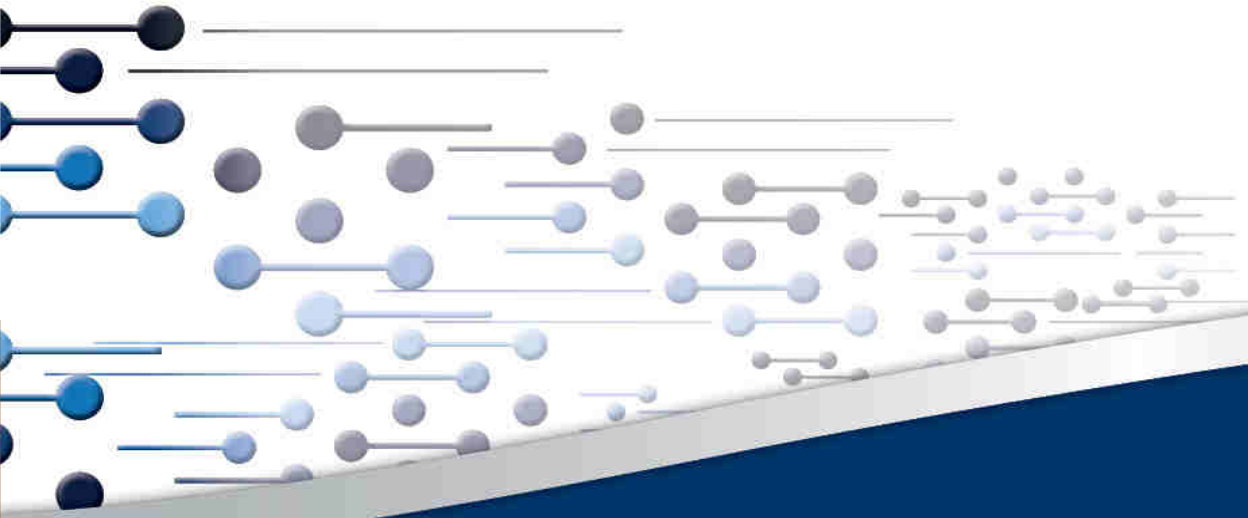
A Renewables-based South African Energy System?

Presentation at the Science Forum South Africa

Dr Tobias Bischof-Niemz, CSIR Energy Centre Manager

Johannesburg, 8 December 2015



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Dr Tobias Bischof-Niemz

Head of CSIR's Energy Centre

Professional Experience

- Member of the Ministerial Advisory Council on Energy (MACE)
- Extraordinary Associate Professor at Stellenbosch University
- Jul 2014 – today: Centre Manager at the CSIR, responsible to lead the establishment of an integrated energy research centre

- 2012 – 2014: PV/Renewables Specialist at Eskom in the team that developed the IRP; afterwards 2 months contract work in the DoE's IPP Unit on gas, coal IPP and rooftop PV

- 2007 – 2012: Senior consultant (energy system and renewables expert) at The Boston Consulting Group, Berlin and Frankfurt, Germany

Education

- Master of Public Administration (MPA) on energy and renewables policies in 2009 from Columbia University in New York City, USA

- PhD ("Dr.-Ing.") in 2006 in Automotive Engineering from TU Darmstadt, Germany

- Mechanical Engineering at Technical University of Darmstadt, Germany (Master – "Dipl.-Ing." in 2003) and at UC Berkeley, USA

