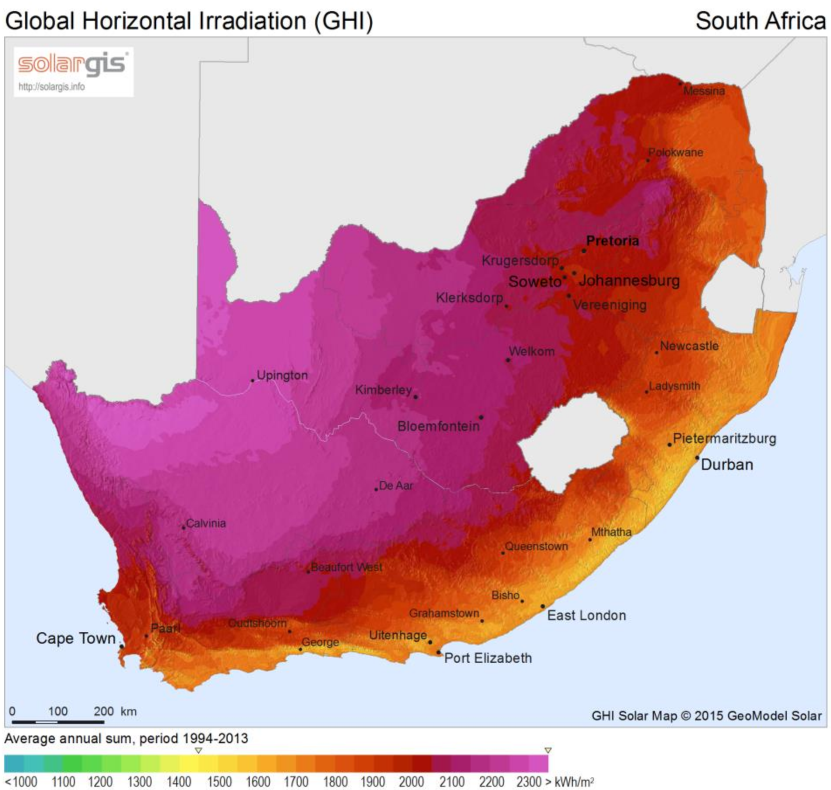
Note: hydro includes imports from Cahora Bassa

Sources: Integrated Resource Plan 2010, as promulgated in 2011; CSIR Energy Centre analysis

South Africa has almost 2-times the solar resource as Germany, where PV is close to cost competitiveness

Solar resource in South Africa…



SA's planned PV capacity by 2030: 8.4 GW target too low

… as compared to Germany

Germany's status today: almost 40 GW PV installed capacity (roughly one Eskom)

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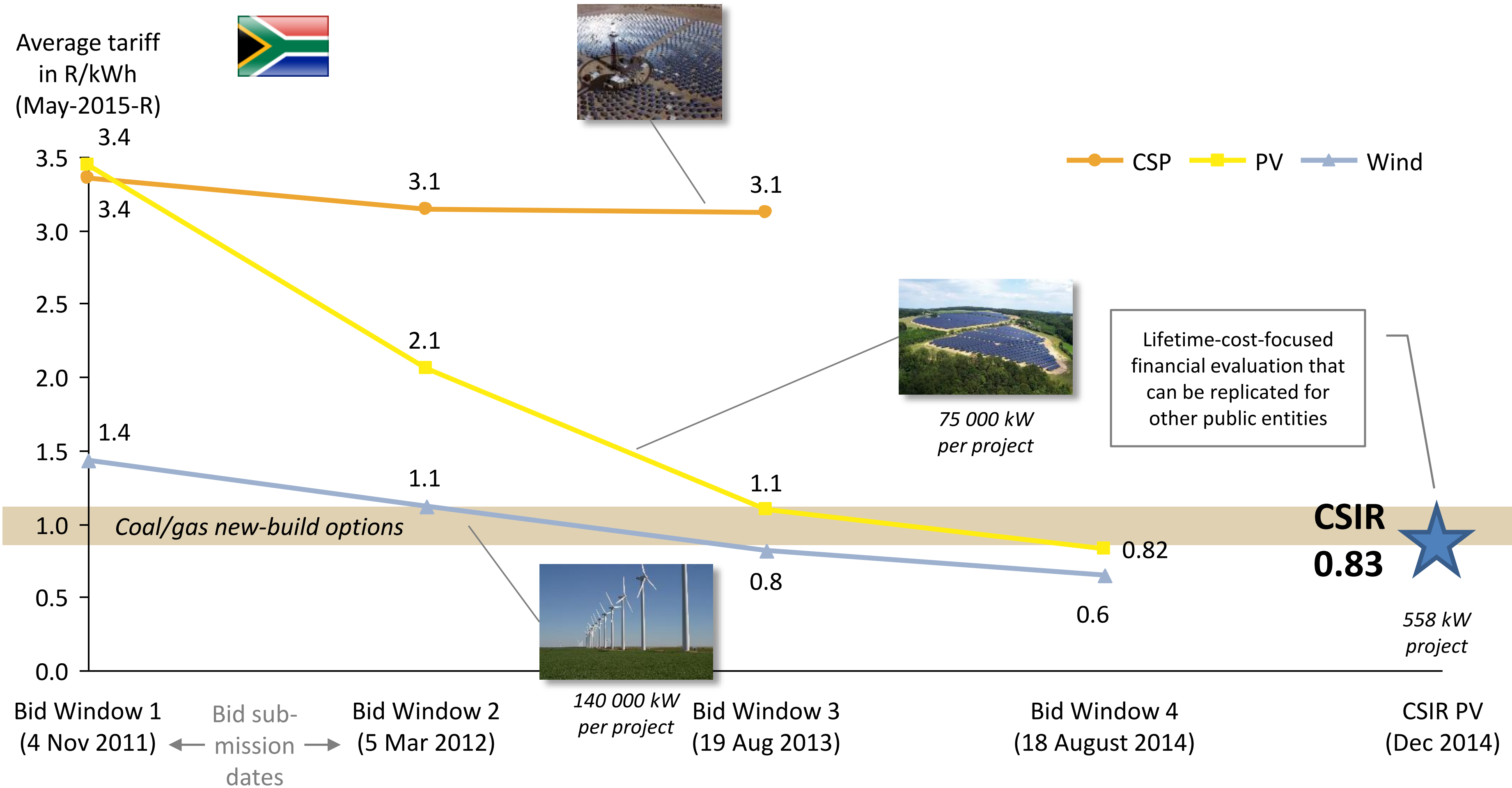
PV makes sense across South Africa: CSIR's first 560 kW PV system in Pretoria can compete with 75 000 kW PV systems in the Northern Cape

