Opportunities for Renewables in South Africa

Public lecture on Climate Change, DEA & UJ

Crescent Mushwana, CSIR Energy Centre

Johannesburg, 14 September 2015

Cell: +27 82 310 2142
Email: cmushwana@csir.co.za

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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.

Education

- M Eng. (Electrical), 2012, University of the Witwatersrand

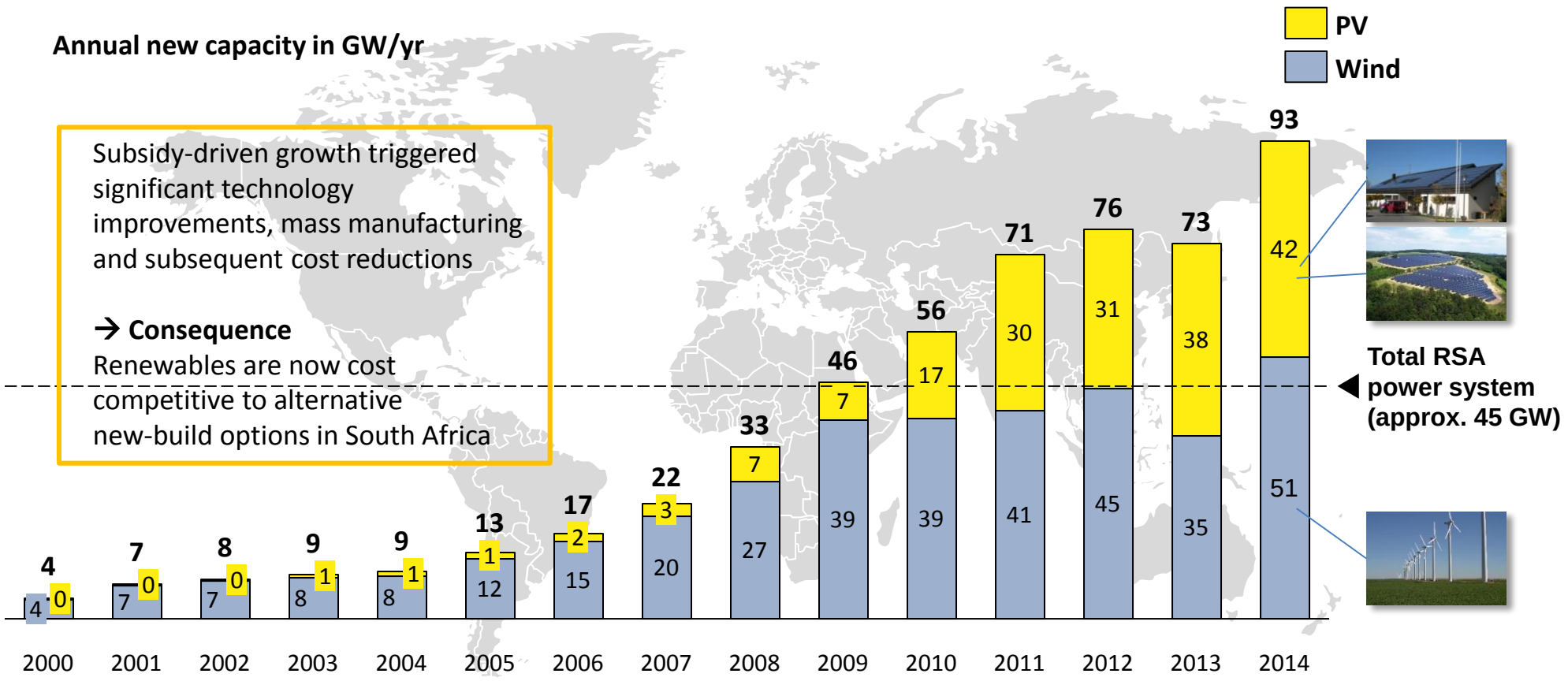
- BSc Hons (Applied Science), 2004, University of Pretoria

- B Tech (Elec. Eng.), 1999, University of Johannesburg

The Context

In 2014, 93 GW of wind and PV were newly installed globally

Annual new capacity in GW/yr

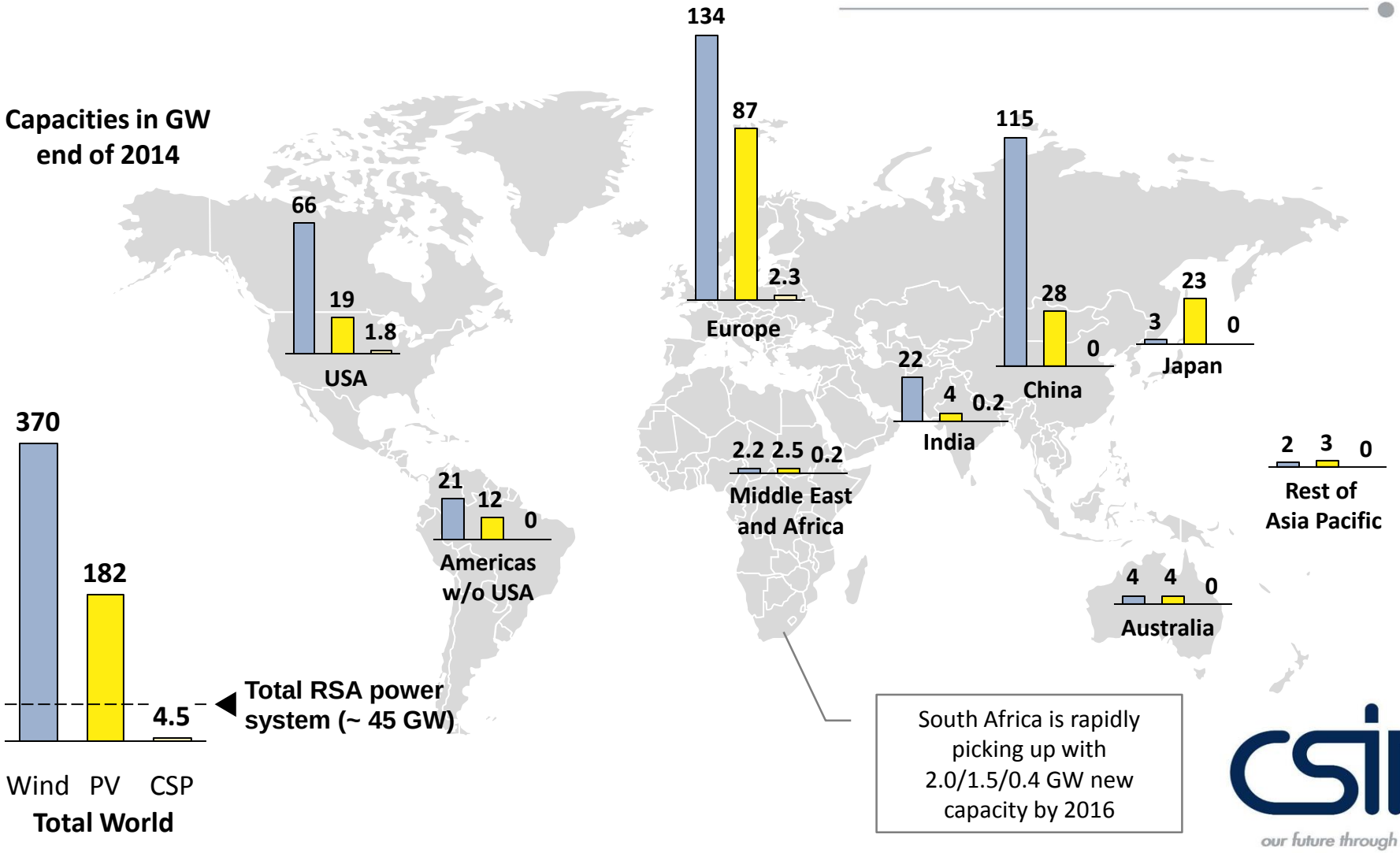


This is all very new: Almost 90% of the globally existing PV capacity was installed during the last five years alone!

Sources: International Energy Outlook of the EIA; GWEC; EPIA; CSIR analysis

Renewables until today mainly driven by US, Europe and China

Globally installed capacities for three major renewables wind, PV and CSP end of 2014



Sources: GWEC; EPIA; CSPToday; CSIR analysis

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

G7 announcement on 8 June 2015

theguardian

Winner of the Pulitzer prize 2014

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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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- 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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The Opportunity