Agenda

International context

Renewables in South Africa

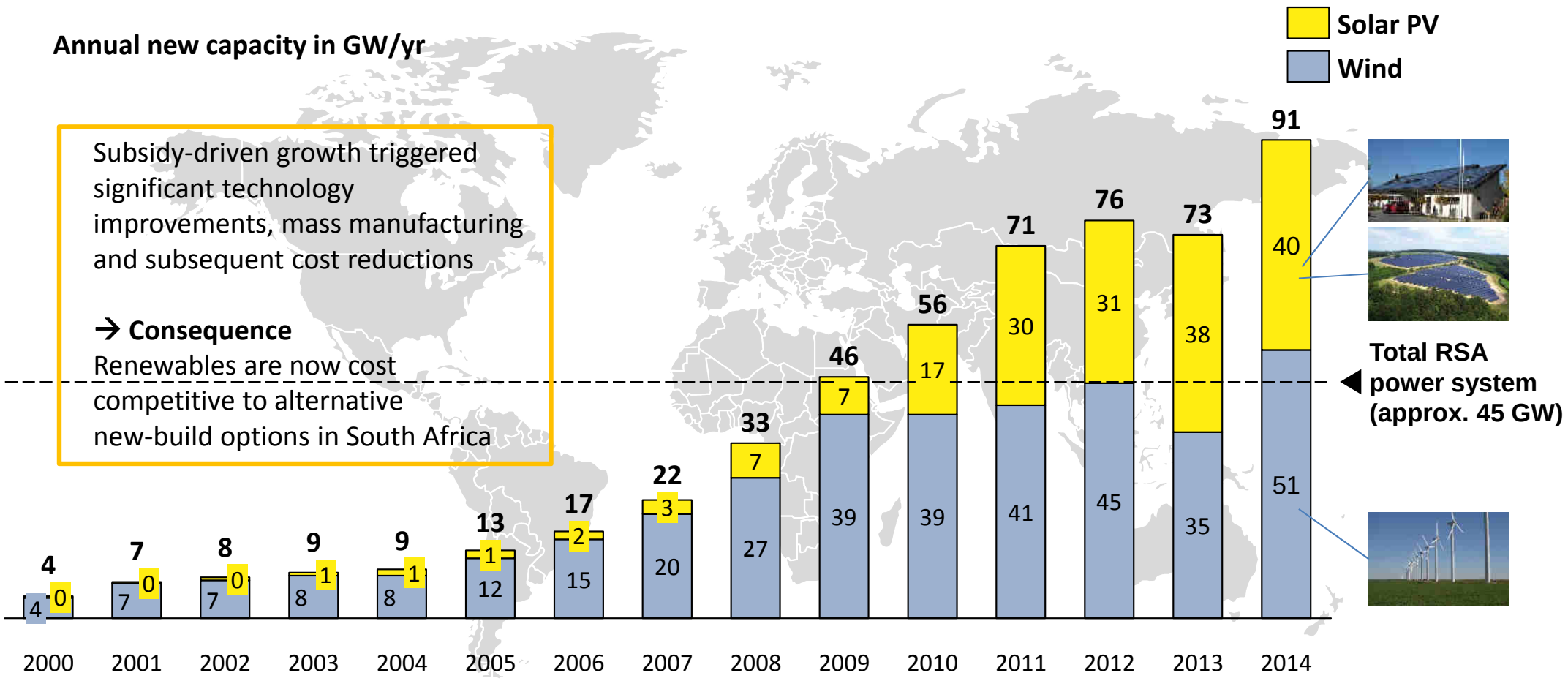
Extreme renewables scenarios

In 2014, more than 90 GW of wind & solar PV newly installed globally

Annual new capacity in GW/yr

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

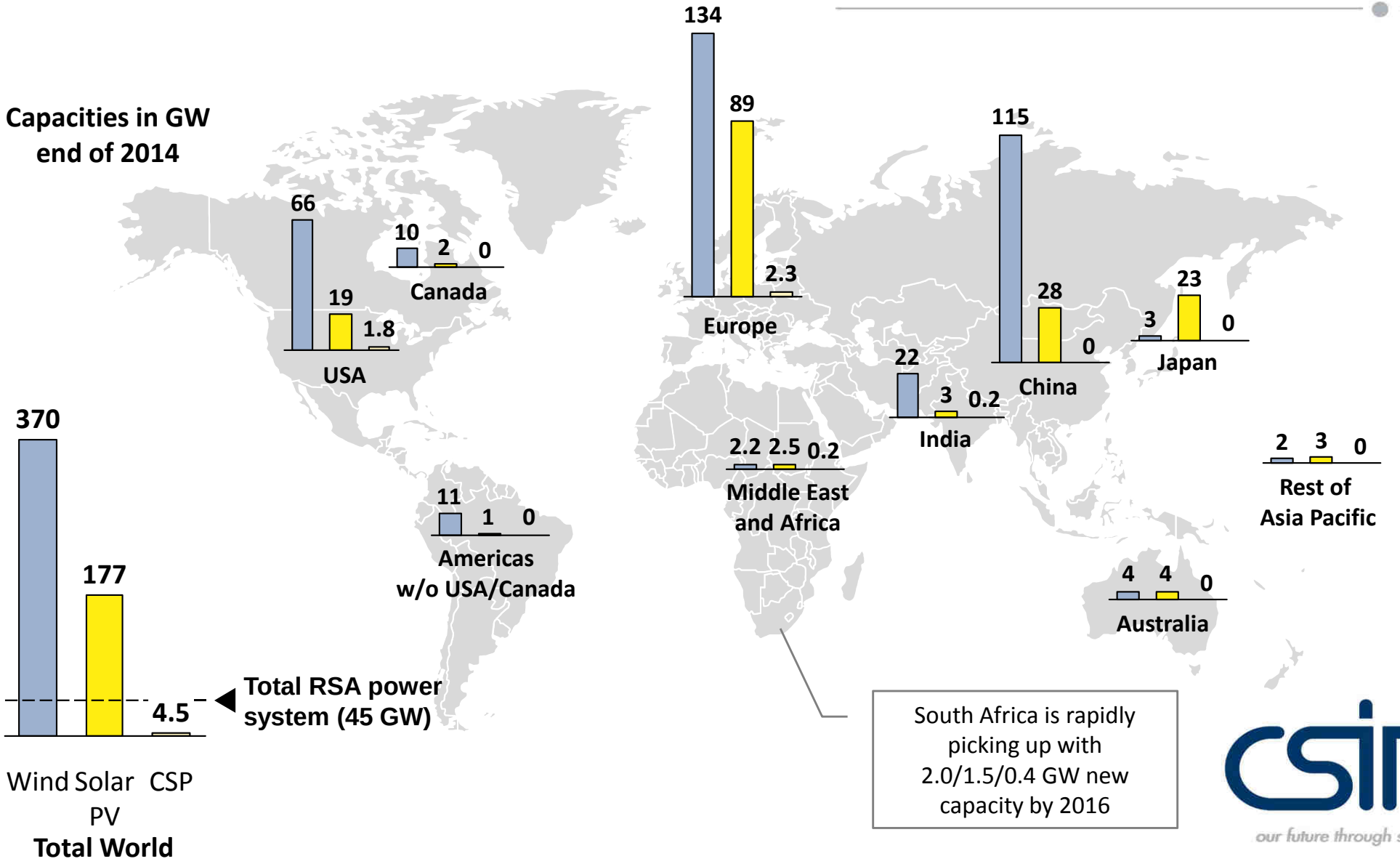


This is all very new: Almost 90% of the globally existing PV capacity was installed during the last five years alone!

Sources: International Energy Outlook of the EIA; GWEC; EPIA; 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 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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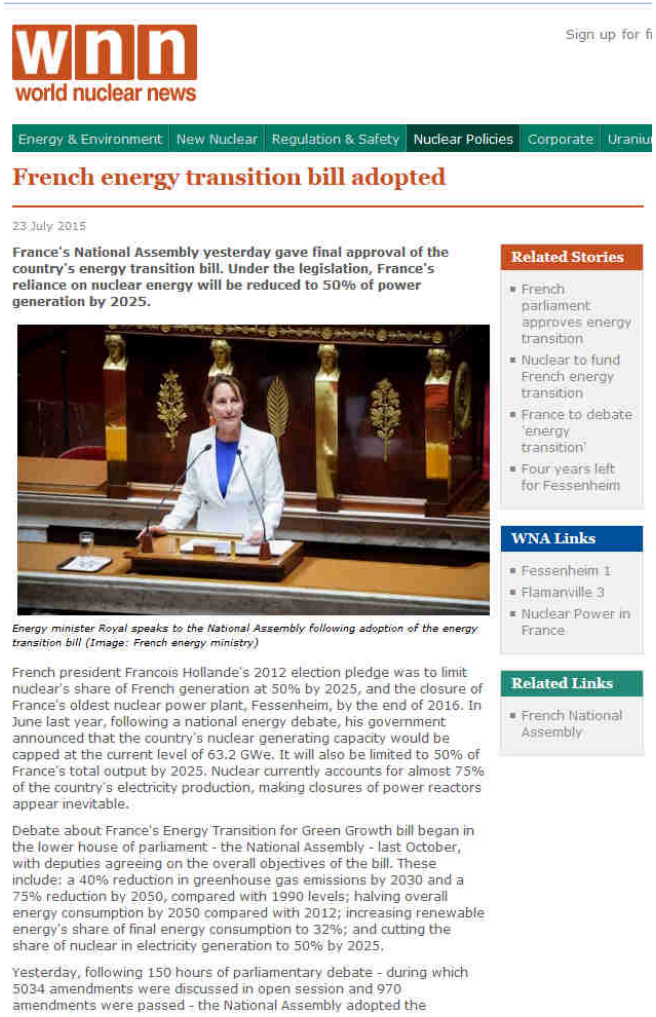
France will phase out “10 Koebergs” by 2025 – replaced by renewables



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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'
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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 passed a bill on 23 July 2015: mandates government to reduce share of nuclear in electricity mix from 75 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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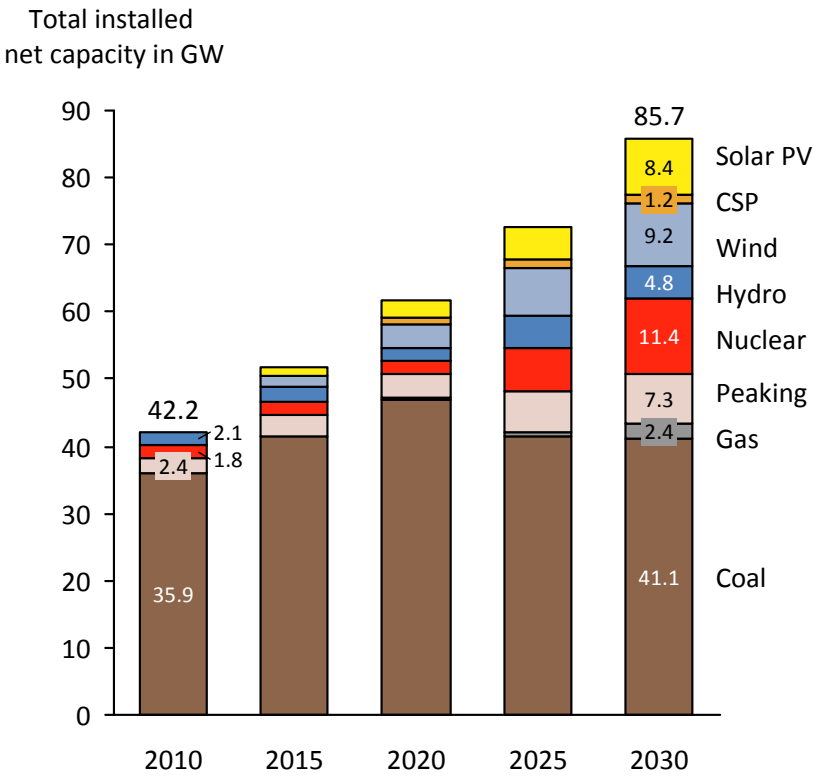
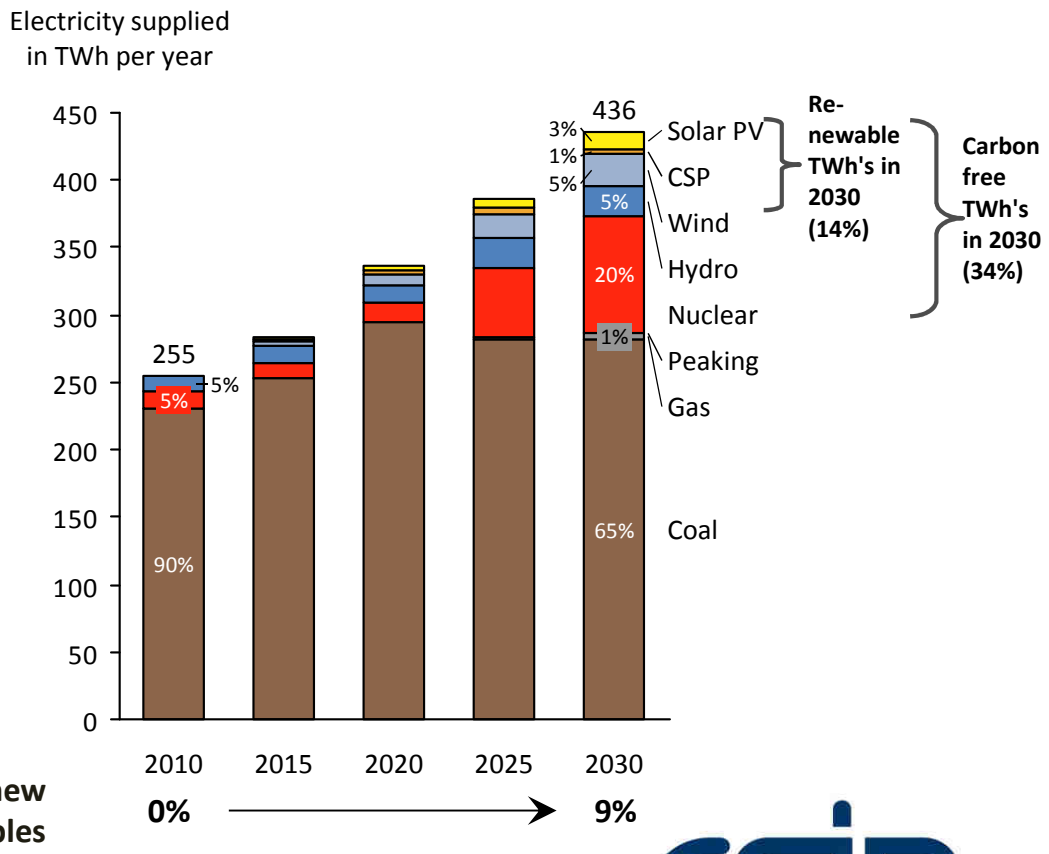
Extreme renewables scenarios

