Statistics of utility-scale solar PV and wind in South Africa in 2015

CSIR Energy Centre

May 2016

Joanne Calitz JRCalitz@csir.co.za
Crescent Mushwana CMushwana@csir.co.za
Dr Tobias Bischof-Niemz TBischofNiemz@csir.co.za

our future through science

Summary of 2015:
2.0 % of system load supplied from wind & solar PV in South Africa

The South African Department of Energy is procuring new generation capacity and has already allocated a total of 8.1 GW of renewables (mainly wind and solar photovoltaic – PV) for procurement from Independent Power Producers (IPPs)

- … 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, ~1 075 MW of wind and 965 MW of solar PV were operational and fed energy into the grid end of 2015

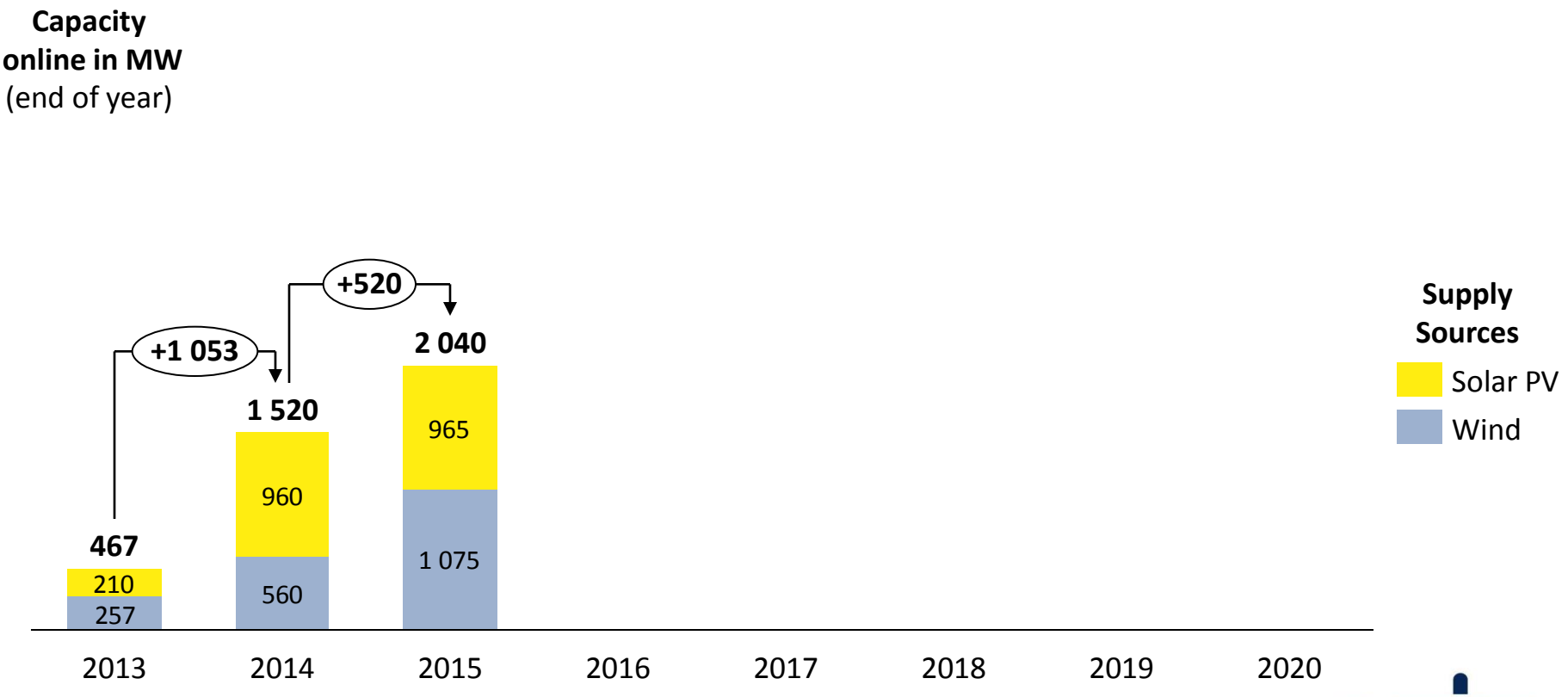
In 2015, total wind and solar PV production was 4.7 TWh, supplying 2.0% of the South African system load

- Maximum daily total energy from solar PV and wind combined was 22.2 GWh (3.4%), which occurred on 2 Nov 2015
- Wind power achieved a maximum peak power production of 898 MW between 17h00-18h00 on 26 Nov 2015
- Solar PV power reached a maximum peak power of 931 MW between 12h00-13h00 on 3 Nov 2015
- Maximum instantaneous power contribution of wind and solar PV was 6.0% on 1 Nov 2015 between 14h00-15h00
- Maximum instantaneous power contribution of wind alone was 4.0% on 7 Sep 2015 between 3h00-4h00
- Maximum instantaneous power contribution of solar PV alone was 3.6% on 26 Dec 2015 between 13h00-14h00

Total monthly wind and solar PV production from Jan to Dec 2015 varied between 331 GWh and 500 GWh

