Financial benefits of renewables in South Africa in 2014

Actual diesel- and coal-fuel savings and avoided “unserved energy” from the first approximately 1.6 GW of wind and PV projects in a constrained South African power system

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10 February 2015

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Background

South Africa's power system is currently under severe constraints, with power generators meant to be the "barely-ever-used" safety net for the system (diesel-fired gas turbines) running at > 15% average annual load factor, and with one controlled load shedding in early March 2014, and several more in late 2014

At the same time, the Department of Energy is running a procurement programme to expand the generation capacity in the country. It has already procured close to 4 000 MW of renewable capacity (mainly wind and solar) from Independent Power Producers (IPPs)

The Power Purchase Agreements (PPAs) of all 4 000 MW have been signed between the IPPs and Eskom, South Africa's state-owned power company, as the off-taker/buyer. By end 2014, approx. 1 600 MW of wind (600 MW) & PV (1 000 MW) projects had been commissioned and are feeding energy into the grid

This study addressed the questions how much fuel costs the first 1 600 MW of wind & PV have saved during the year 2014 (by reducing utilisation of diesel-fired gas turbines & of the expensive part of the coal fleet) & how much of "unserved energy" they have avoided that would have been necessary without them

Sources: CSIR Energy Centre analysis

Summary of results:
2014 sees financial benefits from renewable energy exceed costs

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 new 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 close to 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

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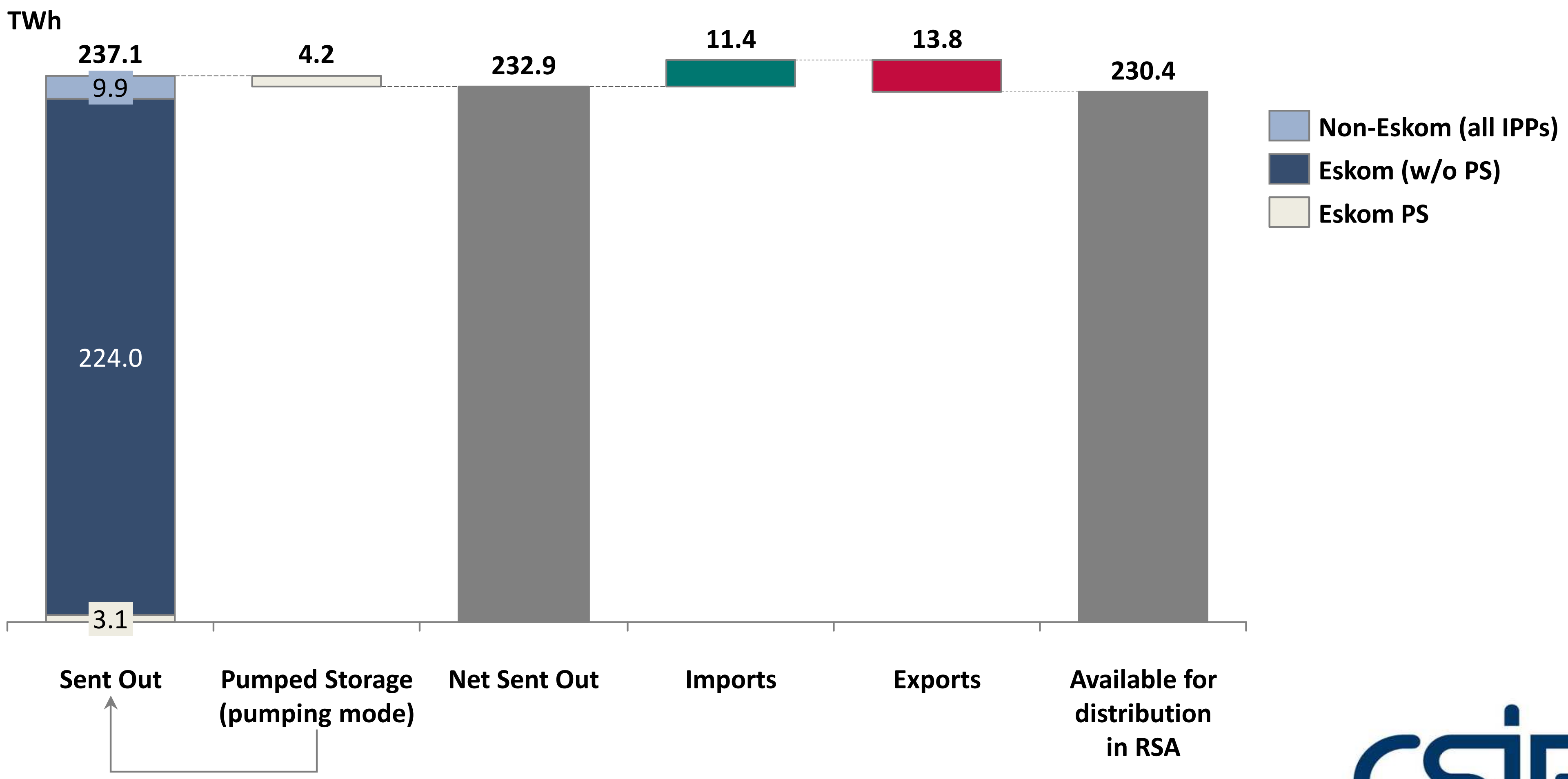
Today, Eskom main supplier of power in RSA

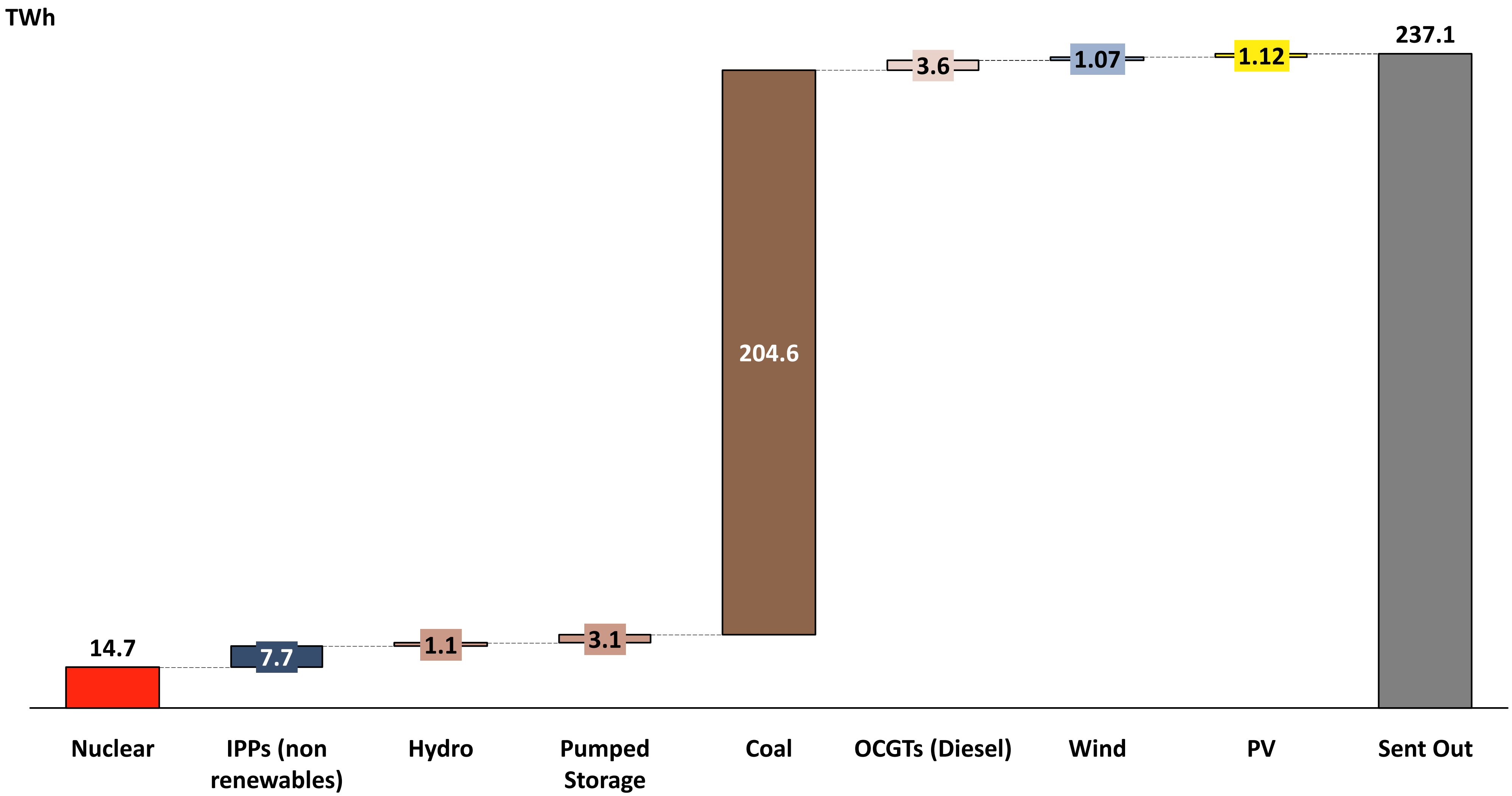
Actual energy captured in wholesale market in 2014 (i.e. without self-consumed energy of embedded plants)