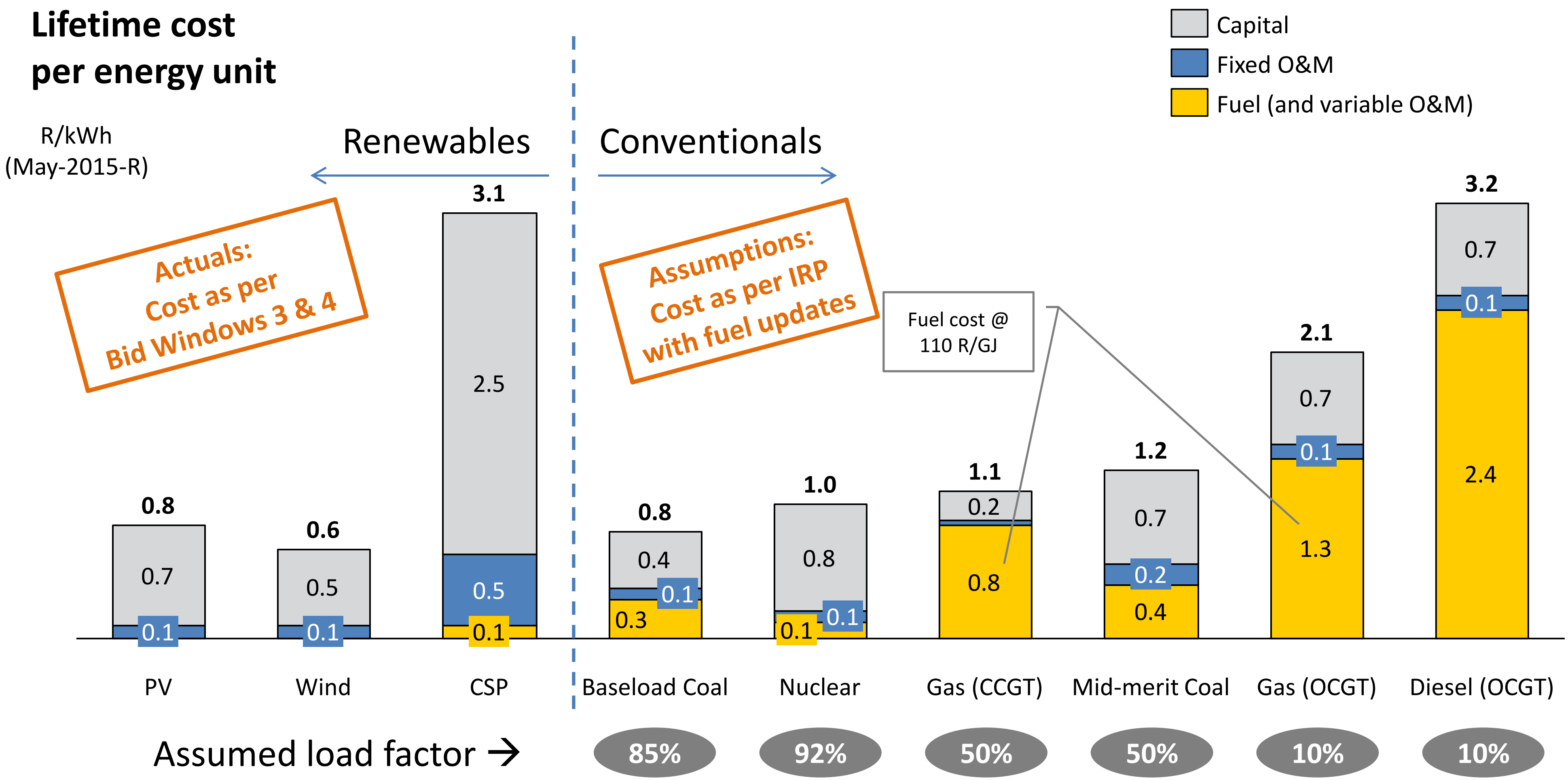
Four bid windows' results of Department of Energy's IPP Procurement Programme and CSIR's first own PV



Notes: For CSP Bid Window 3, the weighted average of base and peak tariff is indicated, assuming 50% annual load factor

Sources: StatsSA on CPI; Department of Energy's publications on results of first four bid windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR analysis

Consequence of renewables' cost reduction:
PV and wind are cost-efficient fuel-savers for CCGTs already today



Note: Changing full-load hours for conventionals drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per MWh);
Assumptions: average efficiency for CCGT = 50%, OCGT = 35%; coal = 37%; nuclear = 33%; IRP cost from Jan 2012 escalated with CPI to May 2015; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; CSP: 50% annual load factor and full utilisation of the five peak-tariff hours per day assumed to calculate weighted average tariff from base and peak tariff
Sources: IRP Update; REIPPPP outcomes; StatsSA for CPI; Eskom financial reports on coal/diesel fuel cost; CSIR analysis