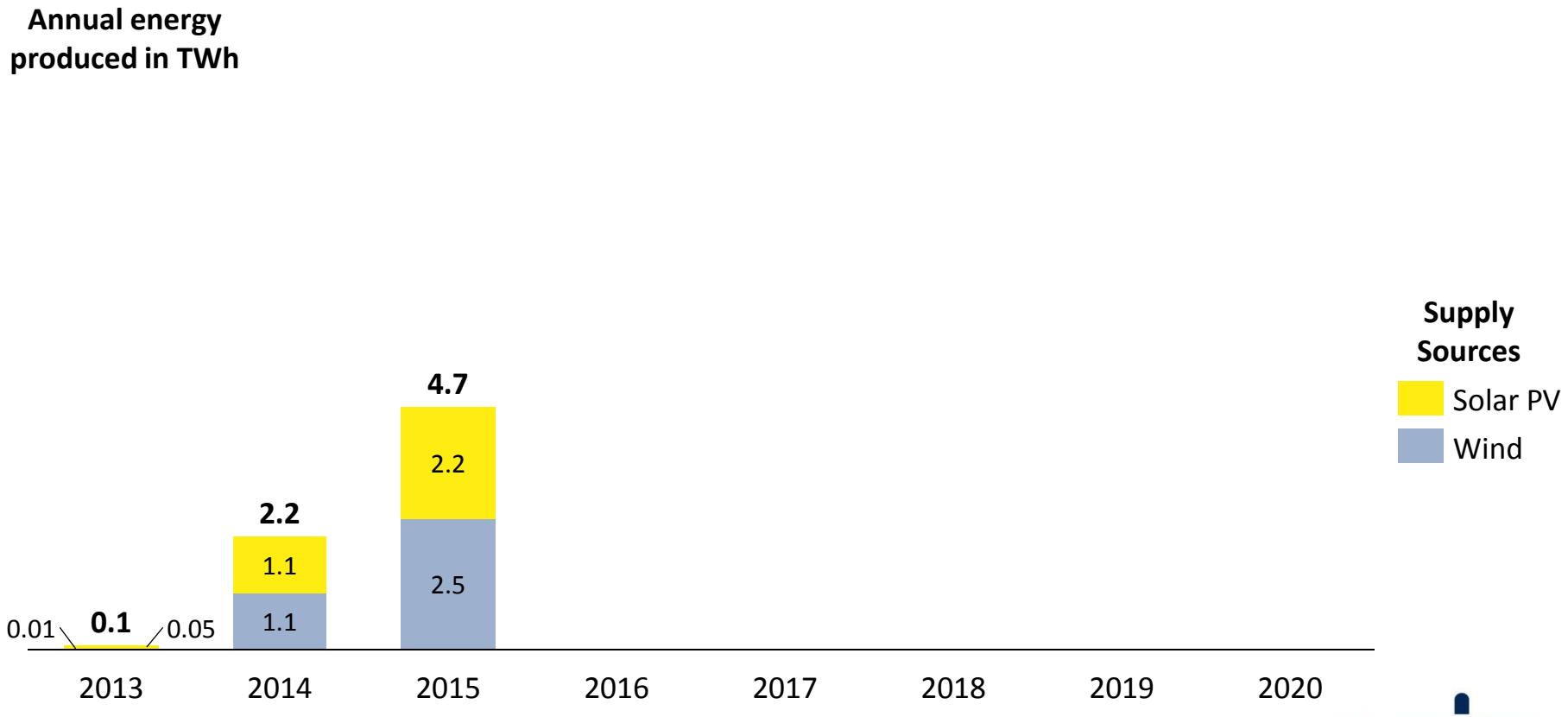
- The monthly wind production from Jan to Dec 2015 varied between 130 and 275 GWh
- The monthly solar PV production from Jan to Dec 2015 varied between 134 and 226 GWh

From 1 November 2013 to 31 December 2015, 1 075 MW of wind and 965 MW of large-scale solar PV were commissioned in RSA



Notes: RSA = Republic of South Africa. Solar PV capacity = capacity at point of common coupling. Wind includes Eskom's Sere wind farm (100 MW)
Sources: Eskom; DoE IPP Office

In 2015, almost 5 TWh of wind and solar PV energy produced in RSA



Notes: Wind includes Eskom's Sere wind farm (100 MW)
Sources: Eskom; DoE IPP Office

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

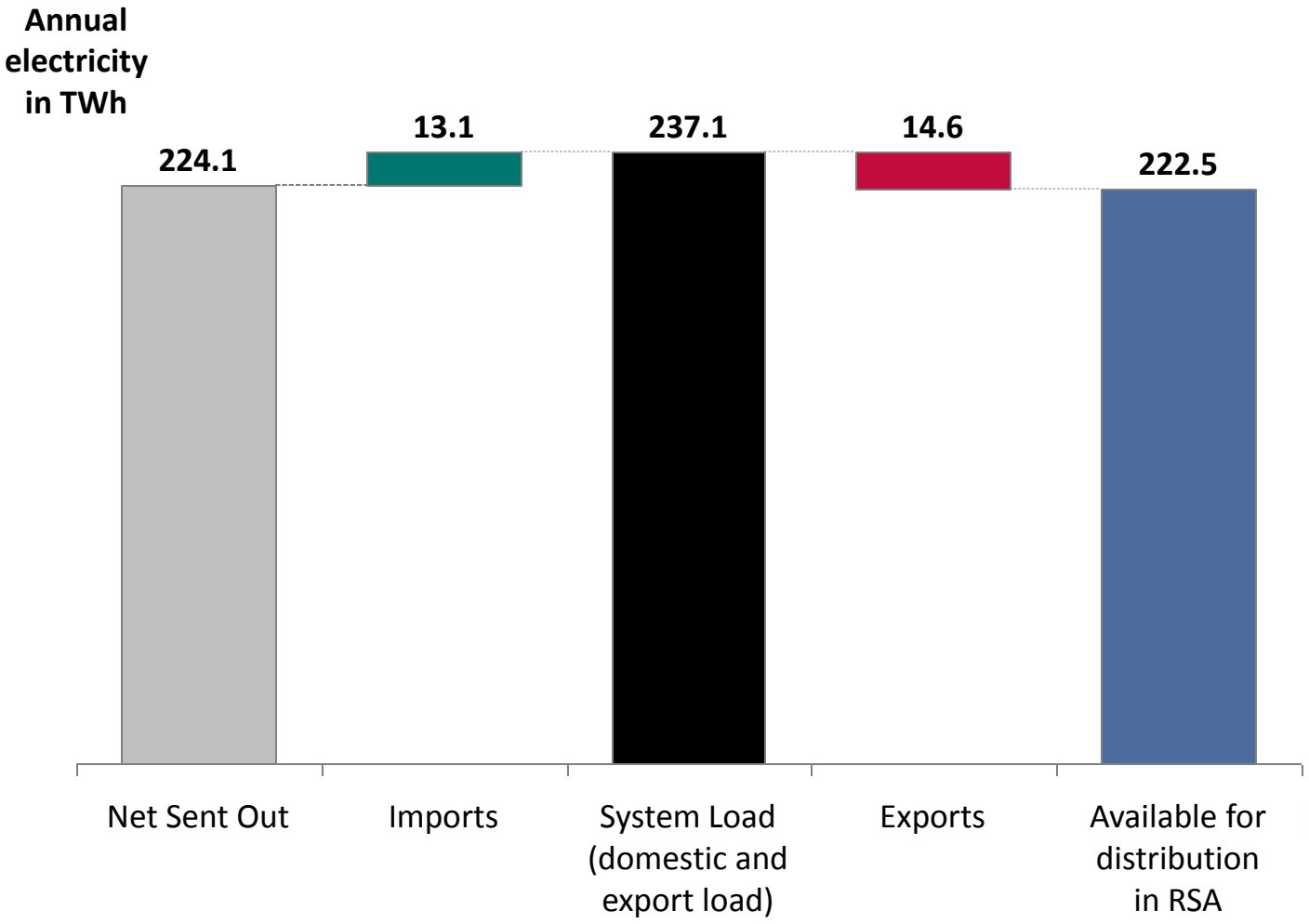
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