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

South African electricity production ("sent out") in 2014

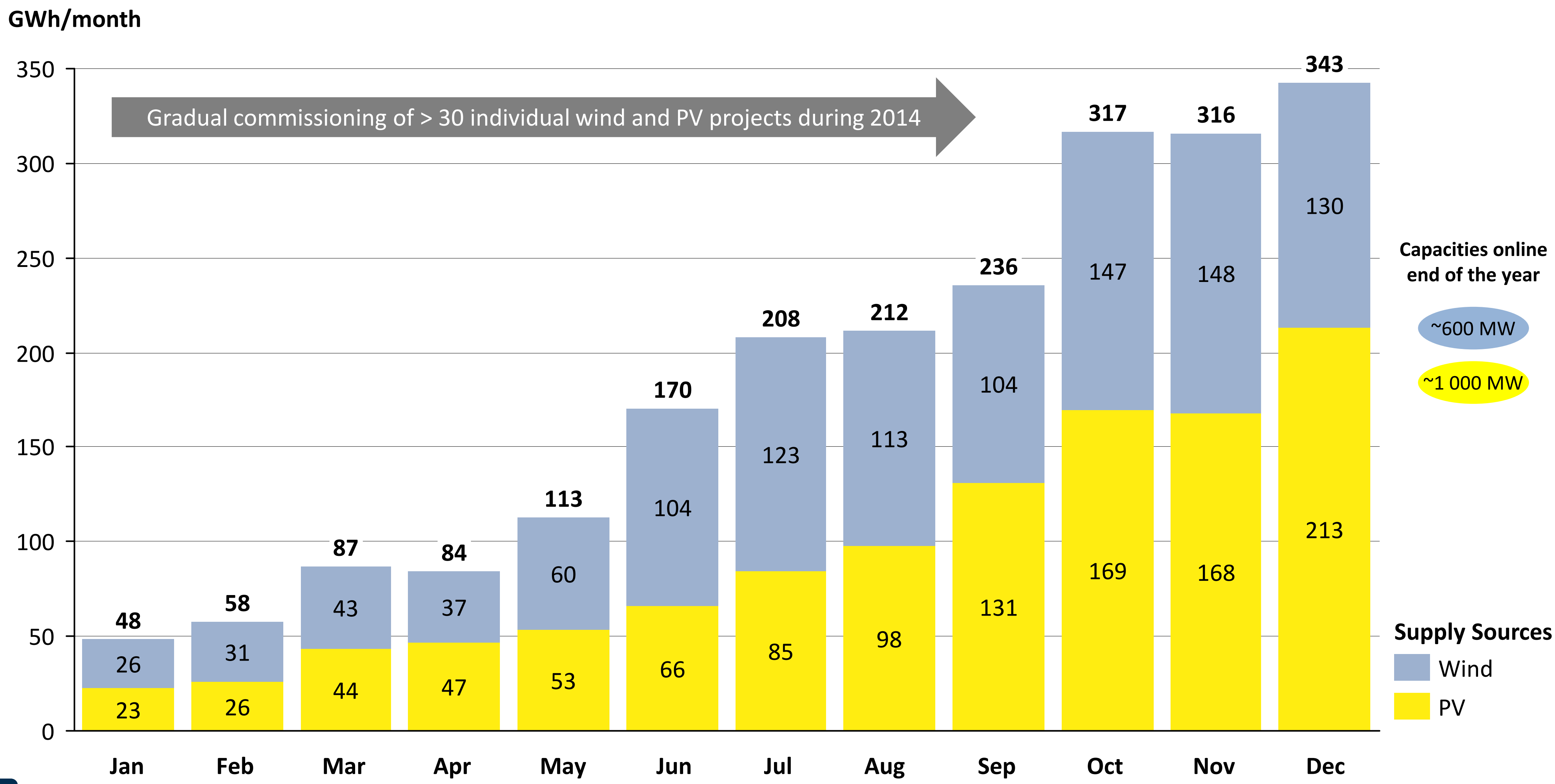
Actual energy captured in wholesale market (i.e. without self-consumed energy of embedded plants)



Sources: Eskom; CSIR Energy Centre analysis

Ramping up of first wind and PV capacities started in 2014

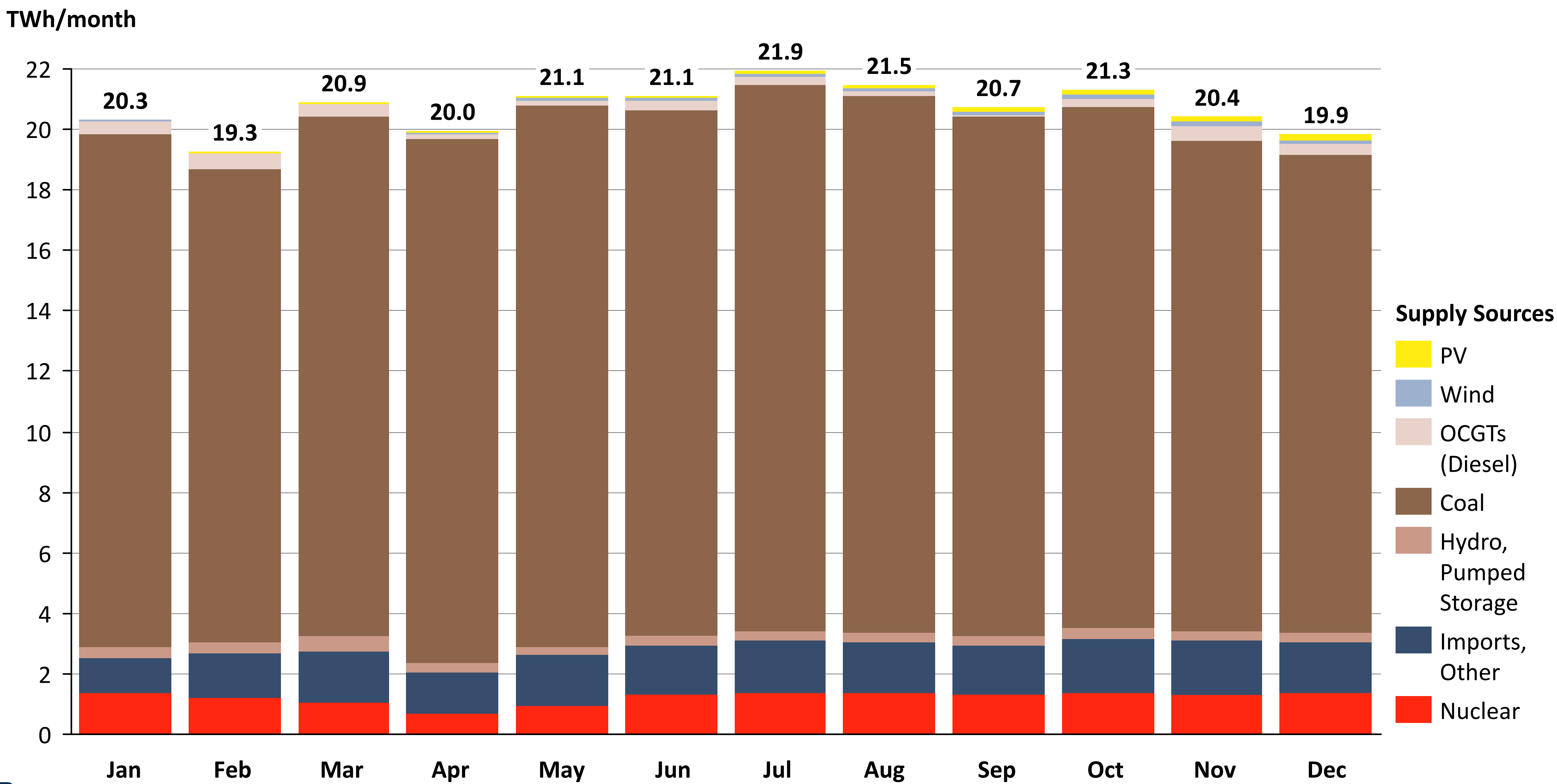
Actual monthly production from large-scale PV and wind plants under the REIPPPP in South Africa in 2014