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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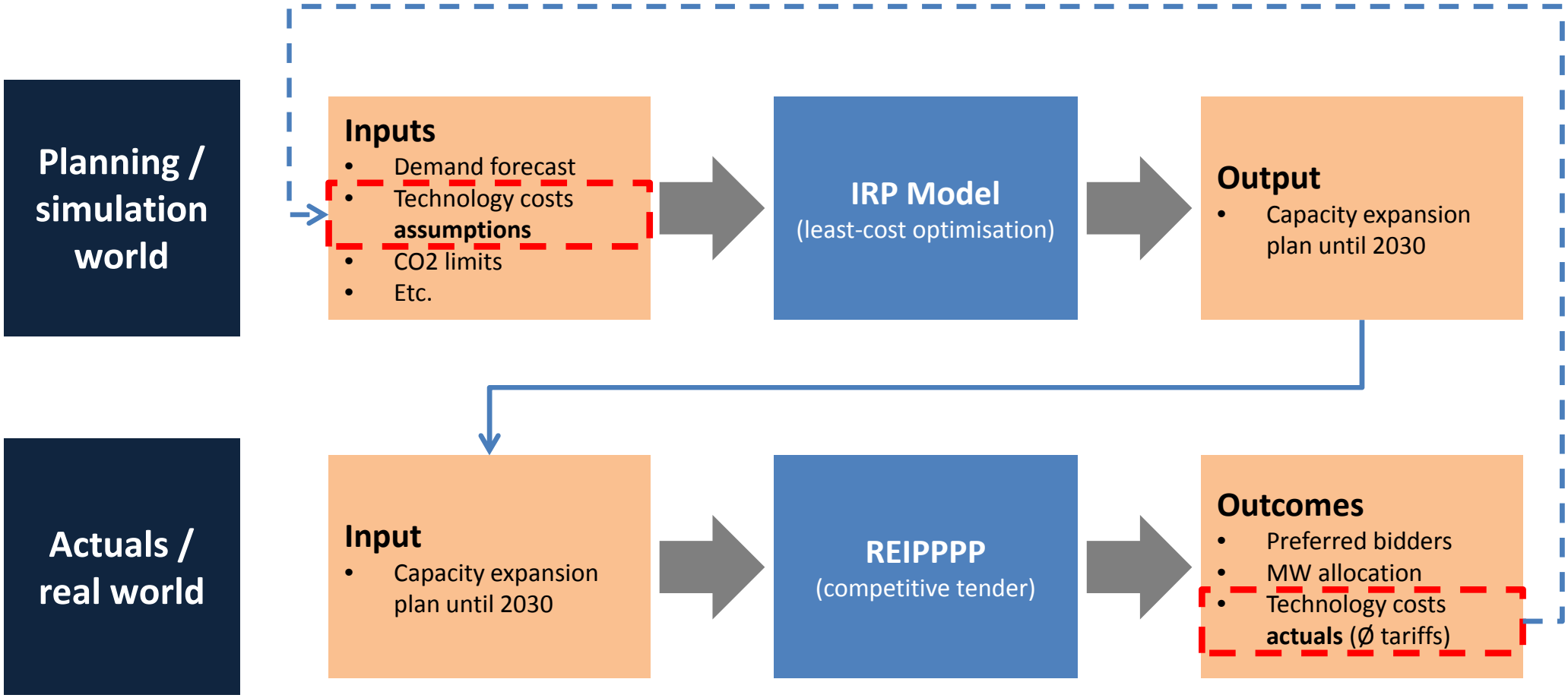
Note: hydro includes imports from Cahora Bassa

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

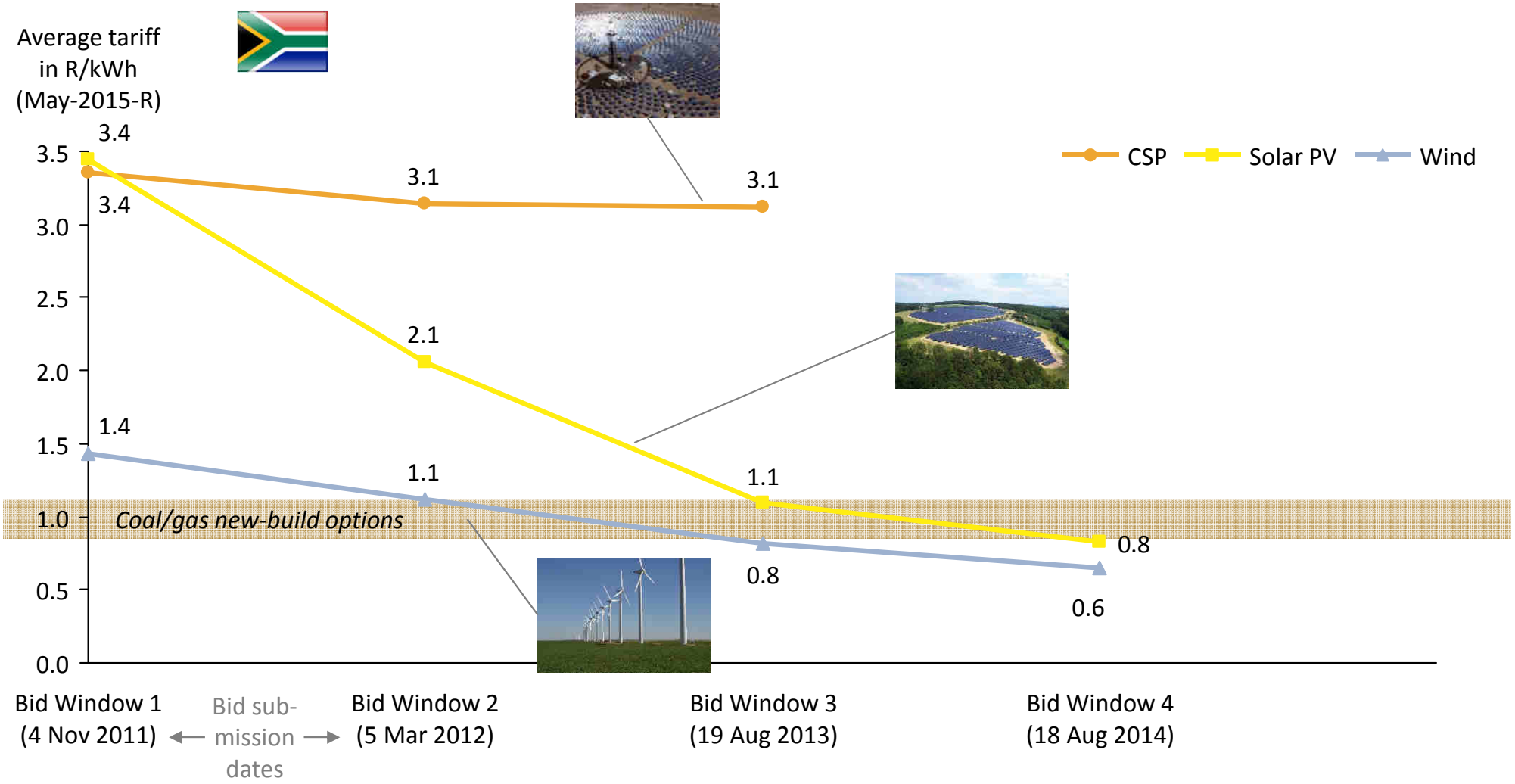
In-principle process of IRP planning and implementation