Agenda

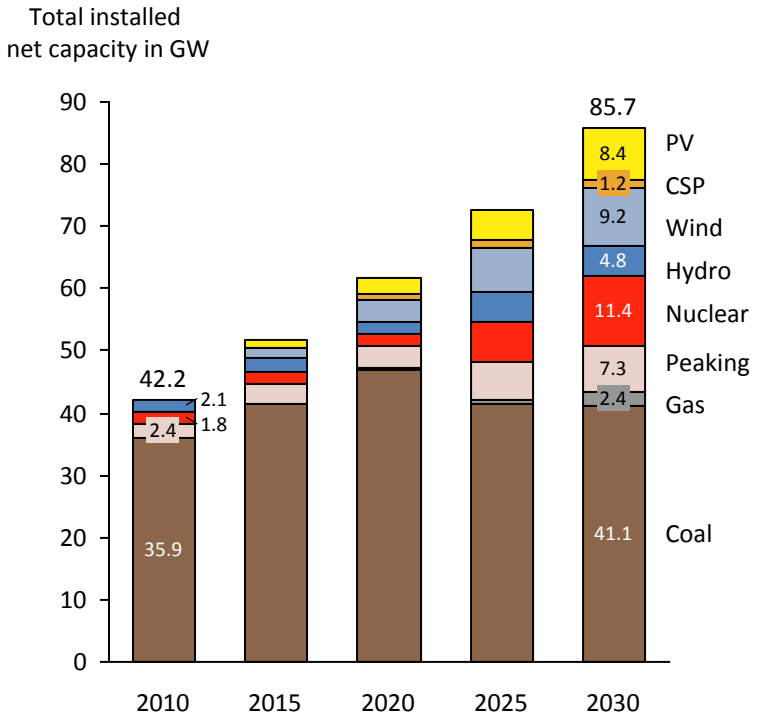
IRP Assumptions and Actuals

Cost-competitiveness of Renewables

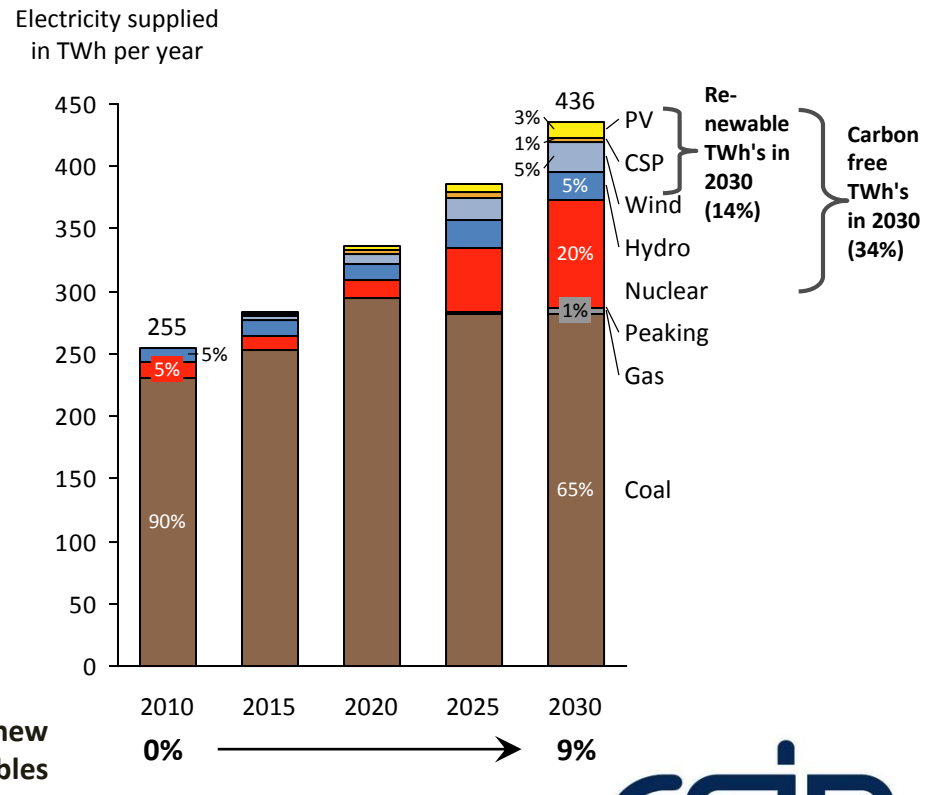
The Baseload Argument

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

Installed capacity



Energy mix



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

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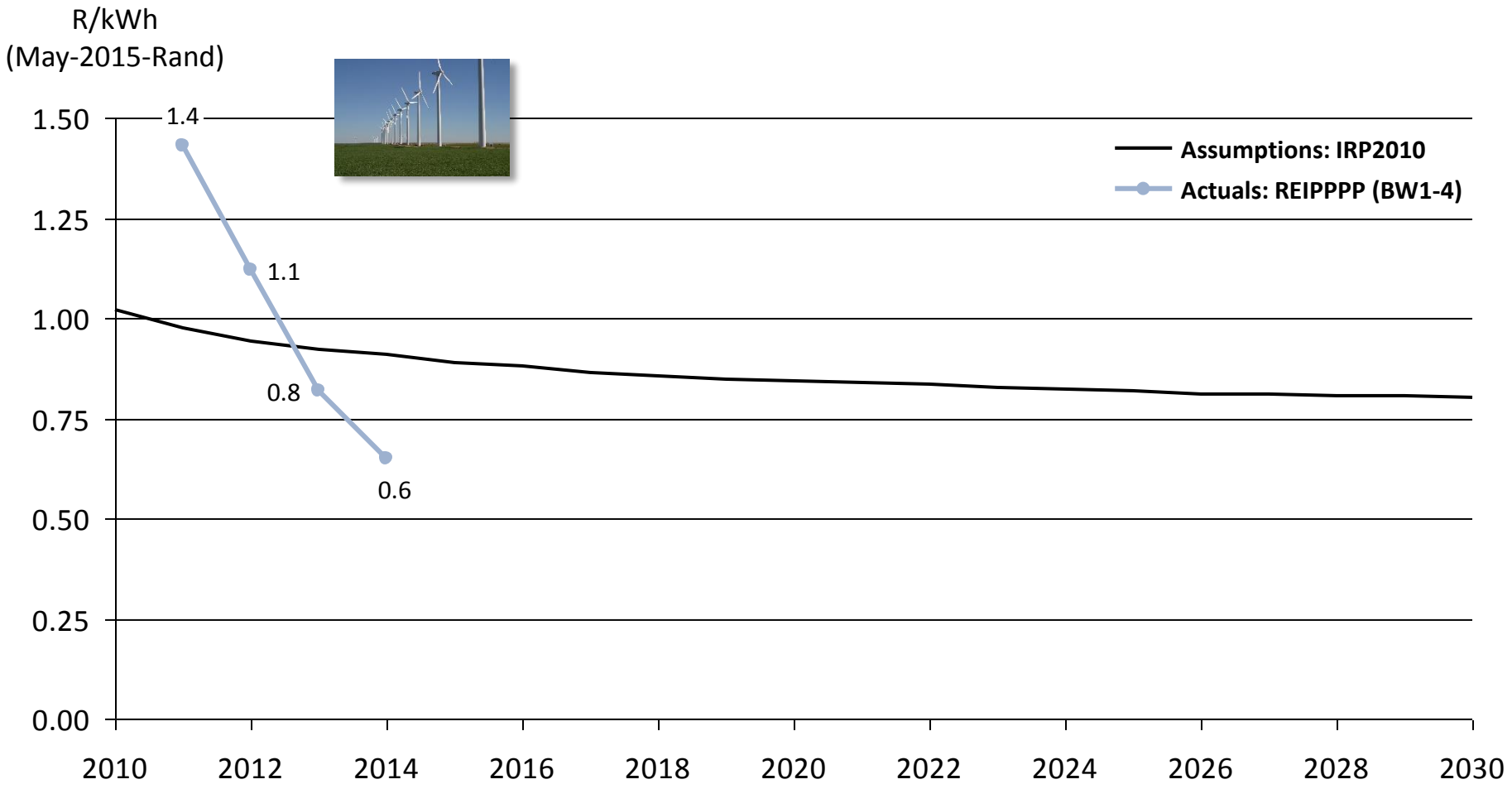
Note: hydro includes imports from Cahora Bassa

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

Actual PV tariffs quickly approached IRP cost assumptions in first four bid windows and are now below the lowest cost assumptions of IRP

Assumptions: CPI used for normalisation to May-2015-Rand; LCOE calculated for IRP with 8% discount rate (real), 25 yrs lifetime, cost and load factor assumptions as per relevant IRP document; "IRP Tariff" then calculated assuming 80% of total project costs to be EPC costs, i.e. divide the LCOE by 0.8 to derive at the "IRP Tariff"
Sources: IRP 2010; IRP Update; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR Energy Centre analysis

Actual wind tariffs in bid window three were already at the level that was assumed for 2030 in the IRP, bid window four is significantly below