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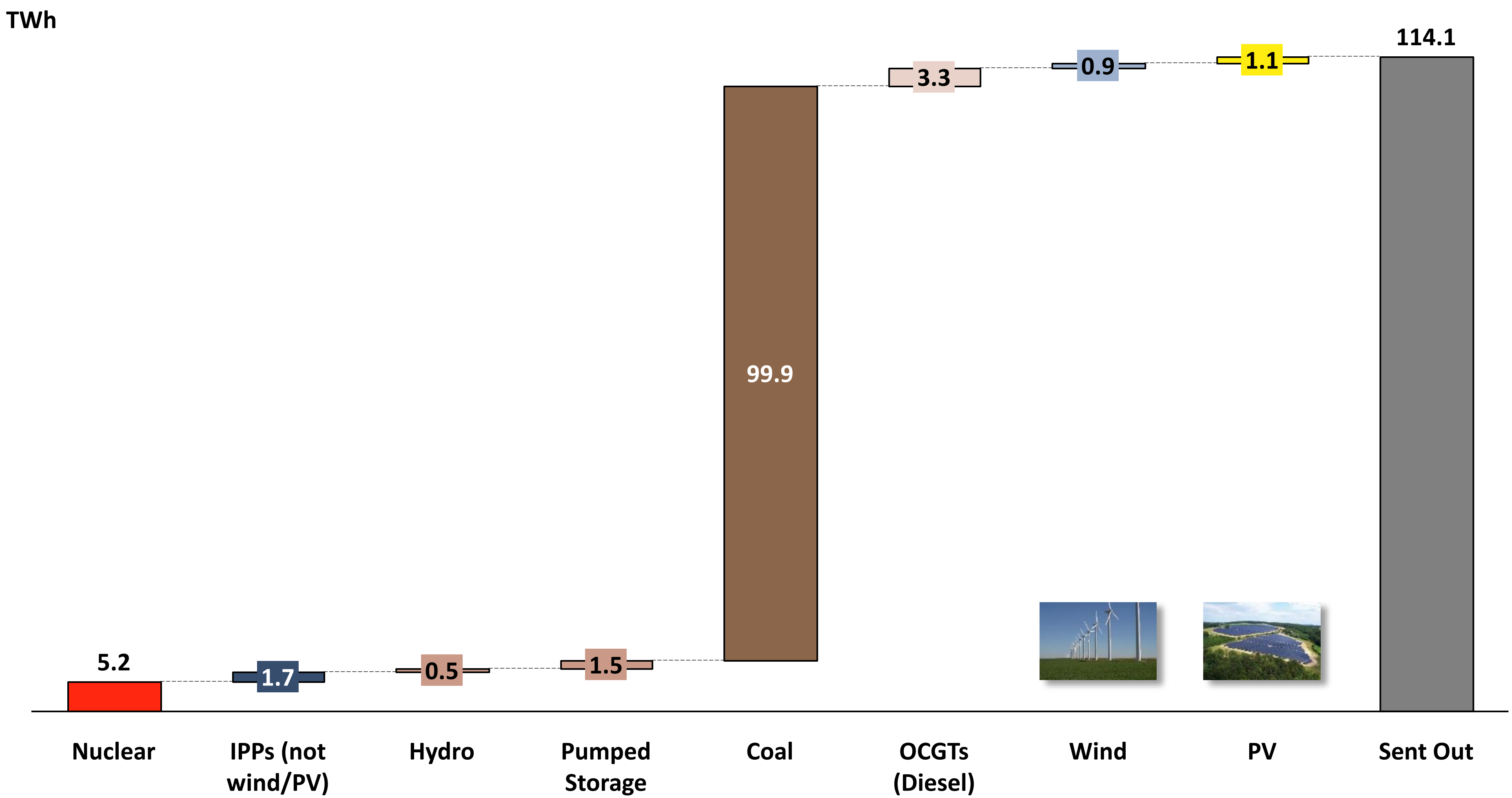
Wind and PV stand for 2% of the electricity sent out from Jan-Jun 2015

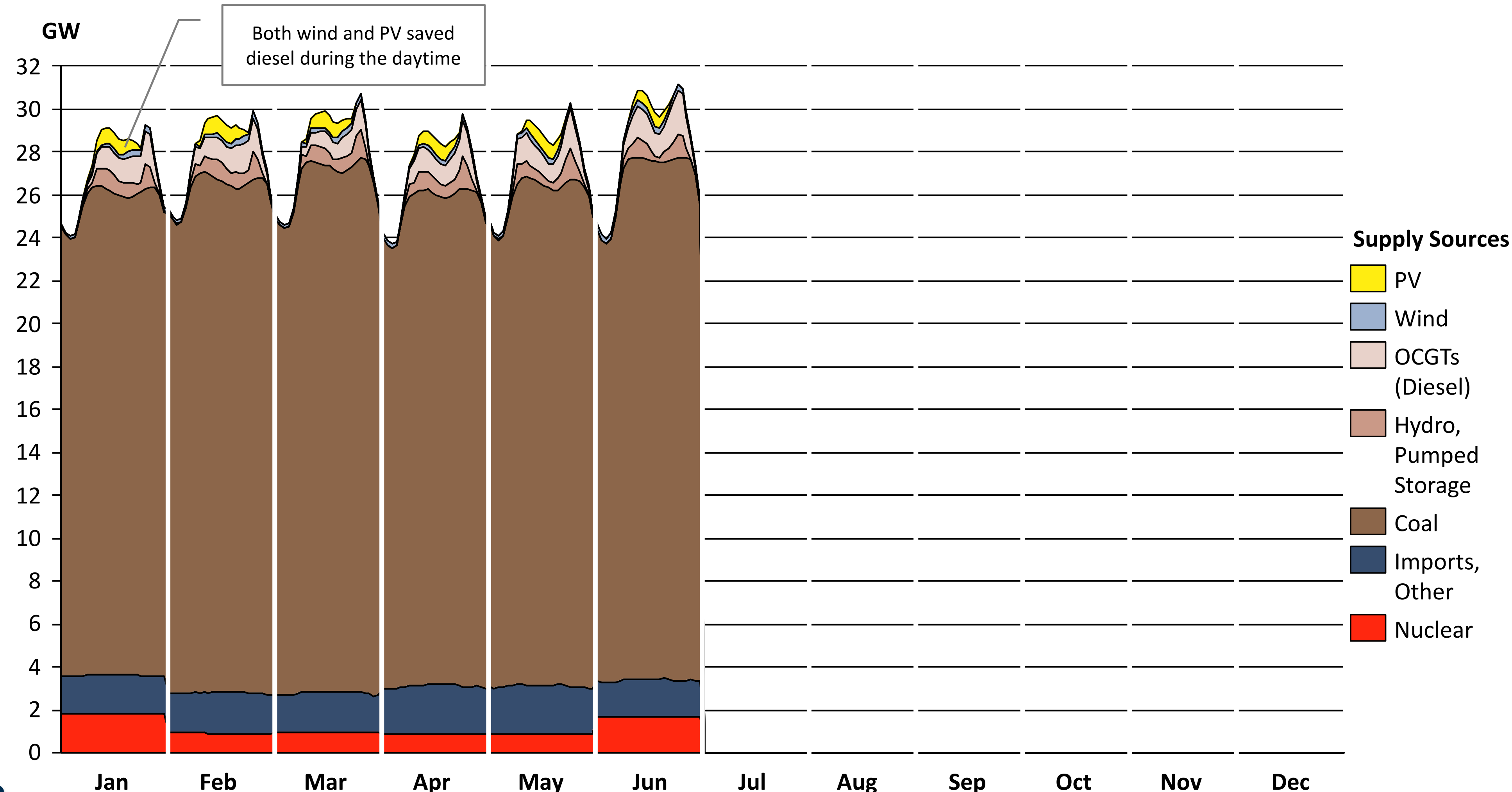
Actual energy captured in wholesale market (i.e. without self-consumed energy of embedded plants)