Sources: Eskom; CSIR Energy Centre analysis

Total electricity produced in 2014 was between 19-22 TWh/month

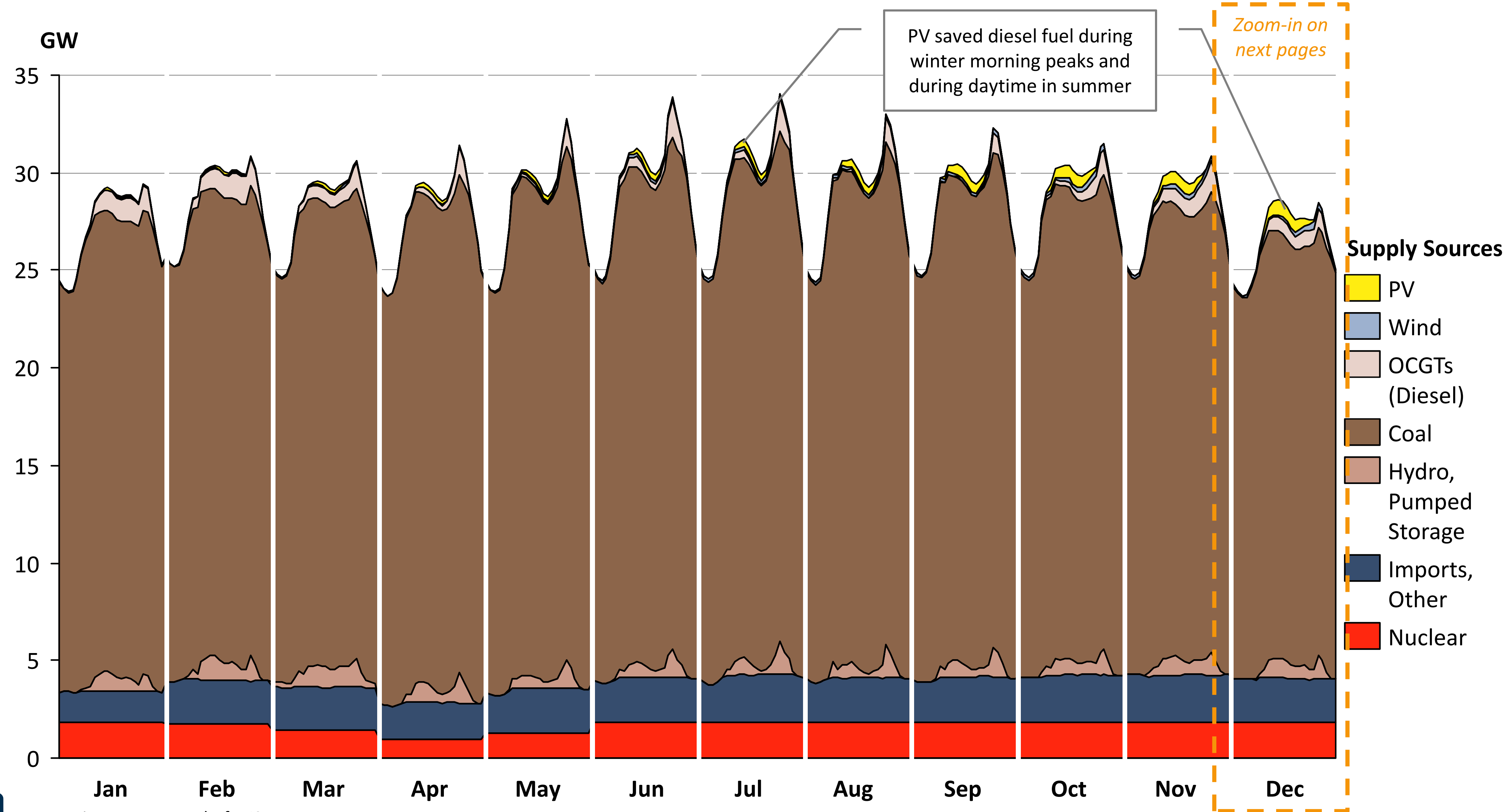
Actual monthly electricity production in 2014 from the different supply sources in South Africa



Sources: Eskom; CSIR Energy Centre analysis

In 2014, OCGTs were used daytime in summer and for winter peaks

Actual monthly average diurnal courses of the total power supply in South Africa for the year 2014

