Quantifying the System-Wide Financial Costs and Benefits of Wind in South Africa

Presentation at the Windaba

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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

Background

Actual electricity production data for Jan-Jun 2015

Illustrative explanation of the methodology

Financial benefits from wind and PV for Jan-Jun 2015

Next steps

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Background

South Africa's power system is currently under severe constraints

- Power generators meant to be the "barely-ever-used" safety net for the system (diesel-fired gas turbines) running at > 30% average load factor in the first half of 2015
- Load shedding occurred during 82 days in the first half of 2015 (out of 181 days)

At the same time, Department of Energy is procuring new generation capacity and has already allocated a total of 8.1 GW of renewables (mainly wind & PV) for procurement from Independent Power Producers

- … of this, 6.3 GW have achieved preferred bidder status
- … of this, 4.0 GW have financially closed and signed the Power Purchase Agreements with Eskom
- … of this, ~1.8 GW were operational and fed energy into the grid as of end of June 2015 (now >2 GW)

The CSIR conducted a study on the financial benefits of the first renewables in South Africa in 2015

- Study is based on actual hourly supply data on aggregated level from the South African power system
- Fuel cost savings by reducing the utilisation of diesel-fired gas turbines and of the expensive part of the coal fleet were assessed, as well as the amount of "unserved energy" that renewables avoided

Sources: CSIR Energy Centre analysis

Summary of first 6 months of 2015 results: 2015 sees financial benefit from renewables exceed cost by R4.0 billion

From Jan-Jun 2015, wind and photovoltaic projects saved the power system R3.6 billion in diesel and coal fuel costs

- 800 MW of wind and 1 GW of PV (capacities as at 30 Jun 2015) generated 2 TWh (0.93/1.06) from Jan to Jun 2015
- This replaced 1.5 TWh from diesel-fired OCGTs (worth R3.5 bn) and 0.5 TWh from coal-fired power stations (R0.1 bn)
- This is a total fuel saving of R3.6 billion, which per kWh of renewables is 1.82 R/kWh (1.65 for wind and 1.98 for PV)

In addition, the 1.8 GW of wind & PV avoided ~200 hours of unserved energy, saving the economy additional R1.2-4.6 bn

- During 203 hours in 2015 so far the OCGT & pumped hydro reserves were less than the capacity supplied by wind/PV
- Without wind & PV and without other countermeasures, the system would have had to reduce load (unserved energy)
- The macroeconomic value of having avoided the associated 52 GWh of so-called "unserved energy" is up to R4.6 bn (@ 90 R/kWh), which translates into additional value of 2.33 R per kWh of renewable energy from wind/PV
- During 15 days from Jan-Jun 2015, renewables either prevented load shedding entirely or avoided a higher stage

In the first half of 2015, renewables thus generated up to R4.0 billion more financial benefits than they cost

- RE generated fuel-saving & macroeconomic value of up to R8.3 bn while they cost only R4.3 bn in IPP tariff payments
- That translates into a total value of wind/PV energy of up to 4.15 R/kWh, whereas the weighted average wind/PV tariff of the projects online (1st bid window's wind & 1st/2nd bid window's PV) is only 2.16 R/kWh in Apr-2015-Rand
- As for wind alone, these projects were cash positive for Eskom by R0.3 billion, saving R1.5 billion in fuel payments while costing R1.2 billion to IPPs (pure fuel-savings value of wind was 1.65 R/kWh, whereas the average tariff for the first bid window wind projects was only 1.34 R/kWh)
- The weighted average tariff for new wind/PV projects is 0.71 R/kWh, i.e. significantly less than the fuel-savings value

Notes: The conclusions are valid as long as the system is constrained (high diesel fuel consumption and high risk of unserved energy), i.e. for the next 3-5 years; all numbers in Apr-2015-Rand; OCGT = Open-cycle Gas Turbine; Sources: CSIR Energy Centre analysis

Summary of 2014 results: 2014 saw financial benefit from renewables exceed cost by R0.8 billion

In 2014, energy from first wind and photovoltaic projects saved the power system R3.64 billion in diesel & coal fuel costs

- 0.6 GW of wind and 1.0 GW of PV (capacities as at 31 Dec 2014) generated 2.2 TWh (1.07/1.12) of electricity in 2014
- This replaced 1.05 TWh from diesel-fired OCGTs (worth R3.28 b) and 1.12 TWh from coal power stations (R0.36 b)
- This is a total fuel saving of R3.64 billion, which per kWh of renewables is 1.66 R/kWh (1.60 for wind & 1.72 for PV)

In addition, 1.6 GW of wind & PV avoided ~120 hours of unserved energy, saving additional R1.67 billion for the economy

- During 117 hours in year 2014 the OCGT & pumped hydro reserves were less than the capacity supplied by wind/PV
- Without wind & PV and without other countermeasures, the system would have had to reduce load (unserved energy)
- The macroeconomic value of having avoided the associated 19.2 GWh of unserved energy is R1.67 billion (@ 87 R/kWh), which translates into additional value of 0.76 R per kWh of renewable energy from wind/PV

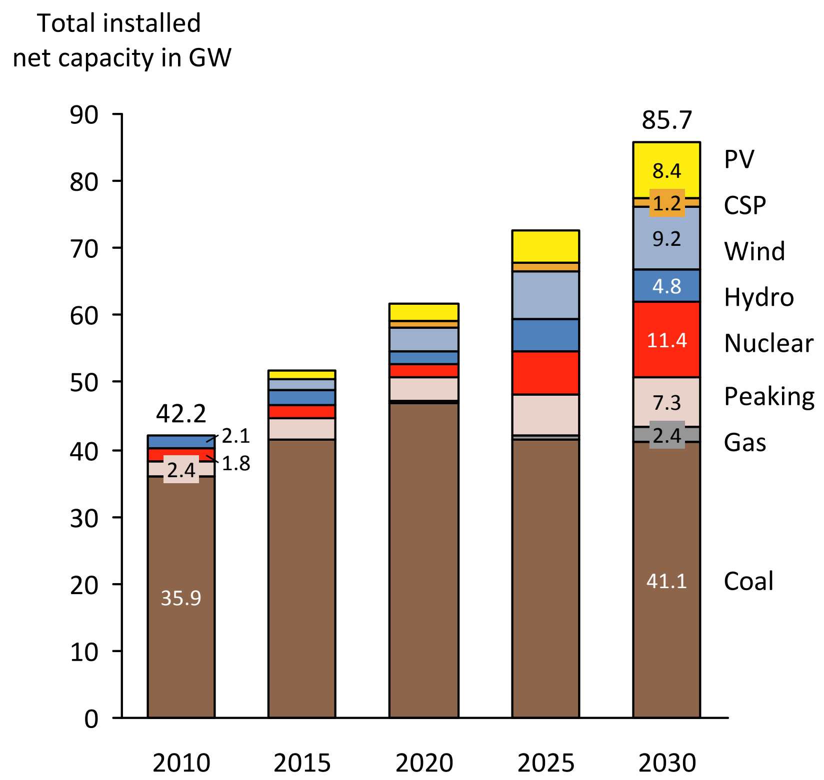
In 2014, RE thus generated financial benefits in the form of fuel-saving and macroeconomic value of R5.3 billion (which is 2.42 R per kWh of renewable energy), while they costs only R4.5 billion in tariff payments to the IPPs (2.07 R/kWh)

- The total value of wind/PV in 2014 was R5.3 billion (3.7+1.6), the total cost in form of tariff payments was R4.5 billion
- That translates into a total value of wind/PV energy of 2.42 R/kWh, whereas the weighted average tariff wind/PV tariff of first bidding window's wind and first/second bidding window's PV is only 2.07 R/kWh
- As for wind alone, 0.6 GW of wind saved the system real cash on a net basis, because the pure fuel savings value of wind was 1.60 R/kWh, whereas the average tariff for the first bidding window wind projects is 1.36 R/kWh
- The weighted average tariff for <u>new</u> wind/PV projects is 0.86 R/kWh and thus significantly less than the fuel savings

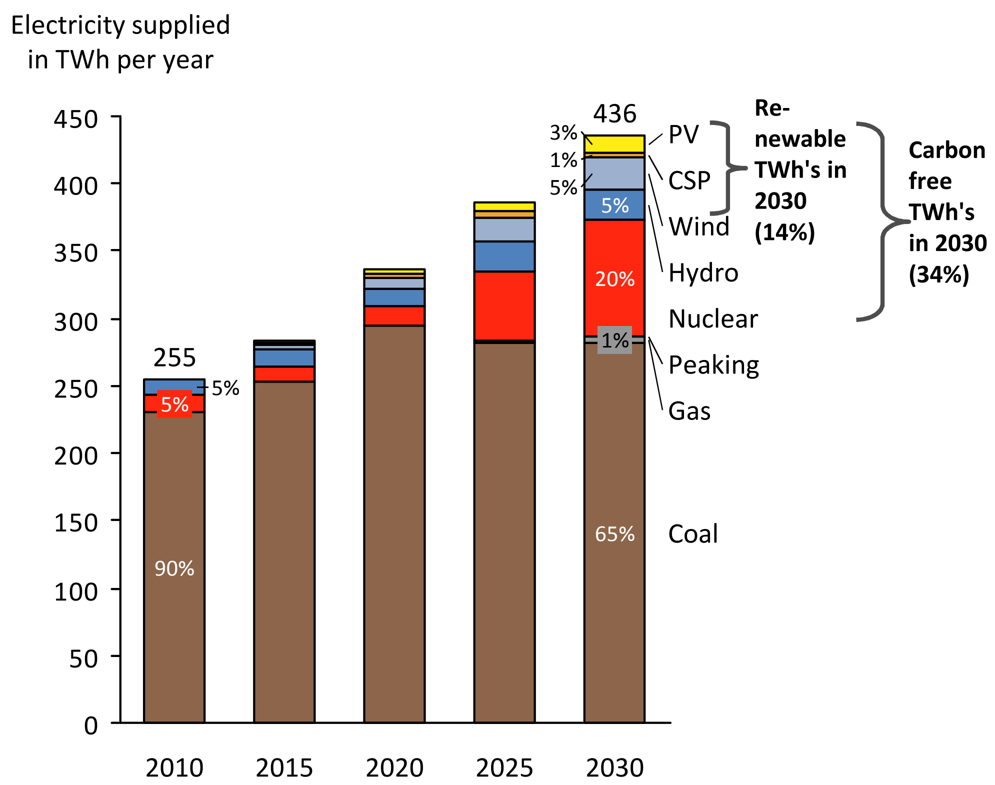
Notes: The conclusions are valid as long as the system is constrained (high diesel fuel consumption and high risk of unserved energy), i.e. for the next 3-5 years; all numbers in Jul-2014-Rand; OCGT = Open-cycle Gas Turbine; Sources: CSIR Energy Centre analysis

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

Planned installed capacity



Resulting energy mix



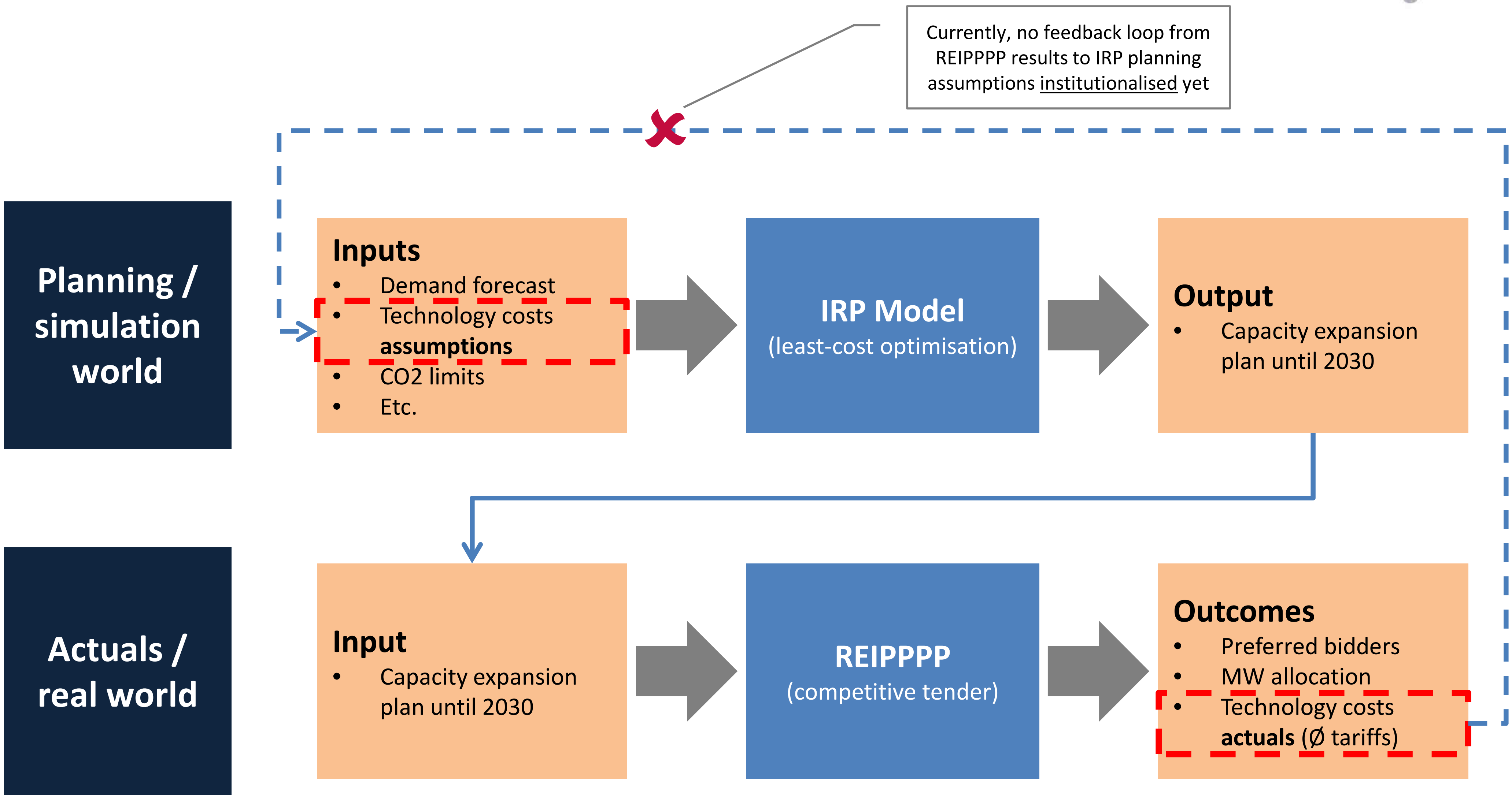
Share new renewables **0%** → **9%**

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

Note: hydro includes imports from Cahora Bassa

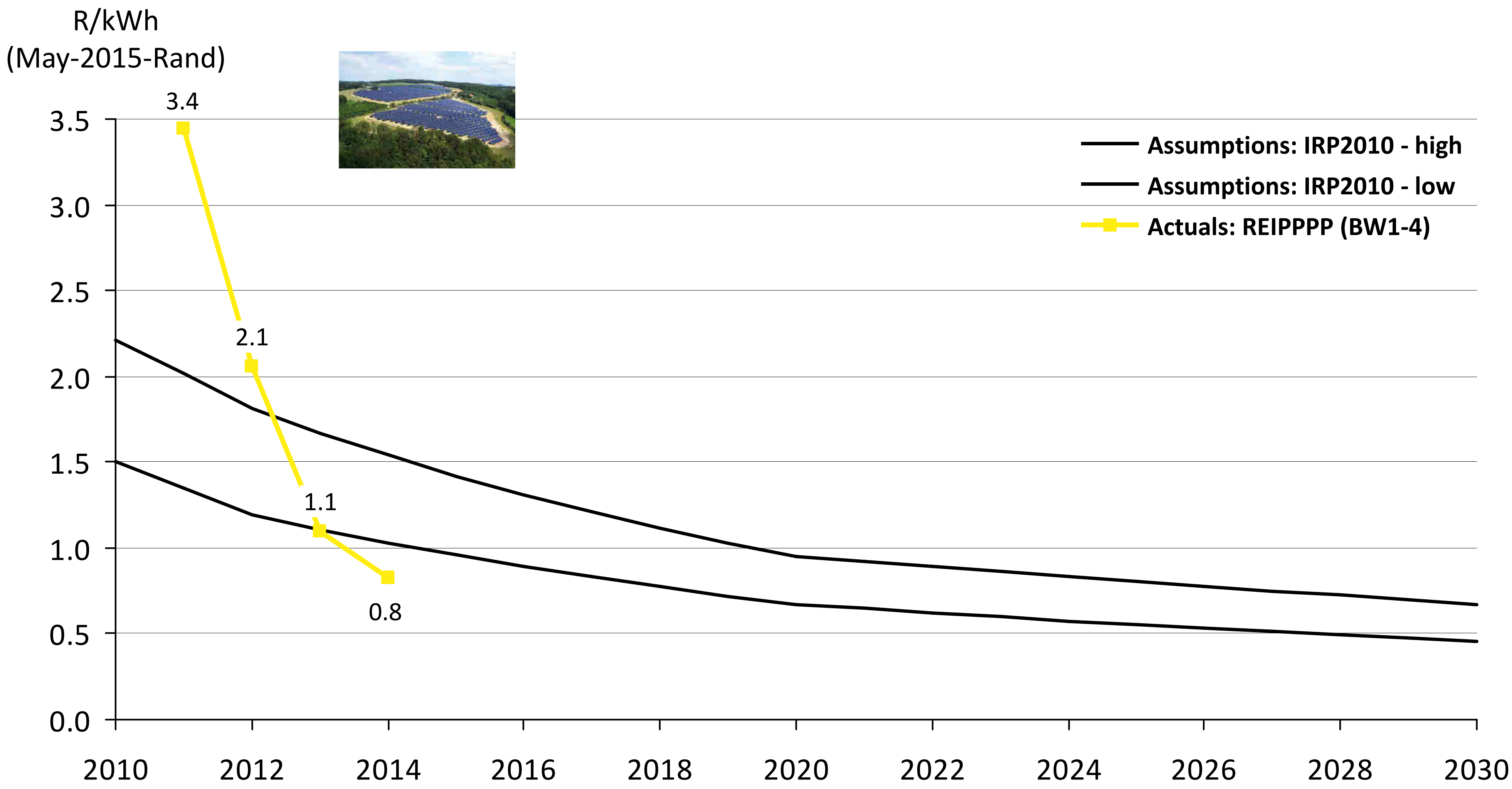
Sources: Integrated Resource Plan 2010, as promulgated in 2011; CSIR Energy Centre analysis