Sources: Eskom; CSIR Energy Centre analysis

From Jan-Jun 2015, OCGTs on average used during the entire daytime

Actual monthly average diurnal courses of the total power supply in RSA for the months from Jan-Jun 2015



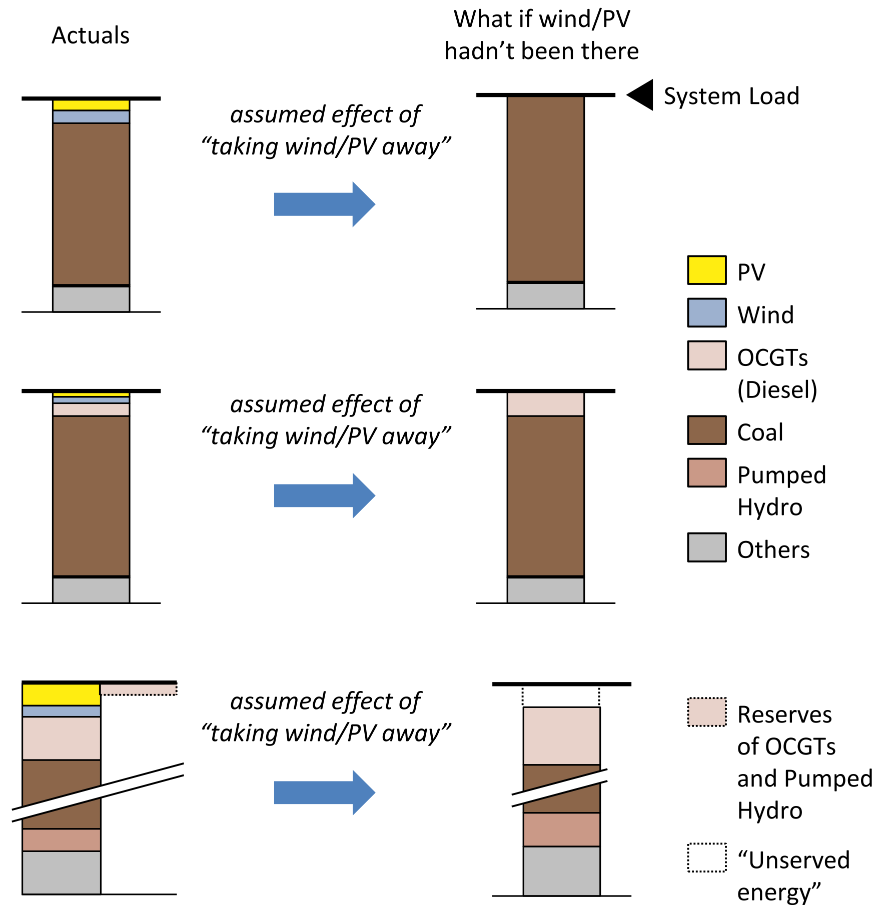
Note: Design as per Fraunhofer ISE

Sources: Eskom; CSIR Energy Centre analysis

CSIR-defined methodology:
In any hour, wind/PV can have one of three effects on the existing fleet

	Applicable if …
A — Saving coal fuel	… output from OCGTs = 0 MWh
B — Saving diesel fuel	… output from OCGTs > 0 MWh
C — Avoiding "unserved energy"	… output from OCGTs > 0 MWh <u>and</u> (reserves of OCGTs and Pumped Hydro) < (wind and PV)