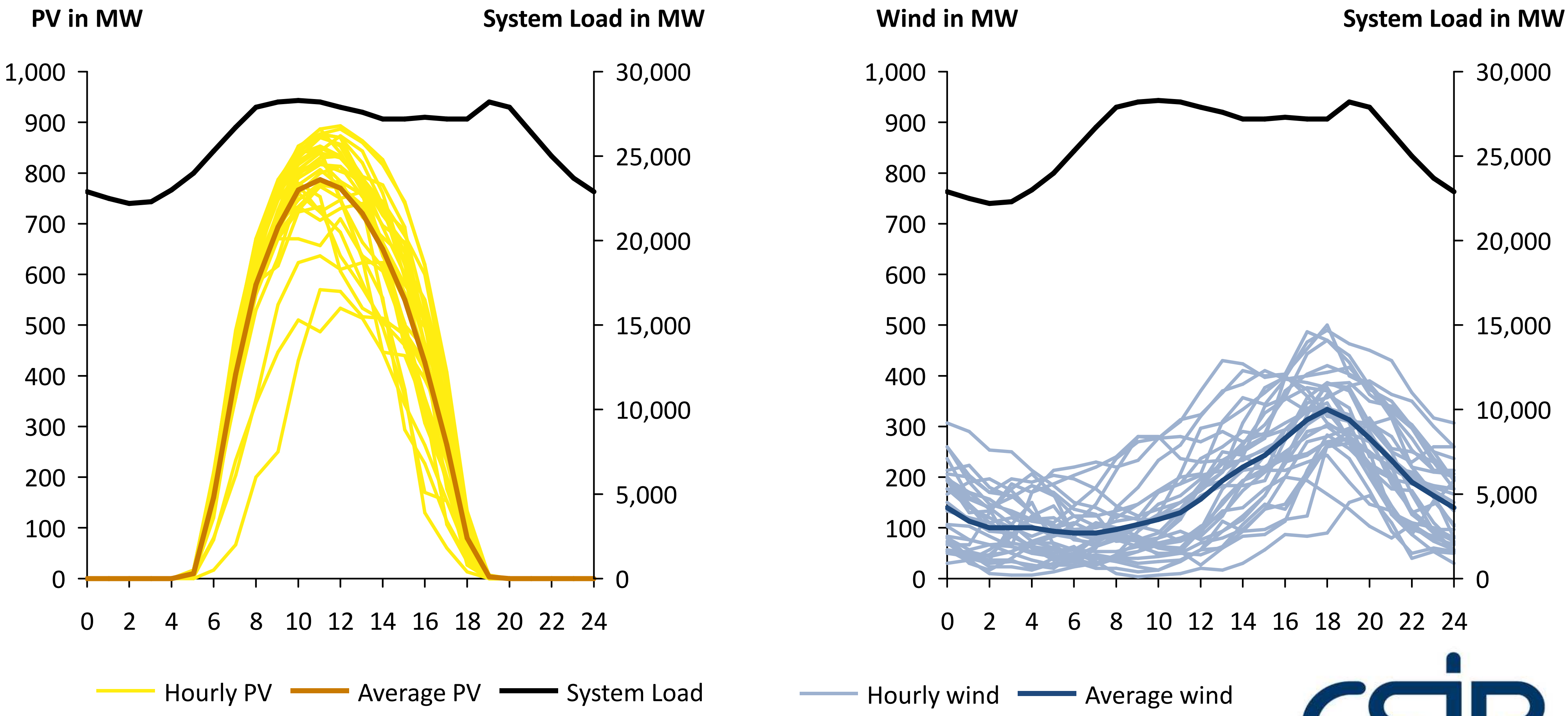


Note: Design as per Fraunhofer ISE

Sources: Eskom; CSIR Energy Centre analysis

PV supply in December 2014 was very stable during the month, wind supplied on average most of the energy during evening peak hours

Hourly PV & wind production profiles for all 31 days of December 2014 & average system load diurnal course



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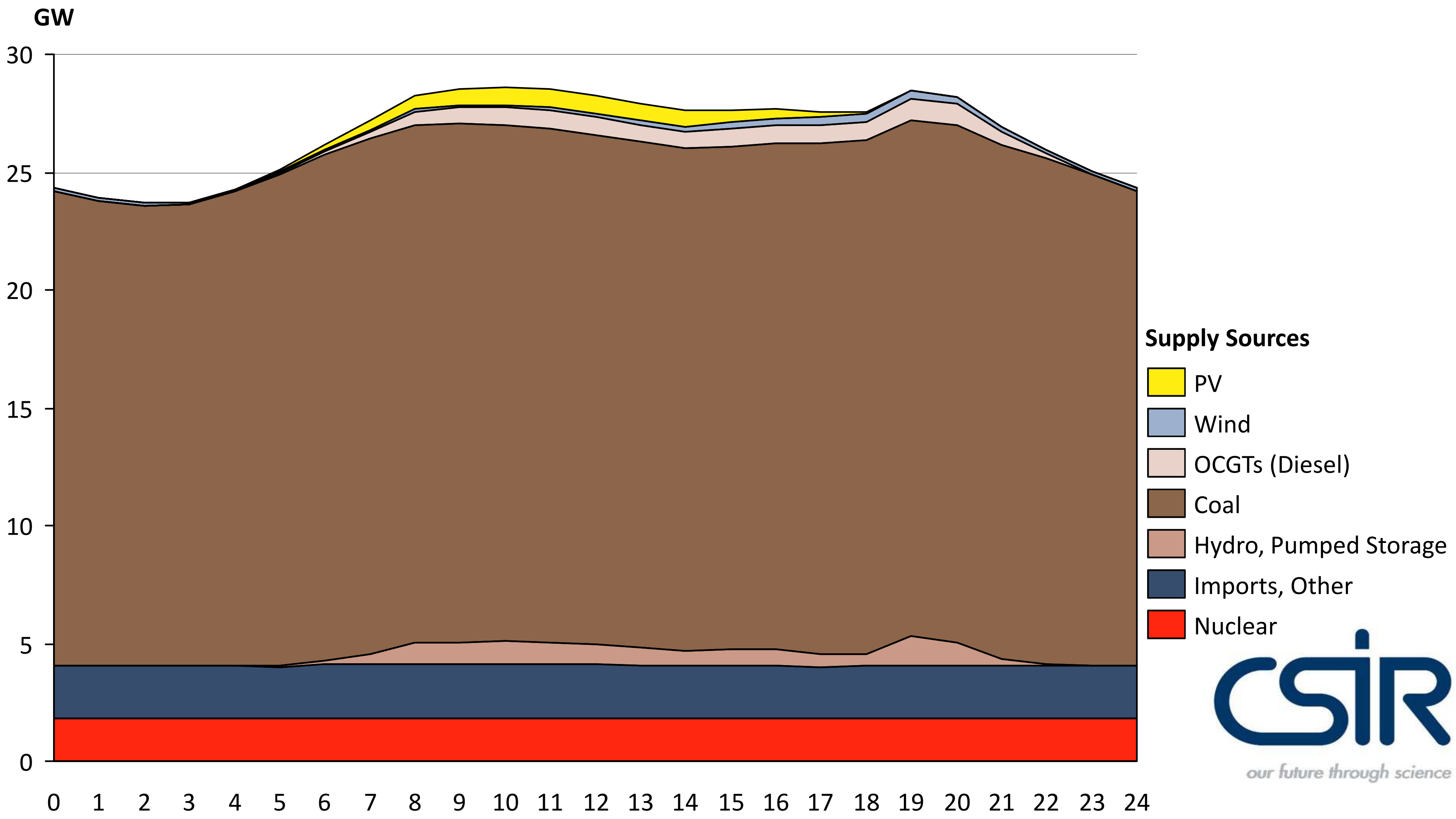
December 2014: PV supplied morning & wind evening peak on average

Average diurnal course of South African power supply in December 2014



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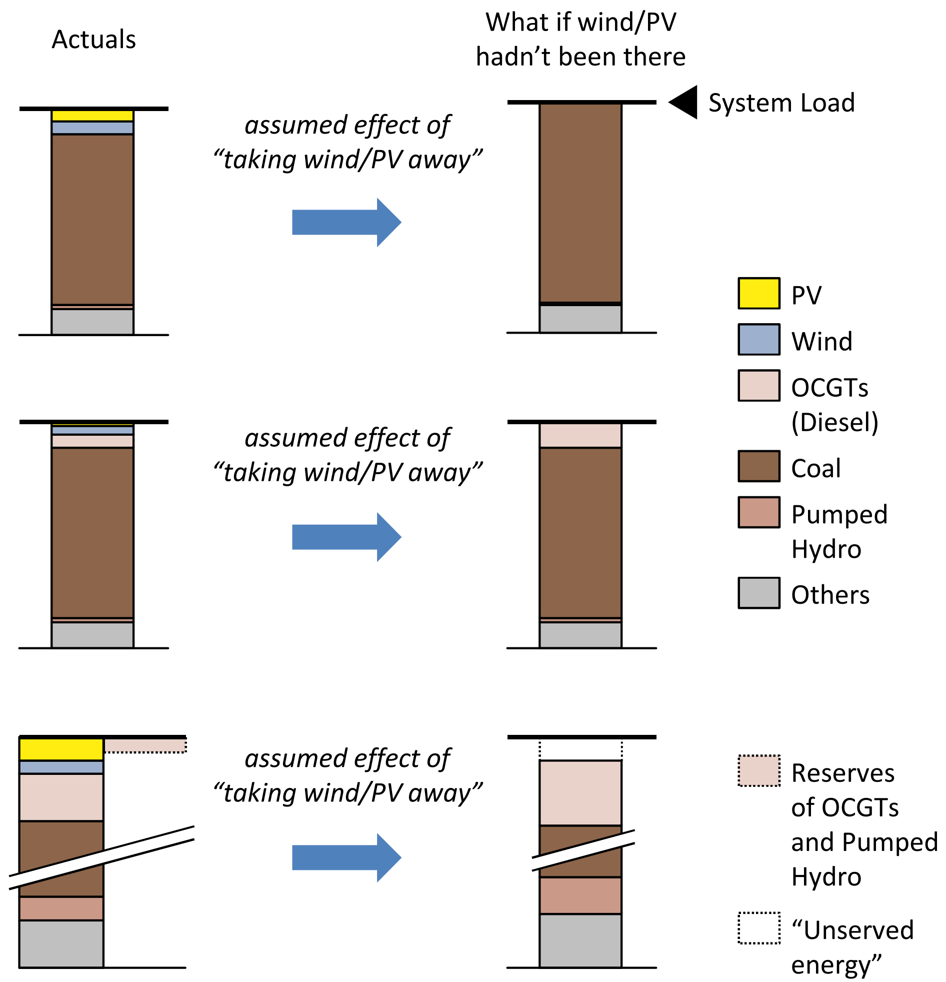
CSIR-defined methodology: In any hour, wind/PV can have one out of three effects on the system