In-principle process of IRP planning and implementation



Sources: CSIR Energy Centre analysis

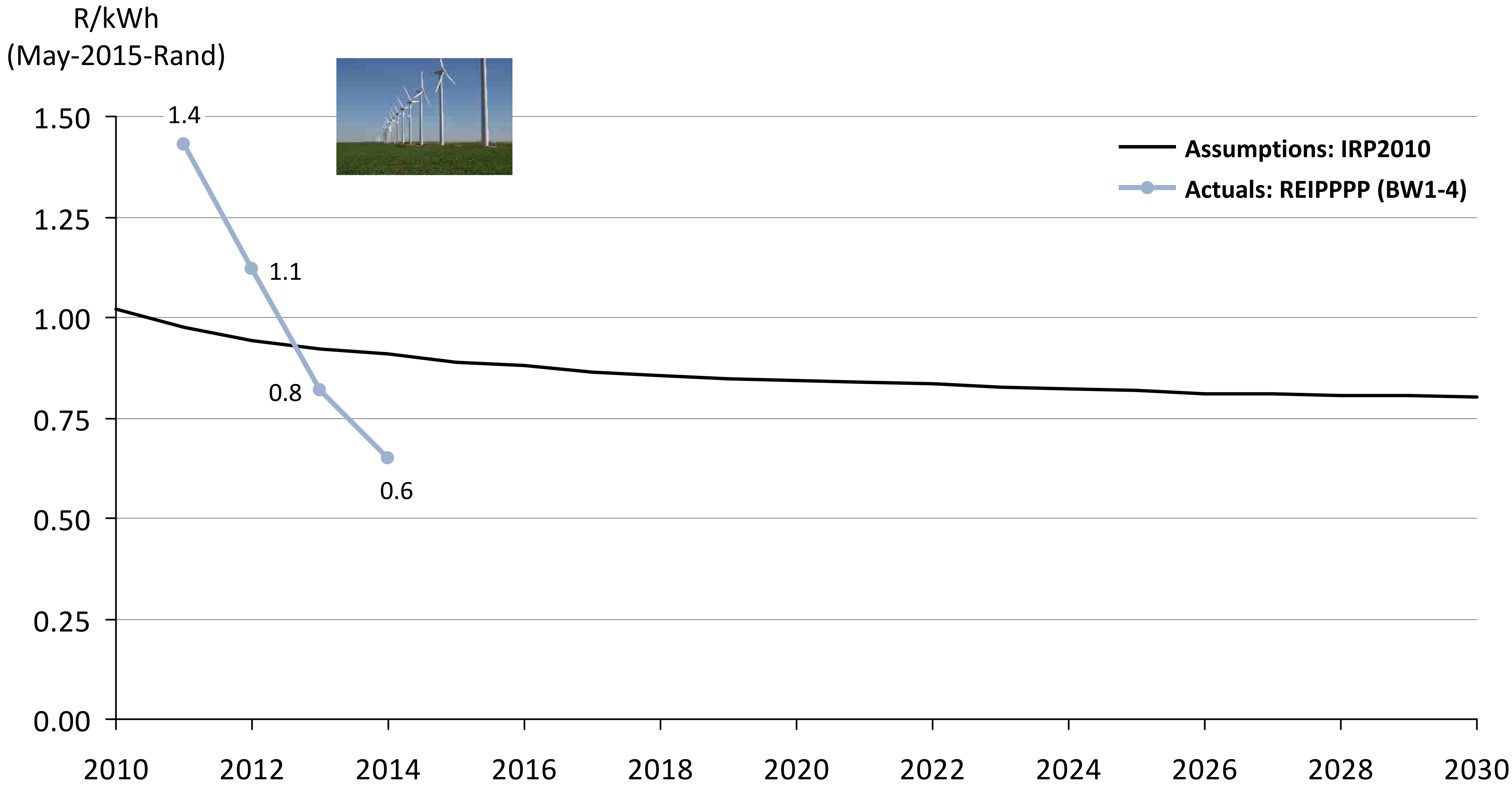
Actual PV tariffs quickly approached IRP cost assumptions in first four bid windows and are now below the lowest cost assumptions of IRP



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

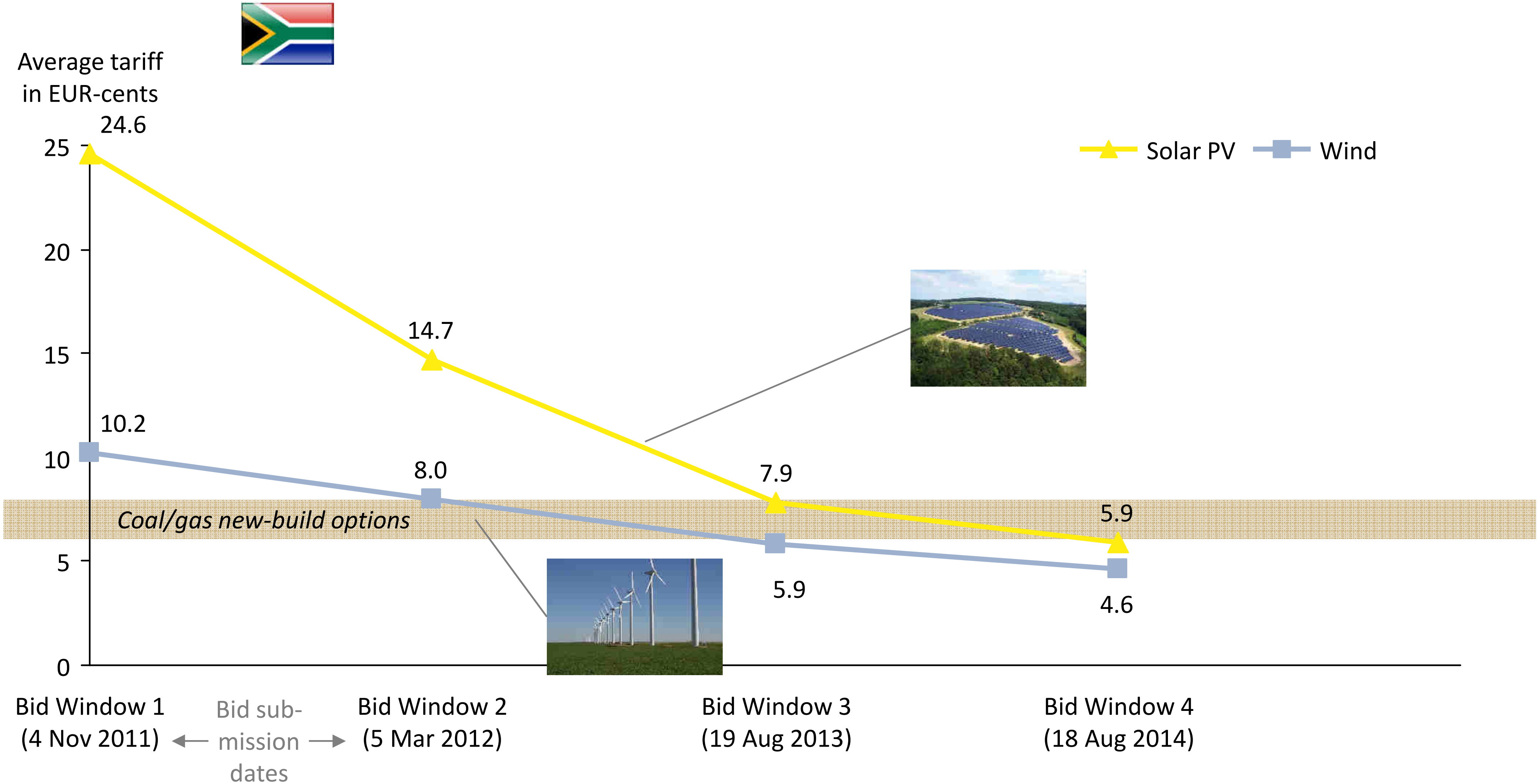


Assumptions: CPI used for normalisation to May-2015-Rand; LCOE calculated for IRP with 8% discount rate (real), 20 yrs lifetime, cost and load factor assumptions as per relevant IRP document; "IRP Tariff" then calculated assuming 80% of total project costs to be EPC costs, i.e. divide the LCOE by 0.8 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 results: solar PV & wind in South Africa cost competitive today

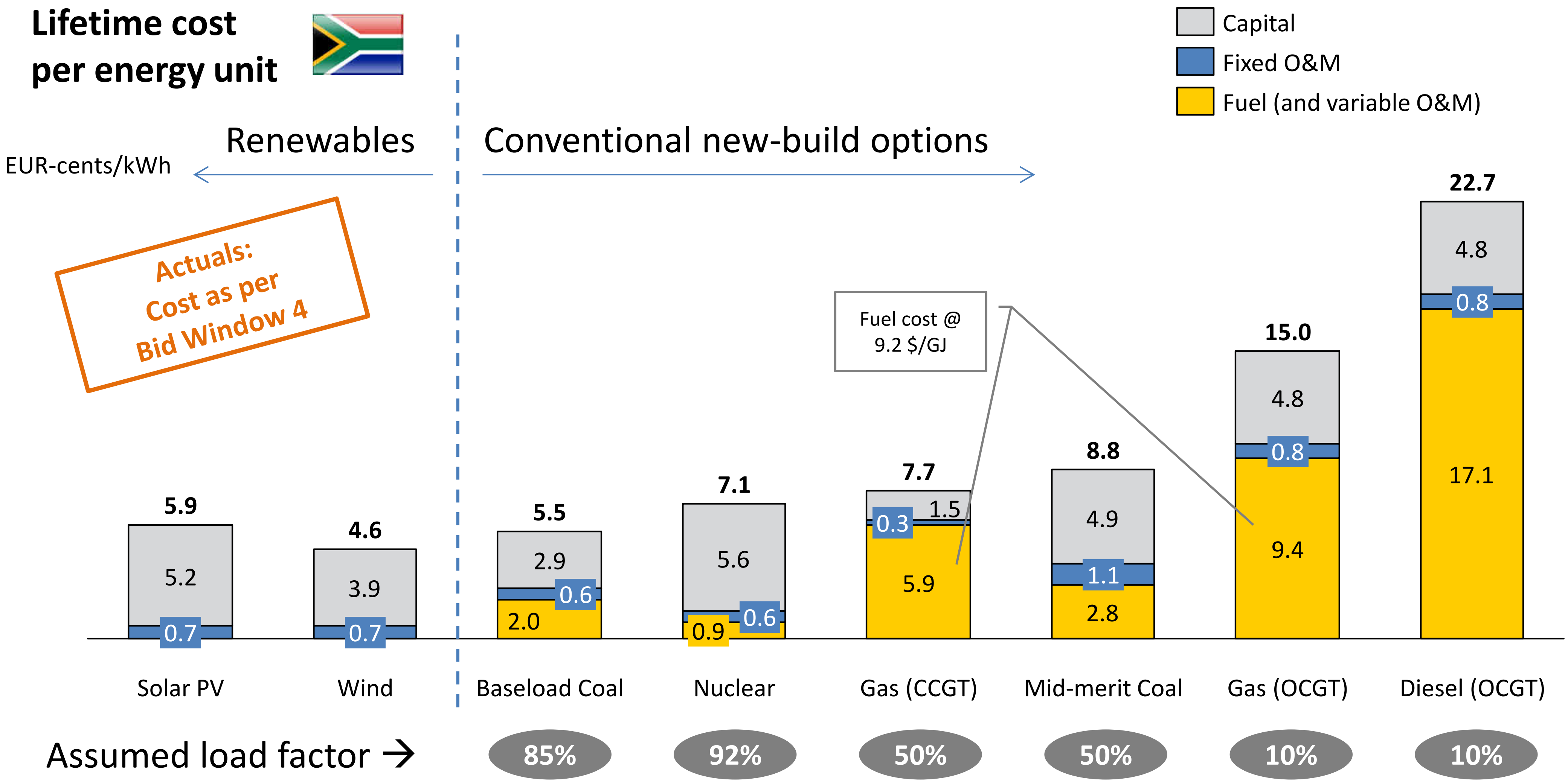
First four bid windows' results of Department of Energy's RE IPP Procurement Programme (REIPPPP)



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

Consequence of renewables' cost reduction: Solar PV & wind cheapest new-build options per kWh in South Africa



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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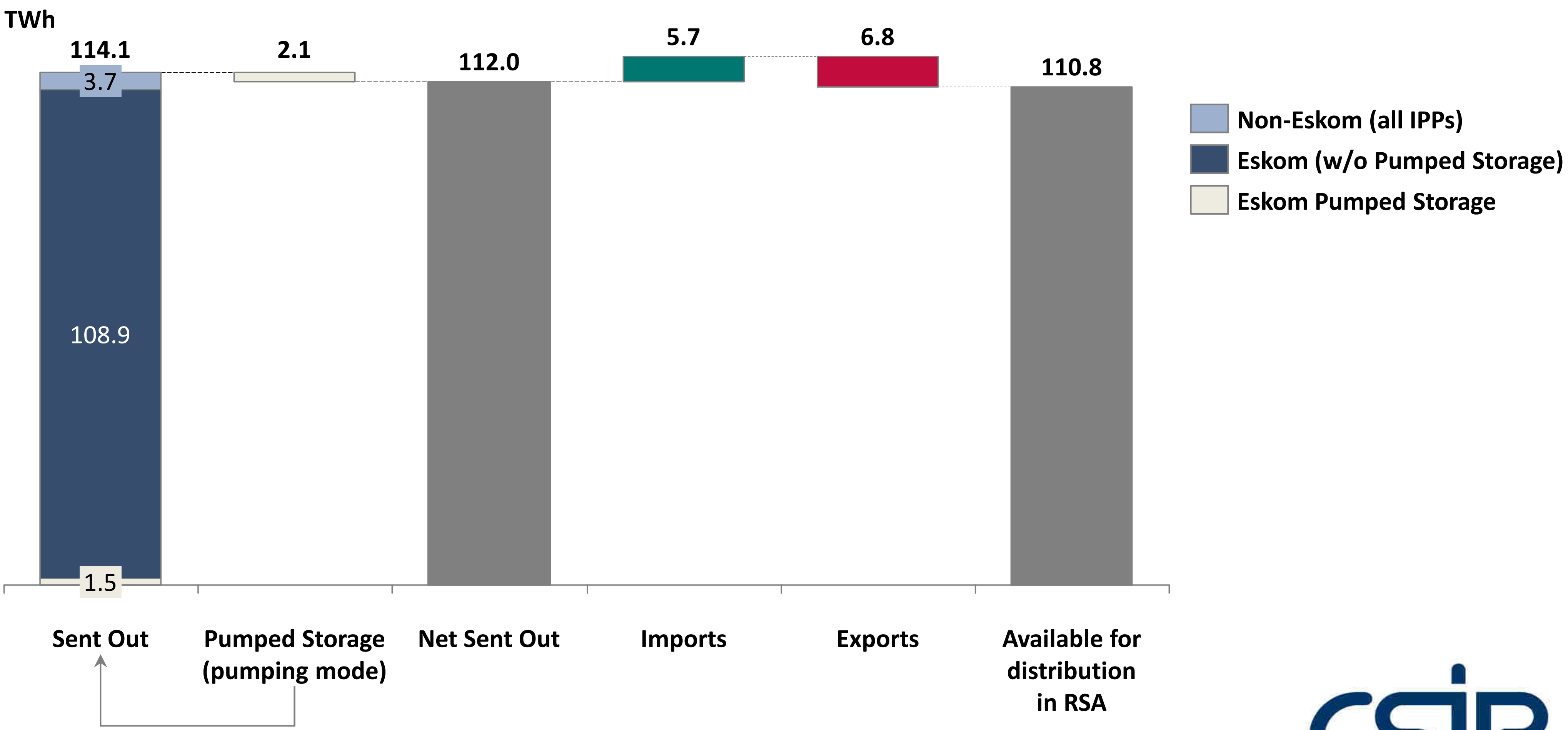
Today, Eskom is the main supplier of electricity in South Africa

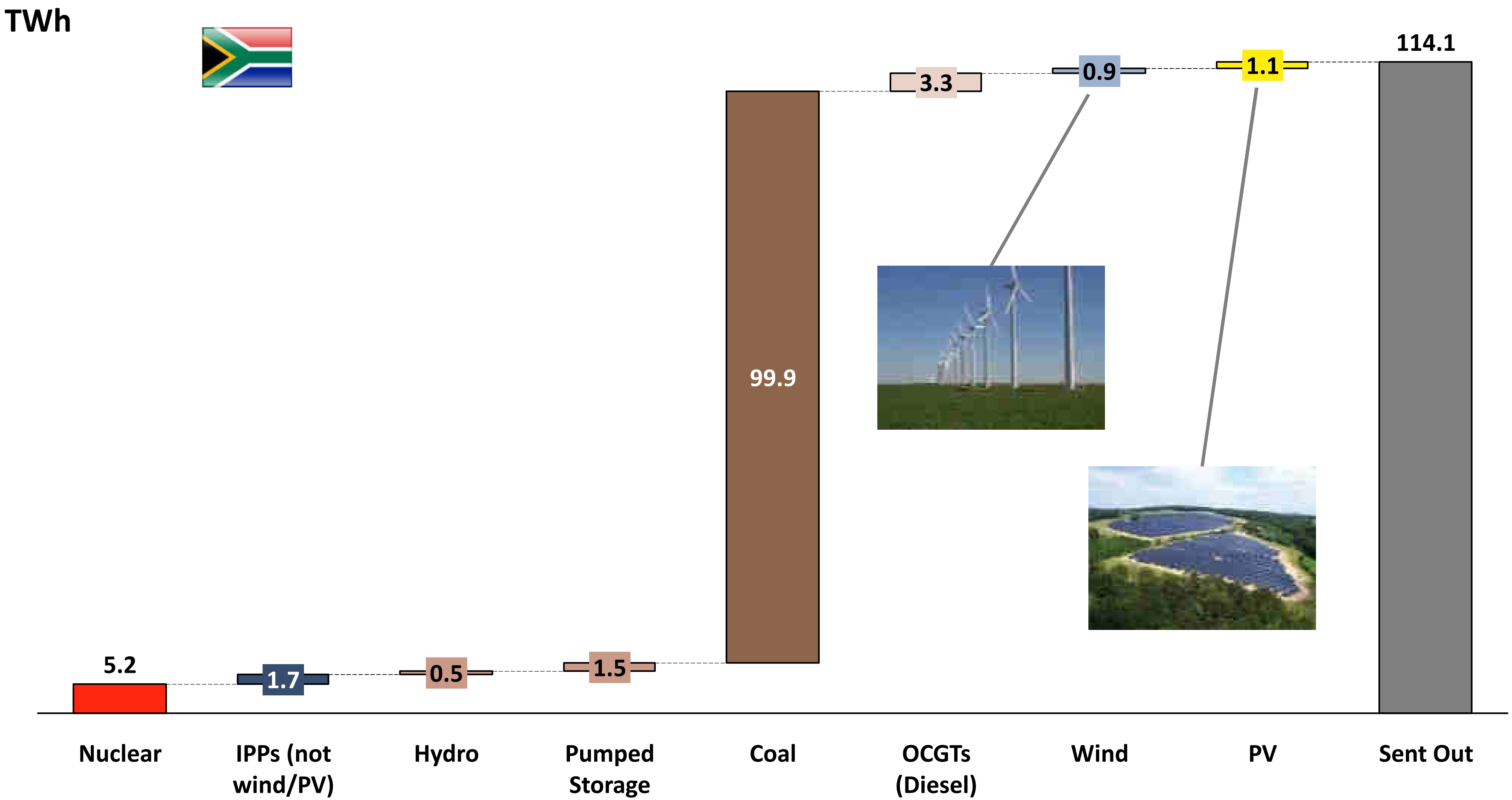
Actuals captured in wholesale market for Jan-Jun 2015 (i.e. without self-consumption of embedded plants)