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Agenda

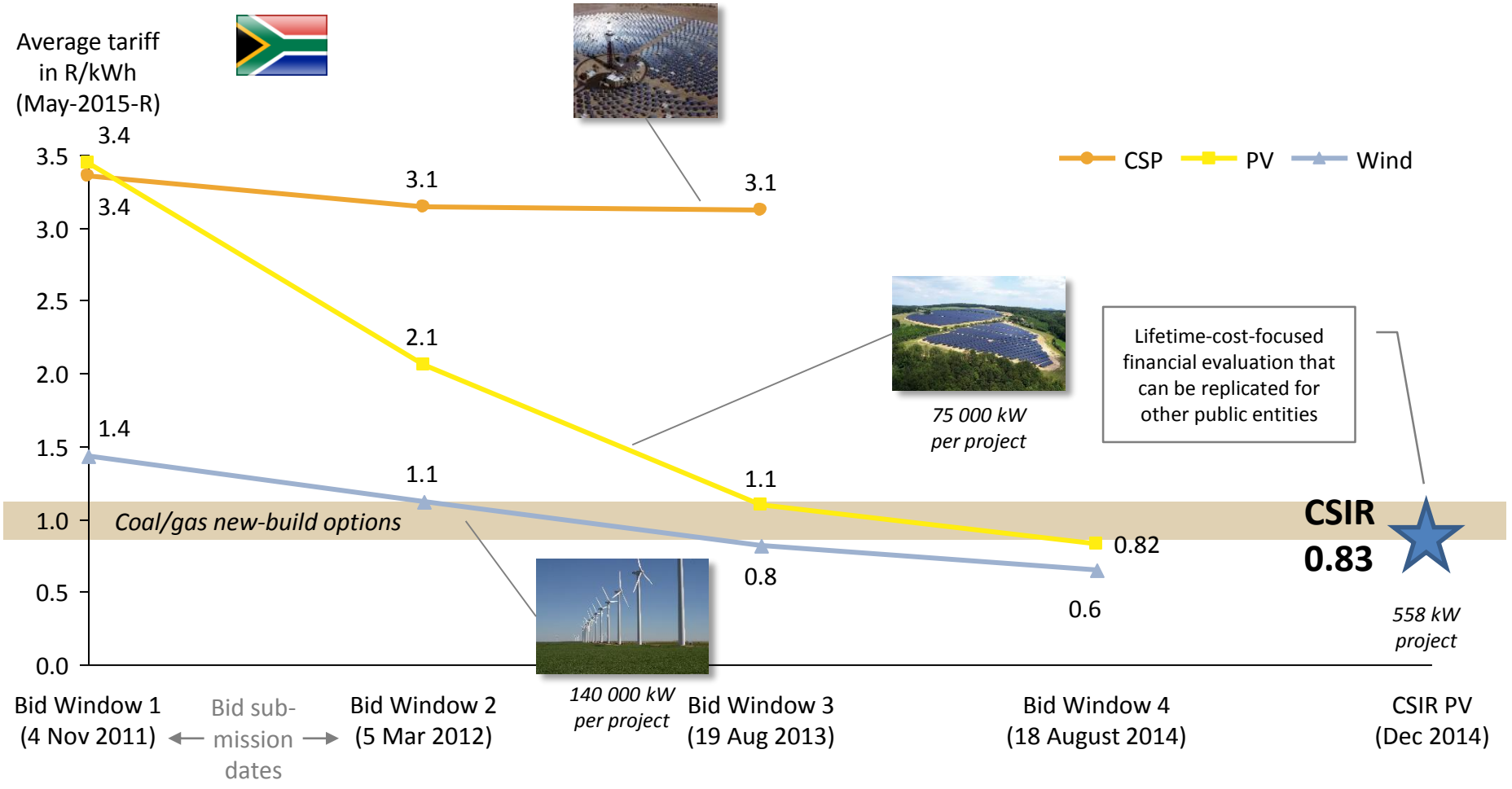
IRP Assumptions and Actuals

Cost-competitiveness of Renewables

The Baseload Argument

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

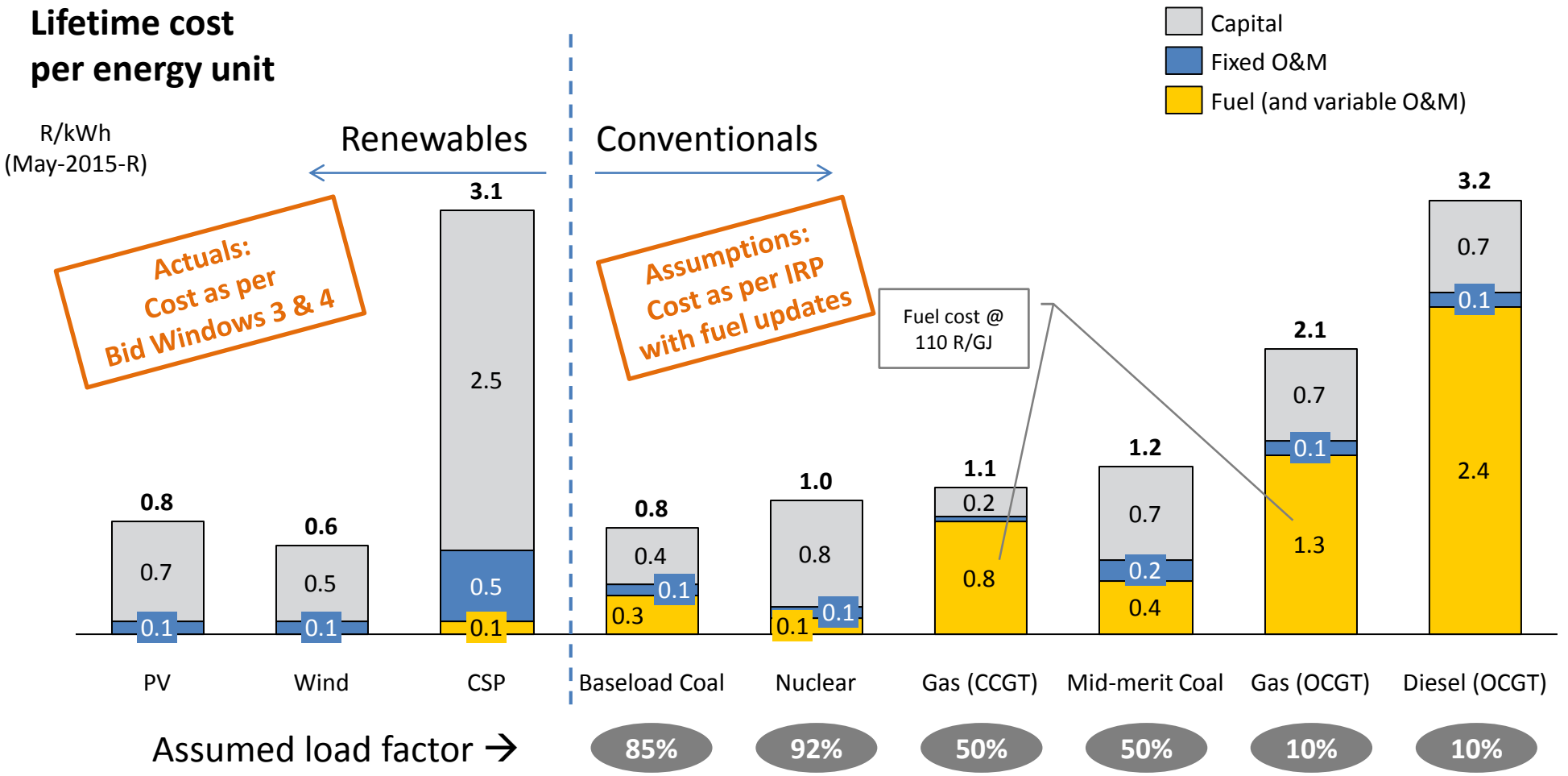
Four bid windows' results of Department of Energy's IPP Procurement Programme and CSIR's first own PV



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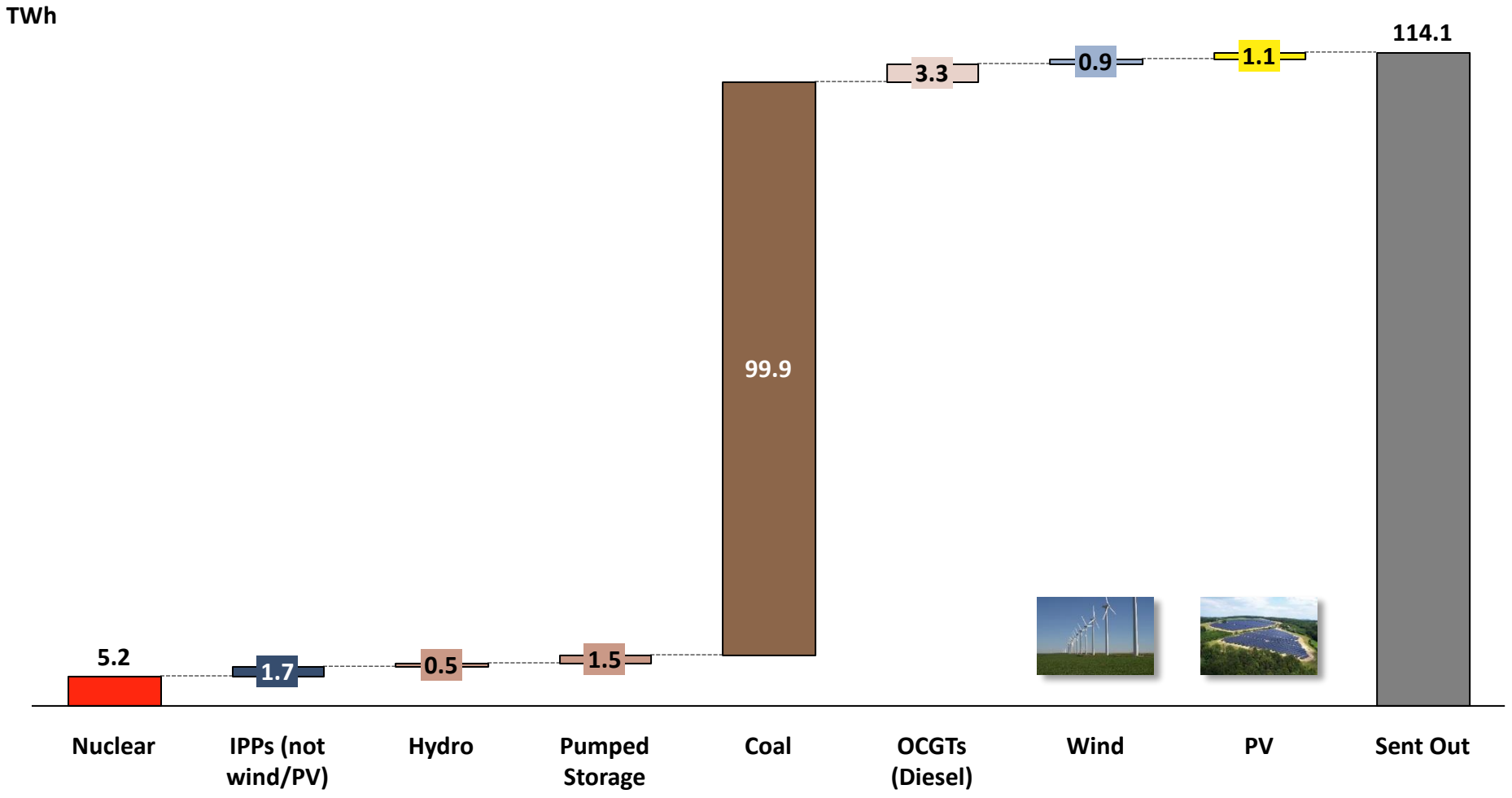
Wind and PV stand for 2% of the electricity sent out from Jan-Jun 2015