Snapshot of supply structure in a particular hour

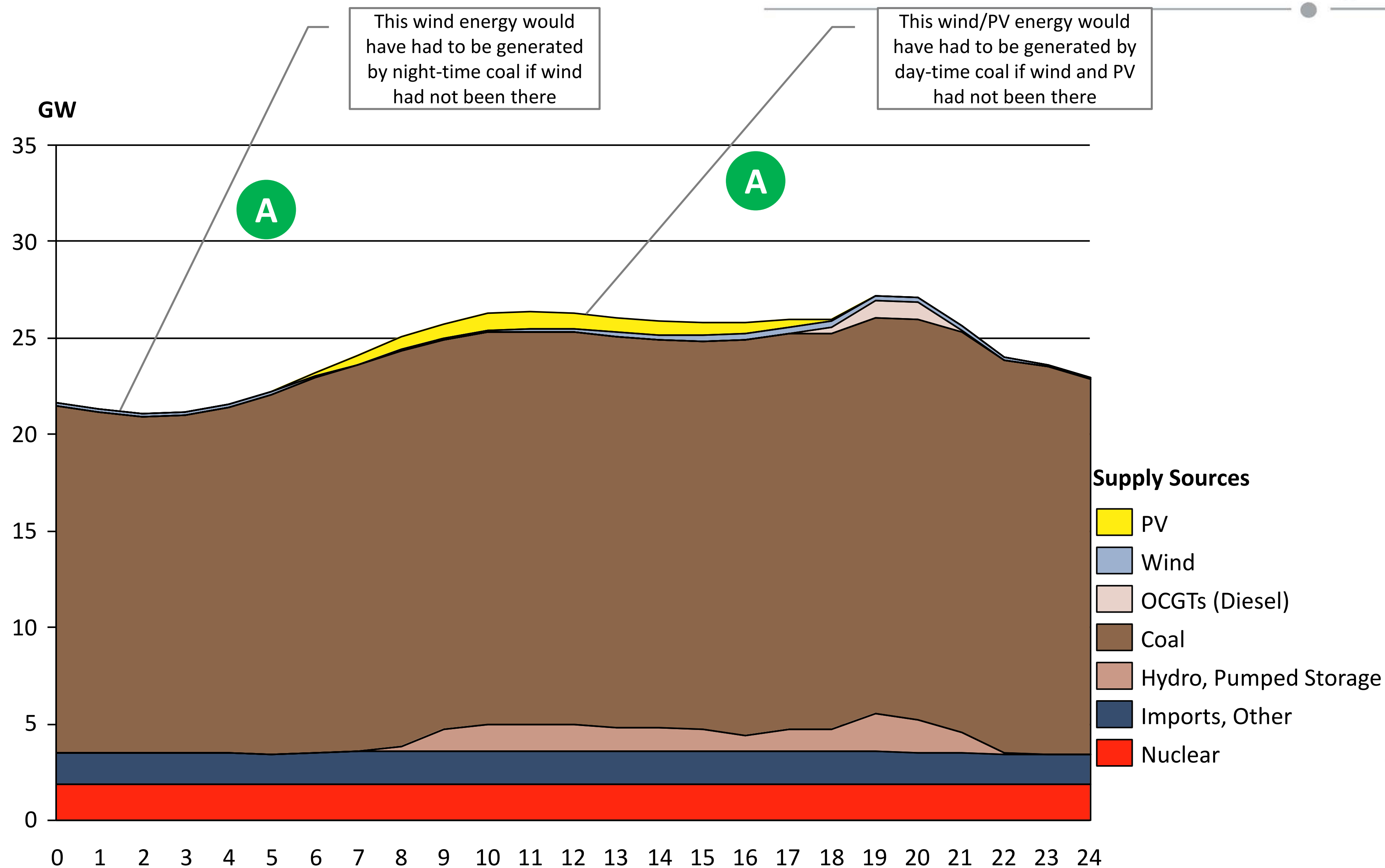


Note: Only applicable in the short run to assess effect of wind/PV on the <u>existing</u> fleet. Not applicable to assess additional value of renewables in new-build scenarios

Sources: CSIR Energy Centre analysis

On an unconstrained day, wind and PV replace mainly coal fuel

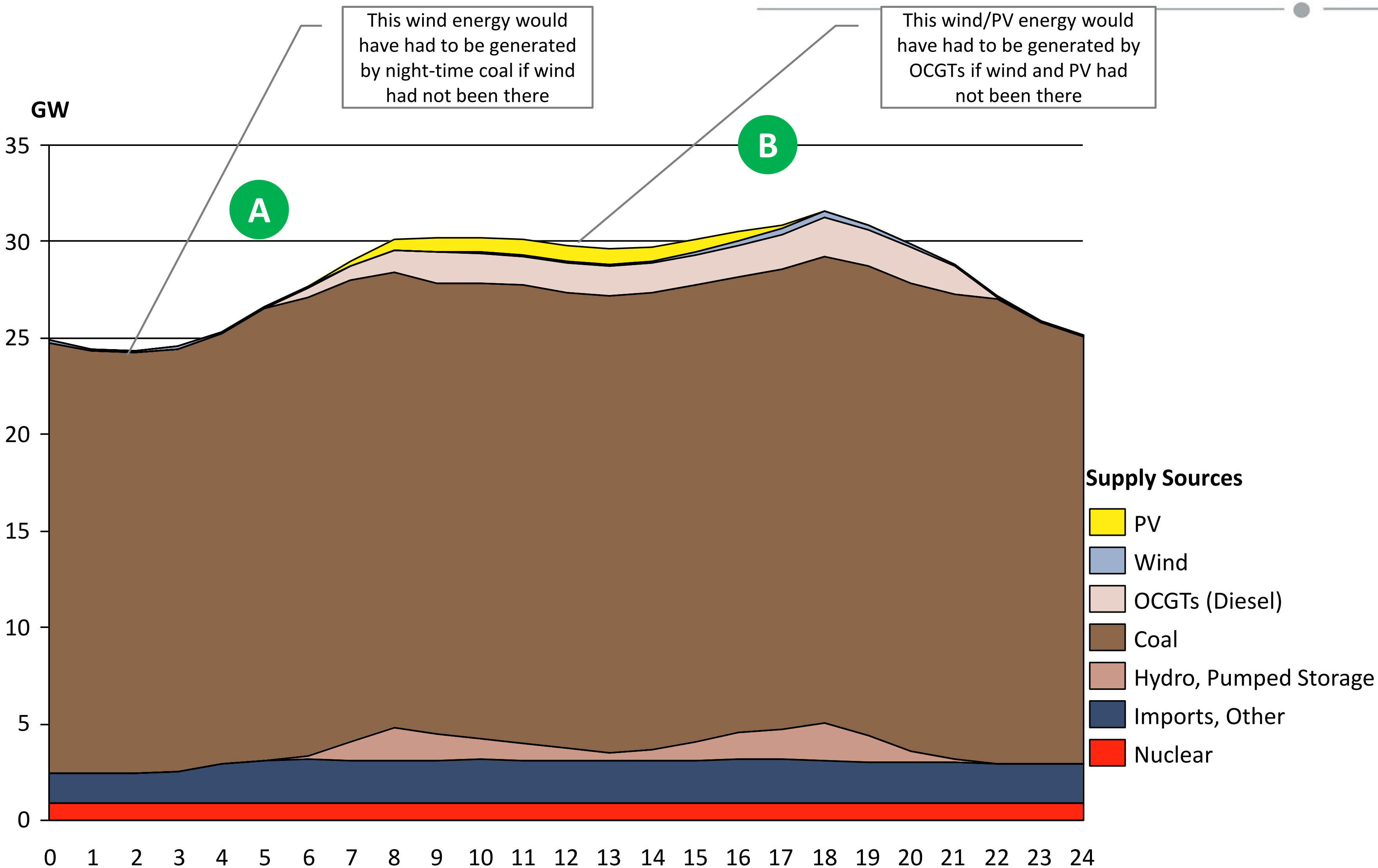
Actual South African supply structure for a summer day, 2 January 2015 (Friday)