Sources: CSIR Energy Centre analysis

Actual results: PV and wind in South Africa are cost competitive today

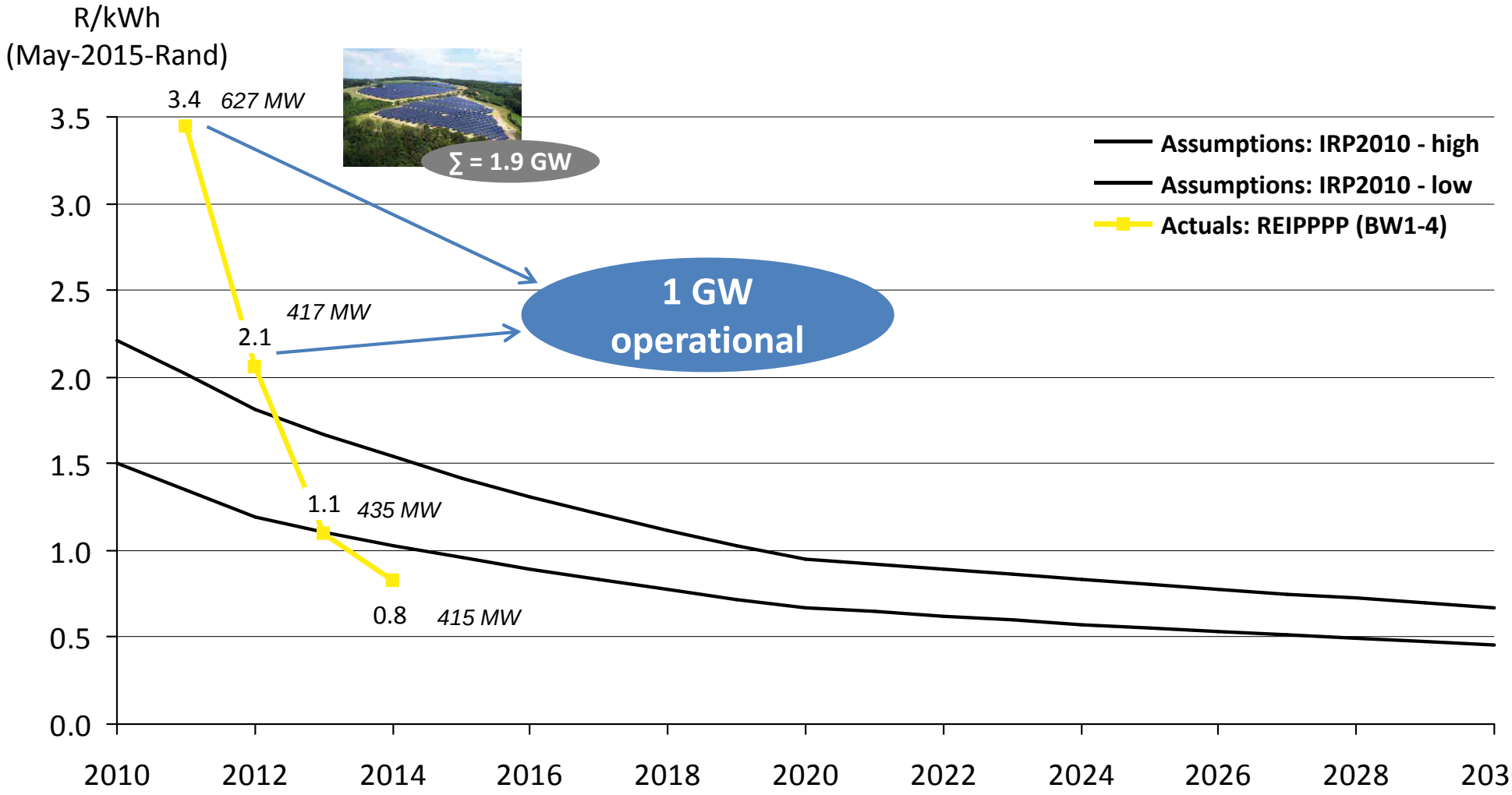
First four bid windows' results of Department of Energy's RE IPP Procurement Programme (REIPPPP)



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

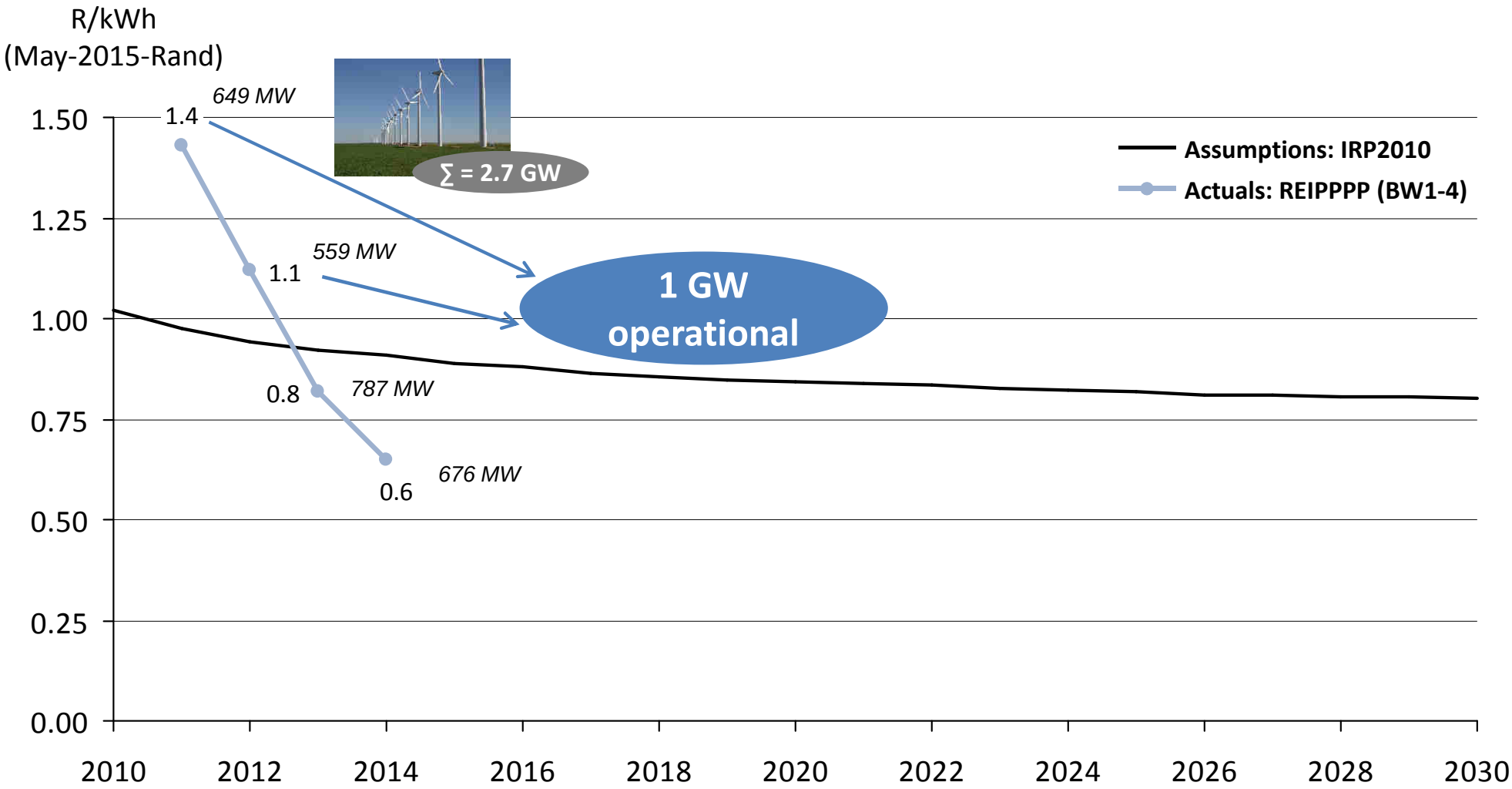
Sources: StatsSA on CPI; Department of Energy's publications on results of first four bid windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; http://www.ipprenewables.co.za/gong/widget/file/download/id/279;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