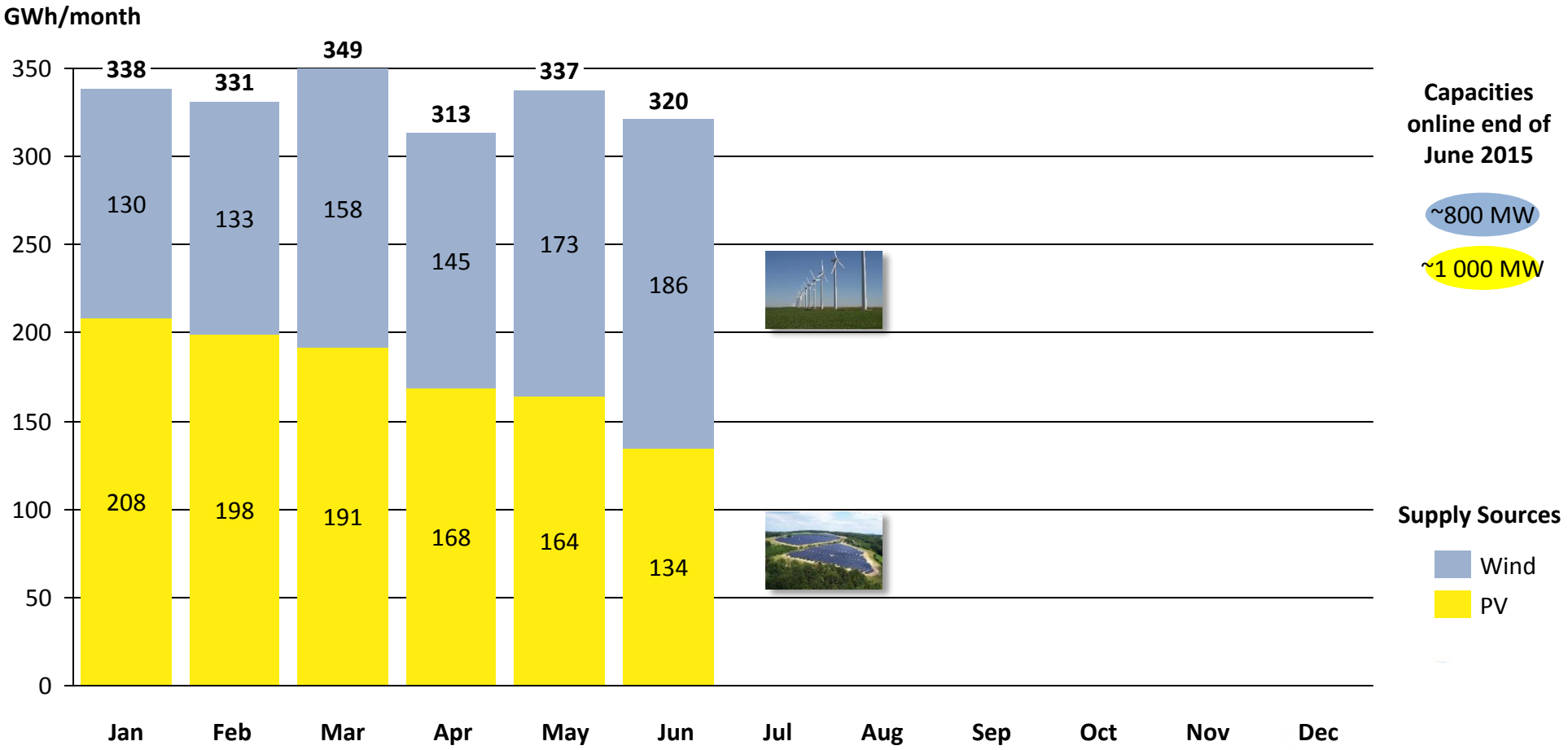
Actual energy captured in wholesale market (i.e. without self-consumed energy of embedded plants)



Sources: Eskom; CSIR Energy Centre analysis

The combined wind/PV fleet supplied 310-350 GWh per month in 2015

Actual monthly production from large-scale PV and wind plants under the REIPPPP in RSA from Jan-Jun 2015

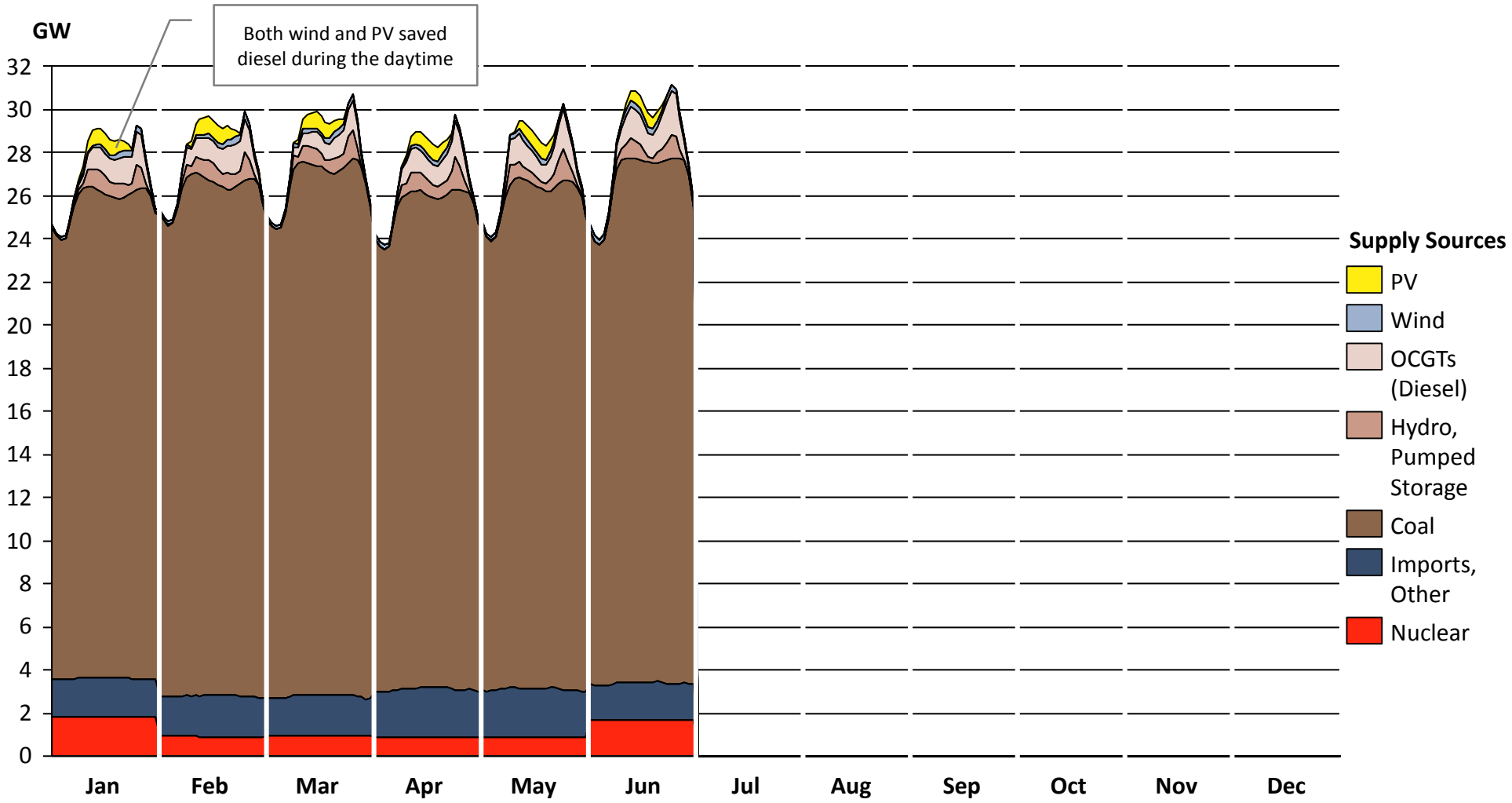


Note: Wind generation excludes Eskom's 100 MW Sere wind farm which came online in 2014 and was fully commissioned by 31 March 2015