In 2015, 224 TWh of net electricity were produced in South Africa

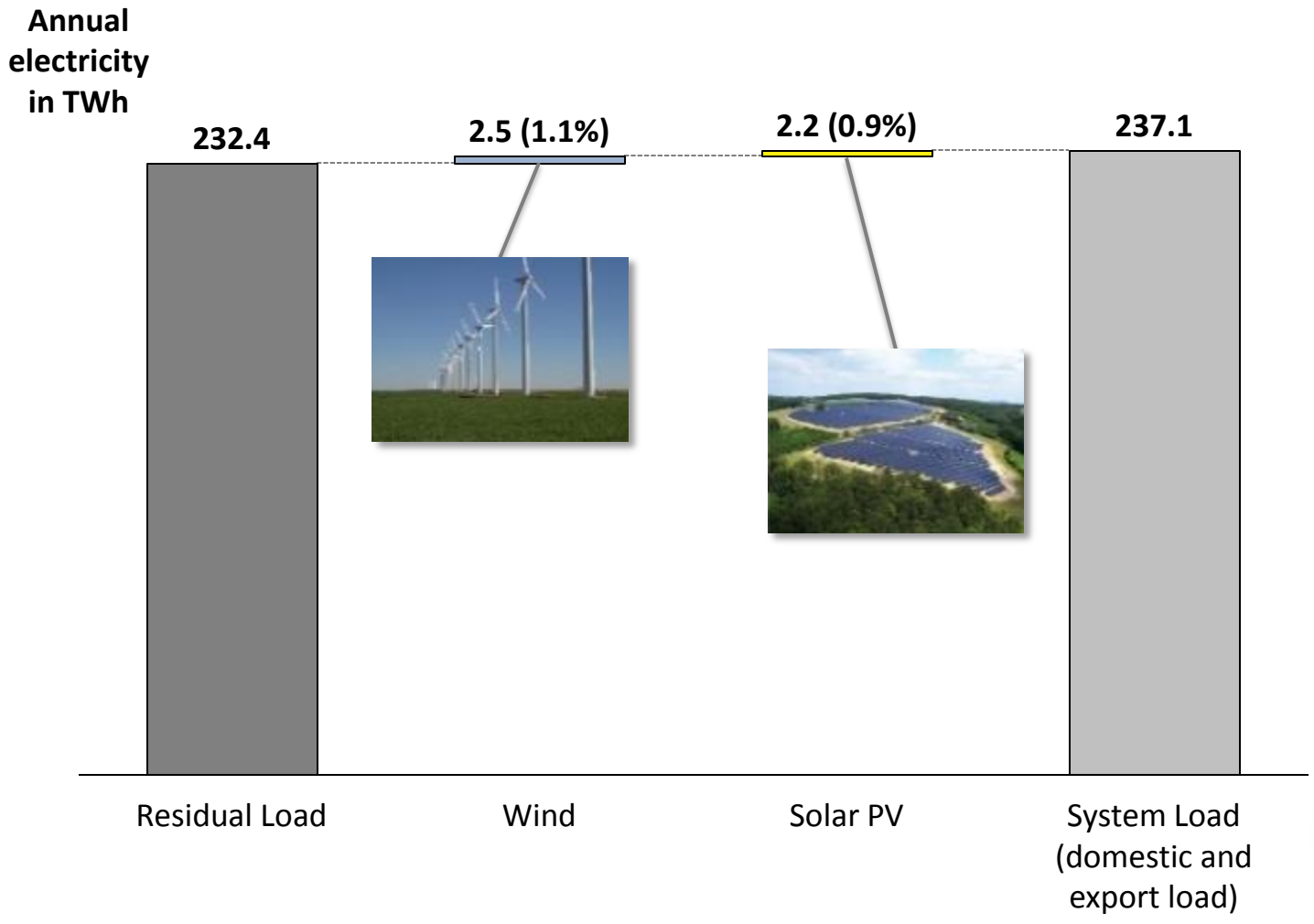
Actuals captured in wholesale market for Jan-Dec 2015 (i.e. without self-consumption of embedded plants)