Applicable if …

Snapshot of supply structure in a particular hour



A – **Saving coal fuel**: … output from OCGTs = 0 MWh

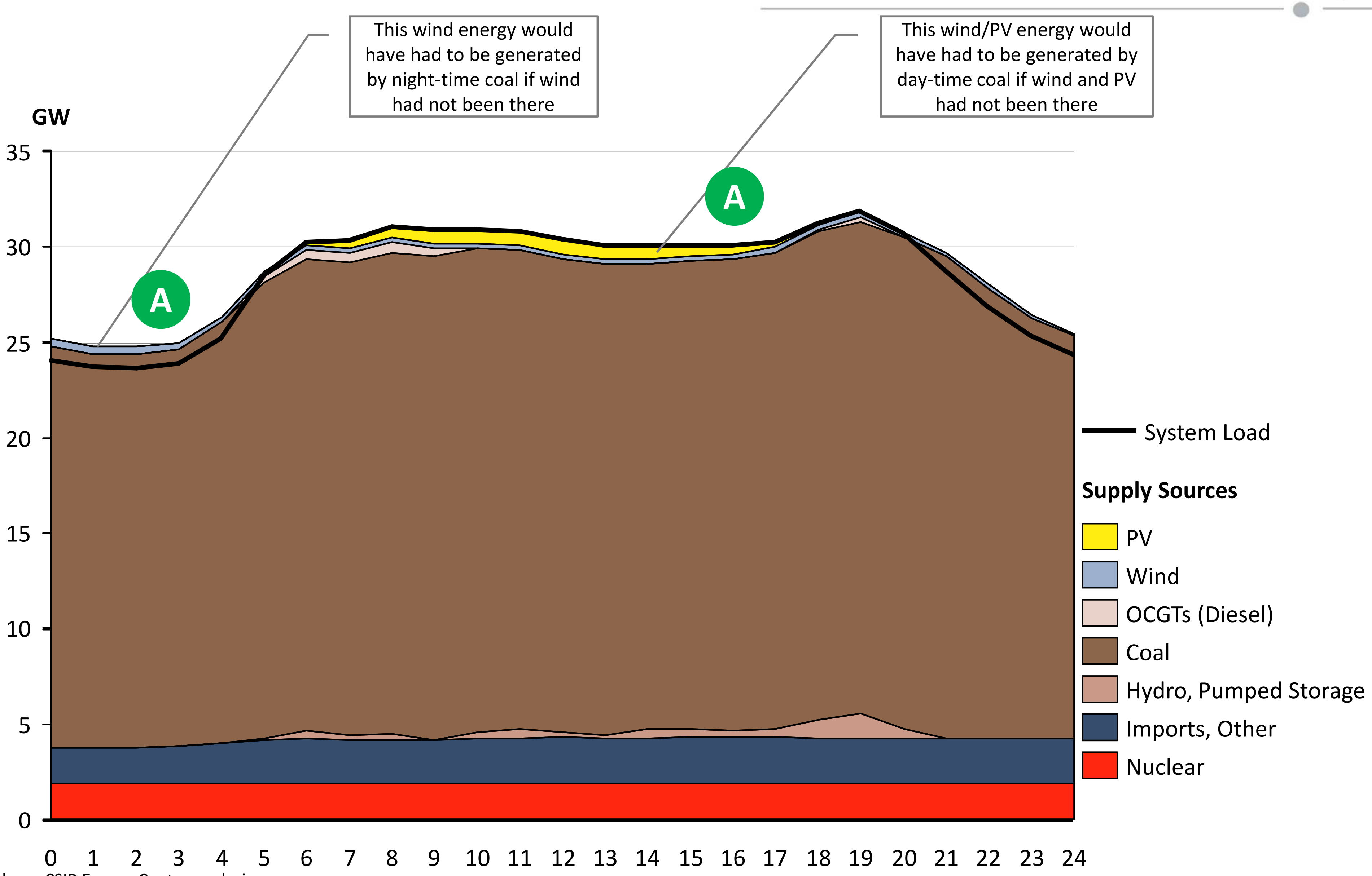
B – **Saving diesel fuel**: … output from OCGTs > 0 MWh

C – **Avoiding "unserved energy"**: … output from OCGTs > 0 MWh <u>and</u> (reserves of OCGTs and Pumped Hydro) < (wind and PV)

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

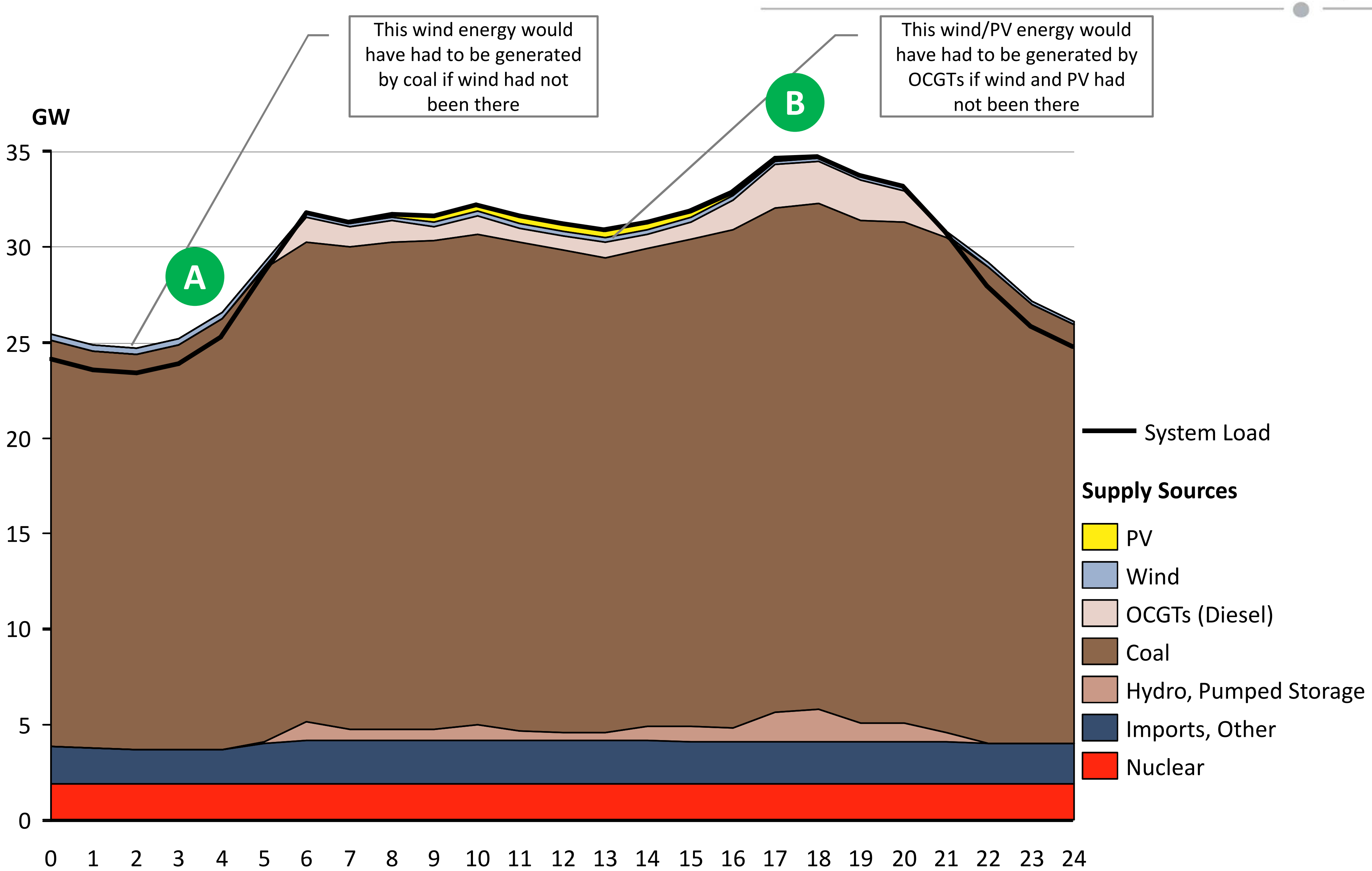
Actual South African supply structure for a spring day, the 17 October 2014