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

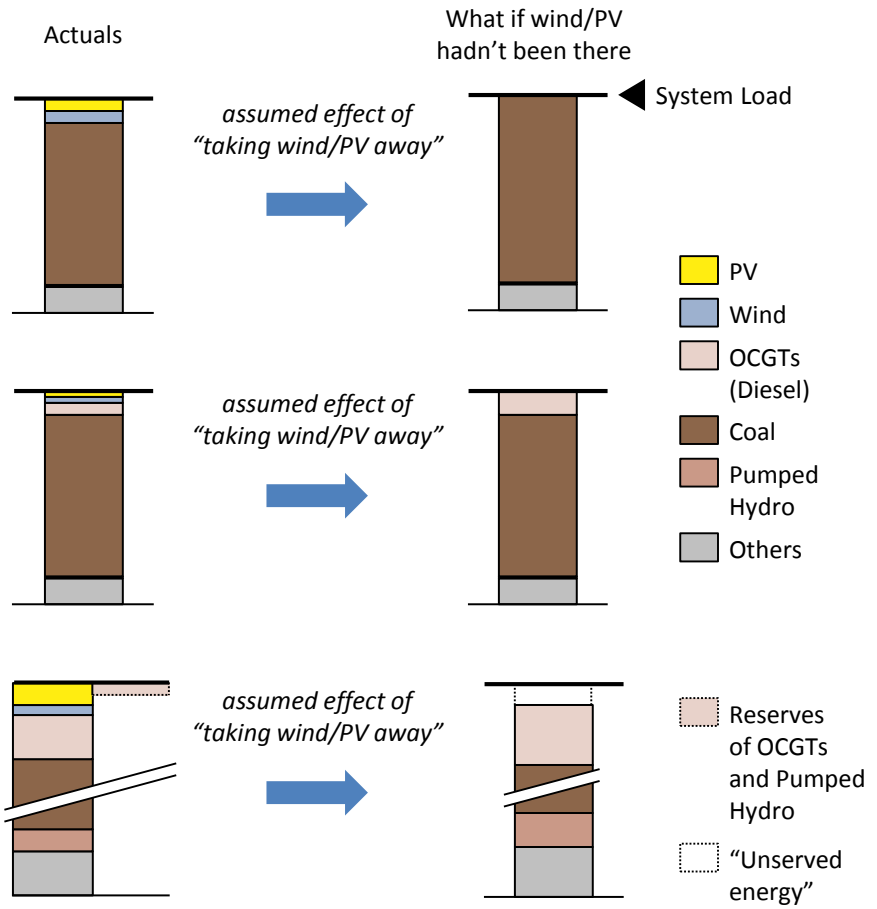


Note: Design as per Fraunhofer ISE

Sources: Eskom; CSIR Energy Centre analysis

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

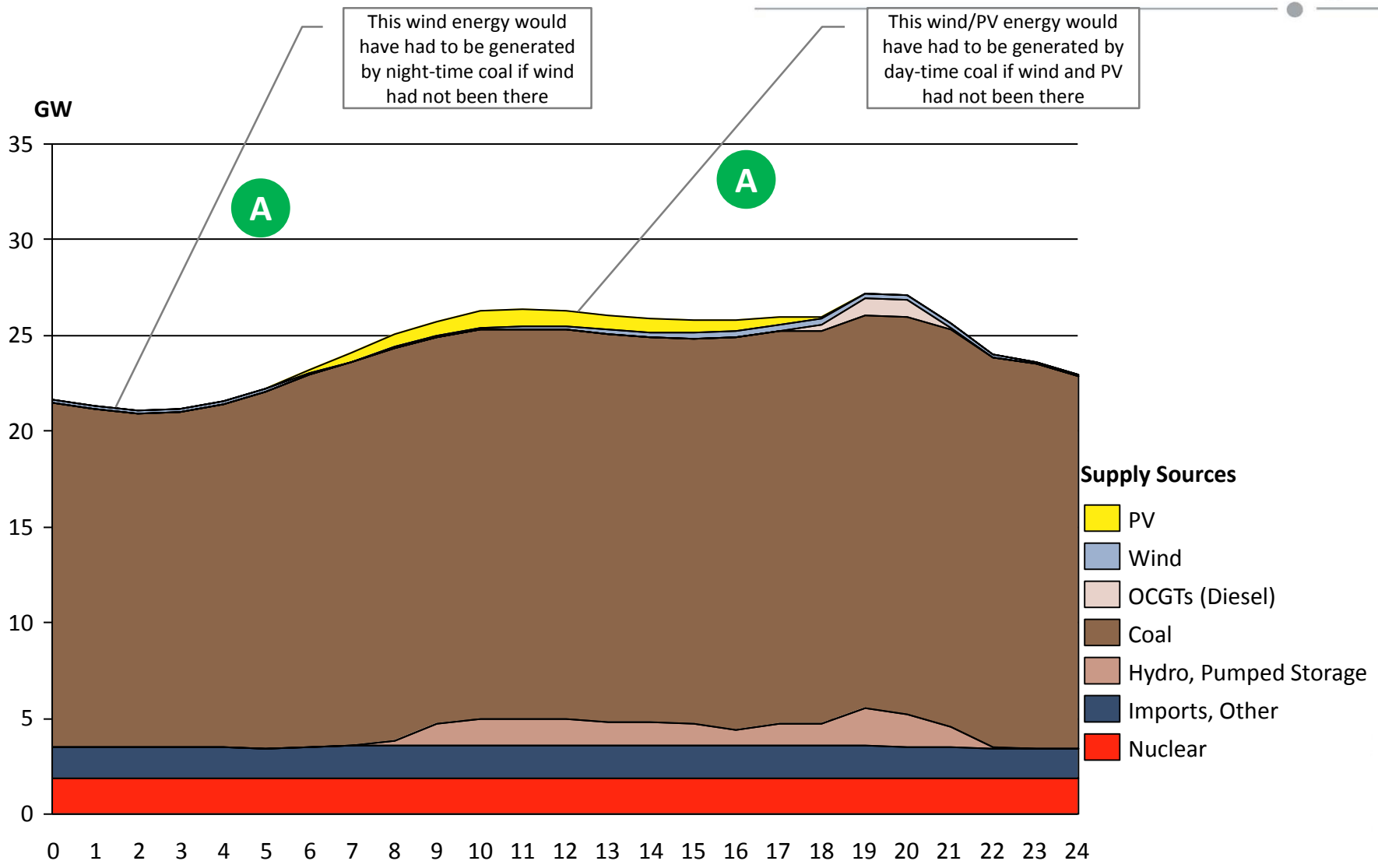
	Applicable if …	Snapshot of supply structure in a particular hour
A Saving coal fuel	… output from OCGTs = 0 MWh	
B Saving diesel fuel	… output from OCGTs > 0 MWh	
C Avoiding "unserved energy"	… output from OCGTs > 0 MWh and (reserves of OCGTs and Pumped Hydro) < (wind and PV)	



Note: Only applicable in the short run to assess effect of wind/PV on the existing 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

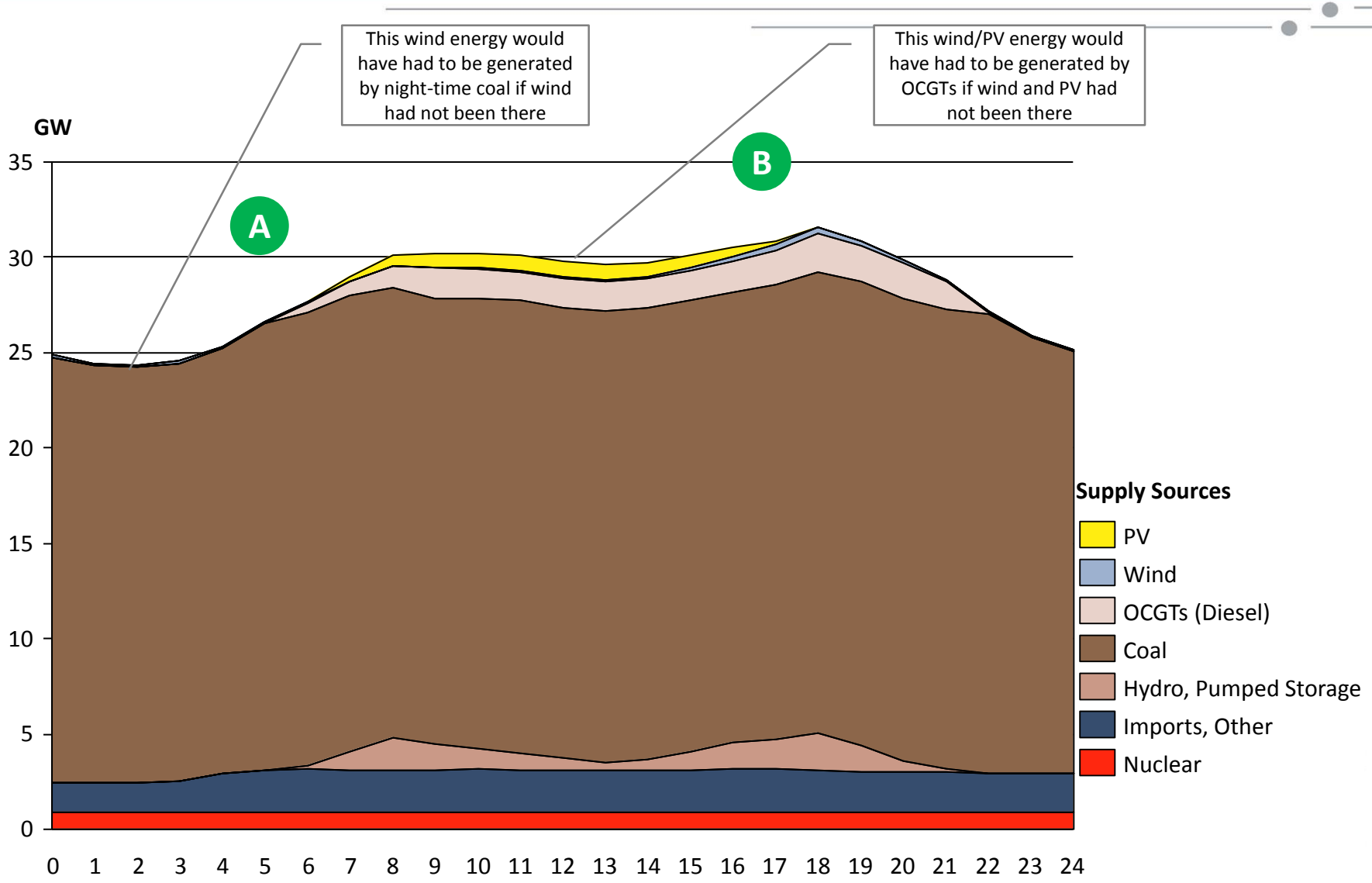
Actual South African supply structure for a summer day, 2 January 2015 (Friday)