Notes: „Net Sent Out“ = Total domestic generation („Sent Out“) minus pumping load (not shown seperately)
Sources: Eskom; Statistics South Africa for imports and exports

Wind & solar PV supplied 2% of total South African system load in 2015

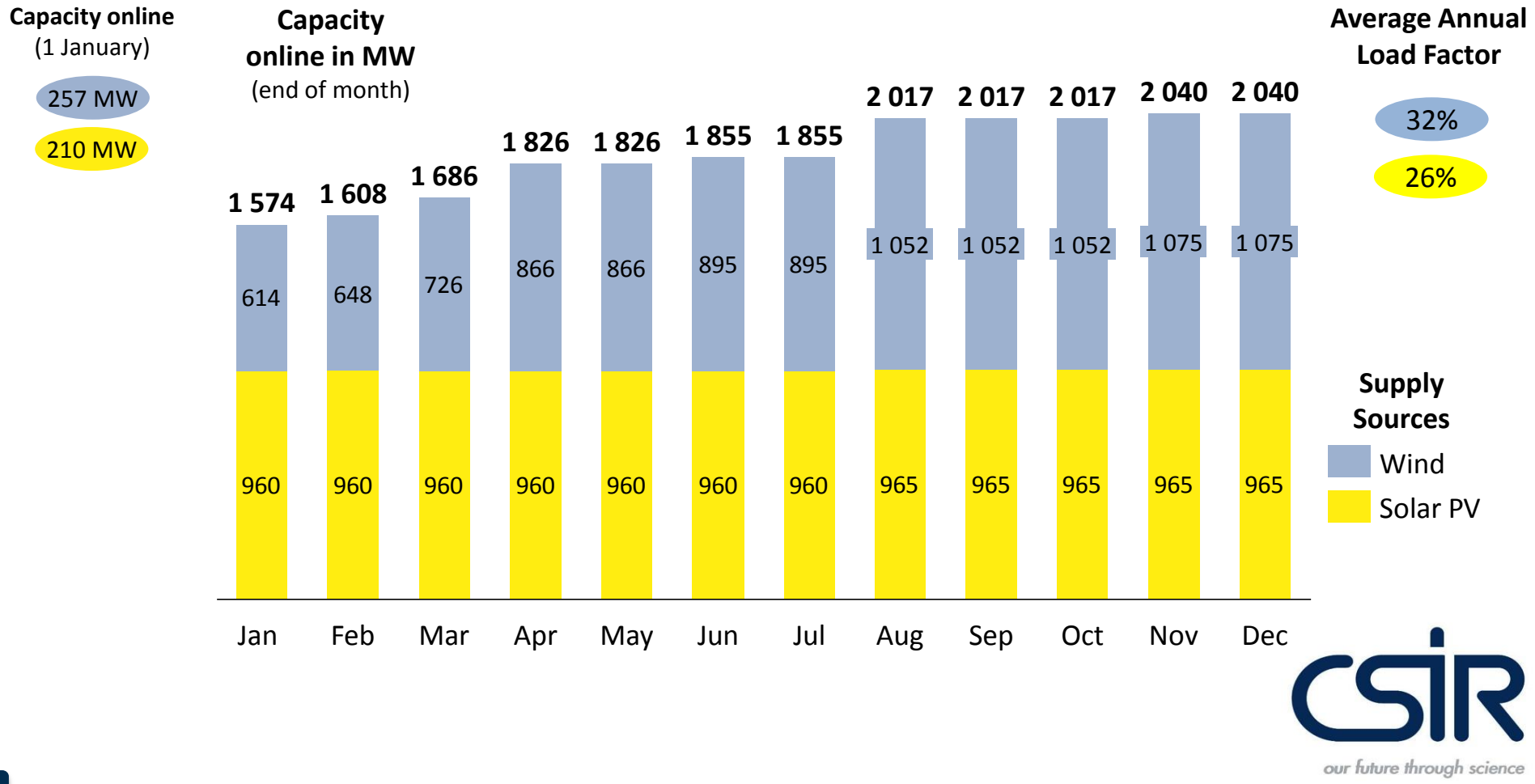
Actuals captured in wholesale market for Jan-Dec 2015 (i.e. without self-consumption of embedded plants)