Sources: Eskom; Statistics South Africa for exports; CSIR Energy Centre analysis

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

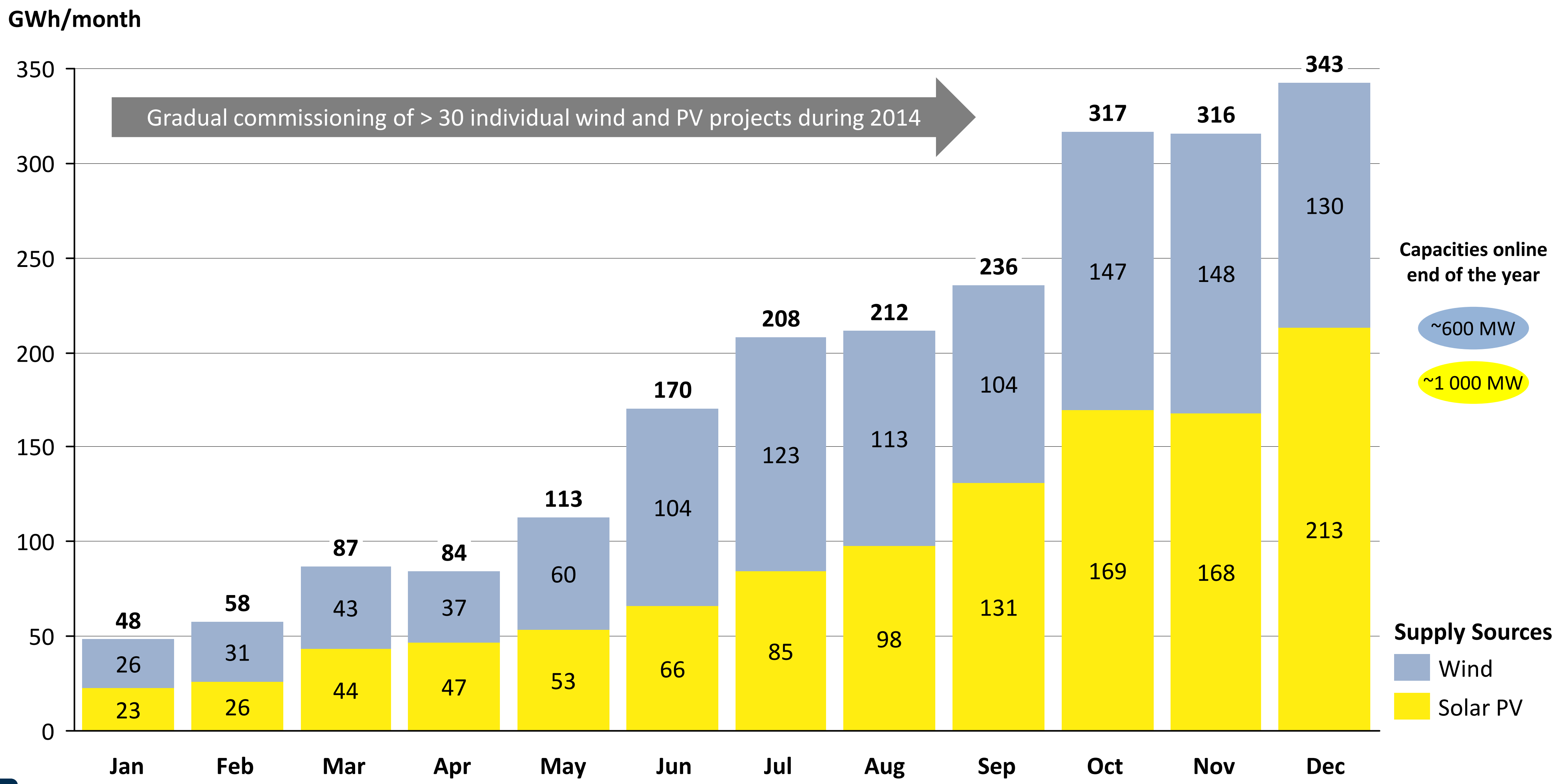
Actual energy captured in South African wholesale market (i.e. without embedded plants' self-consumption)



Sources: Eskom; CSIR Energy Centre analysis

Ramping up of first wind and PV capacities started in 2014

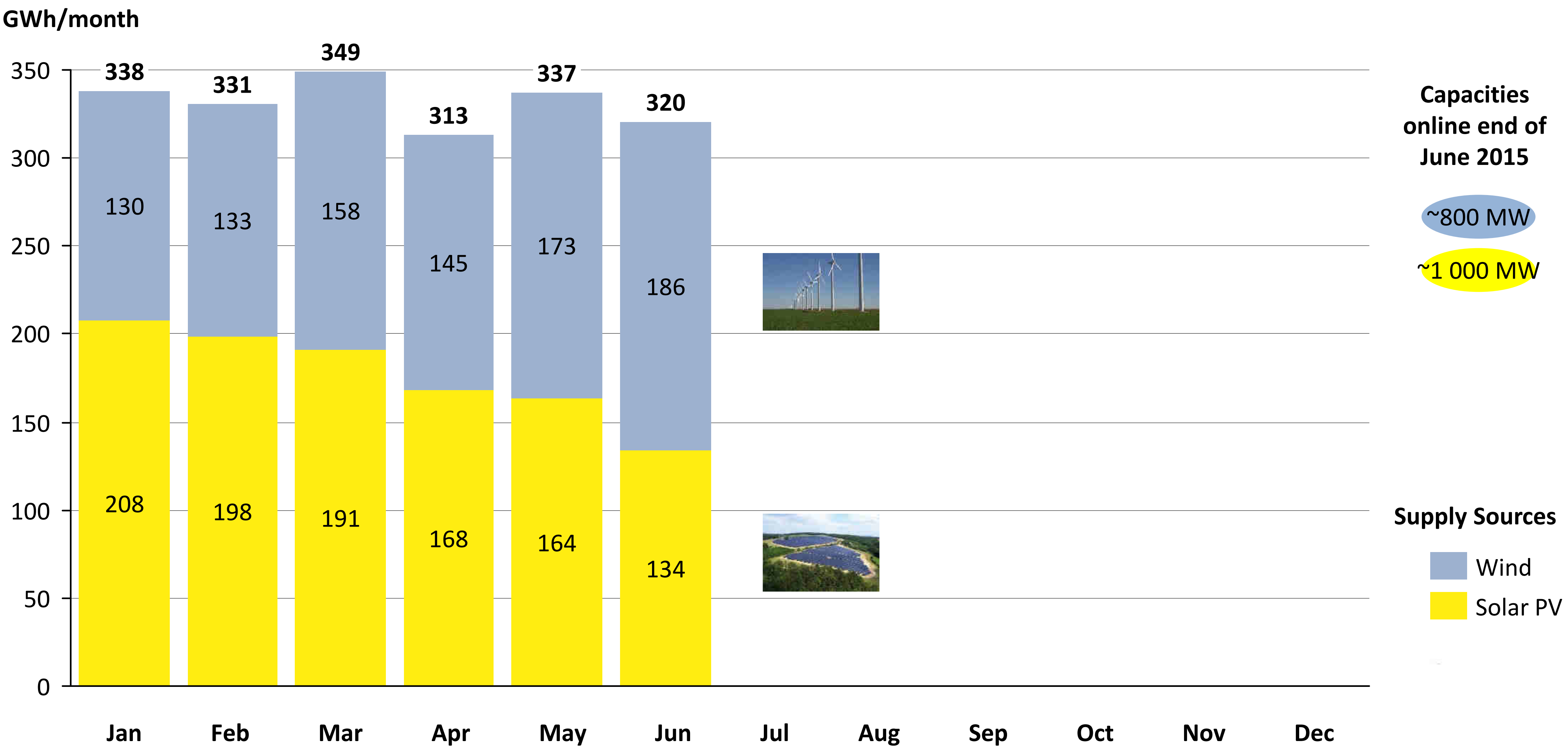
Actual monthly production from large-scale PV and wind plants under the REIPPPP in South Africa in 2014



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

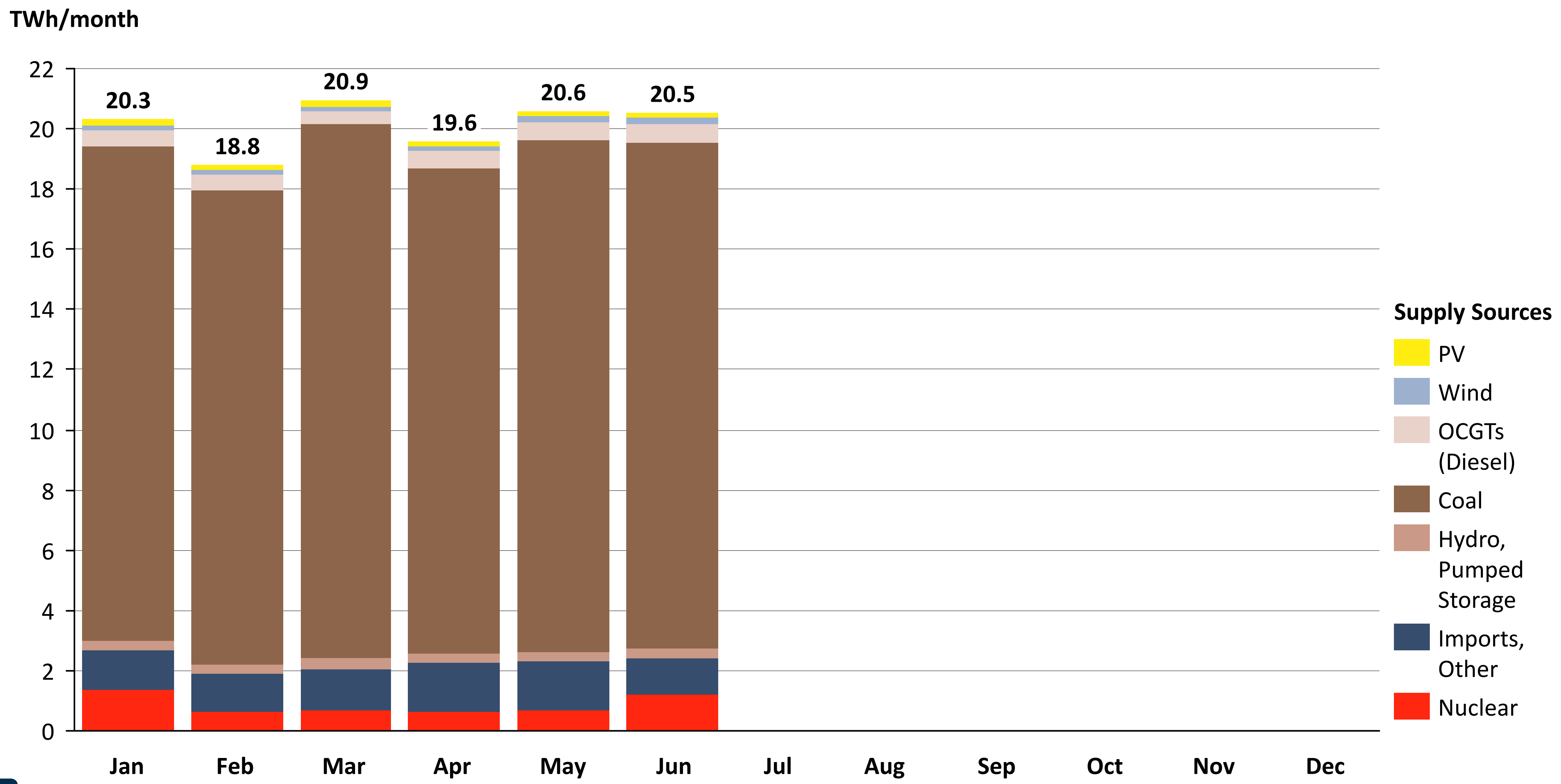


Note: Wind generation excludes Eskom's 100 MW Sere wind farm which came online in 2014 and was fully commissioned by 31 March 2015

Sources: Eskom; CSIR Energy Centre analysis

Total electricity produced in 2015 was between 18-21 TWh/month

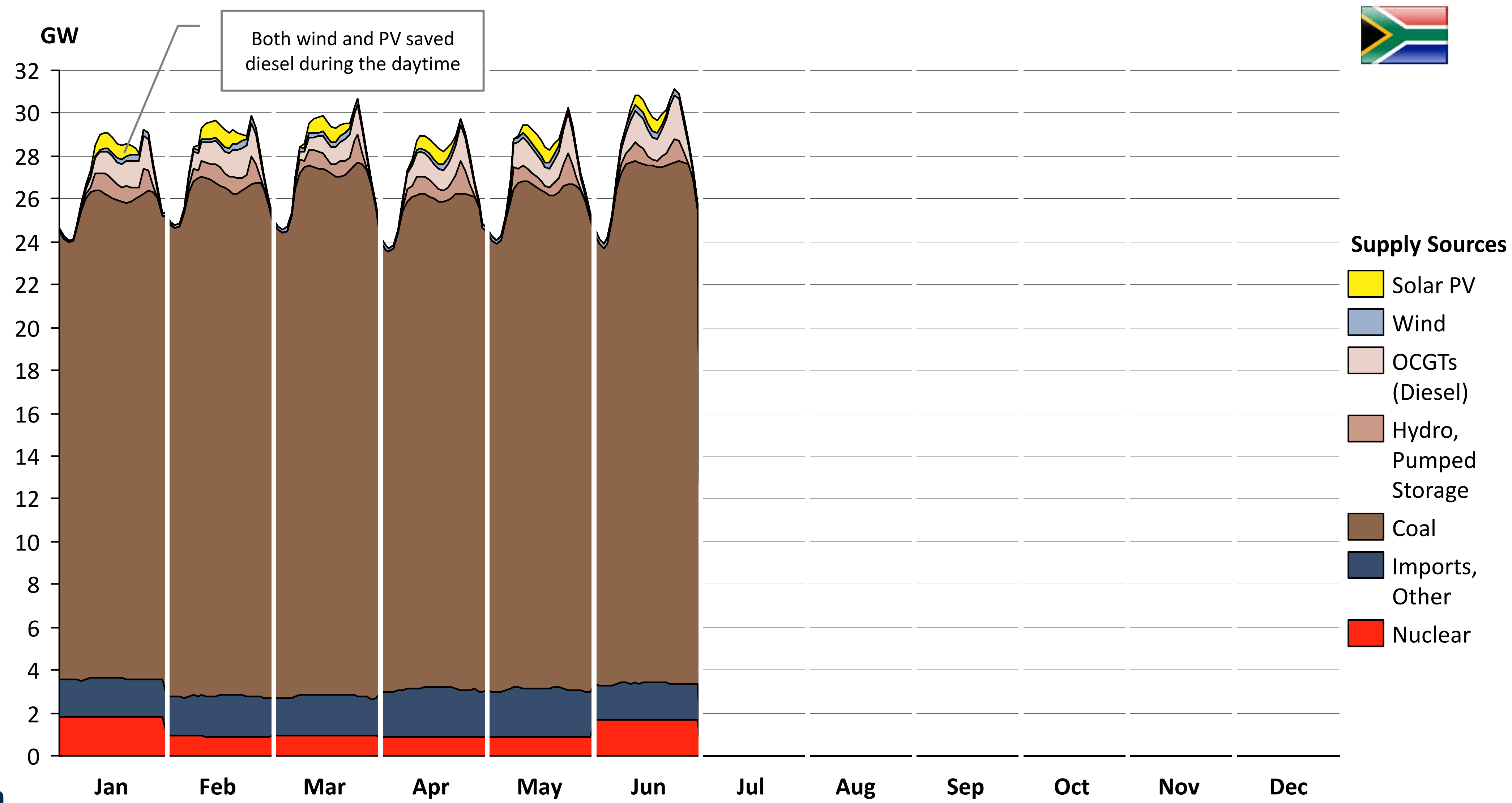
Actual monthly electricity production Jan-Jun 2015 from the different supply sources in RSA



Sources: Eskom; CSIR Energy Centre analysis

From Jan-Jun 2015, diesel 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

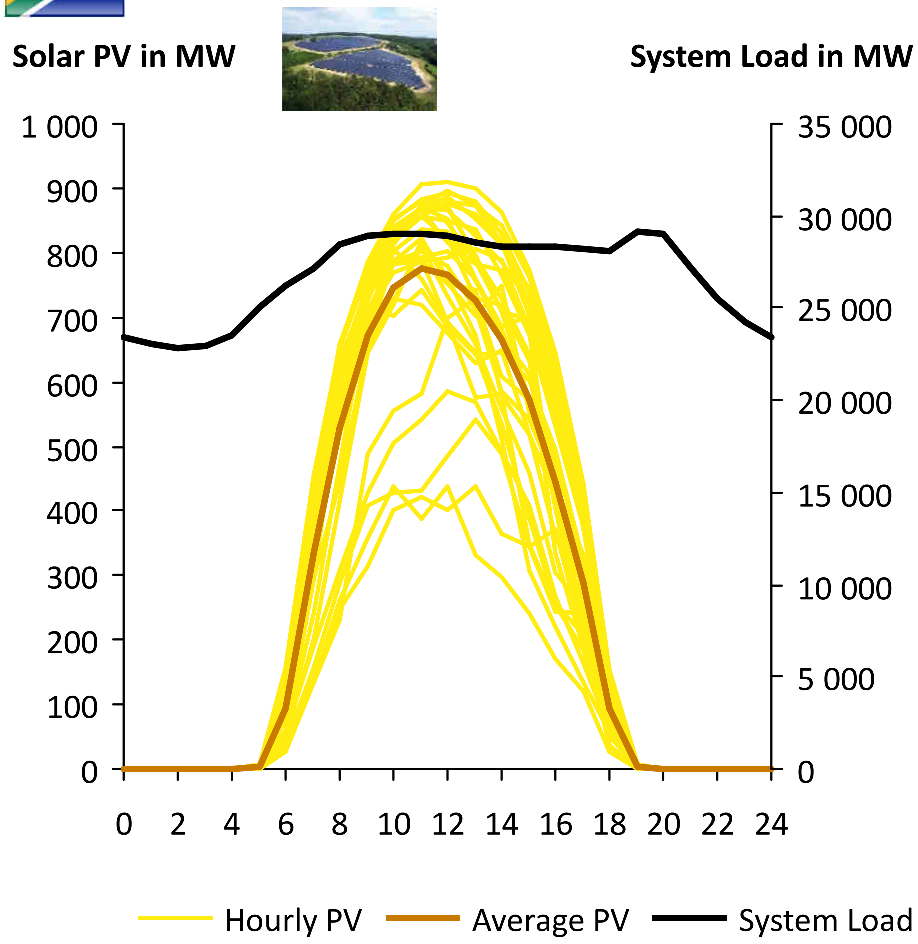


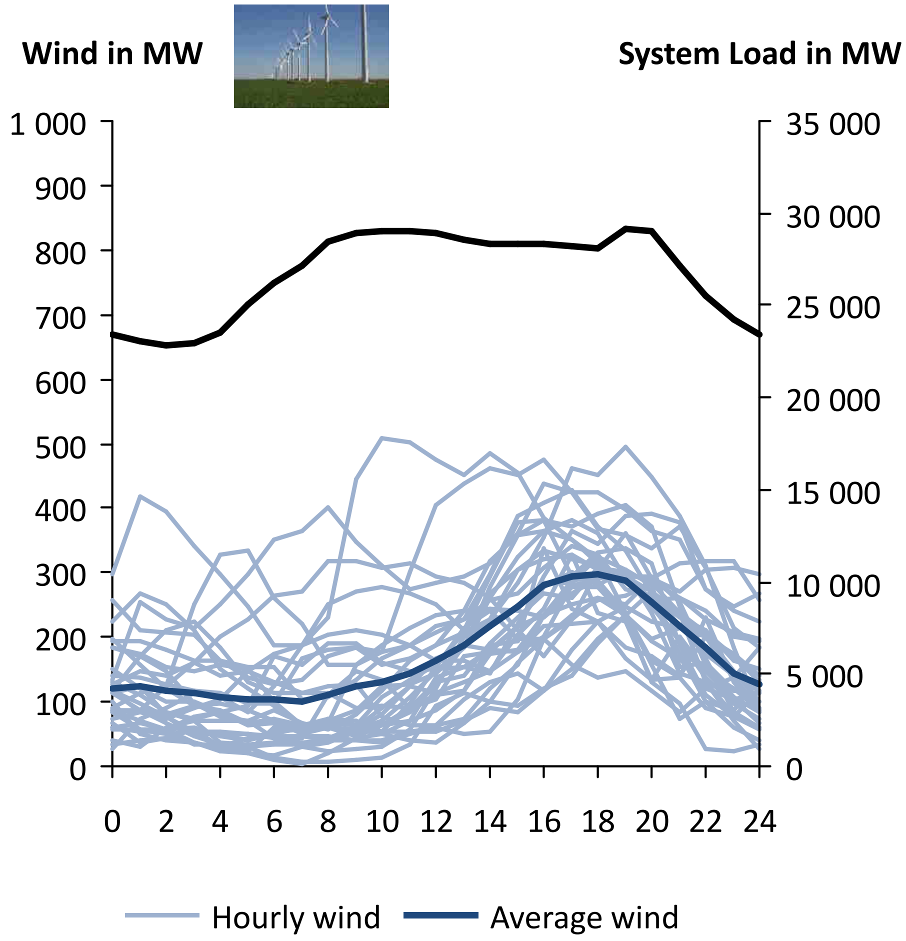
Note: Design as per Fraunhofer ISE

Sources: Eskom; CSIR Energy Centre analysis

PV supply in January 2015 was very stable, wind supplied in evenings

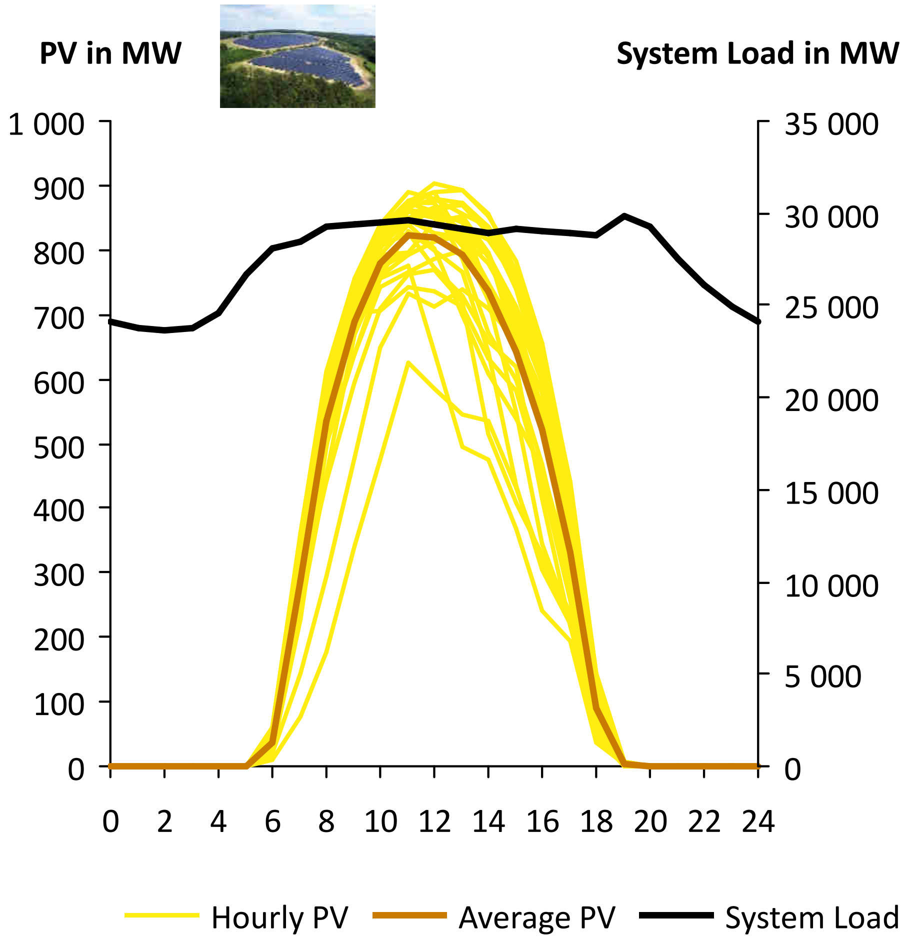
Hourly PV and wind production profiles for all 31 days of January 2015 & average system load diurnal course