Sources: Eskom; CSIR Energy Centre analysis

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

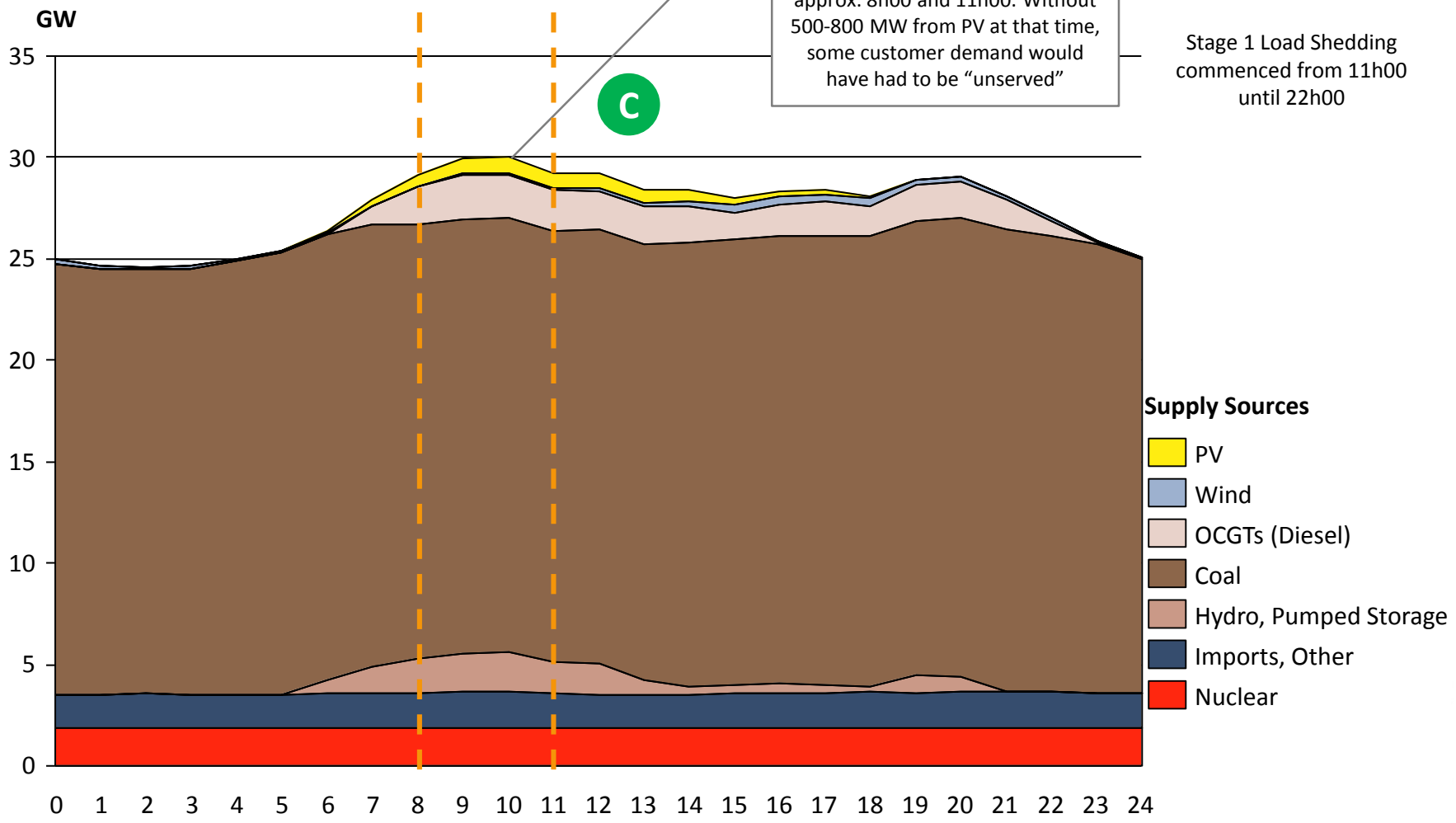
Actual South African supply structure for an autumn day, 9 April 2015 (Thursday)



Sources: Eskom; CSIR Energy Centre analysis

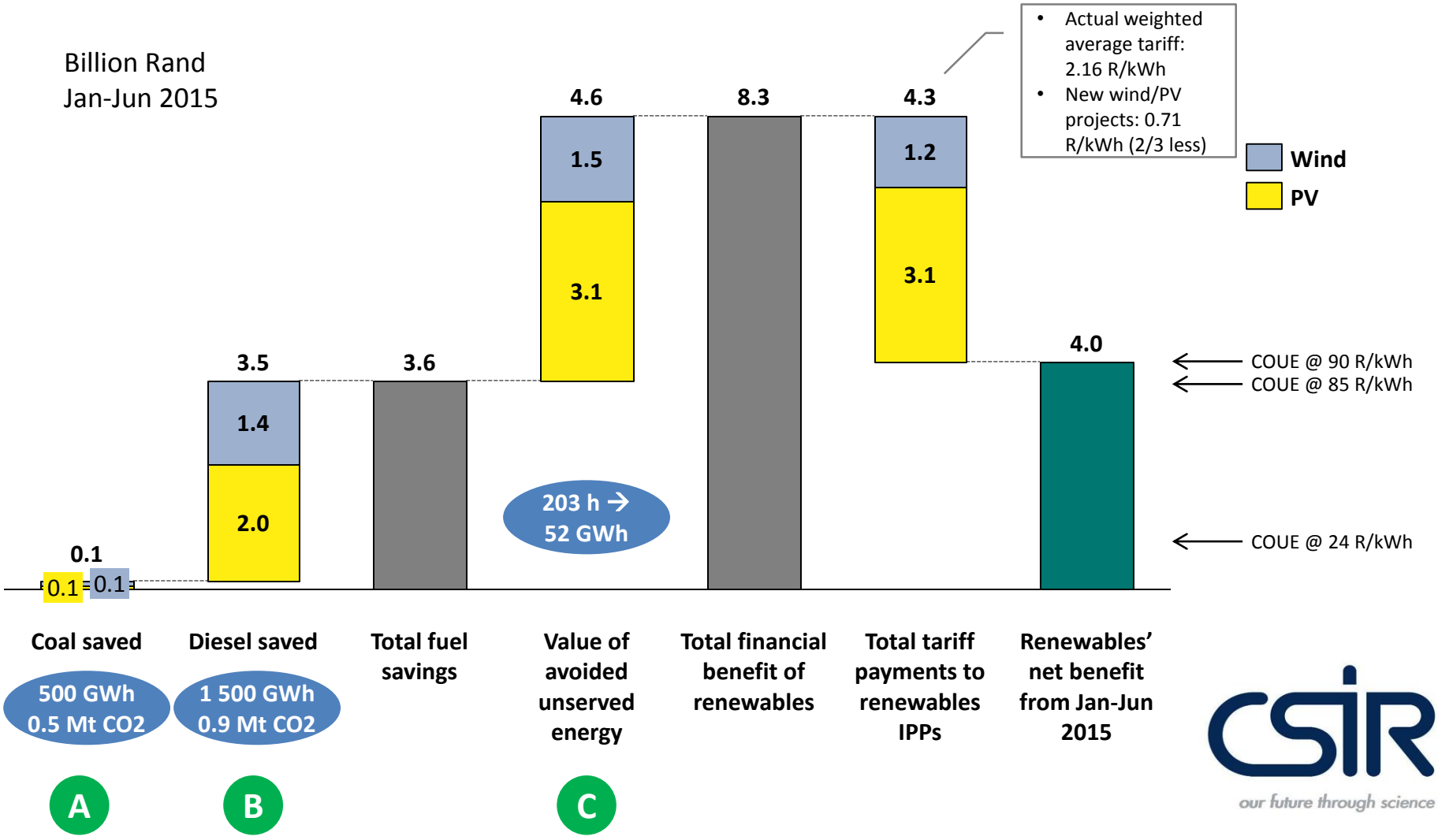
On 9 January, PV even prevented unserved energy between 8h-11h00

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



Sources: Eskom; CSIR Energy Centre analysis

In summary (Jan-Jun 2015):
Renewables generated a net benefit for the economy of up to R4.0 bn



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Sources: CSIR Energy Centre analysis

In addition:
On 15 days wind/PV avoided load shedding entirely or a higher stage

There were 15 days where avoided unserved energy exceeded 1 000 MWh, of which

- 4 days where wind and PV avoided load shedding entirely
- 5 days where wind and PV delayed the initiation of Stage 1 load shedding for a number of hours
- 4 days where wind and PV avoided the need to move from Stage 1 to Stage 2 load shedding for a number of hours
- 2 days where wind and PV avoided the need to move from Stage 2 to Stage 3 load shedding for a number of hours

Plus: environmental benefit CO2 avoidance

- Wind and solar PV in H1 2015 avoided 1.4 million tonnes of CO_2 emissions

Notes: If on a day avoided unserved energy was greater 1 000 MWh and on that day the avoided unserved energy occurred during at least four consecutive hours, or avoided unserved energy was greater than 1 500 MWh, then on that day either stage 1 load shedding was avoided or an additional stage of load shedding was avoided Sources: CSIR Energy Centre analysis

Common perceptions and paradigms

IRP Assumptions and Actuals

Cost-competitiveness of Renewables

The Baseload Argument

Thought experiment: Build a new power system from scratch

Annual demand: **11.1 TWh/yr (4-5% of today's South African demand)**

Base load: **1 GW**

Day load: **1.3 GW in summer**
1.5 GW in winter

What is cheaper to supply that profile?

1) Base and mid-merit coal?
2) A blend of wind and solar PV, mixed with gas to fill the gaps?