Actual solar PV tariffs quickly approached IRP cost assumptions in first four bid windows & 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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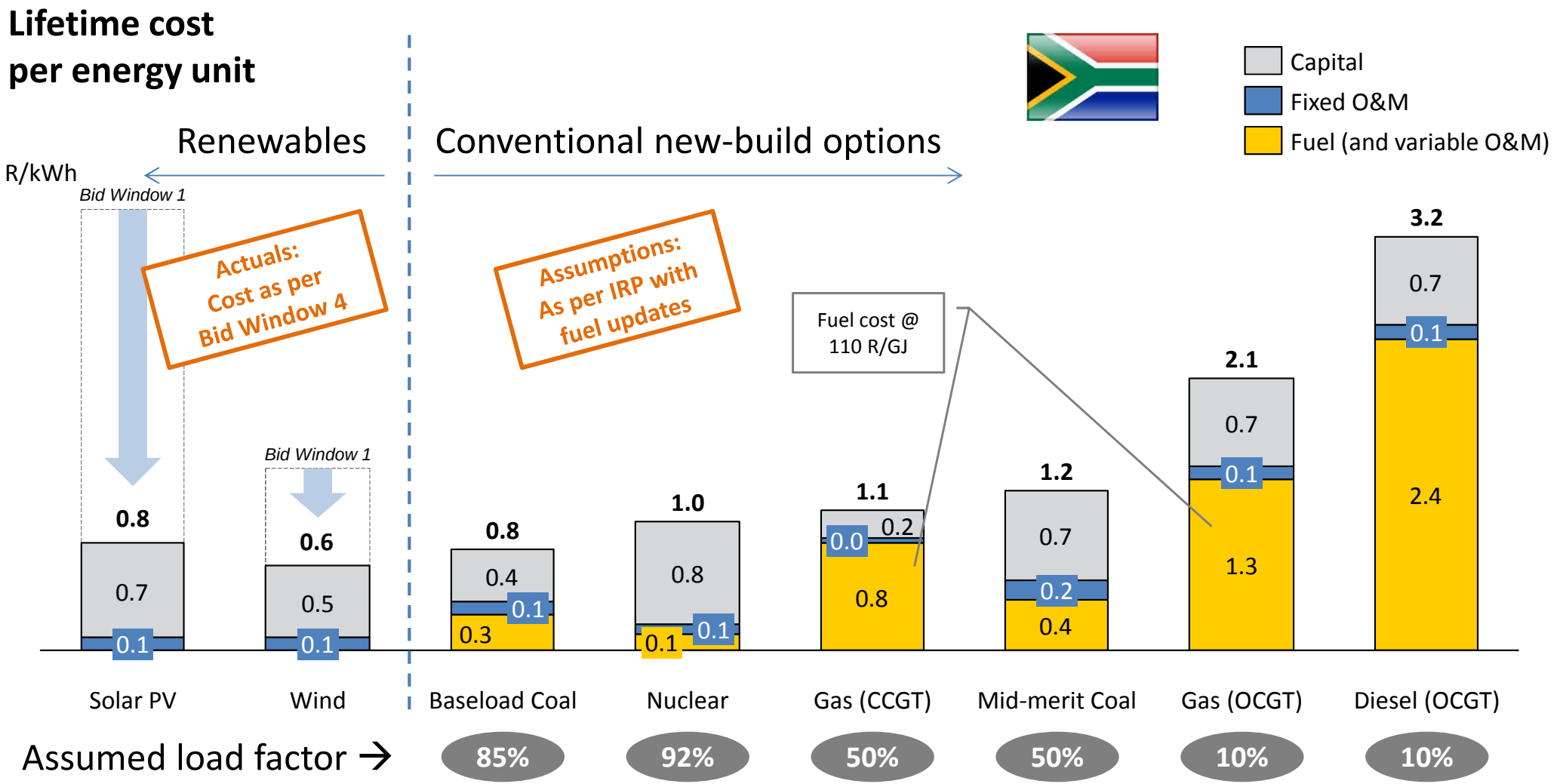
Sources: IRP 2010; IRP Update; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR Energy Centre analysis

Consequence of renewables' cost reduction for South Africa: Solar PV and wind are the cheapest new-build options per kWh 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; Sources: IRP Update; REIPPPP outcomes; StatsSA for CPI; Eskom financial reports on coal/diesel fuel cost; CSIR analysis

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

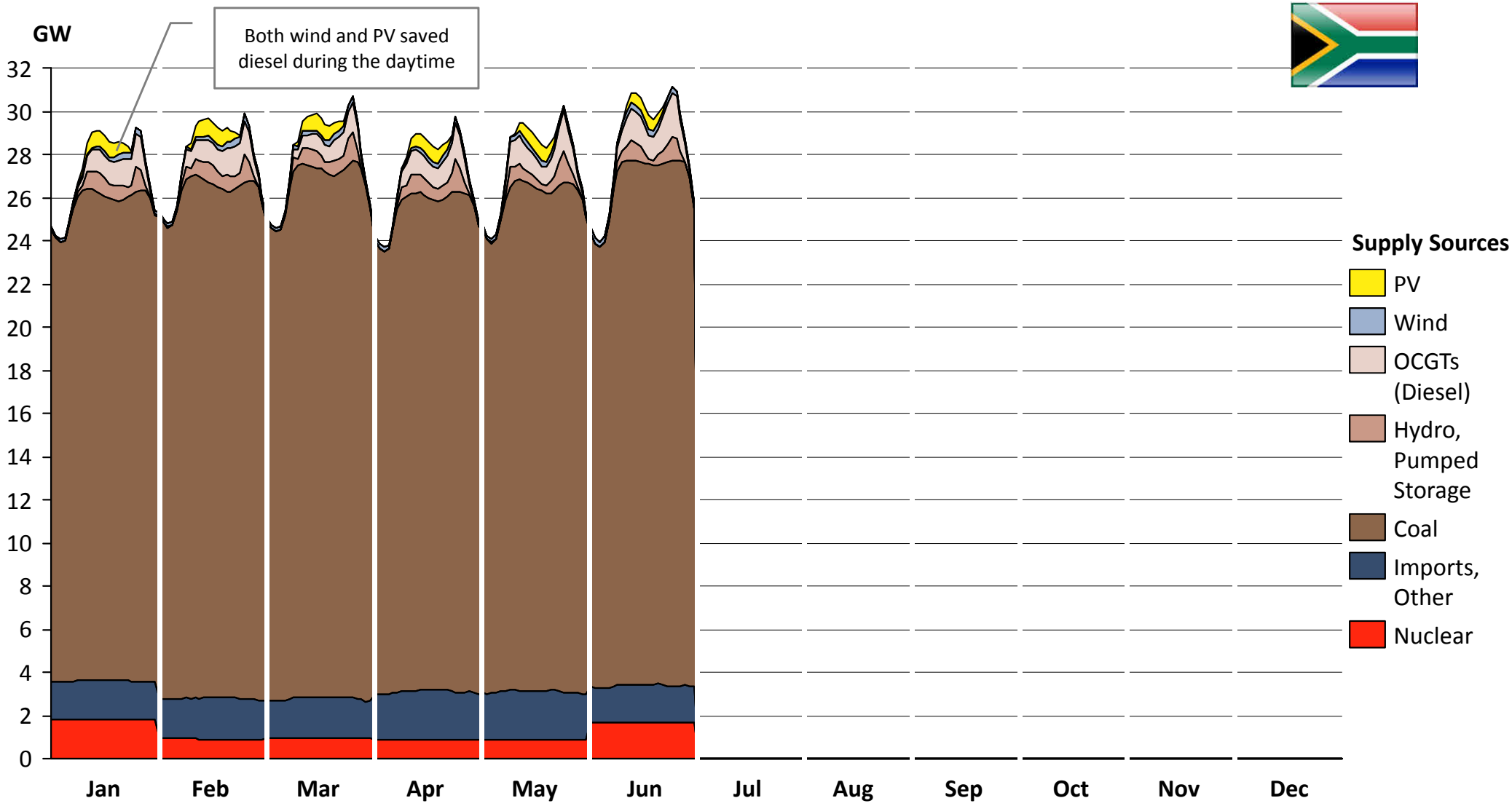
Actual energy captured in RSA wholesale market (i.e. without self-consumed energy of embedded plants)

Energy supplied from Jan-Jun 2015 in TWh

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

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Extreme renewables scenarios