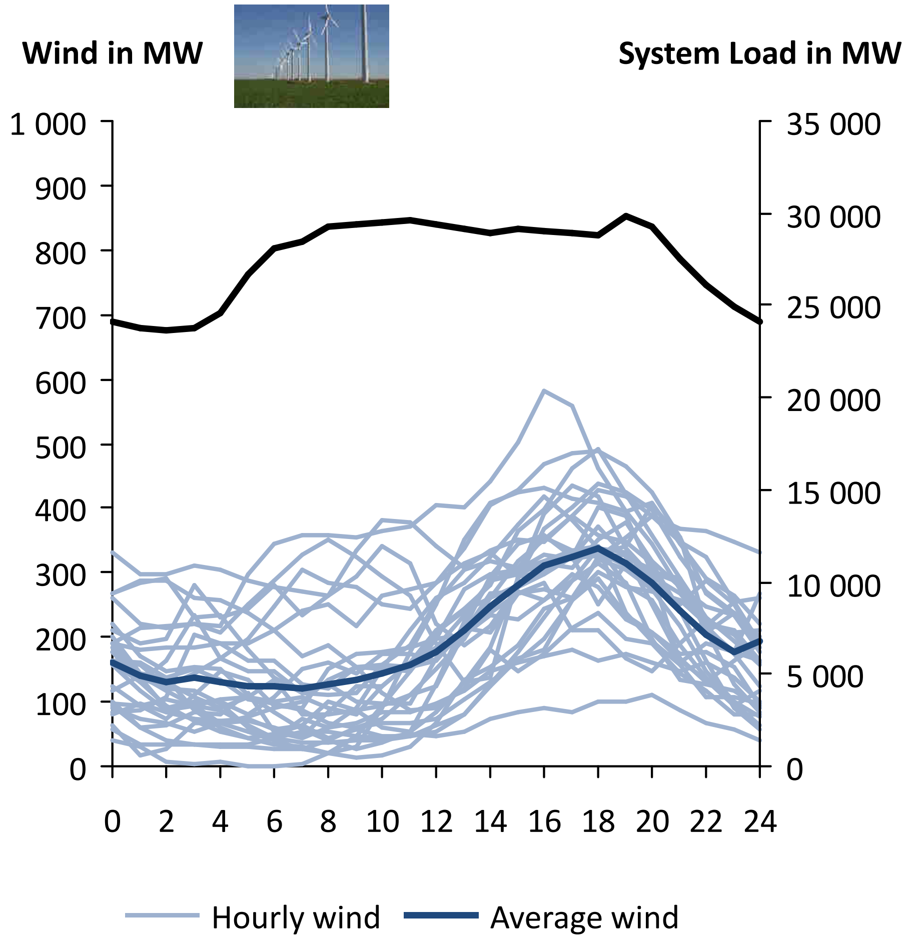




PV supply in February 2015 was very stable, wind supplied evenings

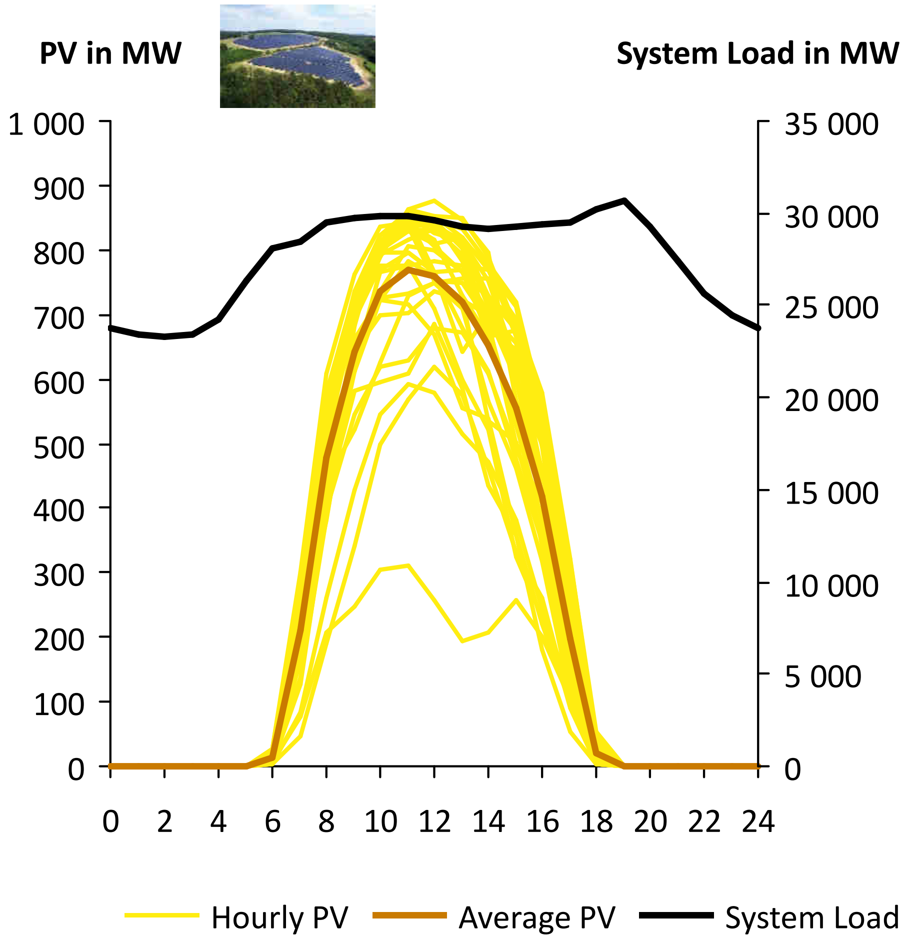
Hourly PV & wind production profiles for all 28 days of February 2015 & average system load diurnal course

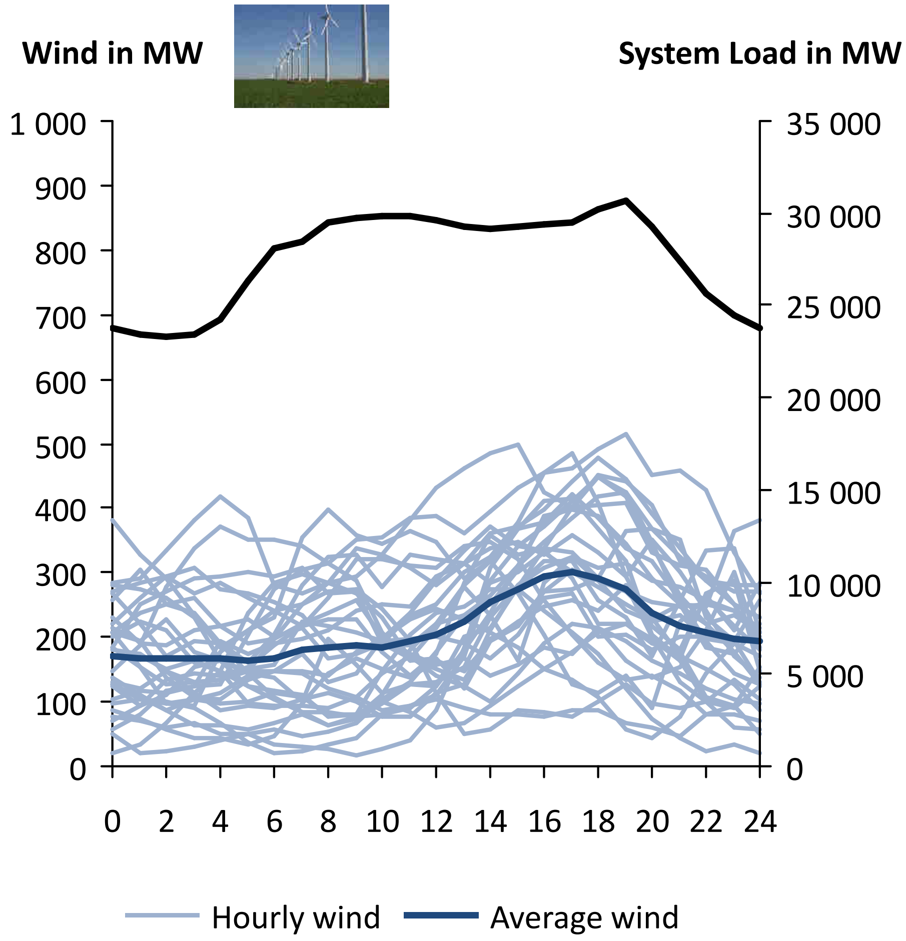




PV supply in March 2015 was very stable, wind fluctuated day-to-day

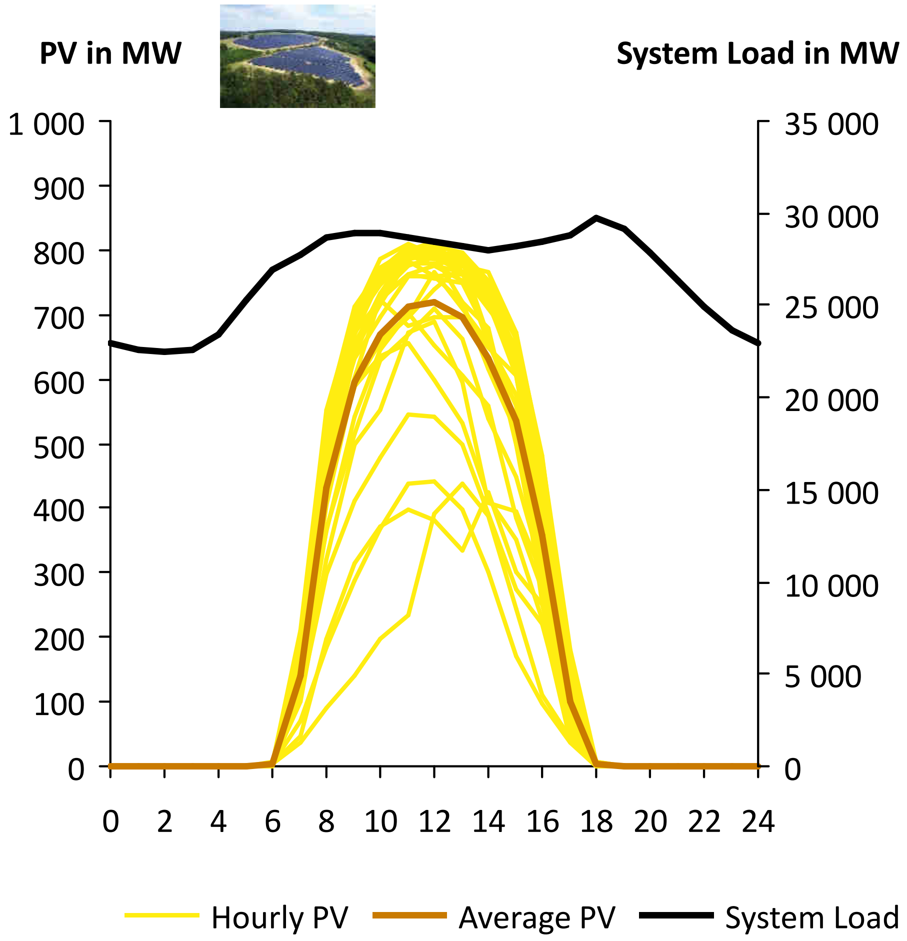
Hourly PV and wind production profiles for all 31 days of March 2015 and average system load diurnal course

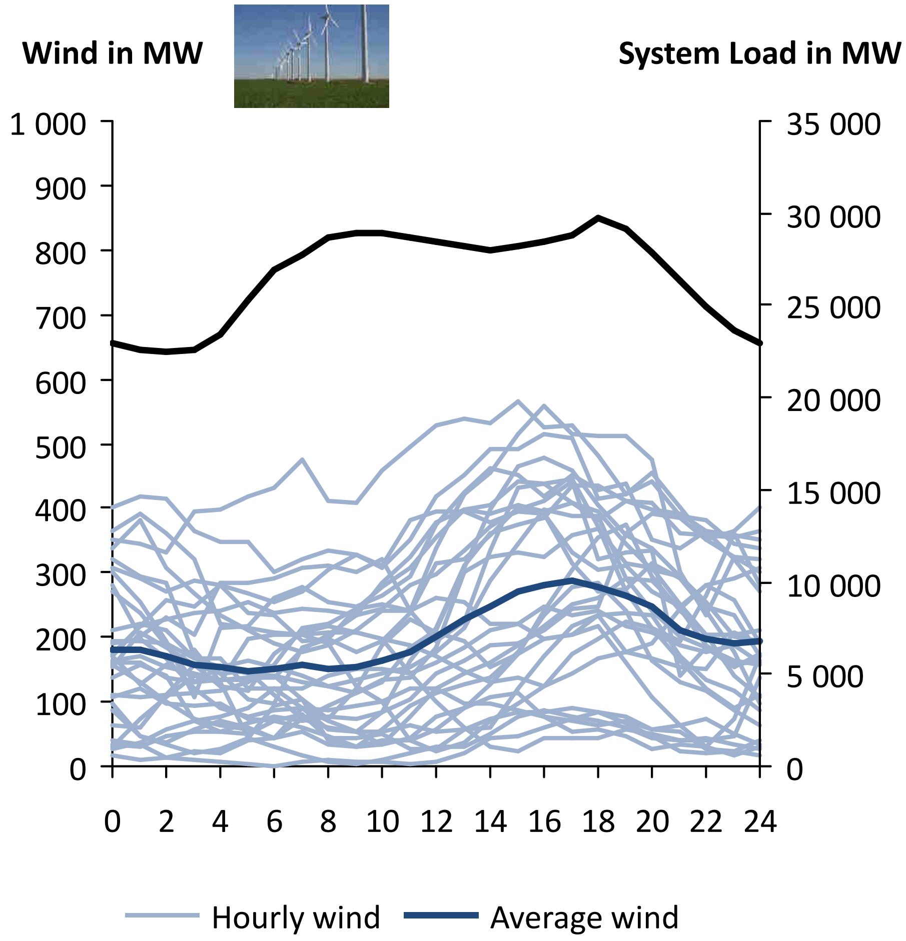




PV supply in April 2015 was very stable, wind fluctuated day-to-day

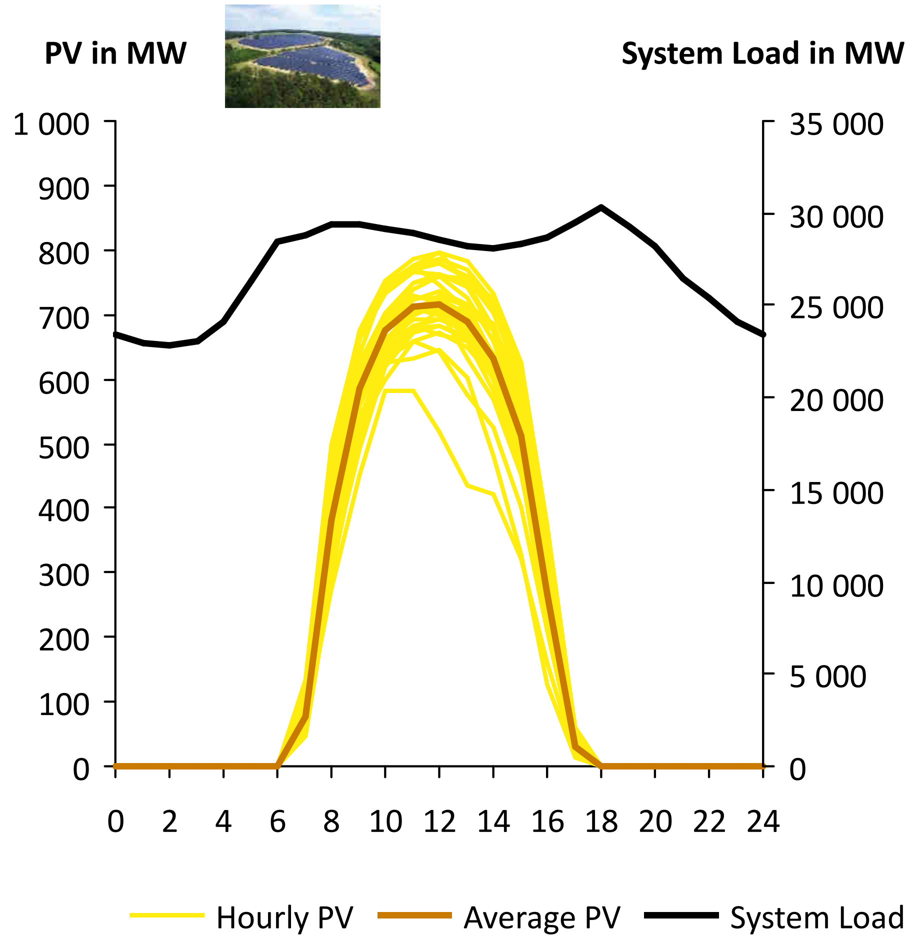
Hourly PV and wind production profiles for all 30 days of April 2015 and average system load diurnal course