Sources: Eskom; CSIR Energy Centre analysis

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

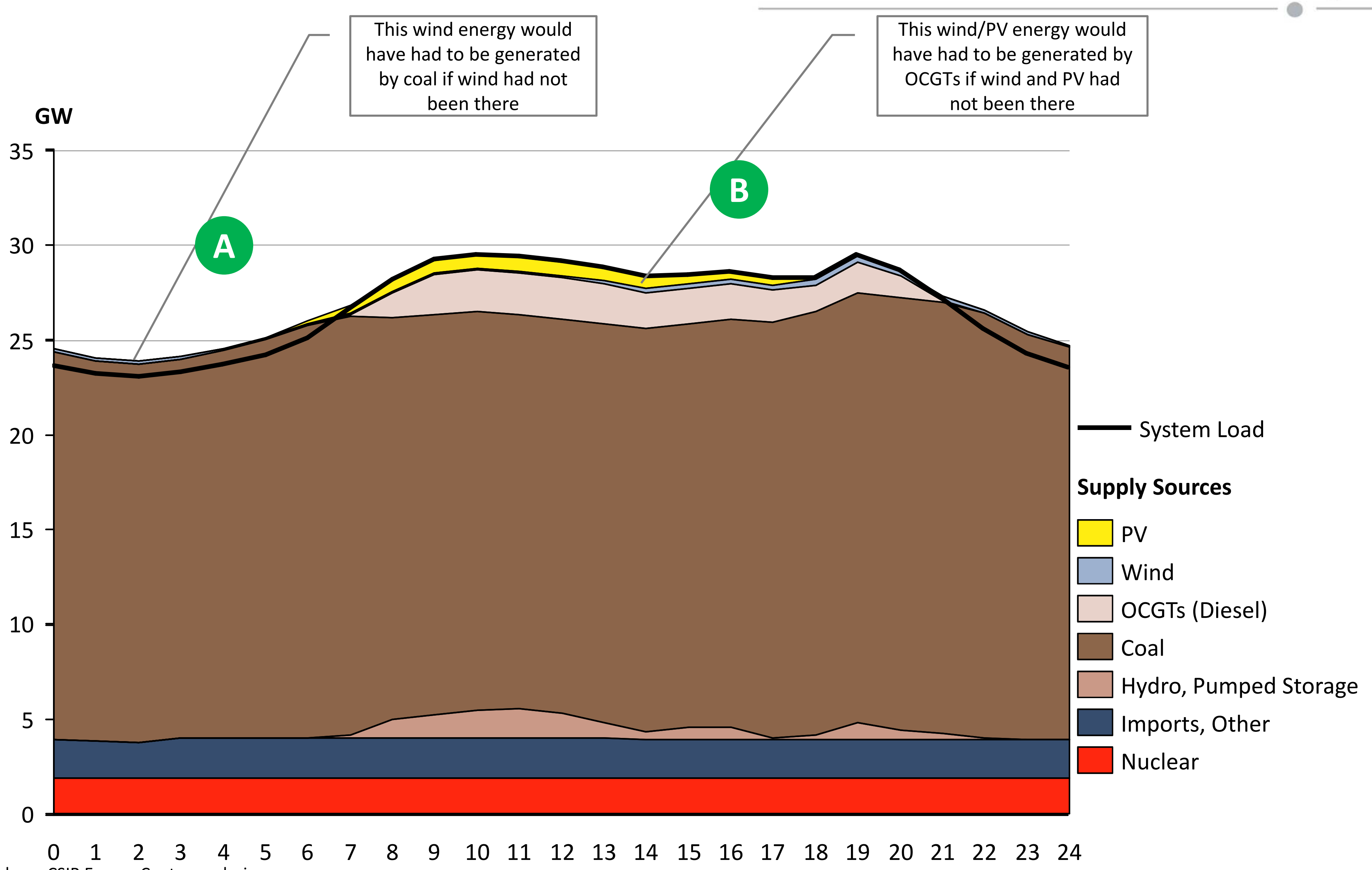
Actual South African supply structure for a winter day, the 19 June 2014



Sources: Eskom; CSIR Energy Centre analysis

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

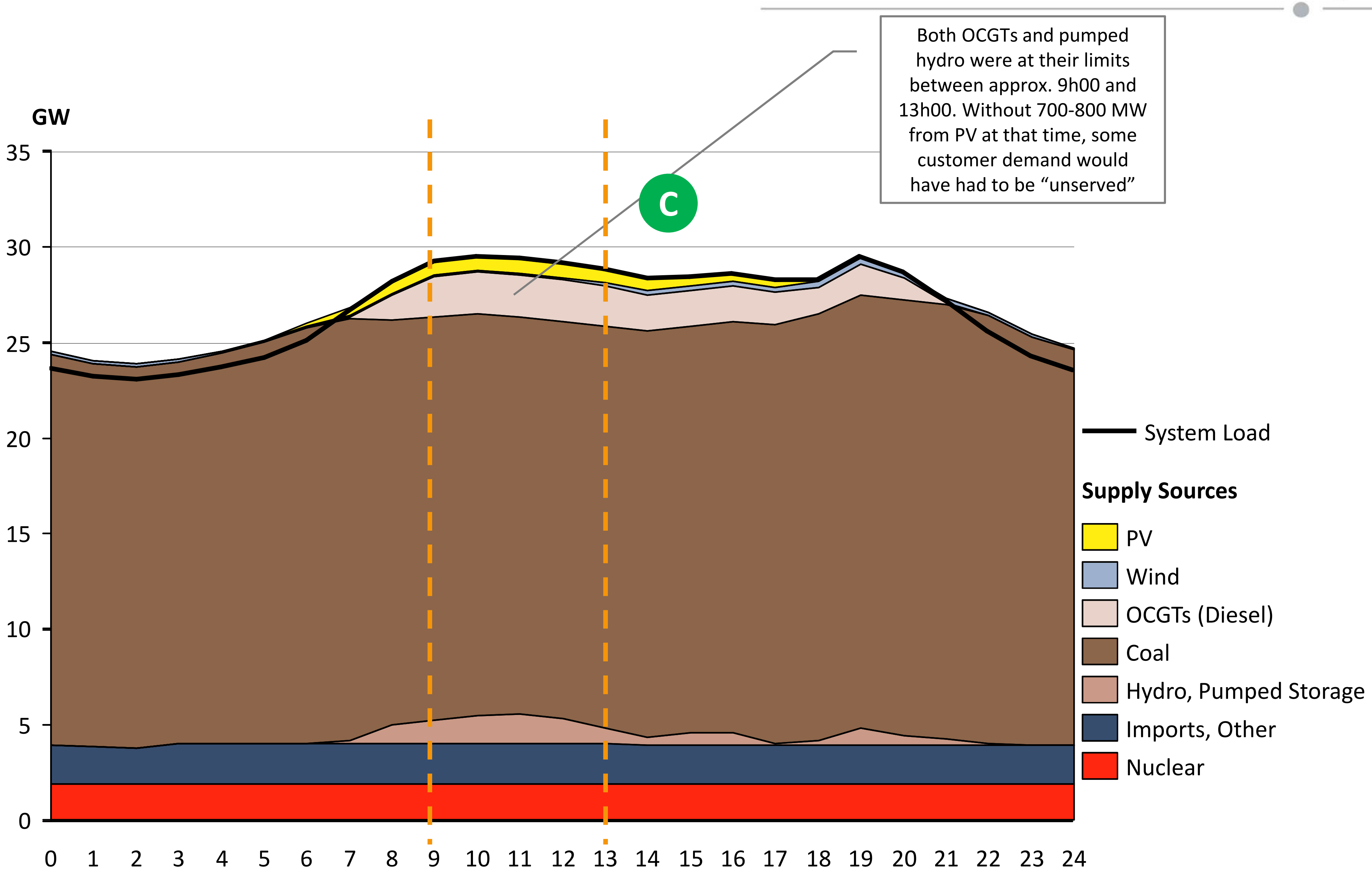
Actual South African supply structure for a summer day, the 16 December 2014