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**

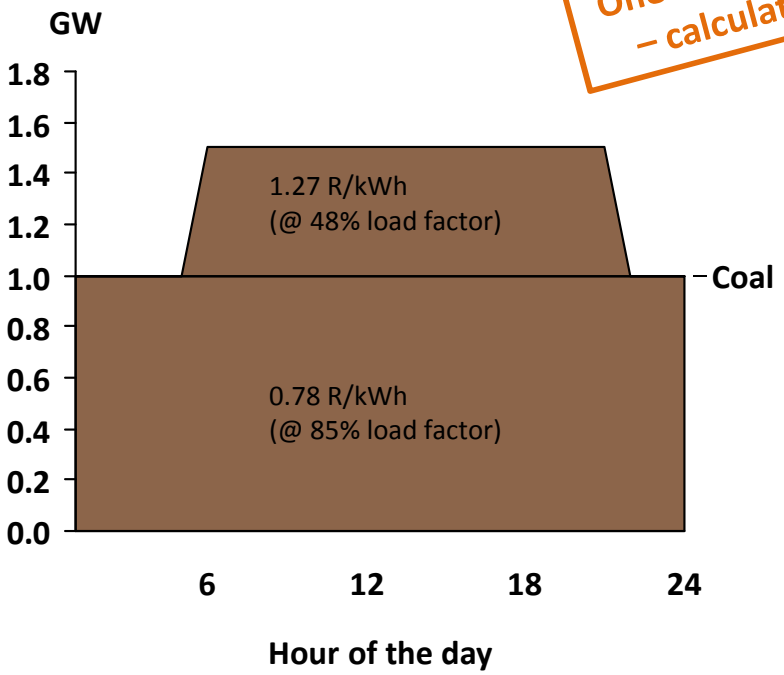
Day load: **1.3 GW in summer**
1.5 GW in winter

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?

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



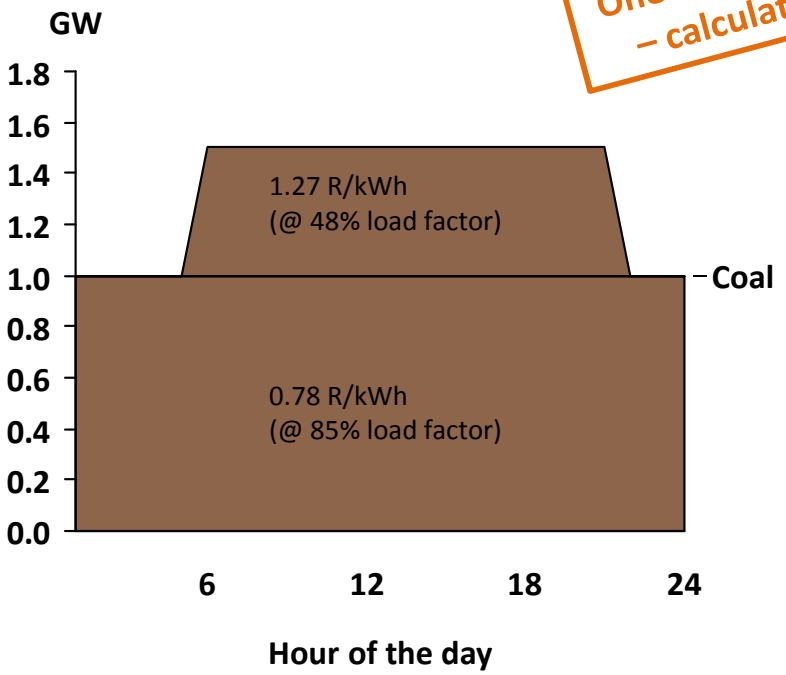
Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

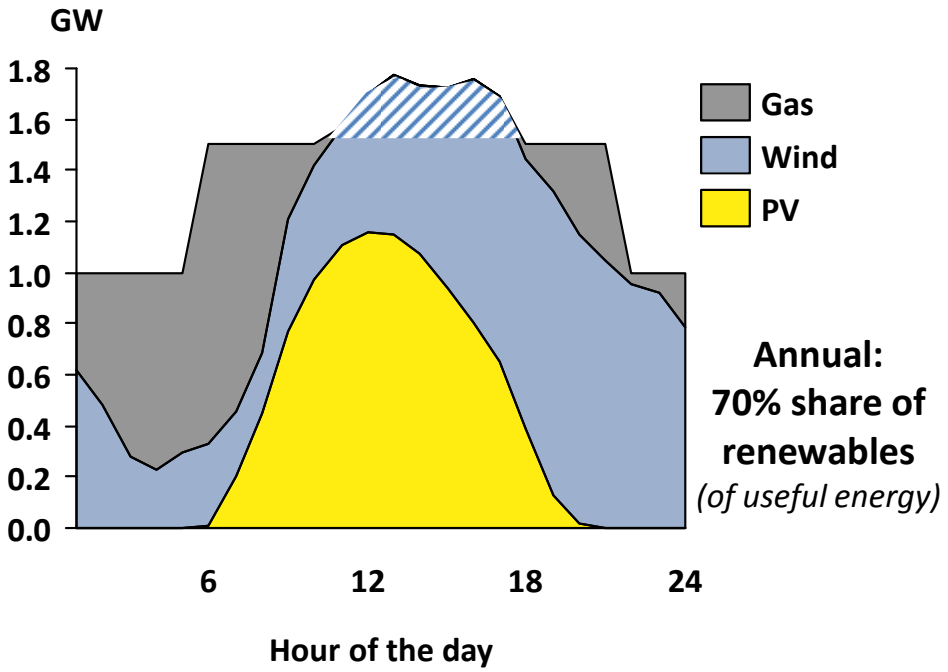
Weighted cost: **0.88 R/kWh**

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)

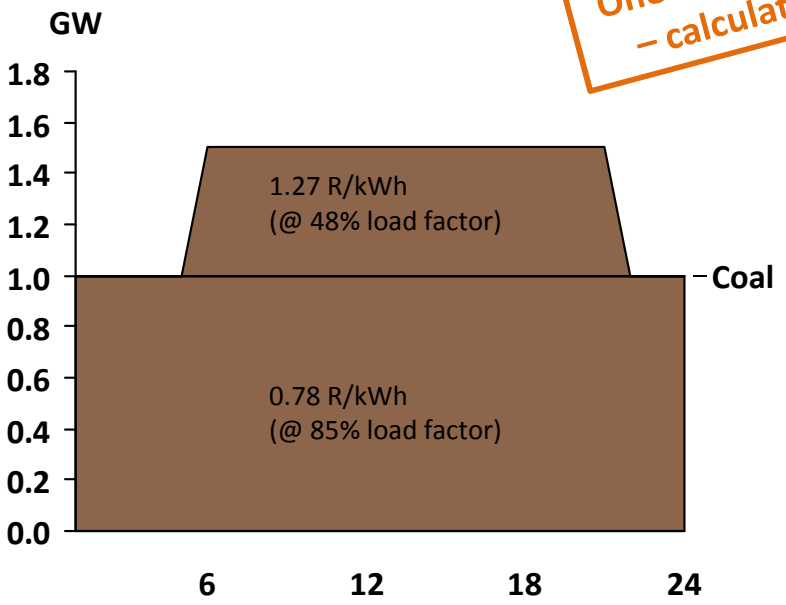
Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

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

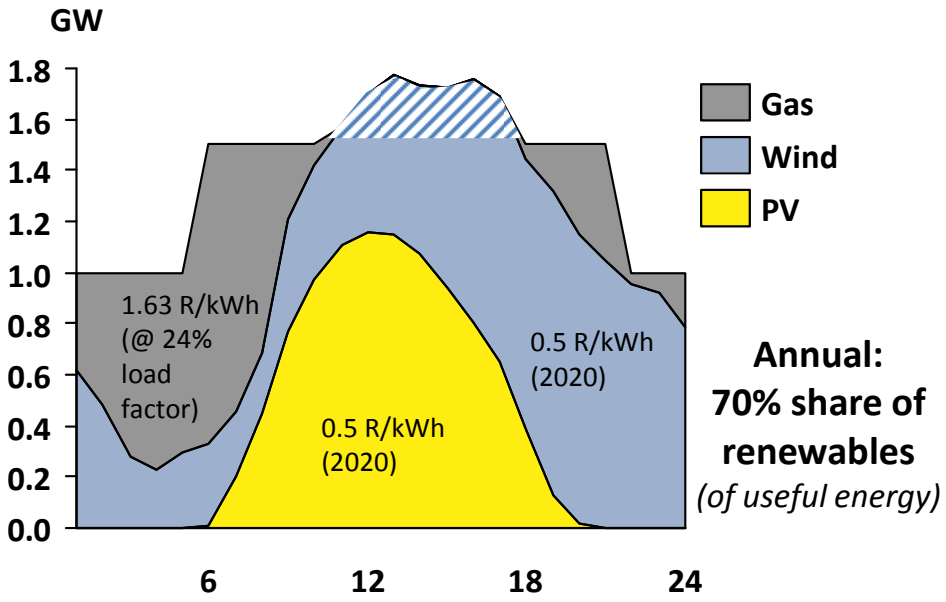
One illustrative winter day in display – calculations done for a full year