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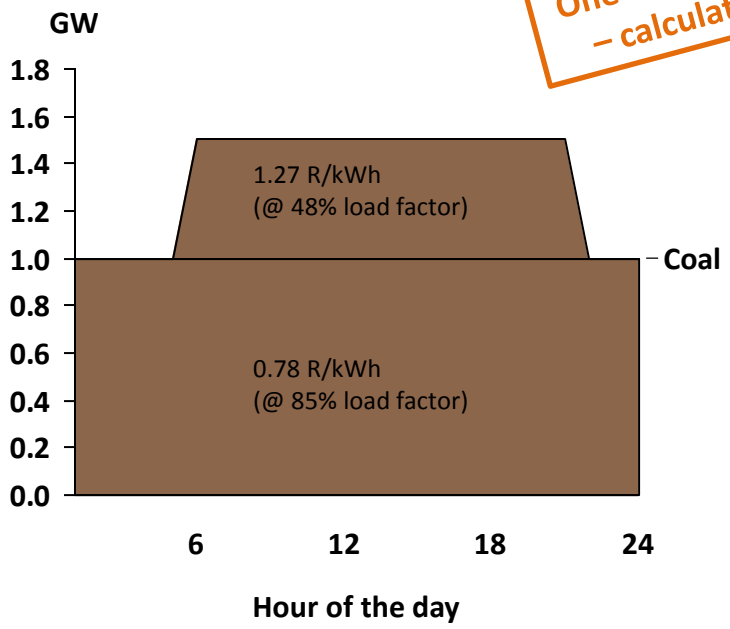
A mix of new baseload-operated coal and new mid-merit coal costs 0.88 R/kWh for the pure cost of power generation

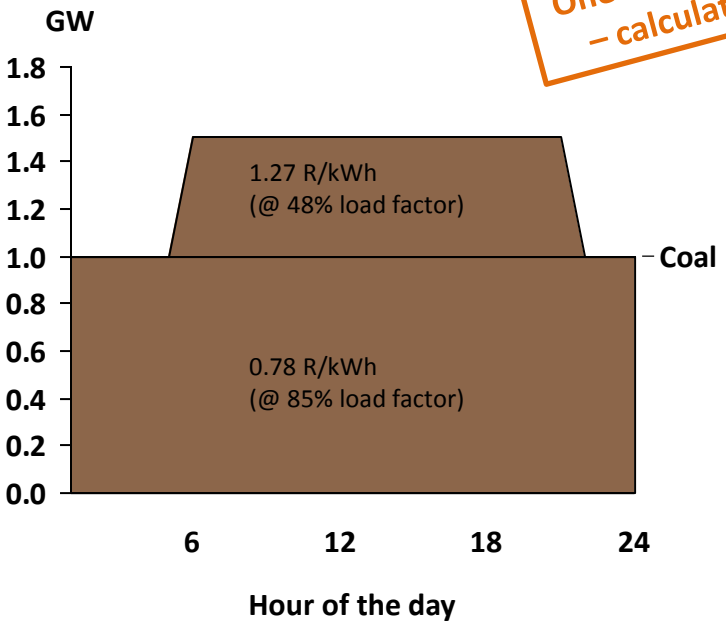
One illustrative winter day in display – calculations done for a full year

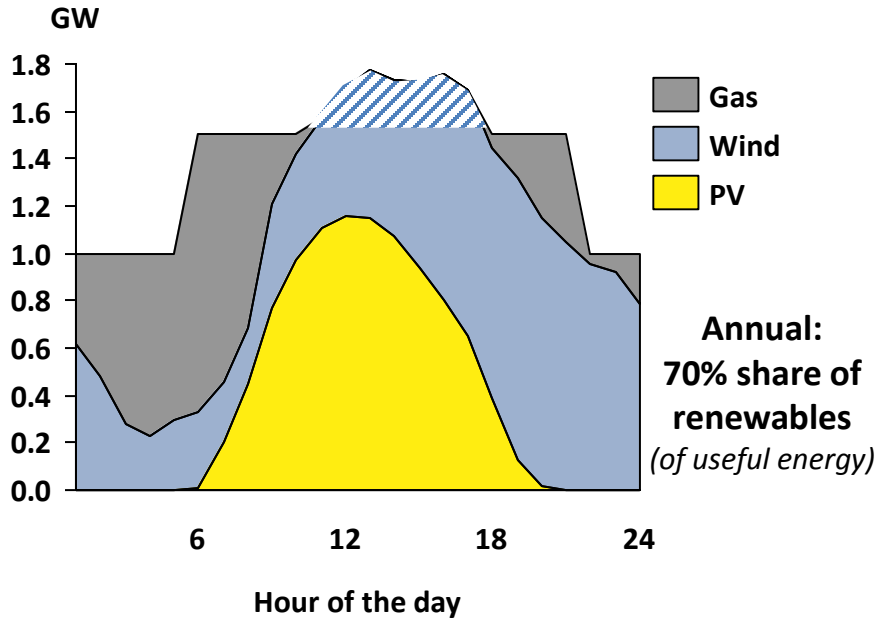


Technology:	Coal base / coal mid-merit
Size:	1.18 / 0.56 GW
Energy:	11.1 TWh/yr
Weighted cost:	**0.88 R/kWh**
CO2:	~0.95 kg/kWh

A fully dispatchable mix of PV, wind and flexible gas can supply the demand similarly in the same reliable manner as the coal mix

One illustrative winter day in display – calculations done for a full year





Annual:
70% share of renewables
(of useful energy)

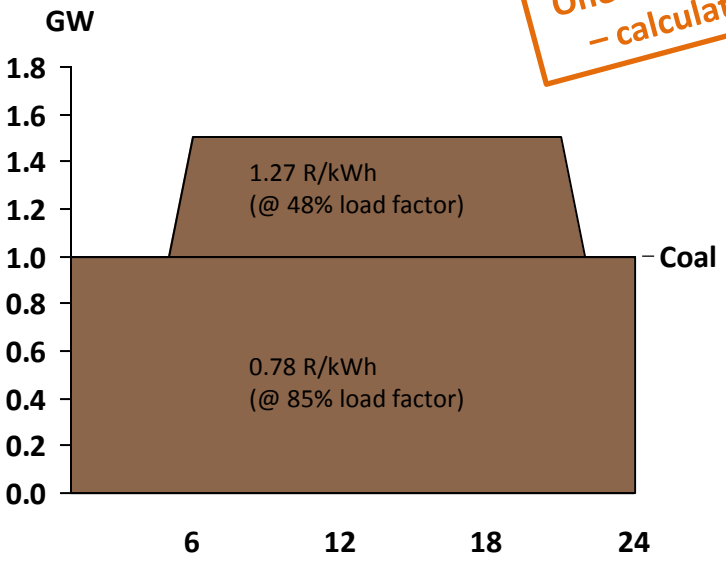
Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

Weighted cost: **0.88 R/kWh**

CO2: ~0.95 kg/kWh

By 2020, a mix of PV, wind and flexible gas (LNG-based) is cheaper than coal, even without any value given to excess wind/PV energy

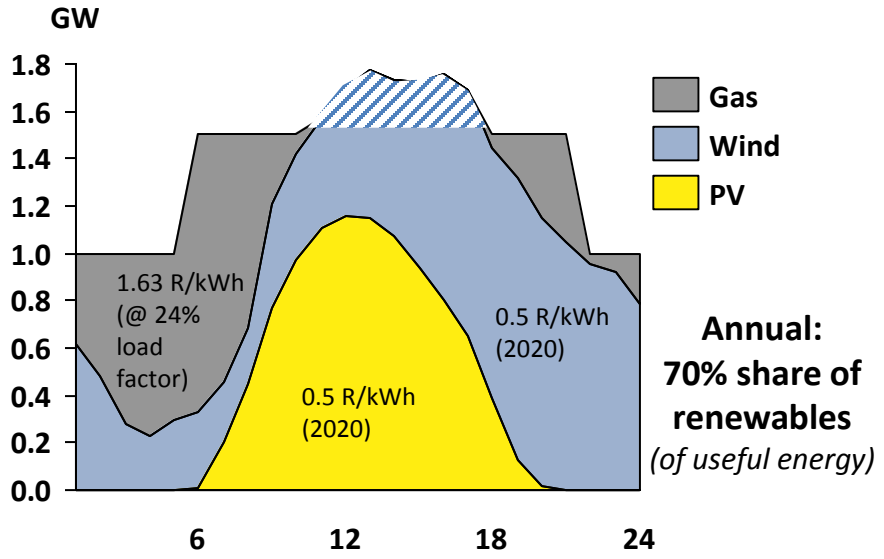
One illustrative winter day in display – calculations done for a full year



Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

Weighted cost: **0.88 R/kWh**

CO2: ~0.95 kg/kWh



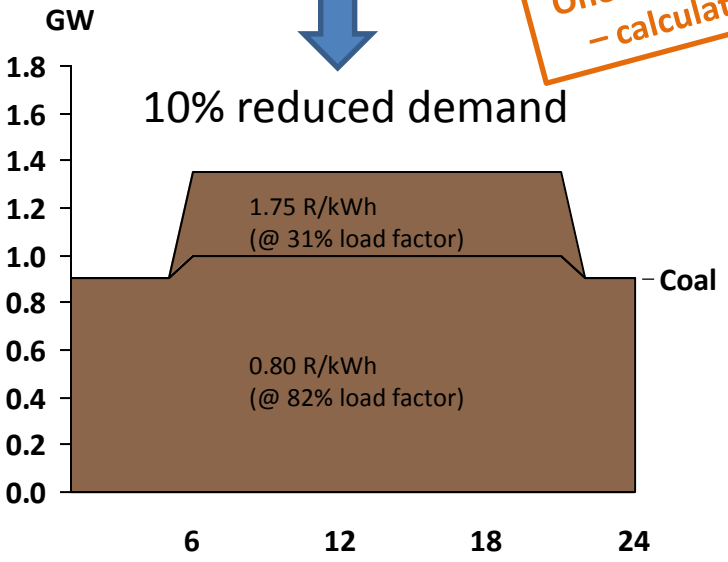
Technology: PV / wind / gas
Size: 1.5 / 2.0 / 1.61 GW
Energy (useful): 11.1 TWh/yr
Energy (total): 3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr