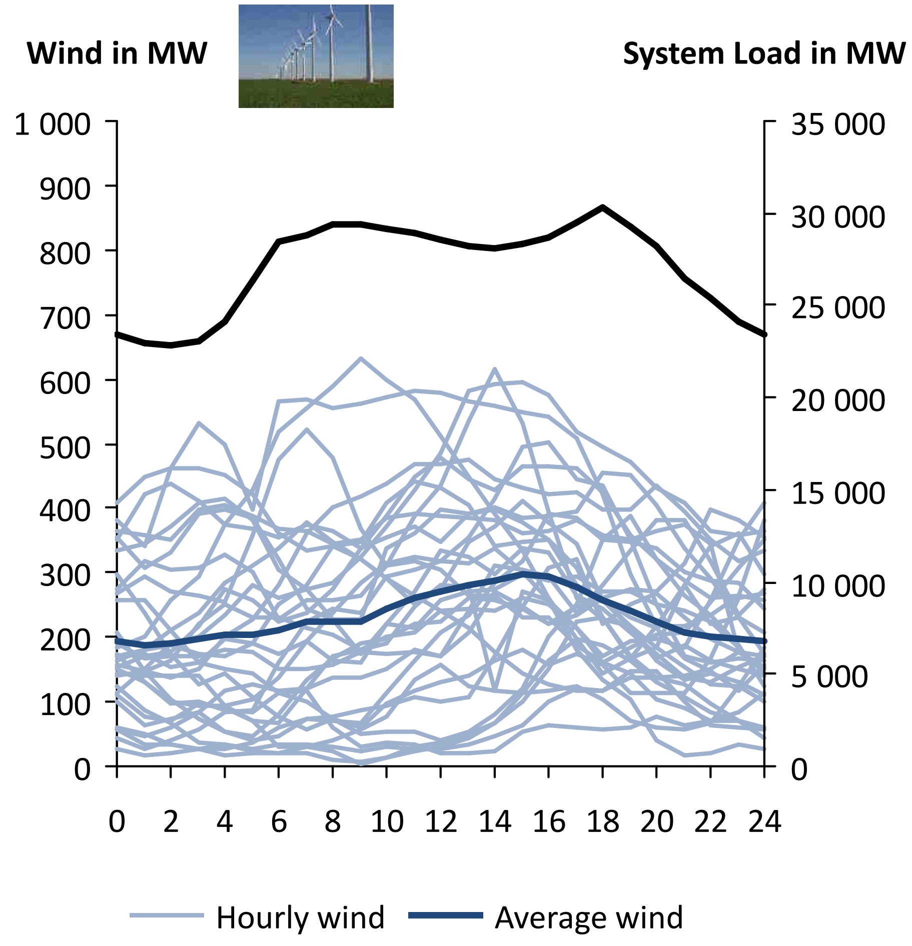




PV supply in May 2015 was very stable, wind fluctuated day-to-day

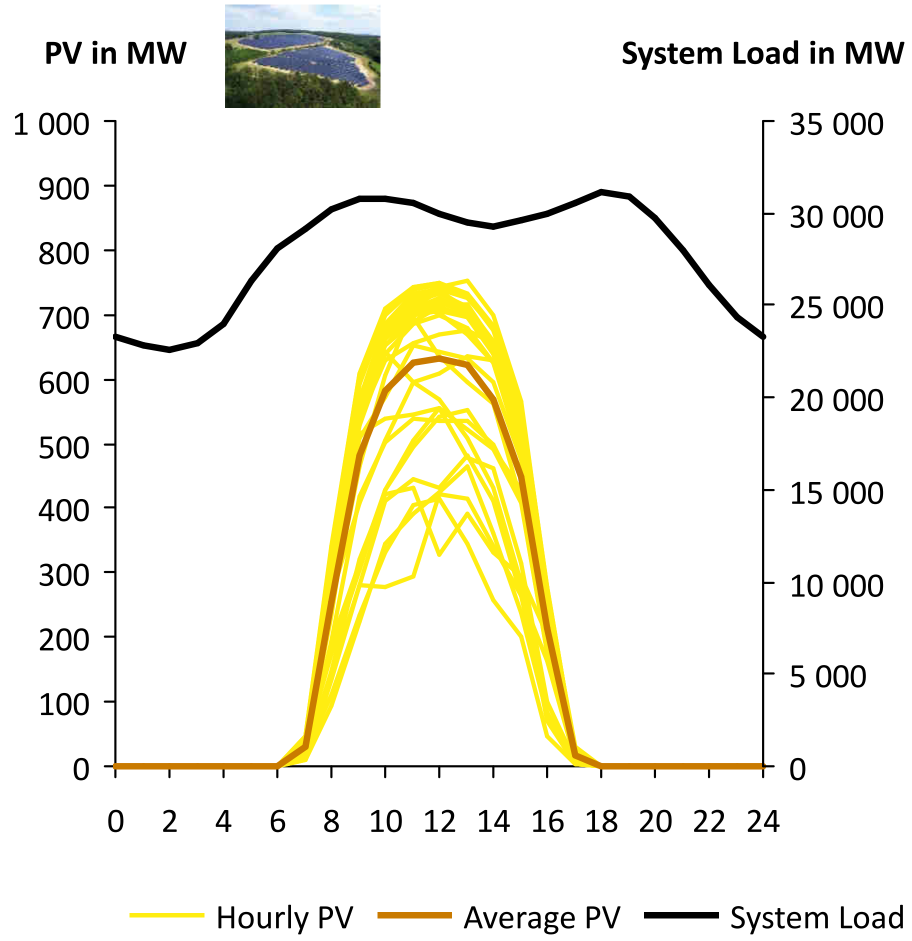
Hourly PV and wind production profiles for all 31 days of May 2015 and average system load diurnal course

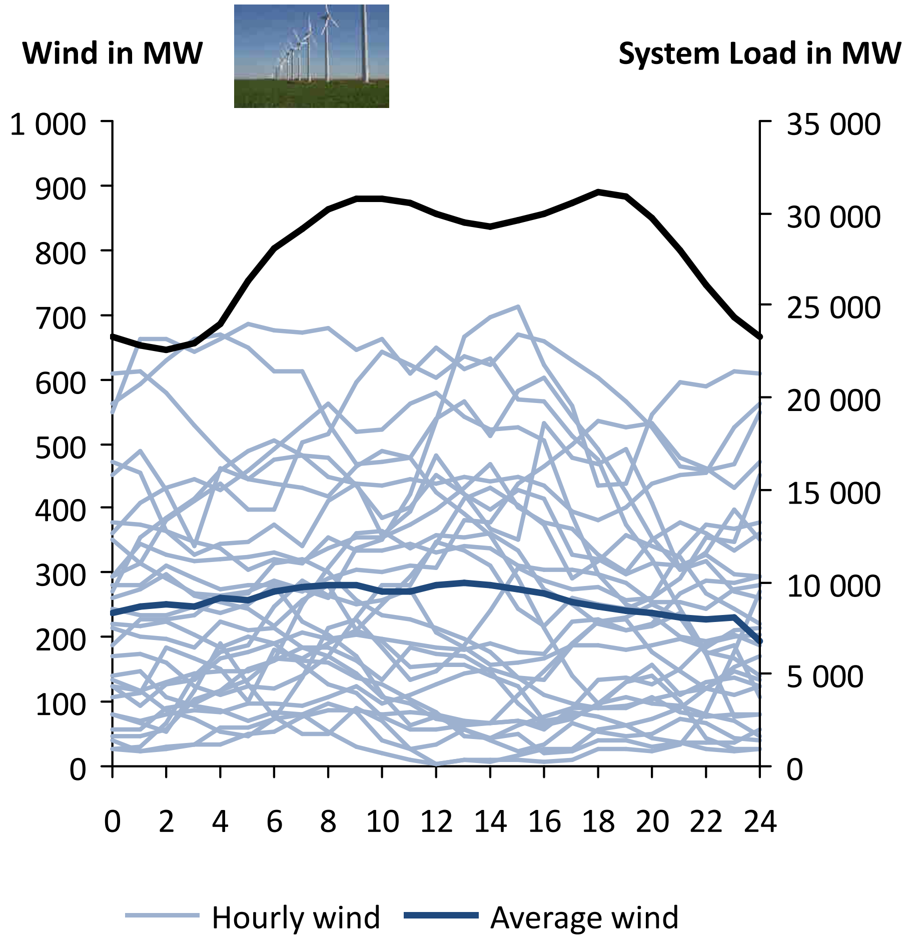




PV supply in June 2015 was very stable, wind fluctuated day-to-day

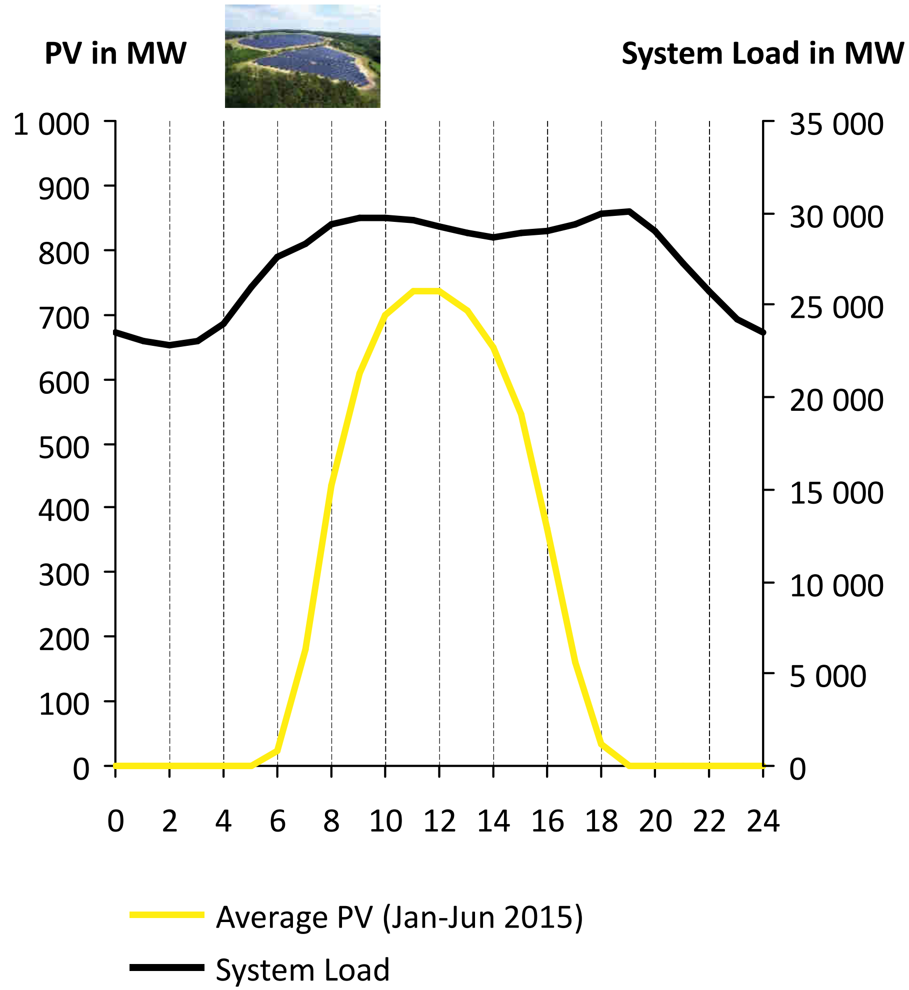
Hourly PV and wind production profiles for all 30 days of June 2015 and average system load diurnal course

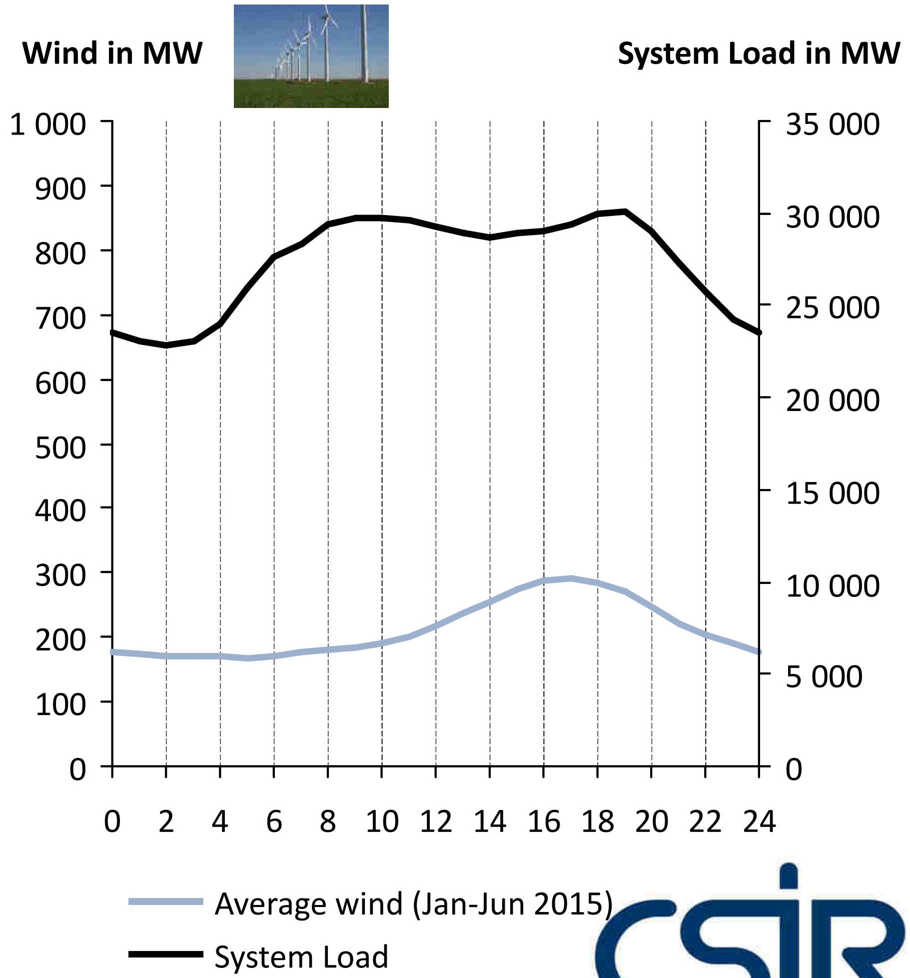




On average from Jan-Jun 2015, wind supply picked up in the evenings

Average diurnal courses for PV/wind production and for the system load for all 181 days from Jan-June 2015





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Load shedding occurred on 82 of the 181 days from January to June 2015

82 days, 709 hours of load shedding

Approx. 1 095 GWh of unserved energy

B

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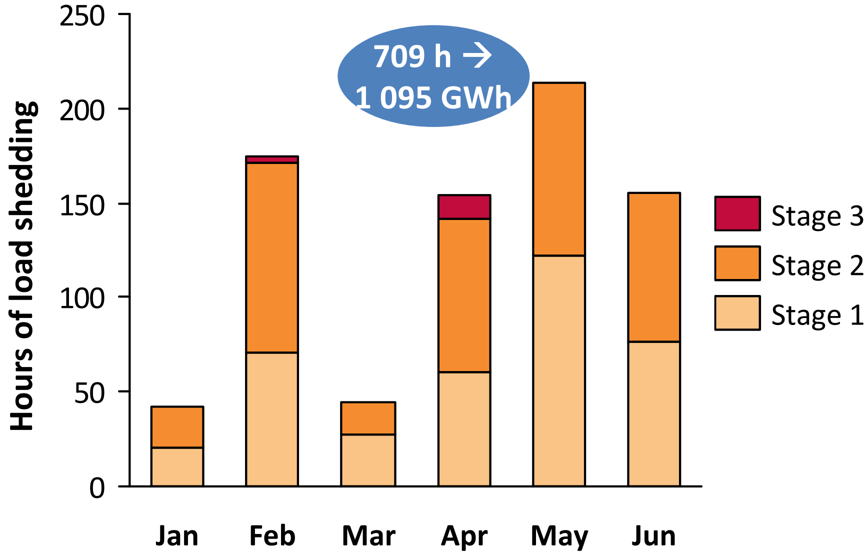
- CSIR-Methodology still applies in hours where actual load shedding occurs
- The System Operator continues to adjust the OCGT output within these hours to balance the system
- PV & Wind can save diesel or avoid more unserved energy



Total unserved energy due to load shedding for all hours per month Jan-Jun 2015 in GWh

Hour of the day -->

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
Jan	0	0	0	0	0	0	0	0	0	0	3	5	5	5	5	5	5	5	5	5	5	5	0	0	58
Feb	0	0	0	0	0	0	0	0	12	12	15	15	17	17	18	18	22	23	25	24	23	23	5	0	269
Mar	0	0	0	0	0	0	0	0	0	2	2	2	4	4	4	4	6	6	6	6	6	5	0	0	57
Apr	0	0	0	0	0	0	5	5	7	7	12	12	12	12	12	12	16	23	26	26	24	24	0	0	235
May	0	0	0	0	0	0	1	4	9	9	10	10	11	11	12	12	20	34	34	34	32	30	0	0	273
Jun	0	0	0	0	0	0	1	1	4	4	5	5	5	5	5	6	16	27	29	30	30	30	0	0	203
Total	0	0	0	0	0	0	7	10	32	34	47	49	54	54	56	57	85	118	125	125	120	117	5	0	1 095

The system is clearly constrained from morning to evening peak

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented, in reality 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

Sources: Eskom Twitter account; CSIR Energy Centre analysis

Hourly distribution of actual load shedding from January to June 2015

Notes: Load shedding assumed to have taken place for the full hours in which it was implemented, in reality 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

Sources: Eskom Twitter account; CSIR Energy Centre analysis

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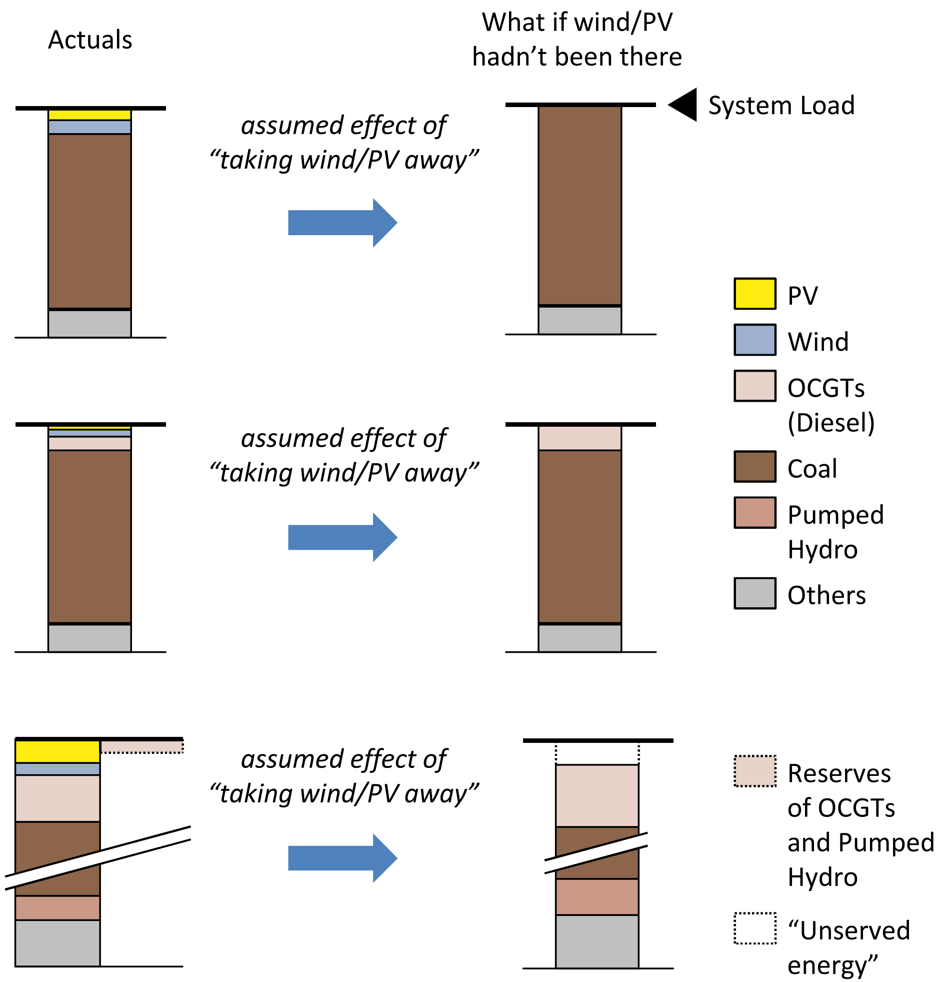
CSIR-defined methodology:
In any hour, wind/PV can have one of three effects on the existing fleet