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



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

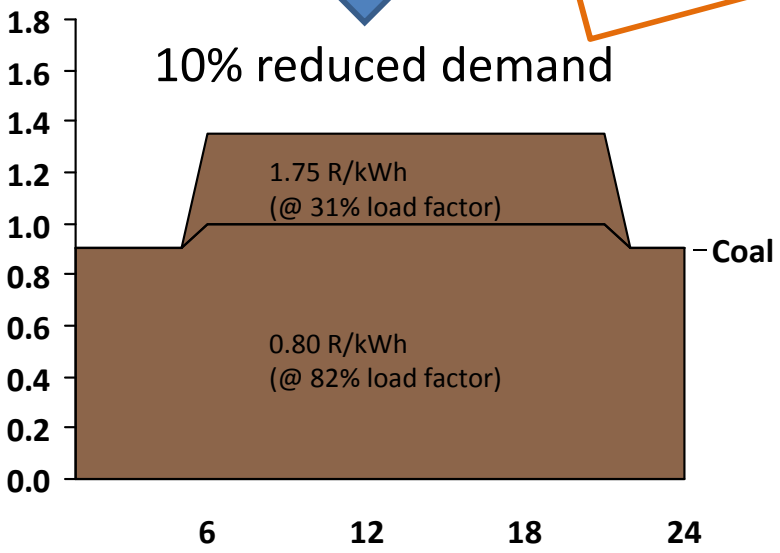
Technology: PV / wind / gas
Size: 1.5 / 2.0 / 1.61 GW
Energy (useful): 11.1 TWh/yr
Energy (total): 3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr

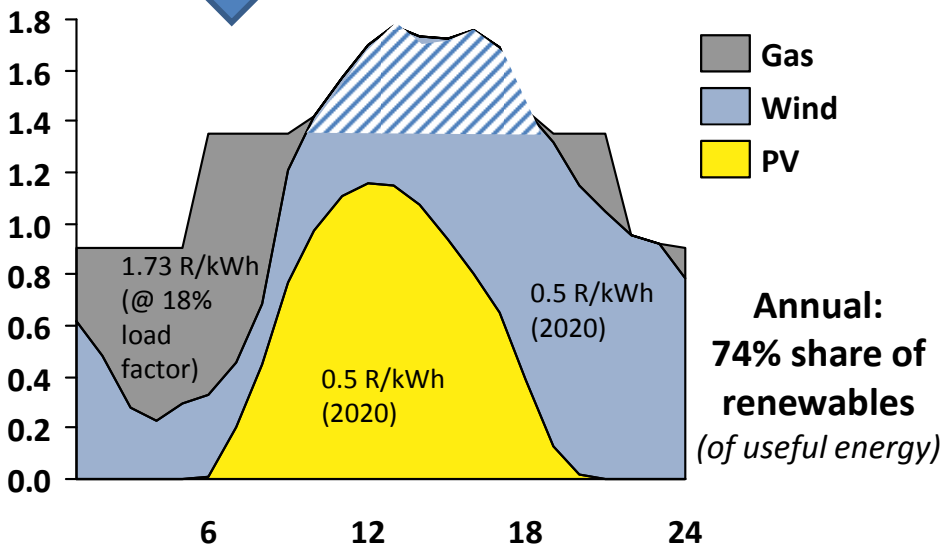
Weighted cost: **0.87 R/kWh**
(per useful energy, i.e. no value given to excess)

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





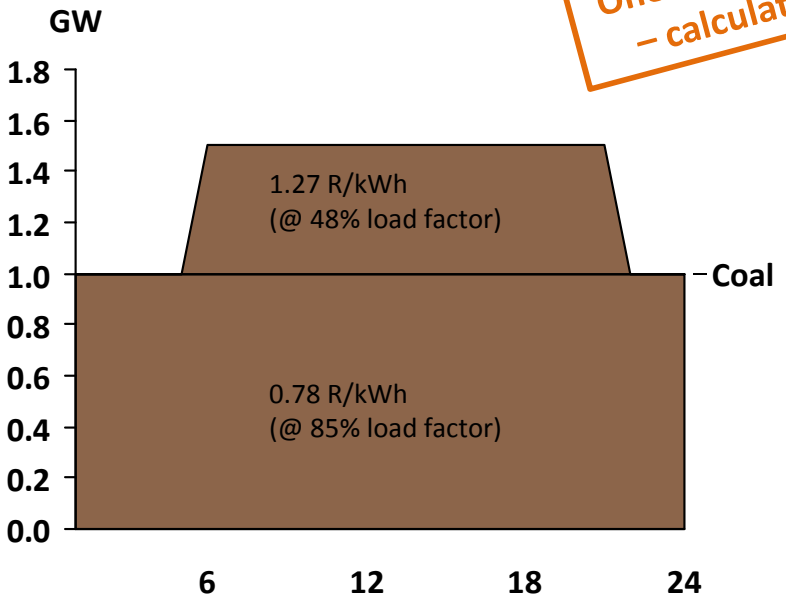
Annual: 74% share of renewables
(of useful energy)

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

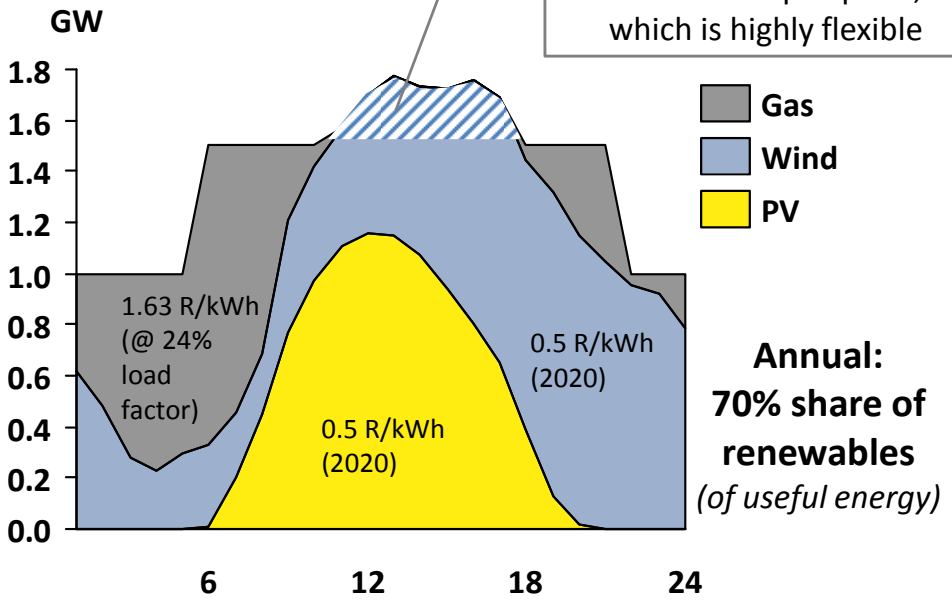
One illustrative winter day in display – calculations done for a full year