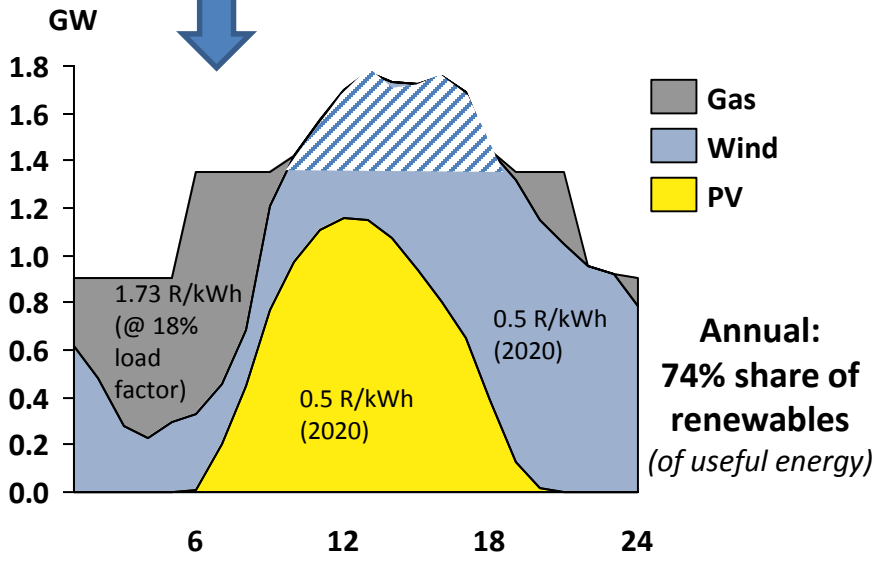
Weighted cost: **0.87 R/kWh**
(per useful energy, i.e. no value given to excess)

CO2: ~0.18 kg/kWh (per useful energy)

In addition, the cost of a PV / wind / gas power plant scale more with reduced demand and thus unit cost per kWh stay more or less constant

One illustrative winter day in display – calculations done for a full year





Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 10.0 TWh/yr

Weighted cost: **0.94 R/kWh** (plus 7%)

CO2: ~0.95 kg/kWh

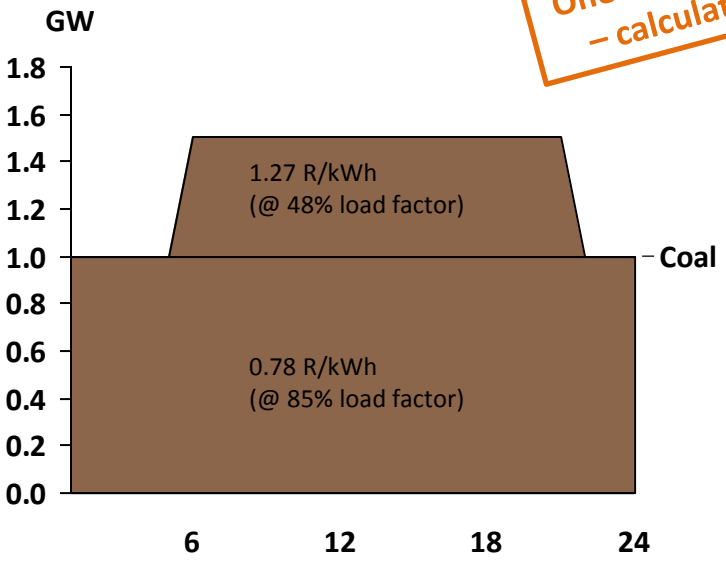
Technology: PV / wind / gas
Size: 1.5 / 2.0 / 1.61 GW
Energy (useful): 10.0 TWh/yr
Energy (total): 3.6 / 5.3 / 2.5 TWh/yr = 11.4 TWh/yr

Weighted cost: **0.87 R/kWh** (constant)
(per useful energy, i.e. no value given to excess)

CO2: ~0.16 kg/kWh (per useful energy)

In reality, flexible, dispatchable loads and/or storage would utilise the excess energy – if value is assigned to it, cost of useful energy go down

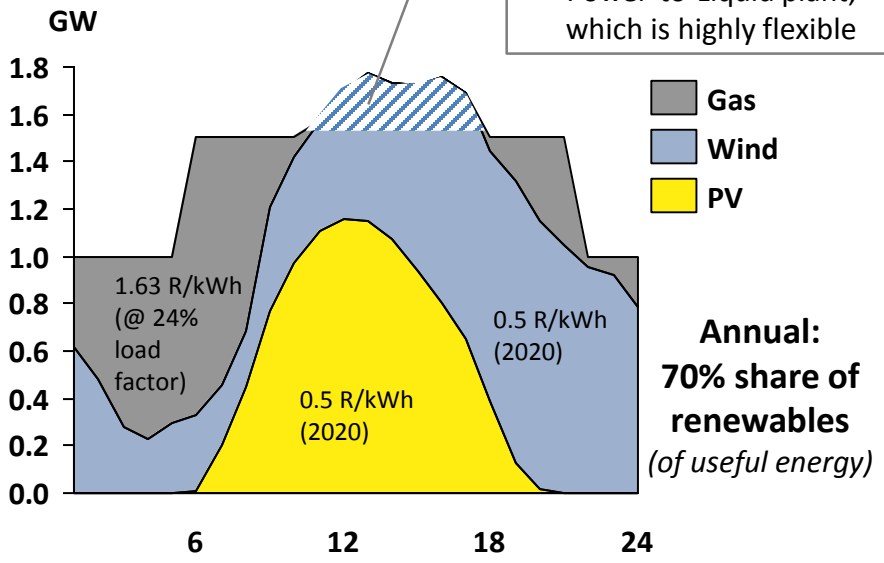
One illustrative winter day in display – calculations done for a full year



Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

Weighted cost: **0.88 R/kWh**

Curtailment of excess wind/ PV energy → could supply a Power-to-Liquid plant, which is highly flexible

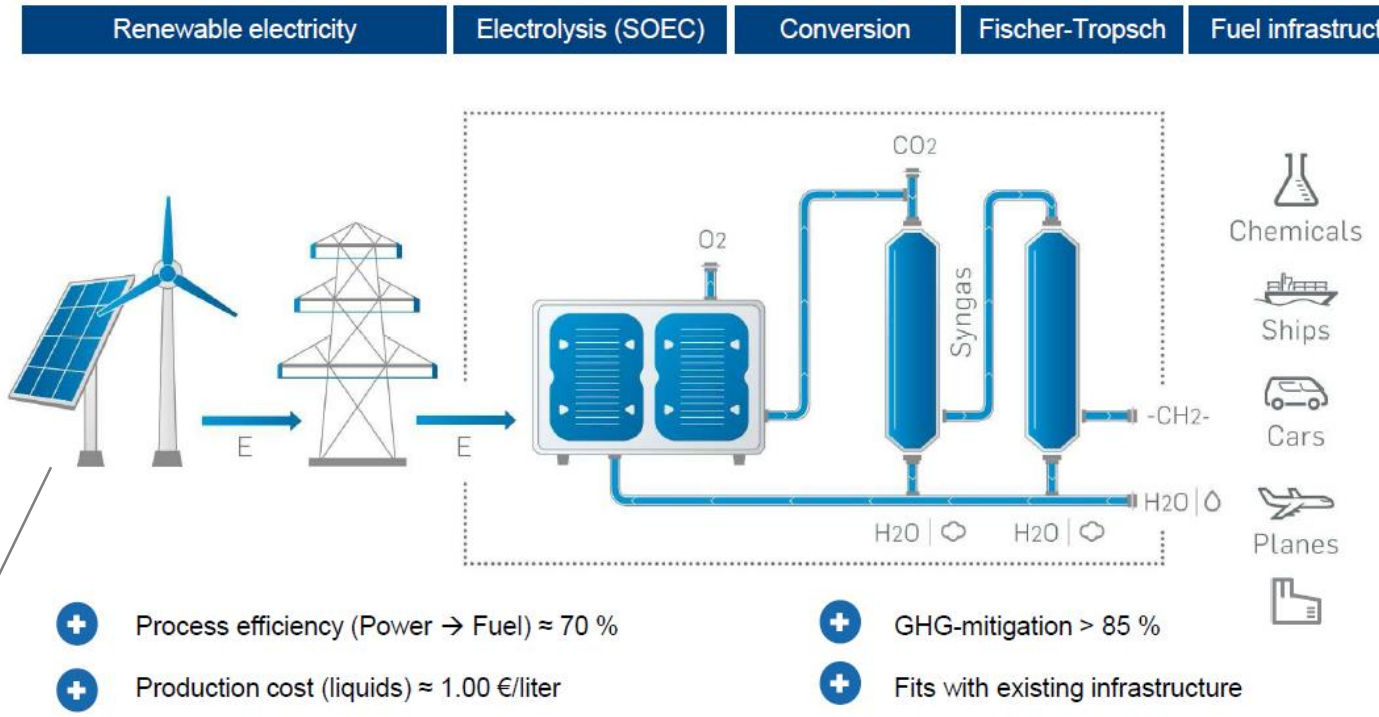


Annual: 70% share of renewables *(of useful energy)*

Technology: PV / wind / gas
Size: 1.5 / 2.0 / 1.61 GW
Energy (useful): 11.1 TWh/yr
Energy (total): 3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr

Weighted cost: **0.827 R/kWh**
(0.87 R/kWh goes down to 0.82 R/kWh, even if only 0.5 R/kWh value is given to excess energy)

Producing carbon-neutral synthetic fuels from cheap renewable power could be a business case for RSA and will be piloted at the CSIR campus



South Africa's competitive advantage: more sun and wind means cheaper renewable electricity

Sources: sunfire

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

Thank you!