	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)

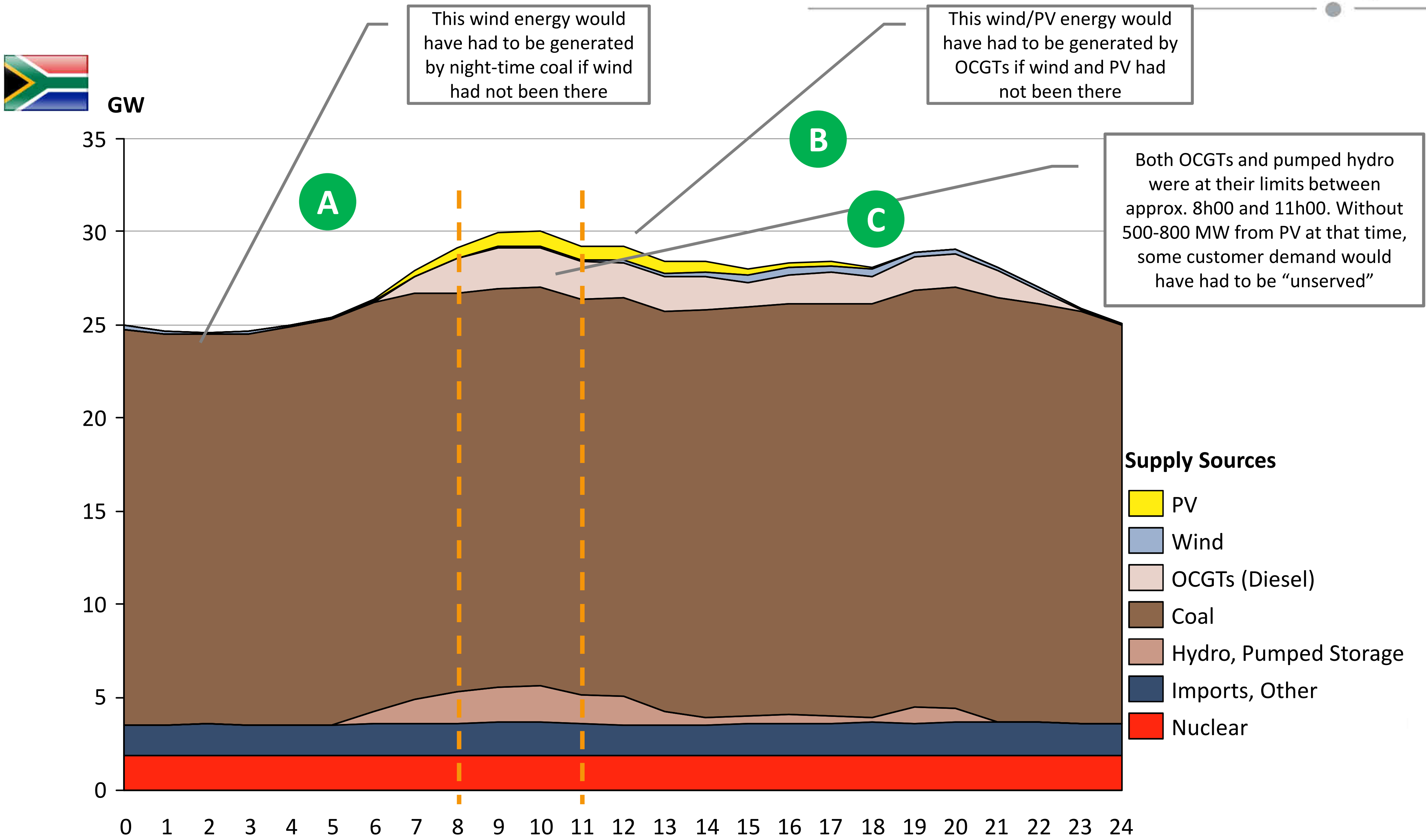
Snapshot of supply structure in a particular hour



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

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

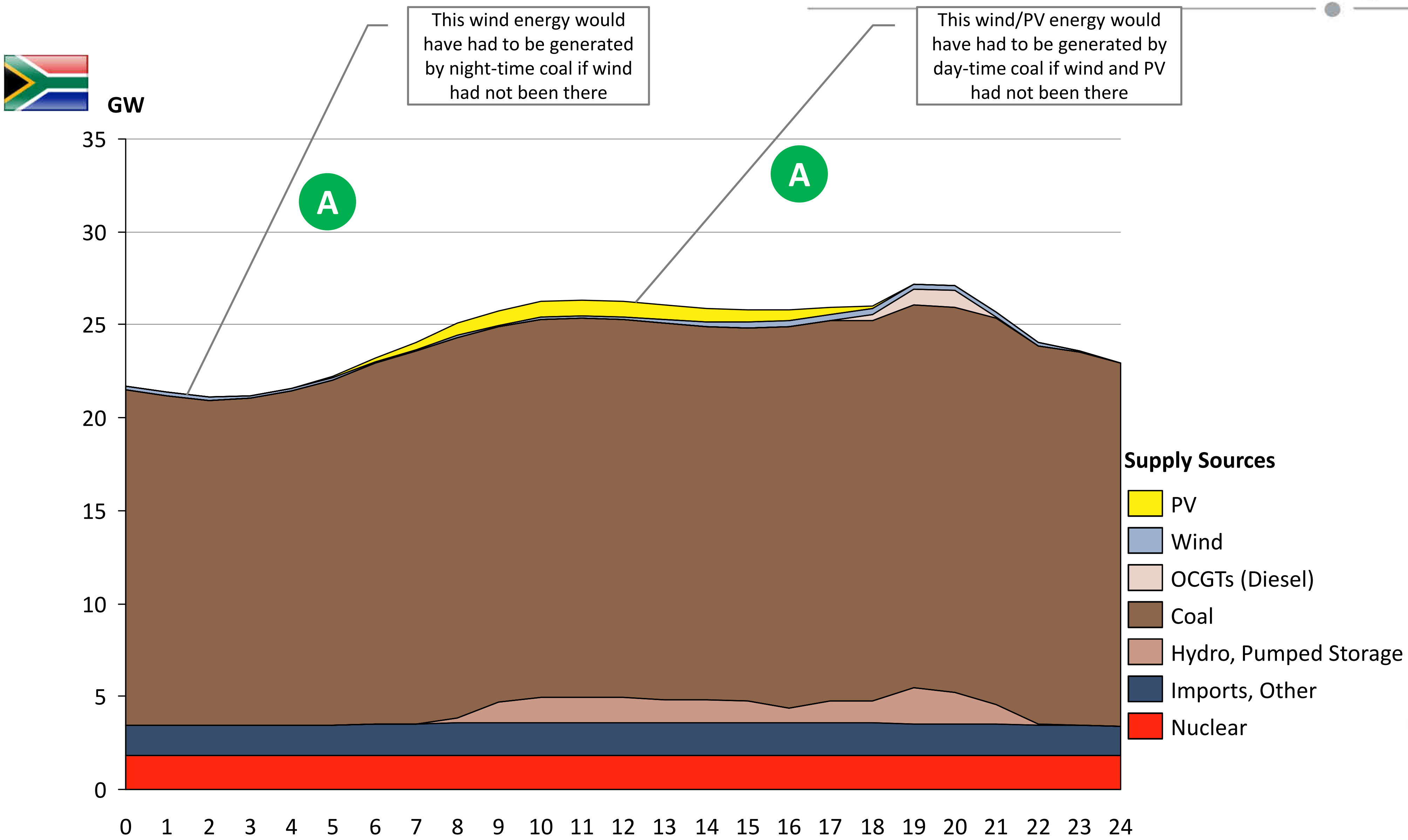
Actual South African supply structure for a summer day, the 9 January 2015 (Friday)



Sources: Eskom; CSIR Energy Centre analysis

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

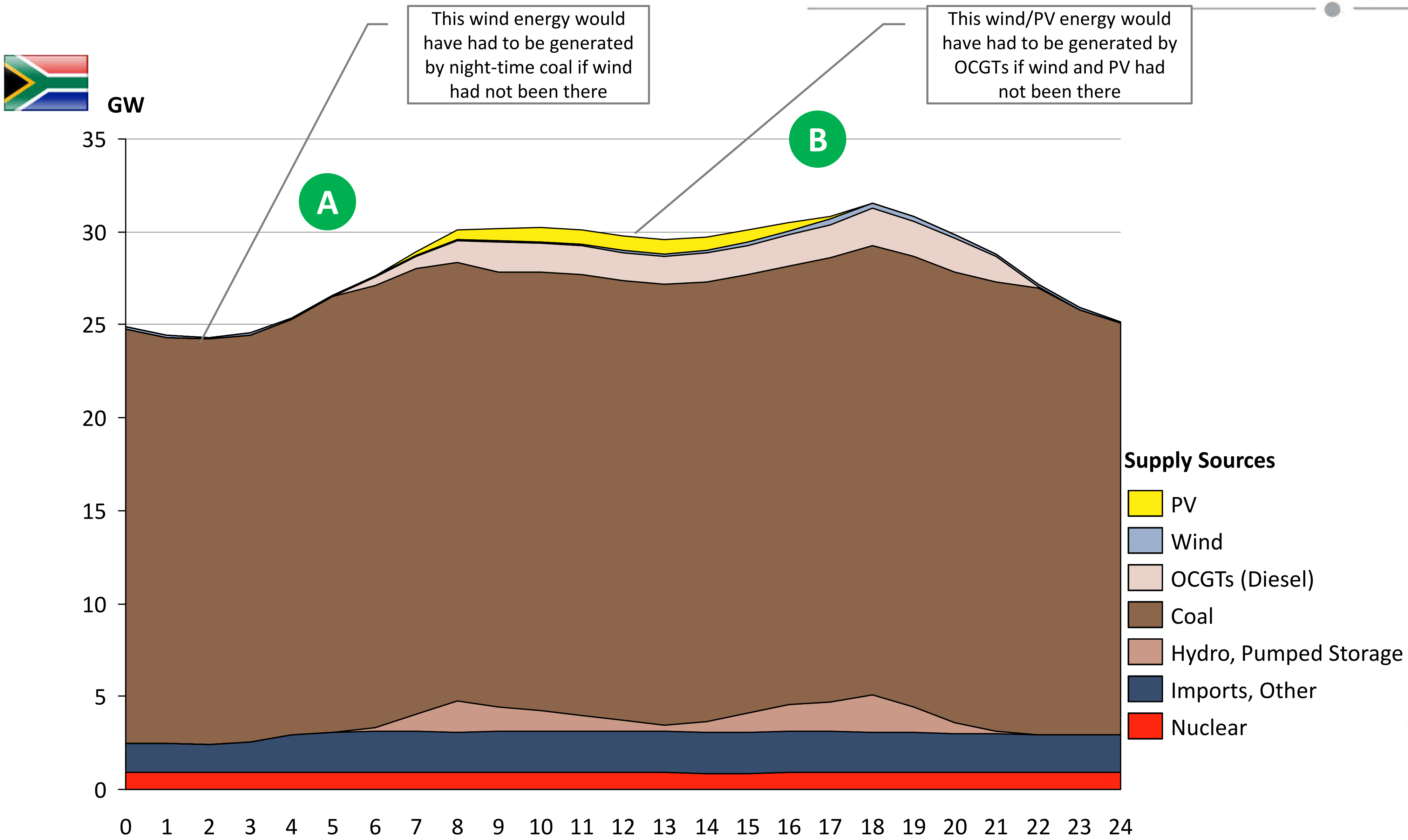
Actual South African supply structure for a summer day, 2 January 2015 (Friday)



Sources: Eskom; CSIR Energy Centre analysis

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

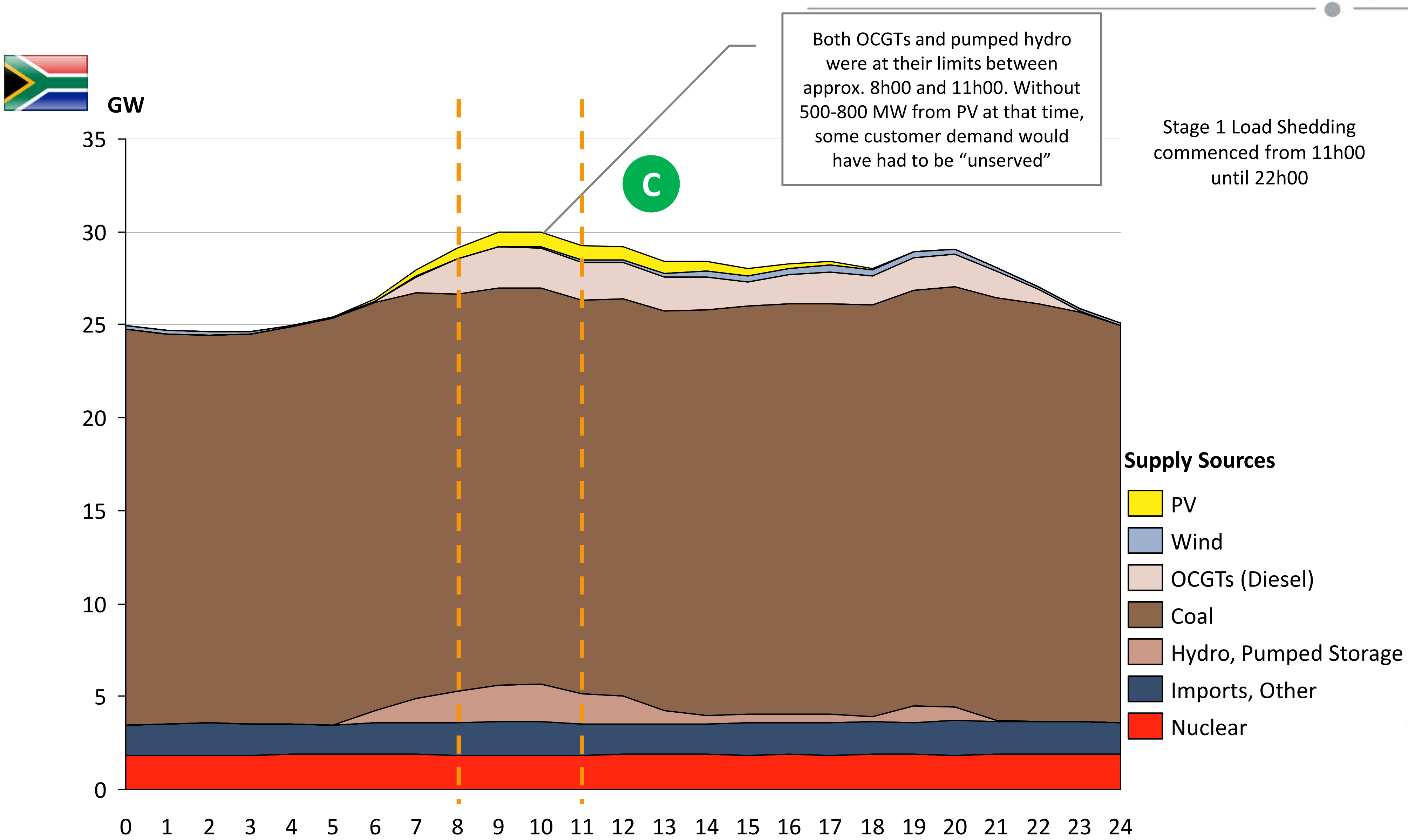
Actual South African supply structure for an autumn day, 9 April 2015 (Thursday)



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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Renewables replaced 0.5 TWh from coal and 1.5 TWh from diesel

Coal/diesel replacement in GWh for Jan-Jun 2015 due to electricity generated from wind and PV

Results for Jan-Jun 2015 from applying CSIR-defined methodology on actual hourly production data

in GWh	A ... electricity from coal	B ... electricity from diesel	C ... unserved energy	**Total**
Wind replaced/ avoided...	305	603	17	**925**
PV replaced/ avoided...	176	852	35	**1 063**
Total	**481**	**1 455**	**52**	**1 988**

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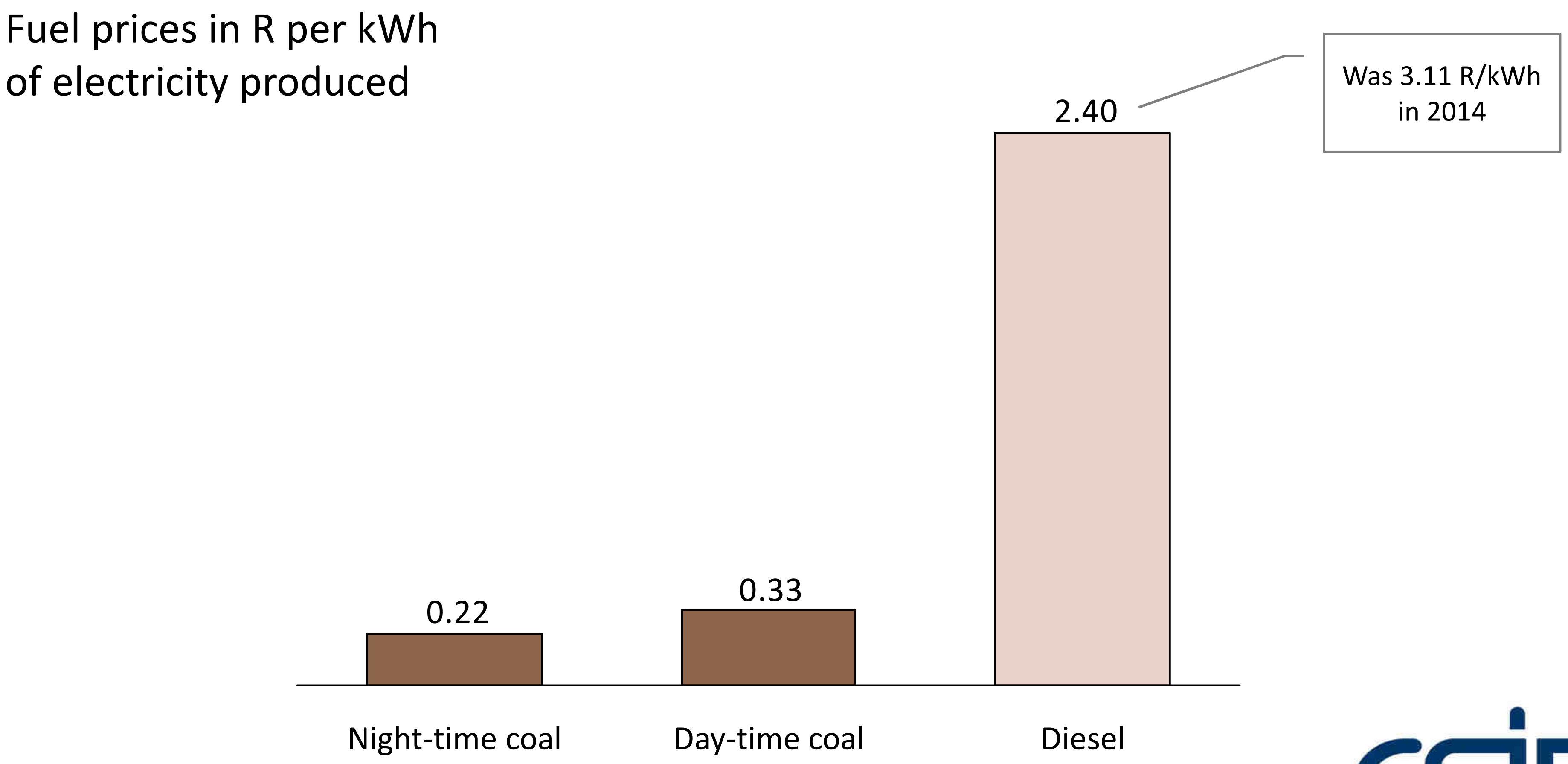
Notes: Inidividual values are rounded and might not add up to the total values