Sources: Eskom; CSIR Energy Centre analysis

On that day, PV even prevented unserved energy between 9h00-13h00

Actual South African supply structure for a summer day, the 16 December 2014



Sources: Eskom; CSIR Energy Centre analysis

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Renewables replaced 1.12 TWh from coal and 1.05 TWh from diesel

Coal/diesel replacement in TWh in 2014 due to electricity generated from wind and PV

Results for 2014 from applying CSIR-defined methodology on actual hourly production data

in TWh	(A) … electricity from coal	(B) … electricity from diesel	(C) … unserved energy	**Total**
Wind replaced/ avoided...	0.56	0.49	0.01	**1.07**
PV replaced/ avoided...	0.56	0.56	0.01	**1.12**
Total	**1.12**	**1.05**	**0.02**	**2.19**

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Notes: Inidividual values are rounded and might not add up to the total values
Sources: CSIR Energy Centre analysis

Wind & PV generated benefits to the economy of R5.31 billion in 2014

Fuel savings in million Rand in 2014 due to electricity generated from wind and PV (all in Jul-2014-Rand)

Results for 2014 from multiplying energy replacement values with financial values for coal/diesel

in million Rand	A ... money spent on coal	B ... money spent on diesel	**Subtotal** *(fuel savings)*	C Value of avoiding "unserved energy"	**Total**
Wind saved...	170	1 540	**1 710**	790	**1 710**
PV saved...	190	1 740	**1 930**	880	**1 930**
Total	**360**	**3 280**	**3 640**	**1 670**	**5 310**

Notes: Inidividual values are rounded and might not add up to the total values
Sources: CSIR Energy Centre analysis

This translates into savings per renewable energy unit of 1.66 R/kWh

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

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

Weighted average of
1.66 R per kWh of renewable energy (Jul-2014-Rand) A + B

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Sources: CSIR Energy Centre analysis

Wind and PV avoided 19.2 GWh of unserved energy in 2014, which saved the economy R1.67 billion, which is 0.76 R/kWh of renewables

Results for 2014 from applying CSIR-defined methodology on actual hourly production data

In 2014, 117 hours with "unserved energy" were avoided

This is 19.2 GWh of avoided unserved energy due to wind/PV

Economic value: R1.67 billion (@ 87 R/kWh in Jul-2014-Rand)

0.76 R economic value per kWh of renewable energy

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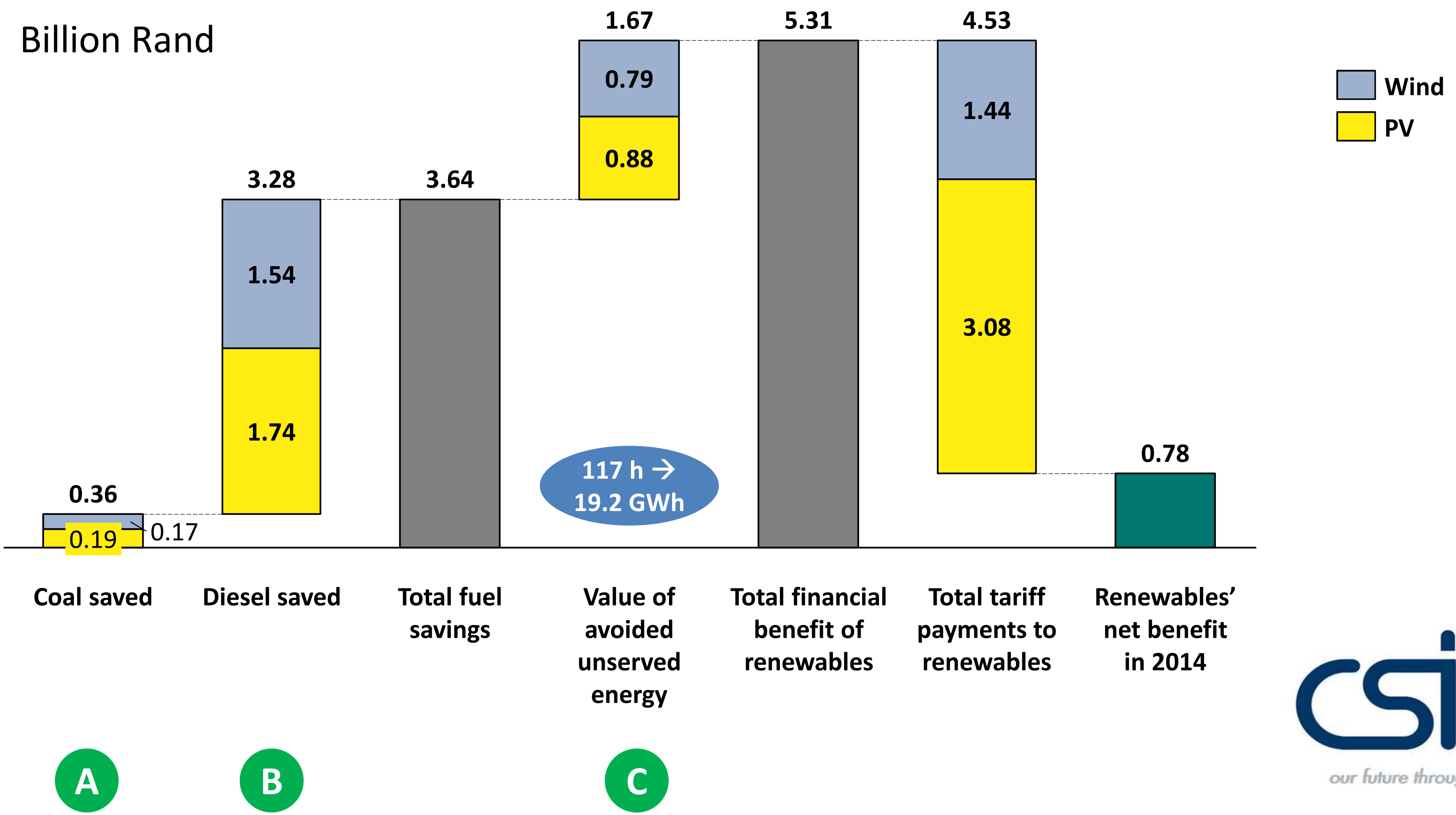
Sources: CSIR Energy Centre analysis