Sources: Eskom; CSIR Energy Centre analysis

In 2015, 461 MW of wind and 5 MW of solar PV were added to the grid

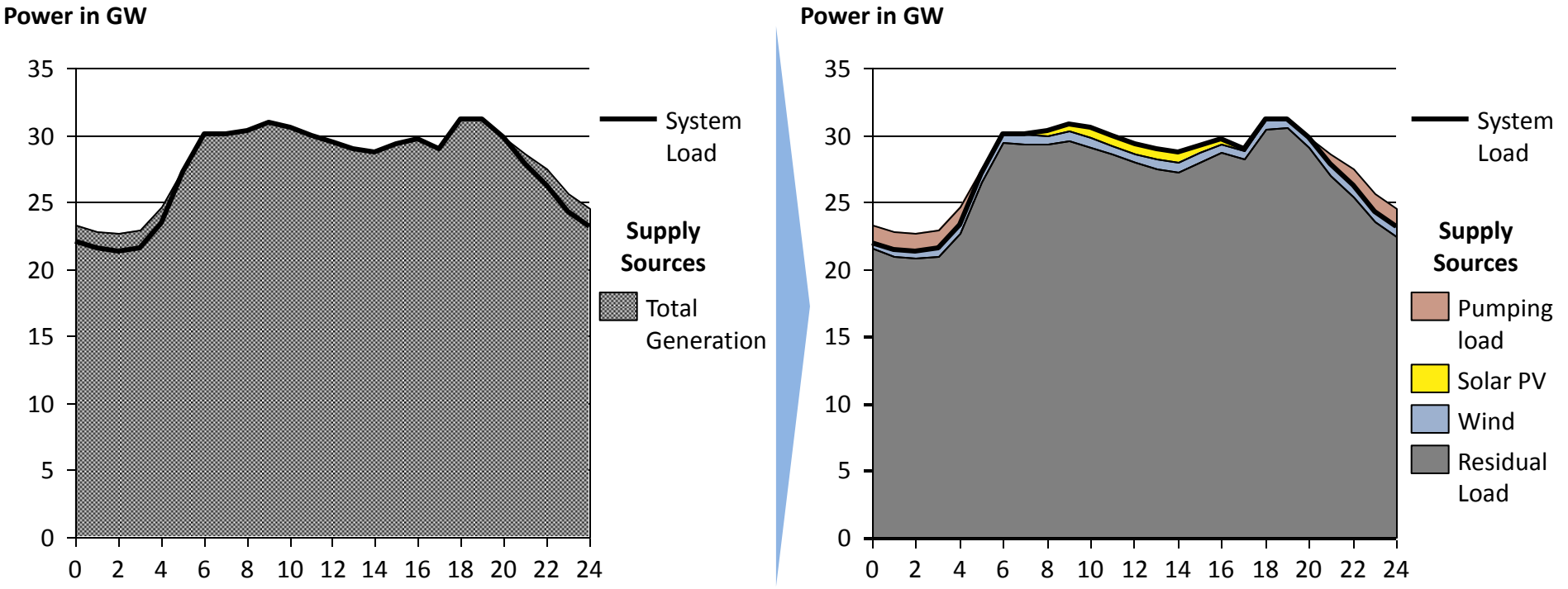
Total monthly installed capacity of wind and Solar PV in MW in RSA from Jan-Dec 2015



Notes: Capacity online as per actual start of operation (can differ from REIPPP contracted date). Wind includes Sere wind farm (100 MW)
Sources: Eskom; DoE IPP Office

Illustrative day explaining terminologies used in this presentation

Hourly South African supply structure for a random day in 2015



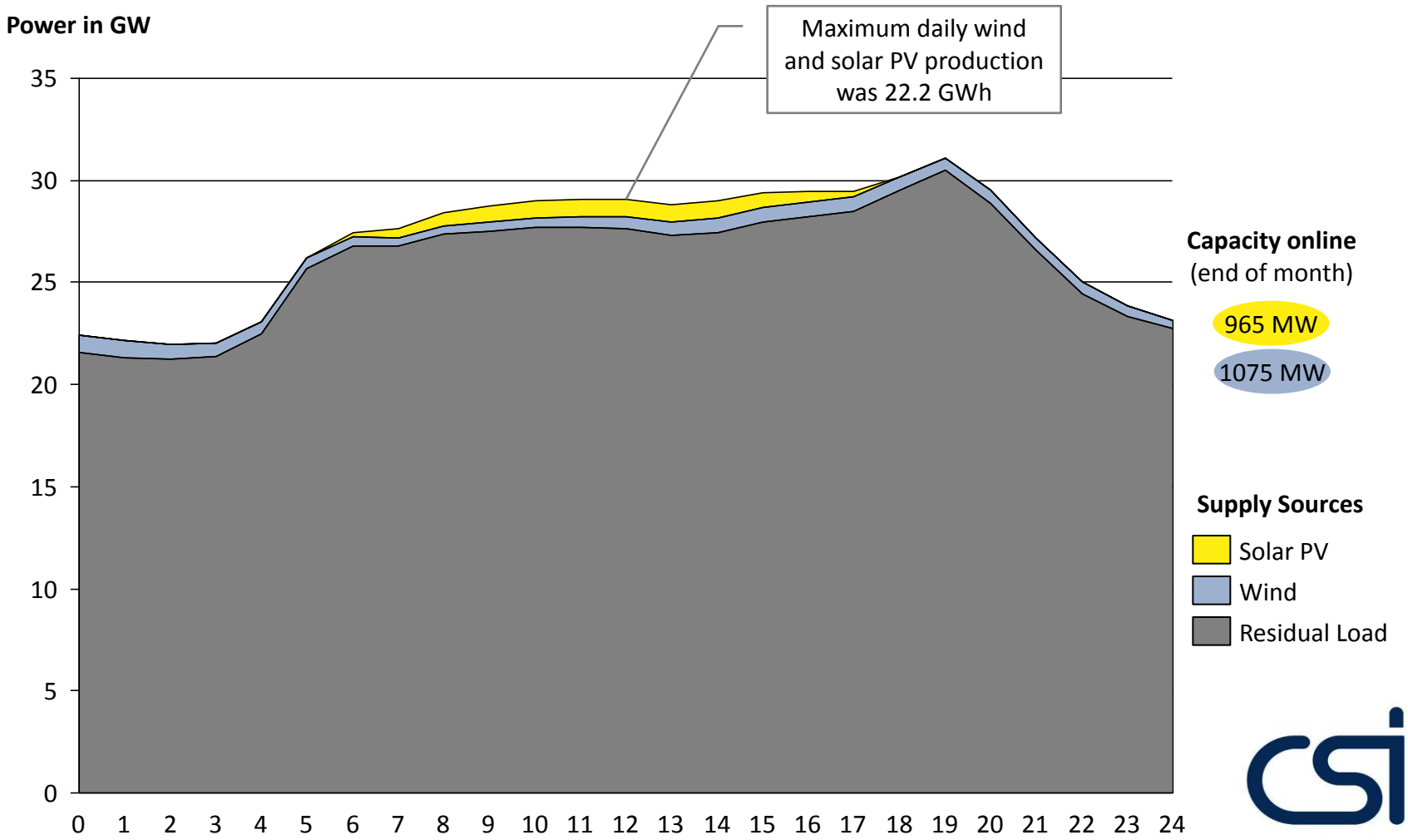
Total Generation	**= domestic generation (Eskom + IPPs) + imported generation**
System Load	**= domestic generation (Eskom + IPPs) + imported generation – pumping load** **= domestic customer load without pumping load (also referred to as simply "domestic load") + export load**
Residual Load	**= System Load – wind – solar PV**