Sources: CSIR Energy Centre analysis

Diesel fuel price significantly decreased from 2014 to 2015



Sources: Eskom; CSIR Energy Centre analysis

Cost of Unserved Energy (COUE) assumed to be 90 R/kWh as per IRP

The "cost of unserved energy" is a macroeconomic cost per kWh to the entire South African economy of not being able to serve customers' electricity demand

The Integrated Resource Plan (IRP) assumes a COUE of 90 R/kWh in Apr-2015-Rand

In March 2015, Eskom submitted a COUE methodology using the "macroeconomic method" to NERSA

- This method uses public macroeconomic data such as gross domestic product (GDP), gross value added (GVA), and household expenditure measures
- The macroeconomic indicators are divided by total electricity usage to estimate cost of interruption
- The economic COUE is expressed both as direct and total impact on the economy

Eskom's study is currently under review, it calculated the national direct and total economic COUE for 2013

- Direct COUE value of **21.63 R GVA/kWh**
- Total COUE value of **77.30 R GVA/kWh**

Escalated to Apr-2015-Rand

24 R/kWh
85 R/kWh

For the purposes of this study, 90 R/kWh is assumed (IRP), as the Eskom study is still in the public consultation process (total COUE of 85 R/kWh however similar to 90 R/kWh)

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Sources: Eskom; CSIR Energy Centre analysis

Wind and PV generated benefits of R8.3 billion from Jan-Jun 2015

Fuel savings in million Rand in 2015 due to electricity generated from wind and PV (all in Apr-2015-Rand)

Results for Jan-Jun 2015 from multiplying energy values with financial values for coal/diesel and COUE

in million Rand	A ... money spent on coal	B ... money spent on diesel	**Subtotal** (fuel savings)	C Value of avoiding "unserved energy" (@ 90 R/kWh)	**Total** (@ 90 R/kWh)
Wind saved...	77	1 446	**1 523**	1 500	**3 023**
PV saved...	58	2 042	**2 101**	3 134	**5 235**
Total	**135**	**3 488**	**3 624**	**4 635**	**8 258**

Notes: Inidividual values are rounded and might not add up to the total values. Cost of Unserved Energy assumed as 90 R/kWh

Sources: CSIR Energy Centre analysis

This translates into fuel saving per wind/PV energy unit of 1.83 R/kWh

Per energy unit, wind saved fuel to the value of
1.65 R per kWh of wind energy

Per energy unit, PV saved fuel to the value of
1.98 R per kWh of PV energy

Weighted average of
1.83 R per kWh of renewable energy (Apr-2015-Rand) A + B

Sources: CSIR Energy Centre analysis

In addition to the fuel-saving value, wind and PV generated value of up to 2.33 R/kWh from having avoided unserved energy for the economy

Per energy unit, wind avoided unserved energy to the value of
1.62 R per kWh of wind energy

Per energy unit, PV avoided unserved energy to the value of
2.95 R per kWh of PV energy

Weighted average of
2.33 R per kWh of renewable energy (Apr-2015-Rand) C
(2.20 R/kWh @ COUE = 85 R/kWh)
(0.62 R/kWh @ COUE = 24 R/kWh)

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Sources: CSIR Energy Centre analysis

Wind and PV IPP tariff assumptions

Wind

- Assumed that total bid window 1 wind allocation (634 MW) as well as 150 MW from bid window 2 are online
- The average tariff of all online wind projects is calculated as the capacity-weighted average of bid window 1 tariff (procured at 1.14 R/kWh in Apr-2011-Rand) and bid window 2 tariff (procured at 1.01 R/kWh in Apr-2013-Rand)

PV

- Assumed that 960 MW of the PV projects from both bid window 1 and 2 are online
- The average tariff for all online PV projects is calculated as the capacity-weighted average of bid window 1 tariff (procured at 2.76 R/kWh in Apr-2011-Rand) and bid window 2 tariff (procured at 1.85 R/kWh in Apr-2013-Rand)

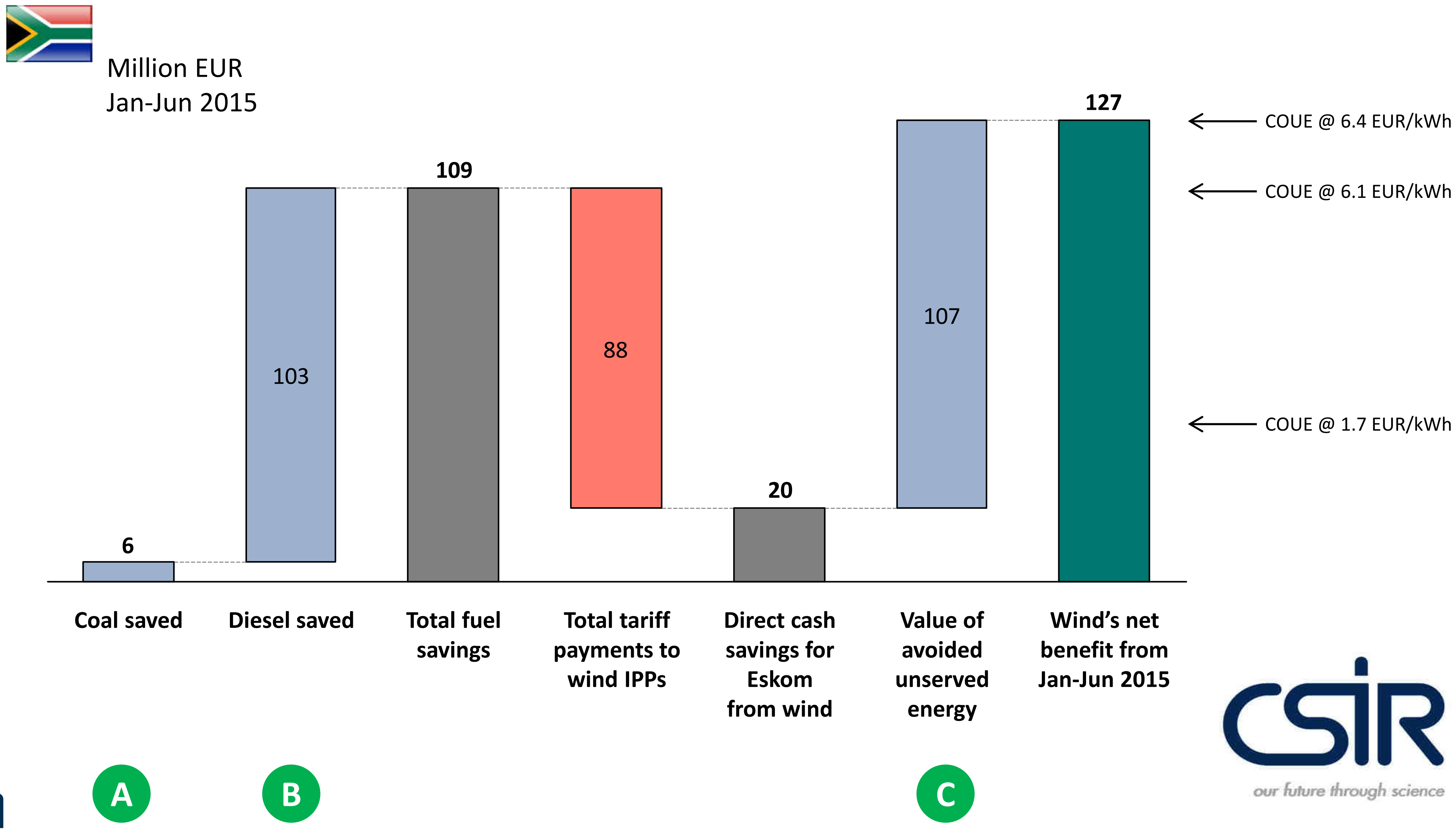
The average wind/PV tariff is then escalated on 1 April 2015 as per the REIPPPP inflationary-adjustment rules

Applicable average tariff in R/kWh[1]	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Jun 2015
Wind	1.31	1.31	1.31	1.37	1.37	1.37
PV	2.82	2.82	2.82	2.95	2.95	2.95

[1] Own calculation; base values inflated as per official Consumer Price Index (CPI) of Statistics South Africa
The tariffs are translated into Apr-2014-Rand for the months Jan – Mar 2015 and translated to Apr-2015-Rand applicable for the months from Apr to Jun 2015. These are the escalation rules of the REIPPPP.

Notes: Exchange rate risk has not been factored in to IPP tariff calculations. All IPP tariff calculations are based on fully indexed tariffs.
Sources: CSIR Energy Centre analysis

In summary (Jan-Jun 2015):
Wind alone was cash positive for Eskom to the tune of EUR20 million



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Notes: COUE = Cost of Unserved Energy   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 CO2 emissions

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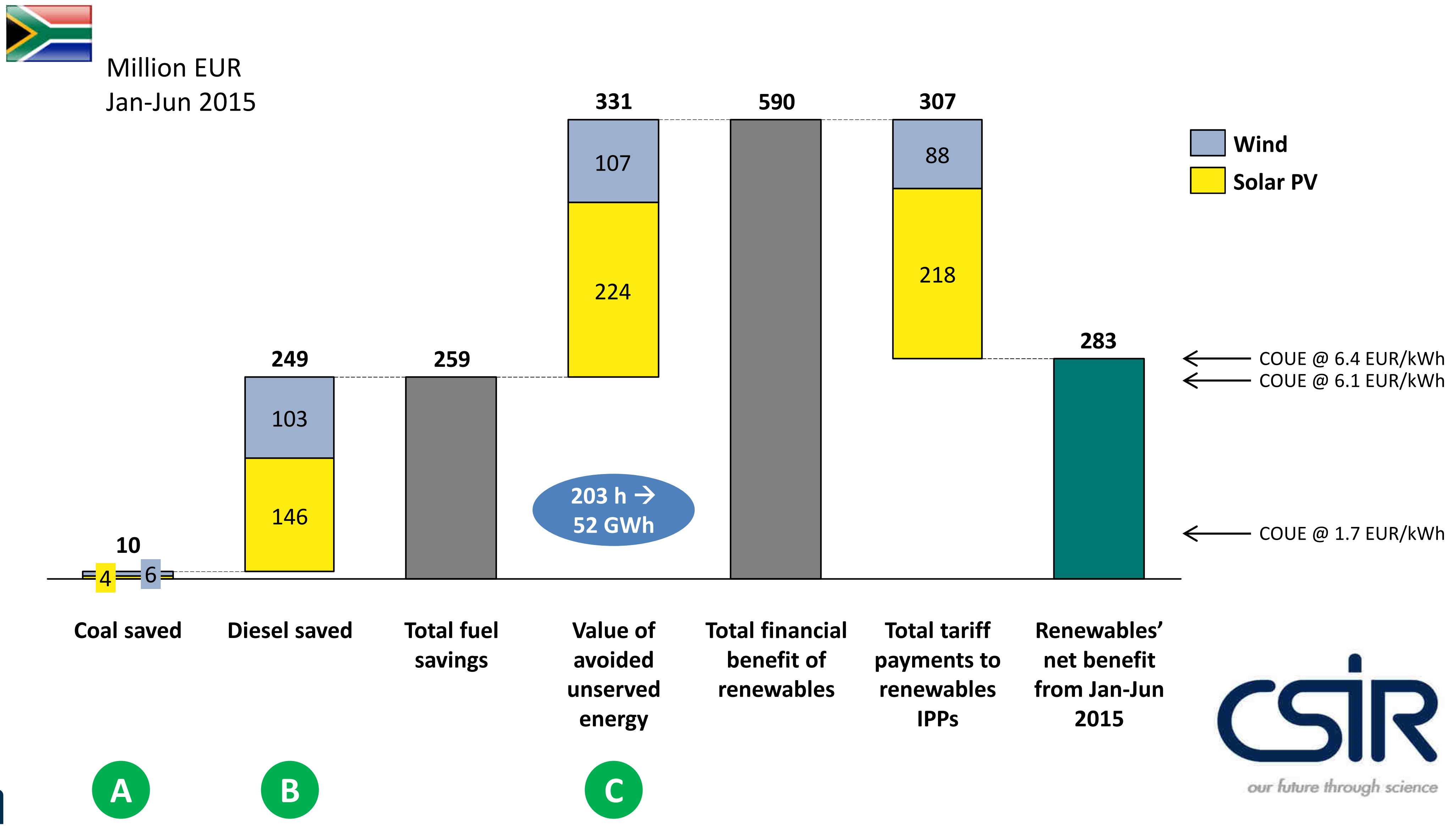
Notes: If on a day avoided unserved energy was greater 1 000 MWh and on that day the avoided unserved energy occurred during at least four consecutive hours, or avoided unserved energy was greater than 1 500 MWh, then on that day either stage 1 load shedding was avoided or an additional stage of load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

In summary (Jan-Jun 2015):
Renewables with net benefit for the economy of up to EUR300 million



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Notes: COUE = Cost of Unserved Energy Sources: CSIR Energy Centre analysis

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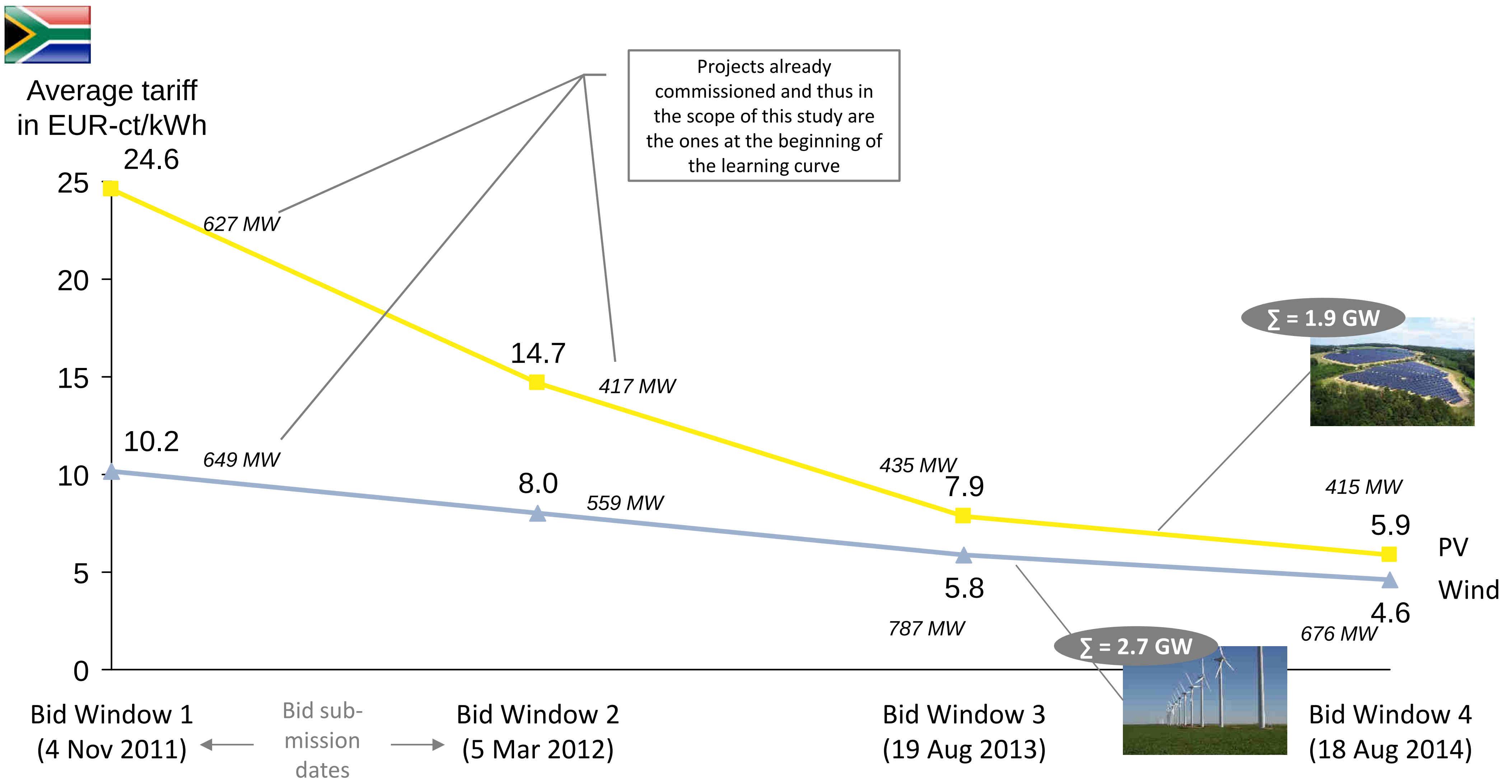
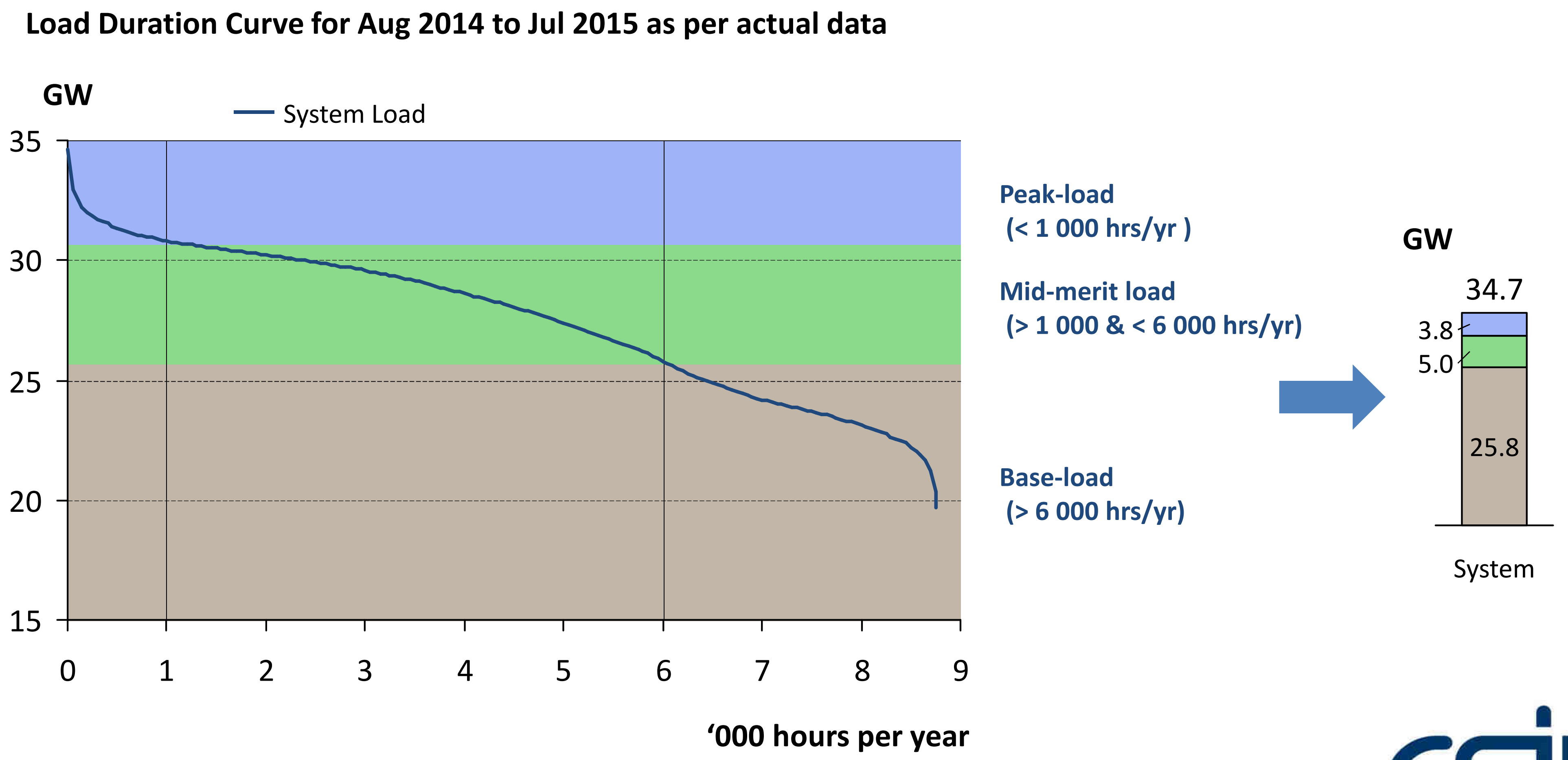
Actual results: new wind/PV projects much cheaper than the first ones