Renewables in 2014 generated R0.8 billion net benefit to the economy



Sources: CSIR Energy Centre analysis

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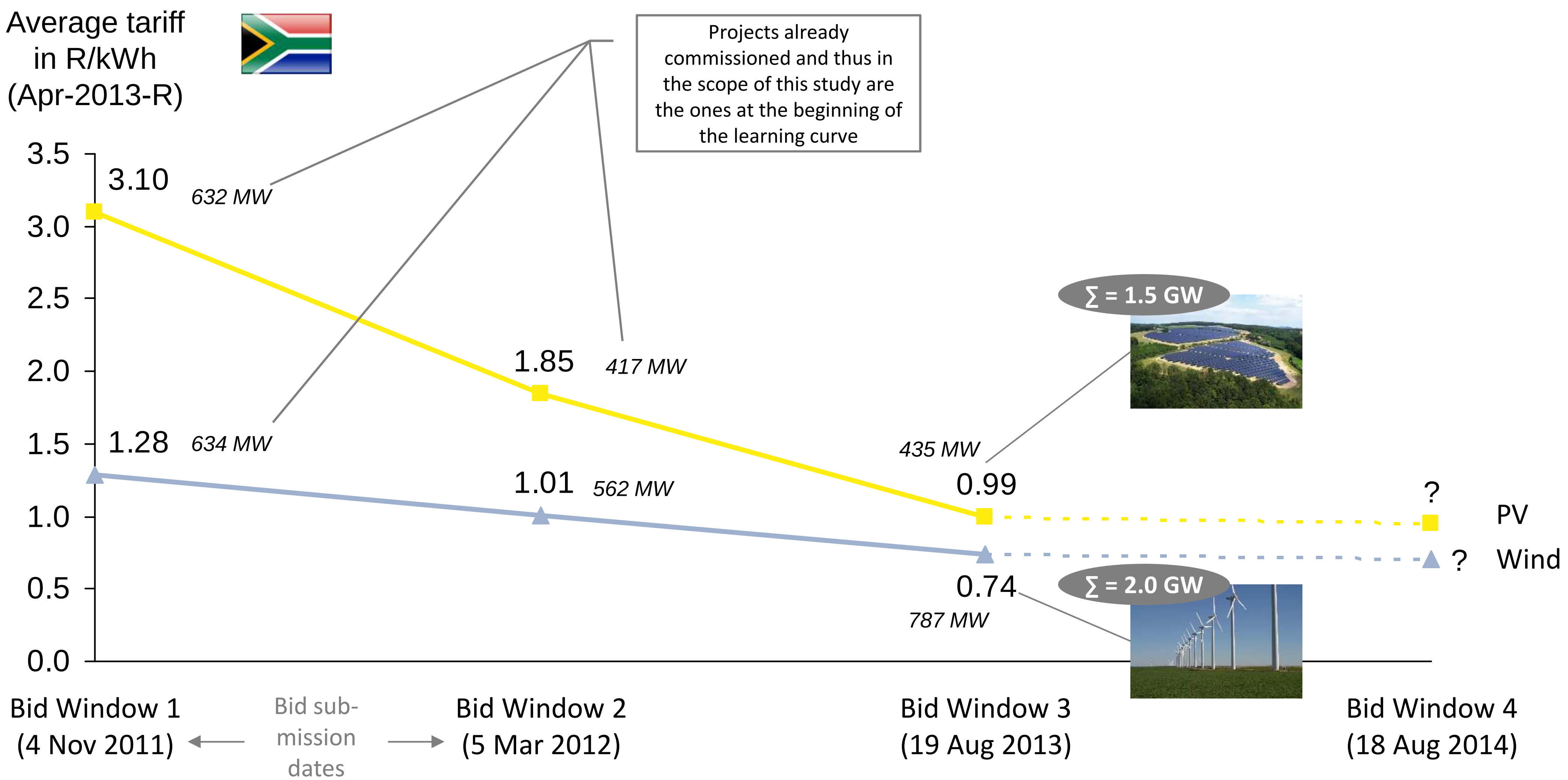
Actual results: new wind/PV projects much cheaper than the first ones

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

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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. 0.23-0.35 R/kWh)
  - Wind/PV replace diesel-fired OCGTs in that hour and therefore save diesel fuel (which is the most expensive fuel at 3.11 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 87 R/kWh in Jul-2014-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 entire year 2014 (8760 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

These tariff information were escalated with CPI to Jul-2014-Rand (basis month for the entire financial analysis)

The sum of wind/PV energy in 2014 times the applicable tariffs give the total tariff payments to IPPs and therefore the total cost of renwables

Sources: CSIR Energy Centre analysis

Data sources (1/2)

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

- Data source: Eskom
- Type of data: Hourly system supply/demand data for the calendar year 2014 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 2014 (http://integratedreport.eskom.co.za/Eskom_interim_integrated_report_30_Sept_2014.pdf), page 51
  - Eskom interim financials 2014 (http://integratedreport.eskom.co.za/Eskom_condensed_interim_financials_30_Sept_2014.pdf), page 14
- Type of data:
  - Diesel: total spent on diesel fuel from April 2014 to September 2014 (reporting period of interim reports)
  - Coal: total spent on coal/nuclear fuel from April 2014 to September 2014 (reporting period of interim reports)

Cost of unserved energy

- Data source: IRP Update (http://www.doe-irp.co.za/content/IRP2010_updatea.pdf), page 68
- Type of data: "opportunity cost to electricity consumers (and the economy) from electricity supply interruptions" (quote IRP Update)

Sources: CSIR Energy Centre analysis

Data sources (2/2)

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
- 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

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.
- The cost of unserved energy was normalised from its nominal value (which is January-2012-Rand) to July-2014-Rand, using CPI. Financial nominal values from Eskom's reports 2014 were assumed to be applicable for the entire calendar year 2014, because the reporting period is from April 2014 to September 2014, which are exactly the middle six months of the calendar year 2014. 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.

Sources: CSIR Energy Centre analysis

Assumptions

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 2014 (page 51), OCGTs produced 1.164 TWh of electricity from April 2014 to September 2014 at operating cost of R3.623 billion (mainly diesel fuel)
  - The avoided fuel cost of not running the OCGTs are therefore R3.623 billion/1.164 TWh = 3.11 R/kWh
- Coal
  - Eskom's coal fleet produced 105.6 TWh of electricity from Apr-Sep 2014, its nuclear power station produced 7.0 TWh, i.e. a combined 112.6 TWh (derived from hourly supply data)
  - For this, as per Eskom's interims financial 2014 (page 14), operating costs of R28.415 b were incurred (coal, uranium & diesel)
  - On average, this means fuel costs of R(28.415 – 3.623) billion / 112.6 TWh = 0.22 R/kWh for the average coal/nuclear fleet
  - Nuclear fuel costs are generally lower than coal fuel, the average fuel costs of the coal fleet only are therefore at least 0.23 R/kWh
  - 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 0.35 R/kWh are the pure fuel cost for the marginal, most expensive coal-fired power station during the day, 0.23 R/kWh at night
- Cost of unserved energy
  - As per IRP Update (page 68), the cost of unserved energy are 75 R/kWh (Jan-2012-Rand), which is 87 R/kWh in Jul-2014-Rand

Wind and PV costs

- It is assumed that the approx. 600 MW of wind and 1 000 MW of PV that are already online (end of 2014) are the projects from bid window 1 for wind, and are projects from both bid window 1 and 2 for PV
- For wind, the cost in 2014 are therefore the average tariff of bid window 1 (procured at 1.14 R/kWh in Apr-2011-Rand)
- For PV, it is the weighted average of BW1 and BW2 tariff (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 2014 are therefore 2.07 R/kWh of renewable energy

Sources: CSIR Energy Centre analysis