Sources: Eskom; CSIR Energy Centre analysis

On a constrained day, both wind and PV replace mainly diesel fuel

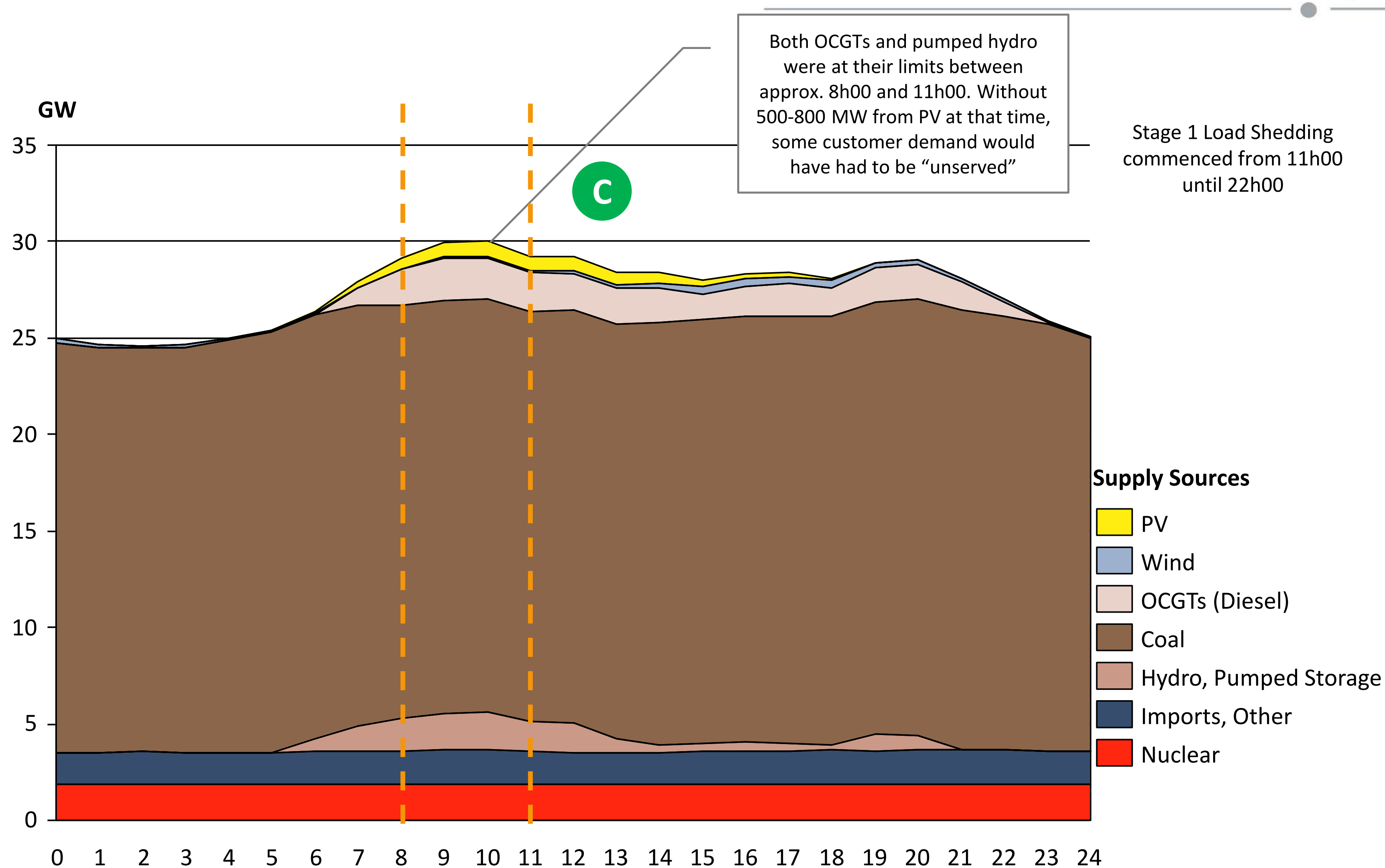
Actual South African supply structure for an autumn day, 9 April 2015 (Thursday)



Sources: Eskom; CSIR Energy Centre analysis

On 9 January, PV even prevented unserved energy between 8h-11h00

Actual South African supply structure for a summer day, the 9 January 2015 (Friday)



Sources: Eskom; CSIR Energy Centre analysis

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A future South African power system & economy with high shares of renewables

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Extreme scenario:
Prerequisites for a 40% renewables share by 2030

40% of the South African electricity demand by 2030 (450 TWh/yr as per IRP2010) from renewables

- 25-30 GW of wind turbines (2-3 GW/yr)
- 25-30 GW of solar PV (2-3 GW/yr)
- 4-5 GW of biomass, biogas and CSP (300 MW/yr)