First three bidding windows' results of Department of Energy's RE IPP Procurement Programme (REIPPPP)



Note: BW = Bid Window; Sources: Department of Energy's publications on results of first three bidding 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; StatsSA on CPI; CSIR Energy Centre analysis

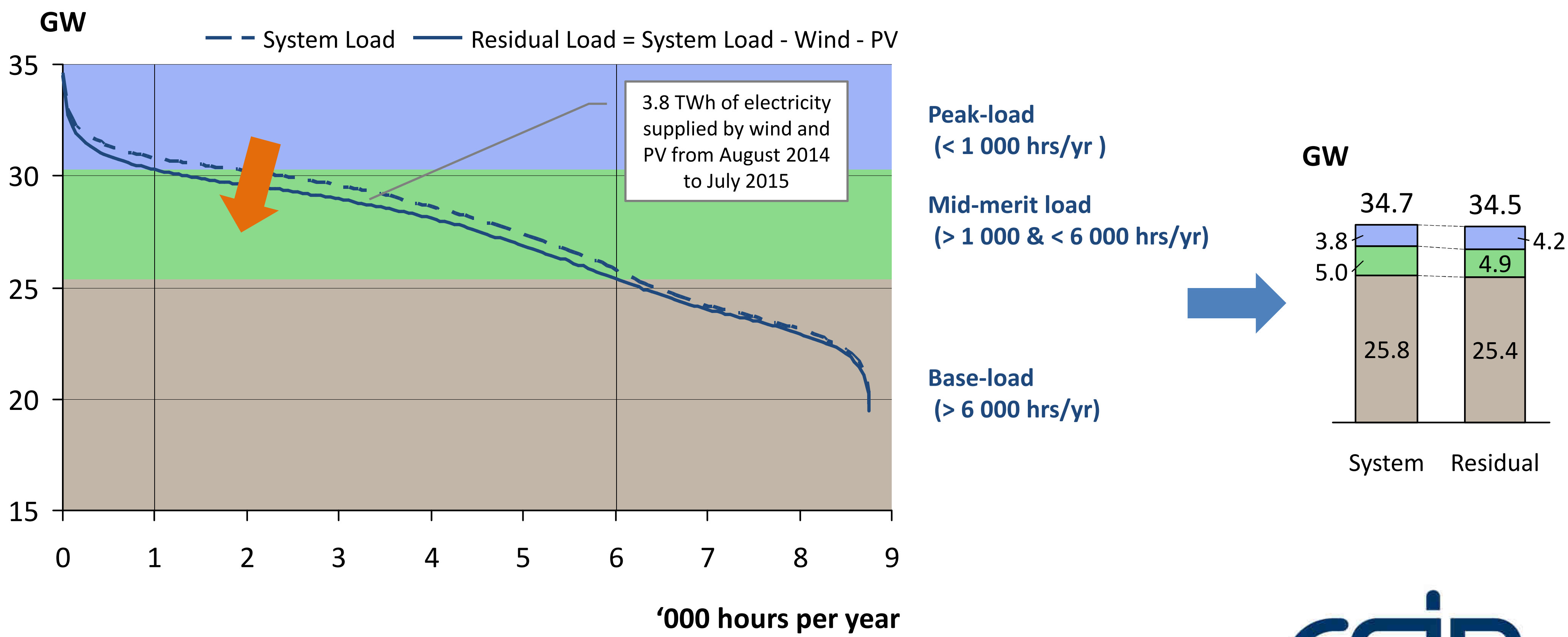
The system load from August 2014 to July 2015 had a peak demand of 3.8 GW, mid-merit of 5.0 GW, and base-load demand of 25.8 GW



Sources: CSIR Energy Centre analysis

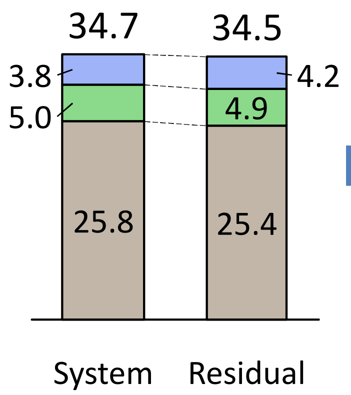
Wind/PV changed the shape of residual load: new peak-demand goes up to 4.2 GW, mid-merit & base-load demand go down to 4.9/25.4 GW

Load Duration Curve for Aug 2014 to Jul 2015 as per actual data



Sources: CSIR Energy Centre analysis

Additional effect CAPEX savings:
Wind & PV change shape of the load and allow for cheaper new-builds



Type	Delta for required new-builds	Assumed cost of new capacity in R/kW
Peak	+400 MW	8 000
Mid-merit	-100 MW	12 000
Base	-400 MW	25 000

Last year, wind and PV changed the residual load such that cheaper new conventional power stations can be built: Annualised R9 billion CAPEX savings translates into additional value of R0.2 per kWh of renewable energy

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Methodology, data sources and assumptions

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Methodology: benefits

Assumed effect of wind and PV on the operation of the conventional fleet, and subsequent fuel savings and avoided "unserved energy"

- It was assumed that the only two power generator categories that changed their operating regime due to wind and PV are coal and OCGTs (i.e. it was assumed that the operations of all other generators were not been affected by wind and PV)
- For each hour of the year, the presence of wind/PV can have one of three effects:
  - Wind/PV replace coal-fired power stations in that hour and therefore save coal fuel (which is cheapest at approx. 0.22-0.33 R/kWh)
  - Wind/PV replace diesel-fired OCGTs in that hour and therefore save diesel fuel (which is the most expensive fuel at 2.40 R/kWh)
  - Wind/PV avoid so-called "unserved energy" (curtailment of customers) in that hour and therefore prevent macroeconomic losses (which is the highest value attributable to renewables at 90 R/kWh in Apr-2015-Rand)
- For each hour of the year, the following logic was therefore applied:
  - If the OCGTs were not operational (output = 0 MWh in that hour), it was assumed that energy generated from wind/PV in this hour replaced coal-fired power stations and therefore saved coal fuel (from 6h00 to 22h00 it was assumed more expensive "daytime" coal to be replaced, whereas between 22h00 and 6h00 it was assumed less expensive "night-time" coal to be replaced)
  - If the OCGTs were operational (output > 0 MWh in that hour), it was assumed that the coal fleet already was at its limits in that particular hour (otherwise the OCGTs would not run), and energy generated from wind and PV in this hour therefore replaced OCGTs and saved diesel fuel. In other words, had wind/PV not been available in this particular hour, the OCGTs would have had to run harder by the amount of energy that wind/PV produced in that particular hour
  - If the OCGTs were operational (output > 0 MWh in that hour) and the sum of wind and PV energy was greater than the combined reserve of OCGTs and pumped hydro, it was assumed that the existence of wind and PV prevented unserved energy in this hour. In other words, had wind/PV not been available in this particular hour, the remaining reserves of OCGTs and pumped hydro together would not have been sufficient to make up the loss of wind/PV energy in that hour, and the wind/PV energy exceeding the remaining reserves of OCGTs and pumped hydro is considered to be avoided unserved energy
- The results for the first six months of 2015 (4 344 hours) are the amount of replaced electricity from coal- and diesel-fired power stations for the wind and PV fleet separately, and the amount of avoided unserved energy for the combined wind/PV fleet
- The results combined with fuel cost of electricity from coal/diesel & with value of unserved energy give renewables' total financial benefit

Sources: CSIR Energy Centre analysis

Methodology: cost

The cost associated with the renewable energy coming online are the tariff payments to the Independent Power Producers

The average tariffs per technology for the three bidding windows were published by the Department of Energy

For the energy from PV projects, the costs in the first six months of 2015 are assumed to be the capacity-weighted average of bid window 1 and bid window 2 tariffs (procured at 2.76 R/kWh in Apr-2011-Rand, which is 3.44 R/kWh in Apr-2015-Rand, and procured at 1.85 R/kWh in Apr-2013-Rand, which is 2.05 R/kWh in Apr-2015-Rand). This weighted average is 2.76 R/kWh in Apr-2014-Rand and is applicable for the months from Jan to Mar 2015. The tariff applicable from Apr-Jun 2015 was escalated with CPI to Apr-2015-Rand. These are the escalation rules of the REIPPPP.

For the energy from wind projects, the costs in the first six months of 2015 are assumed to be the capacity-weighted average of bid window 1 and bid window 2 tariffs (procured at 1.14 R/kWh in Apr-2011-Rand, and procured at 1.12 R/kWh in Apr-2015-Rand. This tariff is 1.36 R/kWh translated into Apr-2014-Rand, and is applicable for the months from Jan-Mar 2015 and escalated with CPI to Apr-2015-Rand applicable from Apr-Jun 2015.

The sum of wind/PV energy per month in 2015 times the applicable tariffs in that month give the total tariff payments to IPPs in every month and in total the total cost of renewables

Sources: CSIR Energy Centre analysis

Data sources (1/3)

Actual production data of wind, PV and of the conventional fleet

- Data source: Eskom
- Type of data: Hourly system supply data for the first six months of calendar year 2015 on aggregated level for different supply categories
- The hourly data of the total power supply is split into the following main supply categories: Nuclear, Coal, Pumped Storage, Gas Turbines (OCGTs, diesel-fired), Hydro, IPP Purchases (non-renewables), Imports, IPP PV and IPP Wind
- For the purpose of this study, IPP purchases (non-renewables) and Imports were clustered into "Imports, Other", and Hydro and Pumped Storage were clustered into "Hydro, Pumped Storage"

Cost of fuels

- Data sources:
  - Eskom Interim Integrated Report 2015 (http://integratedreport.eskom.co.za/Eskom_interim_integrated_report_30_Sept_2014.pdf), page 51
  - Eskom Integrated Report 2015 (http://www.eskom.co.za/IR2015/Documents/EskomIR2015single.pdf), page 97
  - Eskom Annual Financial Statements (http://www.eskom.co.za/IR2015/Documents/EskomAFS2015.pdf), page 88
- Type of data:
  - Diesel: total spent on diesel fuel from April 2014 to September 2014 (reporting period of interim report), total spent on diesel fuel from April 2014 to March 2015 (reporting period of integrated report)
  - Coal: total spent on coal fuel from April 2014 to Mar 2015 (reporting period of integrated report); total take-or-pay penalty value for Medupi coal (subtracted from total coal spent to derive at coal cost purely for the operational part of the fleet)

Sources: CSIR Energy Centre analysis

Data sources (2/3)

Cost of unserved energy

- Data sources:
  - IRP Update (http://www.doe-irp.co.za/content/IRP2010_updatea.pdf), page 68
  - Eskom Cost of Unserved Energy (COUE) Methodology, March 2015, (http://www.nersa.org.za/Admin/Document/Editor/file/Electricity/Consultation/Documents/NERSA%20Consultation%20Paper%20on%20Eskom%20COUE%20Methodology.zip), page 21
- Type of data: “opportunity cost to electricity consumers (and the economy) from electricity supply interruptions” (quote IRP Update), escalated to Apr-2015-Rand. “The Total Economic COUE for 2013 is R77.30 GVA/kWh” (quote Eskom COUE Methodology)

Cost of renewables

- Data source: South African Department of Energy, announcement of results of bidding windows of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) (http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf), pages 26, 28, 35
  (Renewables_IPP_ProcurementProgramme_WindowFourAnnouncement Apr 2015.pdf), pages 13, 14, 15
- Type of data:
  - Average tariffs to be paid to the IPPs for the different technologies and different bidding windows of the REIPPPP
  - Capacities per technology and bidding window

Sources: CSIR Energy Centre analysis

Data sources (3/3)

Inflation index

- Data source: Statistics South Africa (http://www.statssa.gov.za/keyindicators/CPI/CPIHistory.pdf)
- Type of data: CPI index numbers
- The financial raw data that were used in this study come from different sources with different base month/year. For comparability, all financial data had to be normalised with the help of the Consumer Price Index table provided by Statistics South Africa. All financial values were normalised to Apr-2015-Rand and are displayed as such.
- The cost of unserved energy from the IRP Update was escalated from its base value of 75 R/kWh in Jan-2012-Rand to Apr-2015-Rand. Eskom's 2015 COUE Methodology Report was normalised from its nominal value (77.3 R GVA/kWh which is July-2013-Rand) to Apr-2015-Rand, using CPI. Financial nominal values from Eskom's 2015 financial report were assumed to be in October-2014-Rand (mid-point of the financial year), and then escalated to Apr-2015-Rand. The tariffs payable to the renewables Independent Power Producers were calculated on a month-by-month-basis according to the escalation rules of the Renewables Independent Power Producer Procurement Programme (REIPPPP), using CPI

Actual load shedding data

- Data source: Tracking of Eskom Hld SOC Ltd Twitter page (https://twitter.com/eskom_sa and https://twitter.com/eskom_mediadesk) load shedding announcements

Sources: CSIR Energy Centre analysis

Assumptions (1/3)

Assumed avoided fuel costs of the conventional fleet and avoided cost of unserved energy

- Gas Turbines (diesel-fired OCGT)
  - As per Eskom's interim integrated report 2015 (page 37), OCGTs produced 3.709 TWh of electricity from April 2014 to March 2015 at a fuel cost of R9.546 billion (diesel fuel). Of this 3.709 TWh, 1.164 TWh of electricity was produced from April 2014 to September 2014 at operating cost of R3.623 billion (interim integrated report, page 51). This means 2.545 TWh of electricity was produced from October 2014 to March 2015 at an operating cost of R5.923 billion. The avoided fuel cost of not running the OCGTs are therefore R5.923 billion/2.545 TWh = 2.33 R/kWh assumed to be in Jan-2015-Rand.
  - Escalating this figure to Apr-2015-Rand equates to 2.40 R/kWh

- Coal
  - Eskom's coal fleet produced 204.8 TWh of electricity from April 2014 to March 2015 (derived from hourly supply data)
  - For this, as per Eskom's integrated report 2015 (page 97), coal fuel costs of R43.752 b were incurred (51.554 - 7.802 for Medupi)
  - On average, this means fuel costs of R43.752 billion / 204.8 TWh = 0.21 R/kWh for the average coal fleet
  - Since coal costs vary widely from coal-fired power station to coal-fired power station (some are located directly at the coal-mine mouth, while at other power stations coal is trucked into the power station), it is considered to be a conservative assumption that 0.32 R/kWh are the pure fuel cost for the marginal, most expensive coal-fired power station during the day, 0.21 R/kWh at night
  - Escalating these figures to Apr-2015-Rand equates to 0.33 R/kWh and 0.22 R/kWh respectively

- Cost of unserved energy
  - As per Eskom's 2015 COUE Methodology (page 21), the direct and total cost of unserved energy are 21.63 and 77.3 R GVA/kWh (Jul-2013-Rand) respectively, which is 24 and 85 R/kWh in Apr-2015-Rand
  - As per the IRP Update, the COUE are 75 R/kWh in Jan-2012-Rand. Escalated to Apr-2015-Rand, this leads to 90 R/kWh
  - Because the Eskom methodology is under public review at the moment, the 90 R/kWh from the IRP were used for this study. The 85 R/kWh total COUE from the Eskom methodology however are very similar to the IRP assumption

Sources: CSIR Energy Centre analysis

Assumptions (2/3)

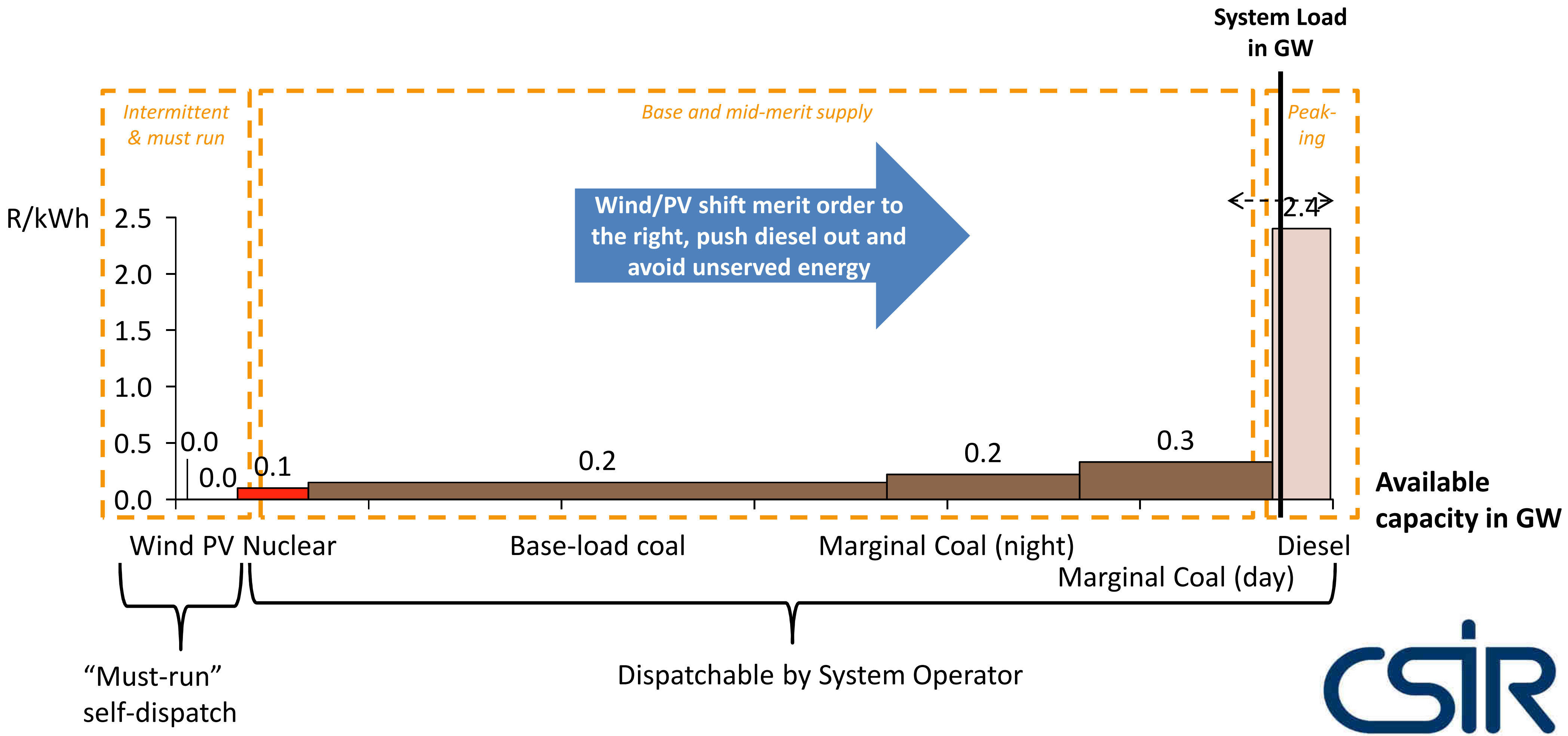
Wind and PV costs

- It is assumed that the approx. 690 MW of wind and 760 MW of PV that are already online (end June 2015) are the projects from bid window 1 and 2 for both wind and PV
- For wind, the cost in 2015 are therefore the capacity-weighted average tariff of BW1 and BW2 (procured at 1.14 R/kWh in Apr-2011-Rand and at 1.12 R/kWh in Apr-2015-Rand)
- For PV, it is the capacity-weighted average tariff of BW1 and BW2 (procured at 2.76 R/kWh in Apr-2011-Rand and at 1.85 R/kWh in Apr-2013-Rand)
- The weighted average cost of wind and PV in Apr-2015-Rand are therefore 2.16 R/kWh of renewable energy

Sources: CSIR Energy Centre analysis

Assumptions (3/3)

Typical order of dispatch, based on short-run marginal cost (fuel cost)



Sources: CSIR Energy Centre analysis

Thank you!

Link to the full study:

http://tinyurl.com/CSIR2015

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