IPPs: Independent Power Producers; pumping load: demand from pumped storage scheme when operated in pumping mode

Sources: Eskom; CSIR Energy Centre analysis

Maximum daily wind & PV energy of 22.2 GWh occurred on 2 Nov 2015

Actual hourly wind and solar PV energy production in South Africa on 2 November 2015 (Monday)

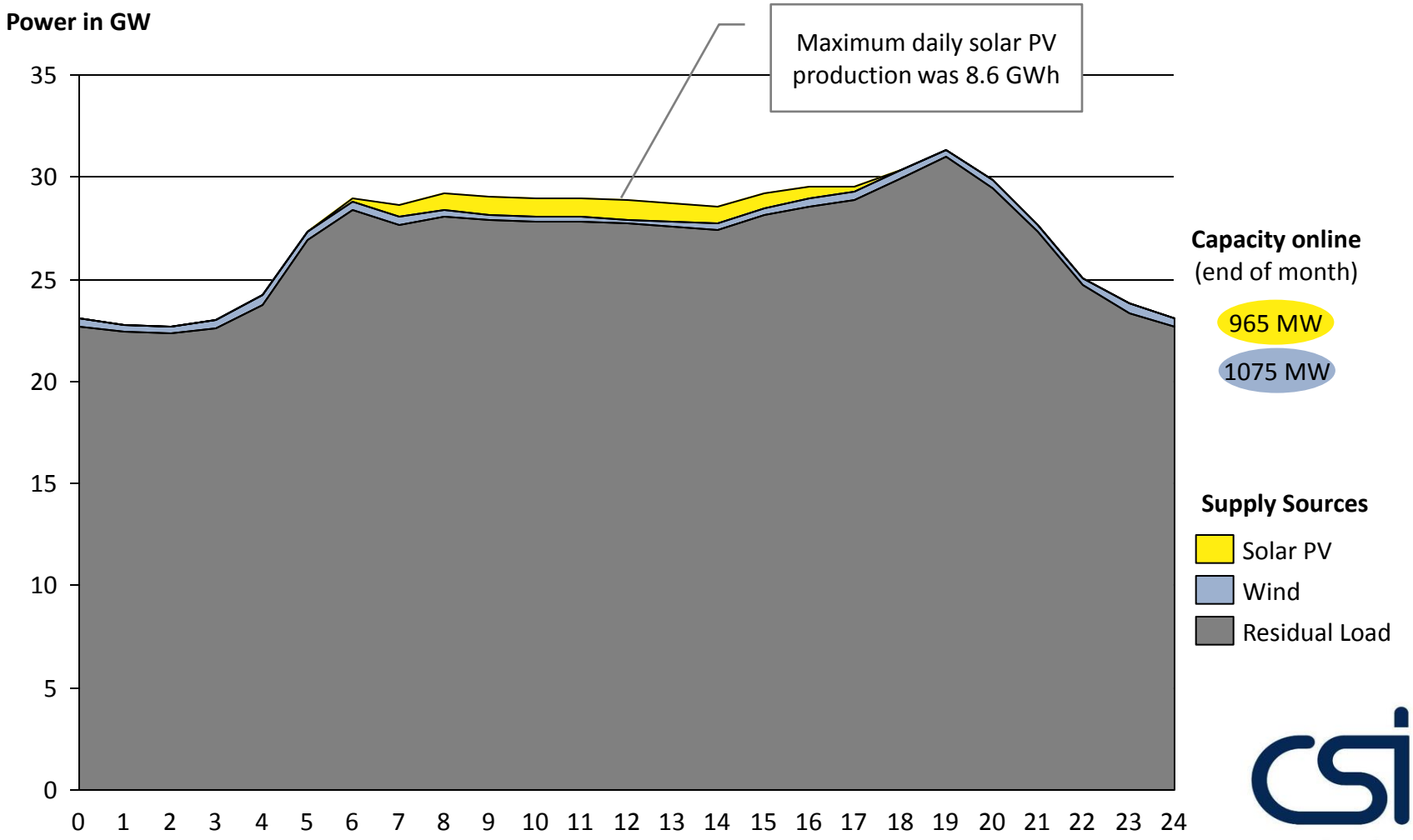


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Maximum daily solar PV energy of 8.6 GWh achieved on 3 Nov 2015

Actual hourly wind and solar PV energy production in South Africa on 3 November 2015 (Tuesday)