Prerequisites for a cost-efficient integration

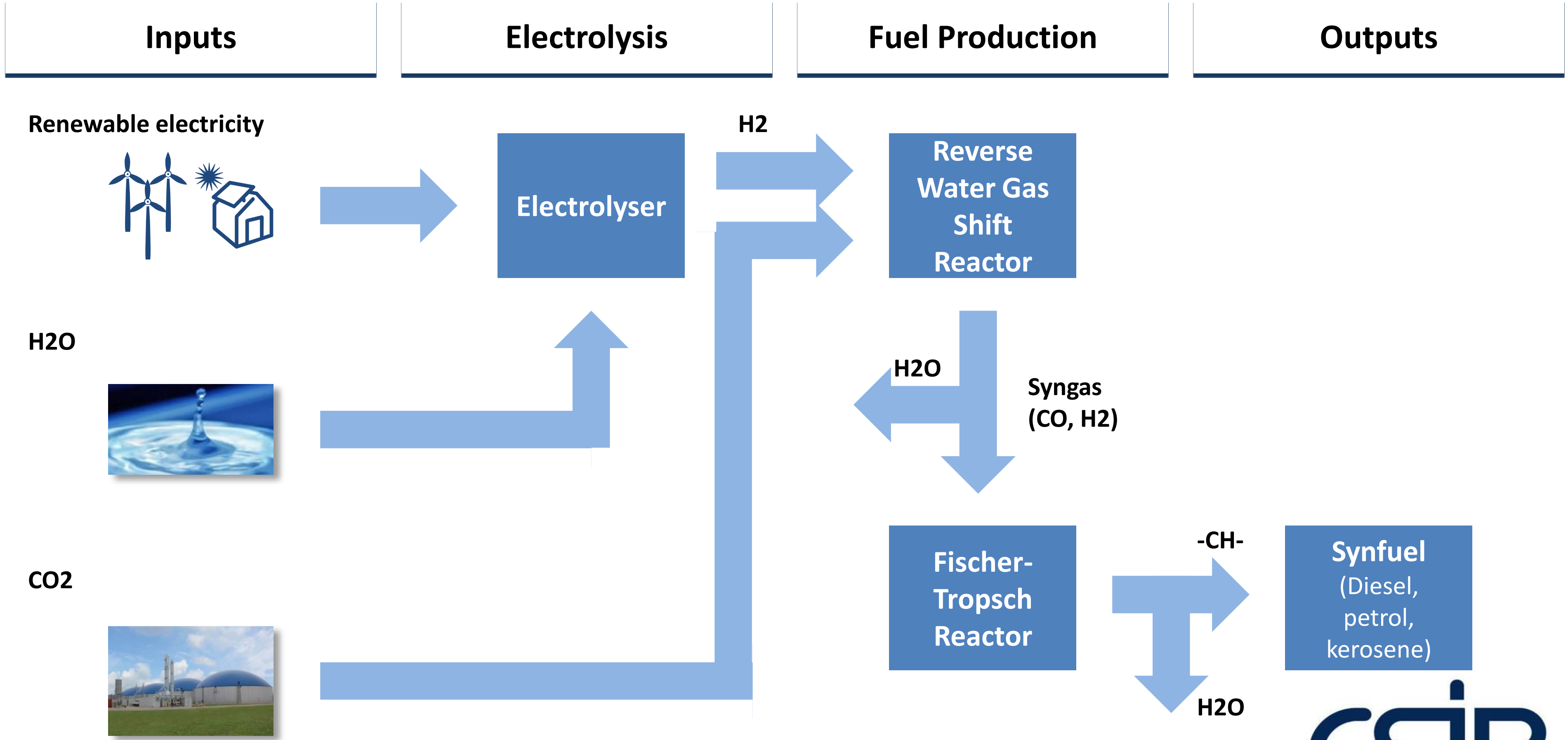
- Possibility to connect medium-sized wind and solar PV farms (approx. 1-30 MW per project) to the existing grid
- Possibility to connect embedded generators behind customers' meters to the grid
- Creation of a procurement platform that allows cost-efficient procurement of energy/capacity, as well as reserves from a wide range of distributed sources through aggregators/Virtual Power Plants

Prerequisites for successful technical integration

- Widespread spatial distribution of wind & PV to reduce short-term volatility of the aggregated profile
- Investments into grid infrastructure to unlock potential for wind integration in windy areas with no grid
- Flexibilisation of the existing conventional fleet to cater for increasing fluctuations of the residual load
- 4-5 GW of flexible power generators from the biomass/biogas/CSP fleet in addition to the flexible gas fleet that is already planned in the IRP 2010 are sufficient to provide the required flexibility

Further cost reduction of electricity storage in form of batteries will be an added bonus to provide flexibility, is however <u>not a necessary pre-condition</u> for achieving a 40% renewables share by 2030

Producing carbon-neutral synthetic fuels from cheap renewable power could be a business case for South Africa …



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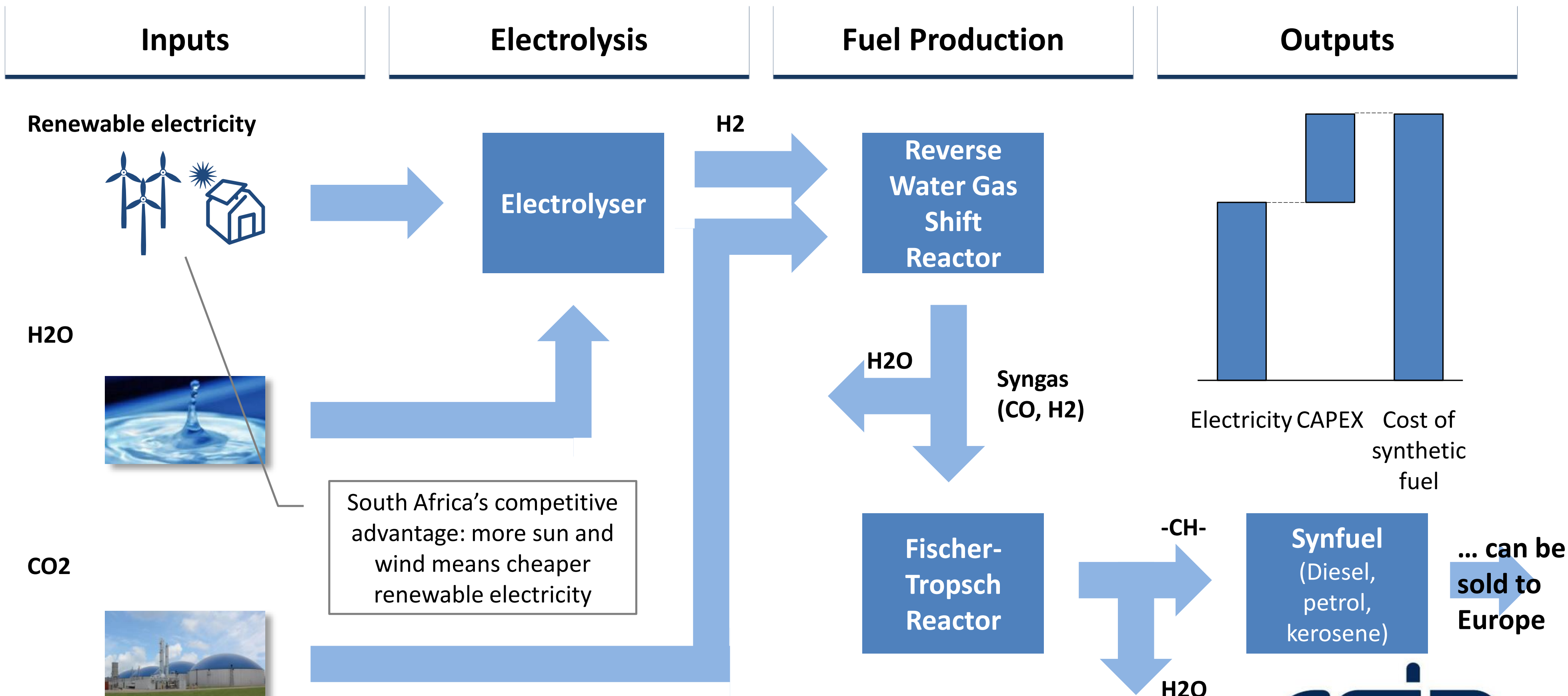
Sources: CSIR Energy Centre analysis