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

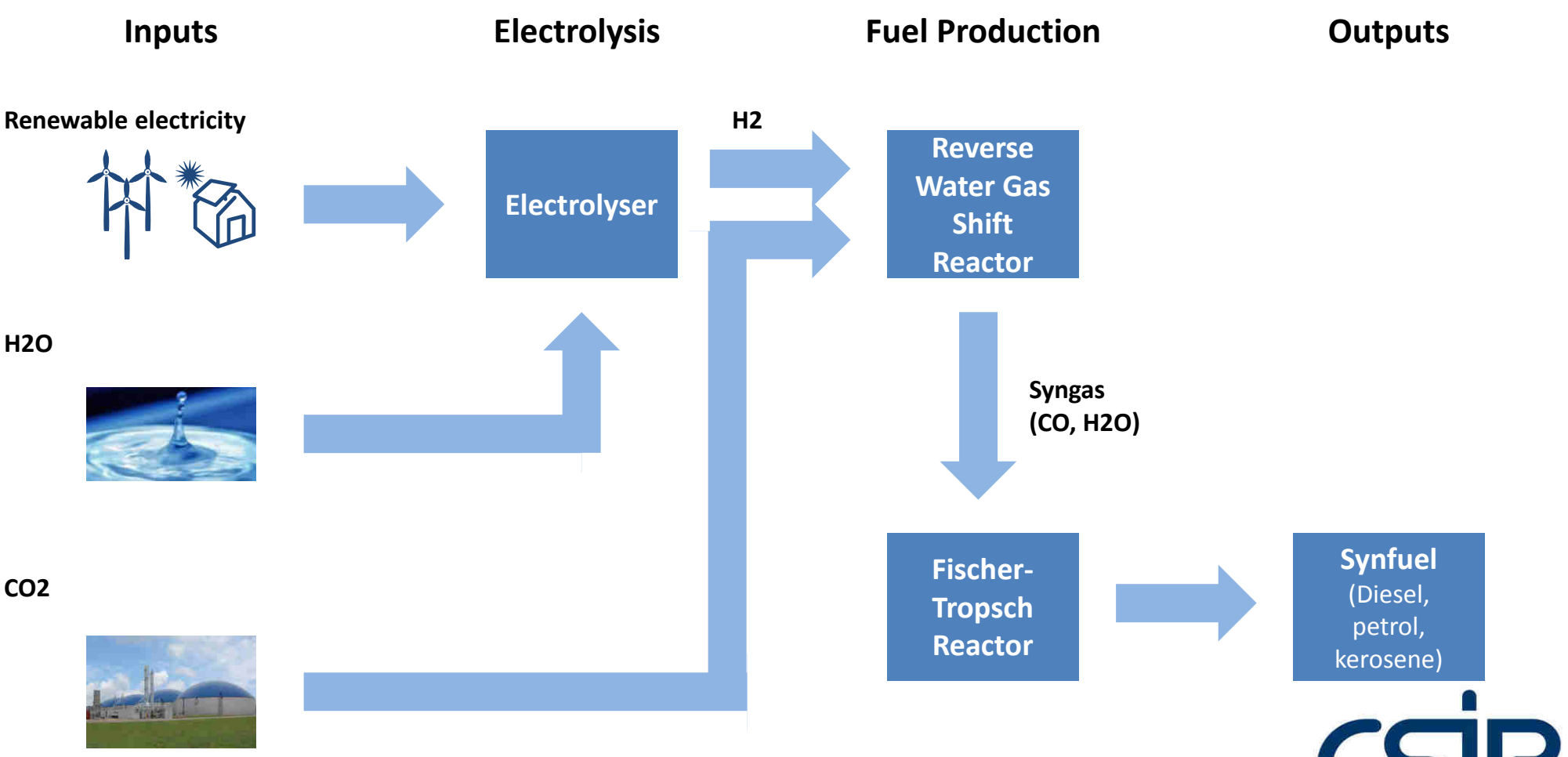


Annual: 70% share of renewables
(of useful energy)

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

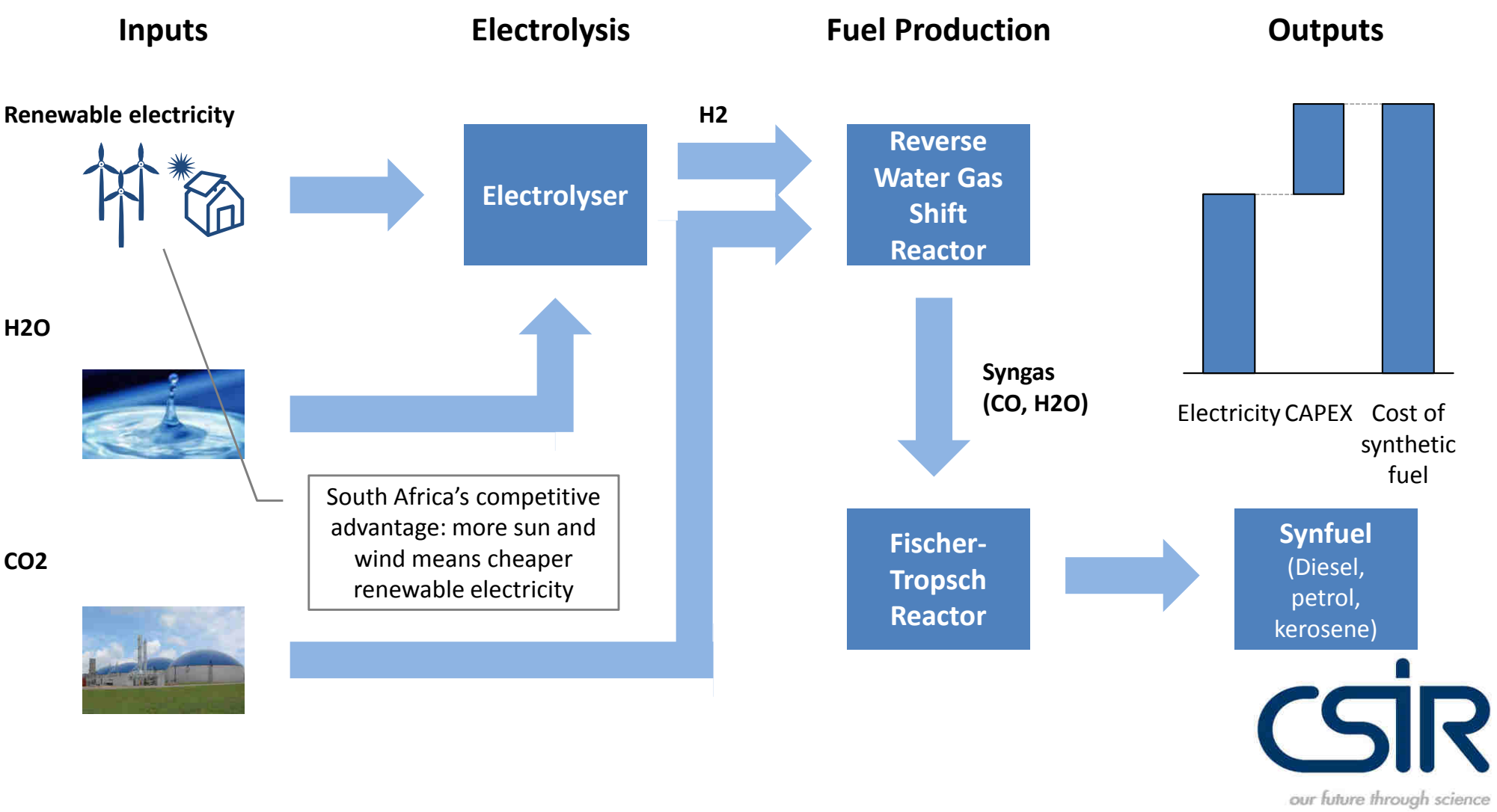
Weighted cost: **0.82~~7~~ R/kWh**
(0.87 R/kWh goes down to 0.82 R/kWh, even if only 0.5 R/kWh value is given to excess energy)

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



Sources: CSIR Energy Centre analysis

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

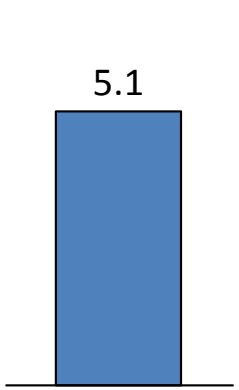


Sources: CSIR Energy Centre analysis

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 today

EUR-ct/kWh



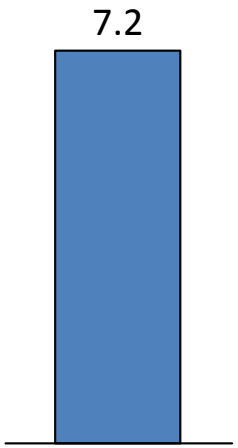
Solar/wind cost

./.

70% efficiency (optimally)

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

EUR-ct/kWh

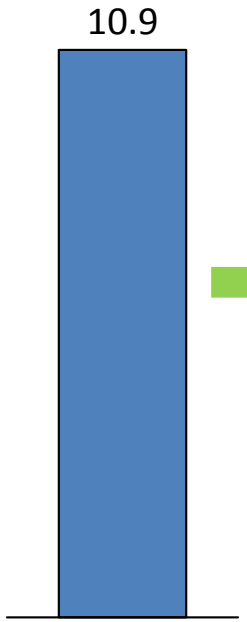


PtL electricity cost component

→ **Electricity approx. 2/3 of total cost**

Total PtL production cost

EUR-ct/kWh



Total PtL cost

Below 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

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 not a necessary pre-condition for achieving a 40% renewables share by 2030 – batteries today can provide system services

Thank you!