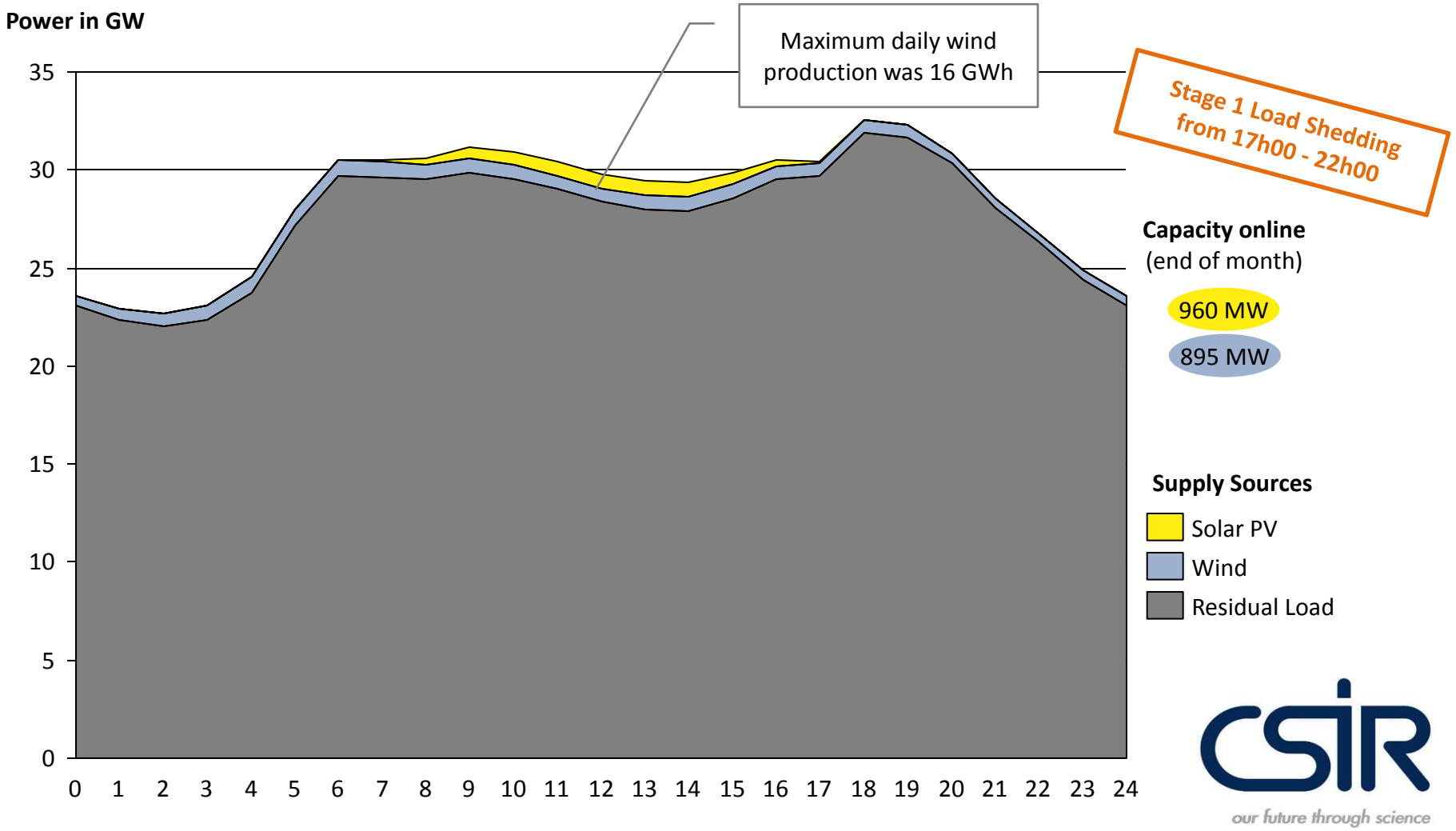


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Maximum daily wind energy of 16 GWh achieved on 30 Jul 2015

Actual hourly wind and solar PV energy production in South Africa on 30 July 2015 (Thursday)