… because the main cost driver is cost of renewable electricity input

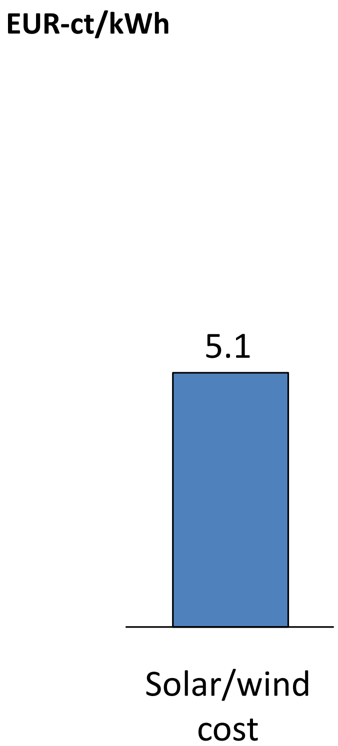


The PtL concept will be piloted and demonstrated on the CSIR campus in Pretoria, with the goal of commercialisation

Sources: CSIR Energy Centre analysis

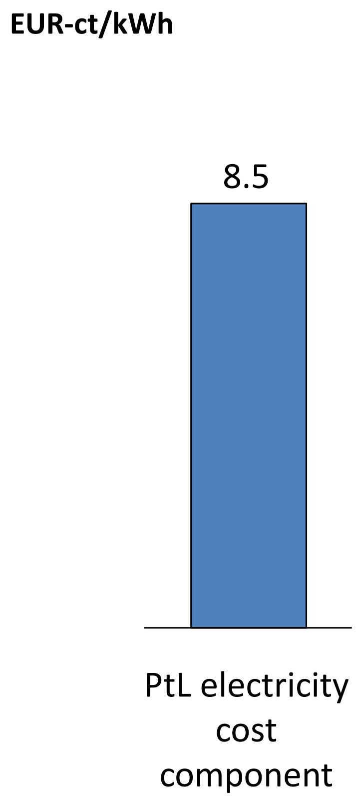
Already at today's renewable electricity cost in South Africa, PtL is not far from competitiveness with production cost of biofuels

Actual average wind/solar PV tariff in South Africa <u>today</u>



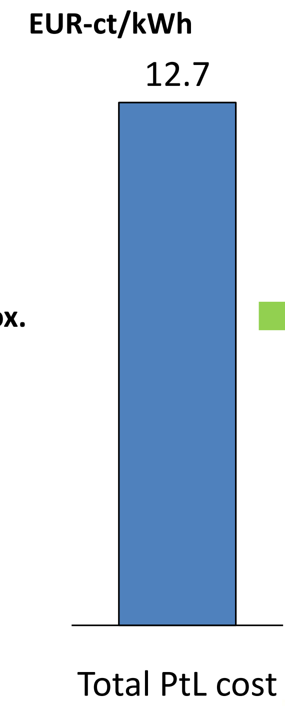
./. **60% efficiency (realistically)**

Pure electricity cost of PtL plant fed with South African wind/PV power



→ Electricity approx. 2/3 of total cost

Total PtL production cost



Approx. 1 EUR/litre

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Sources: CSIR Energy Centre analysis

New principle approach for long-term capacity expansion planning?

Solar PV and wind are cost competitive to alternative new-build options today

- Solar PV and wind are the cheapest bulk electricity sources per kWh in South Africa already today
- Costs will further decrease, especially on the side of solar PV

The technical potential for solar PV and wind can be considered to be "unlimited" in most countries

At the same time, solar PV and wind are so called variable renewables

- Both technologies are however dispatched by the weather and not by the owner or system operator
- They are "must run" technologies in any market setting, because marginal costs are zero

That has implications for long-term energy planning

- As a rule of thumb, solar PV and wind should be deployed up to the maximum technically needed level
- The mix of solar PV and wind should be optimised to reduce the "behaviour" of the residual load
- Widespread spatial aggregation of solar PV and wind will reduce fluctuations of the combined profile
- The residual load then needs to be supplied cost optimally by flexible dispatchable power generators (CSP, hydro, natural gas, biogas, biomass, pumped hydro, other storage, etc.)
- Additionally, the flexibilisation of the dispatchable part of the load will help to balance supply and demand instantaneously
- Introduction of Power-to-Liquid is a very flexible demand-side intervention and a "pressure valve" for power systems

Thank you!

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