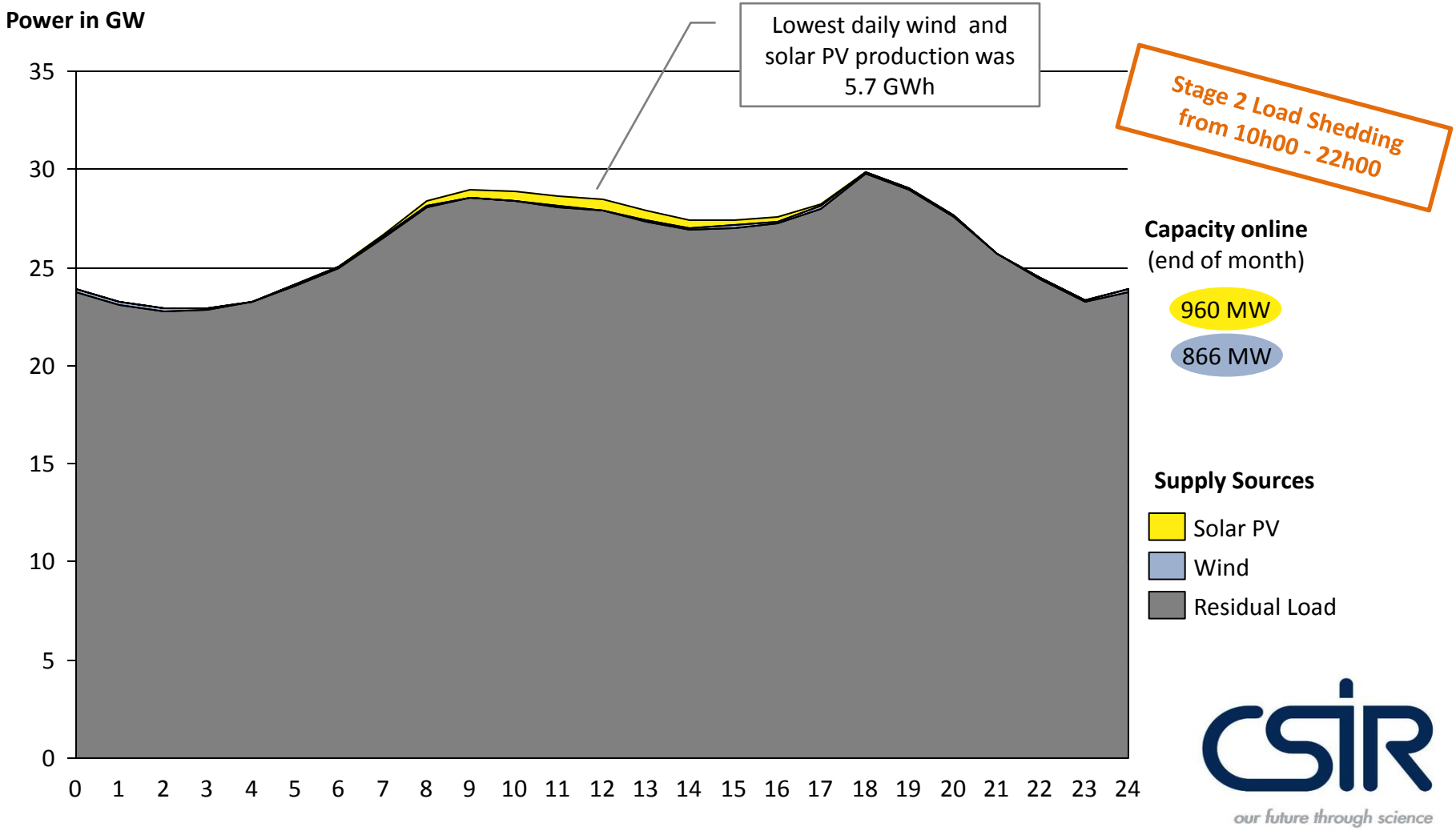


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Lowest combined wind & solar PV energy of 5.7 GWh on 11 Apr 2015

Actual hourly wind and solar PV energy production in South Africa on 11 April 2015 (Saturday)

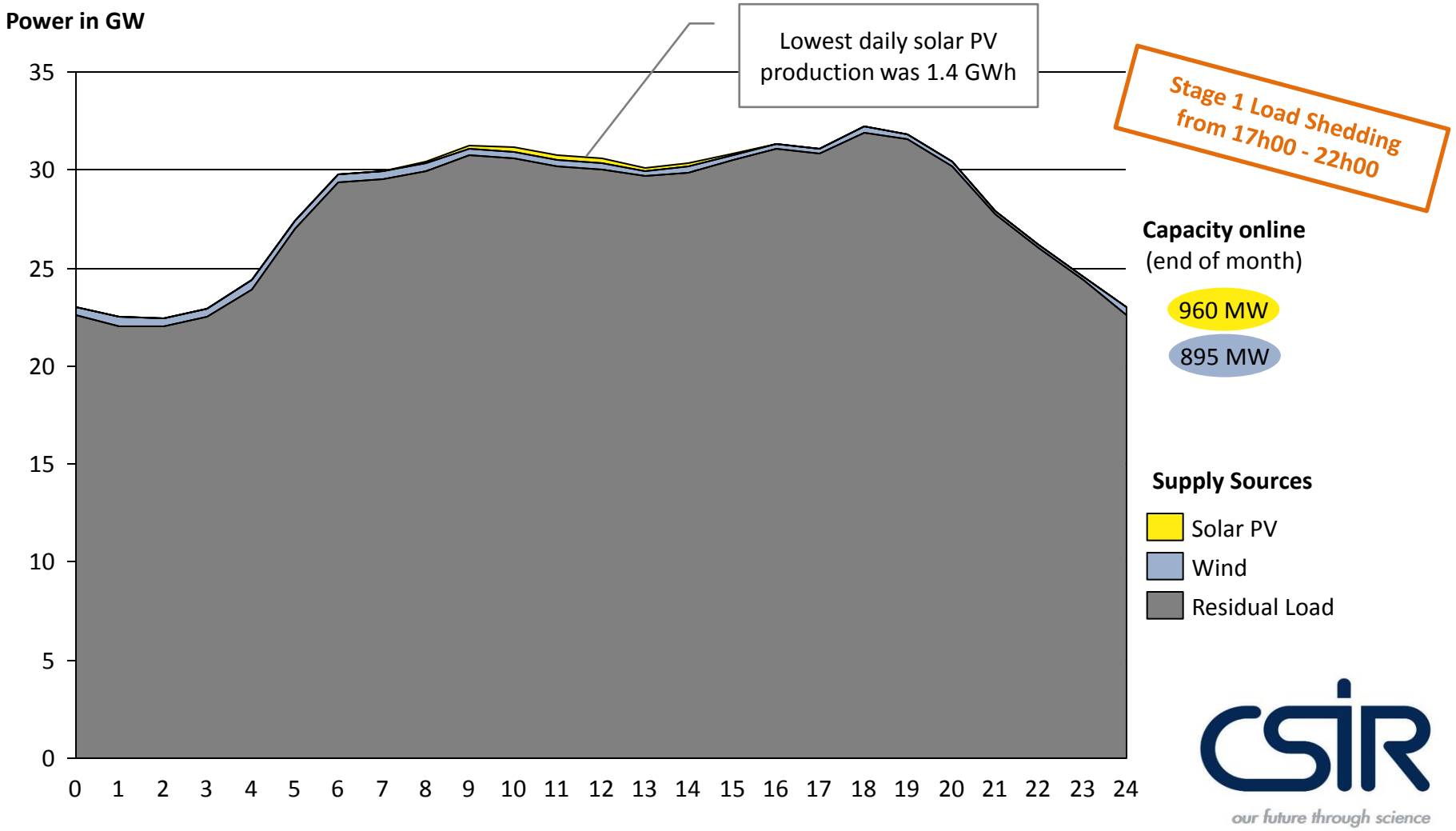


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Lowest solar PV energy production of 1.4 GWh occurred on 22 Jul 2015

Actual hourly wind and solar PV energy production in South Africa on 22 July 2015 (Wednesday)

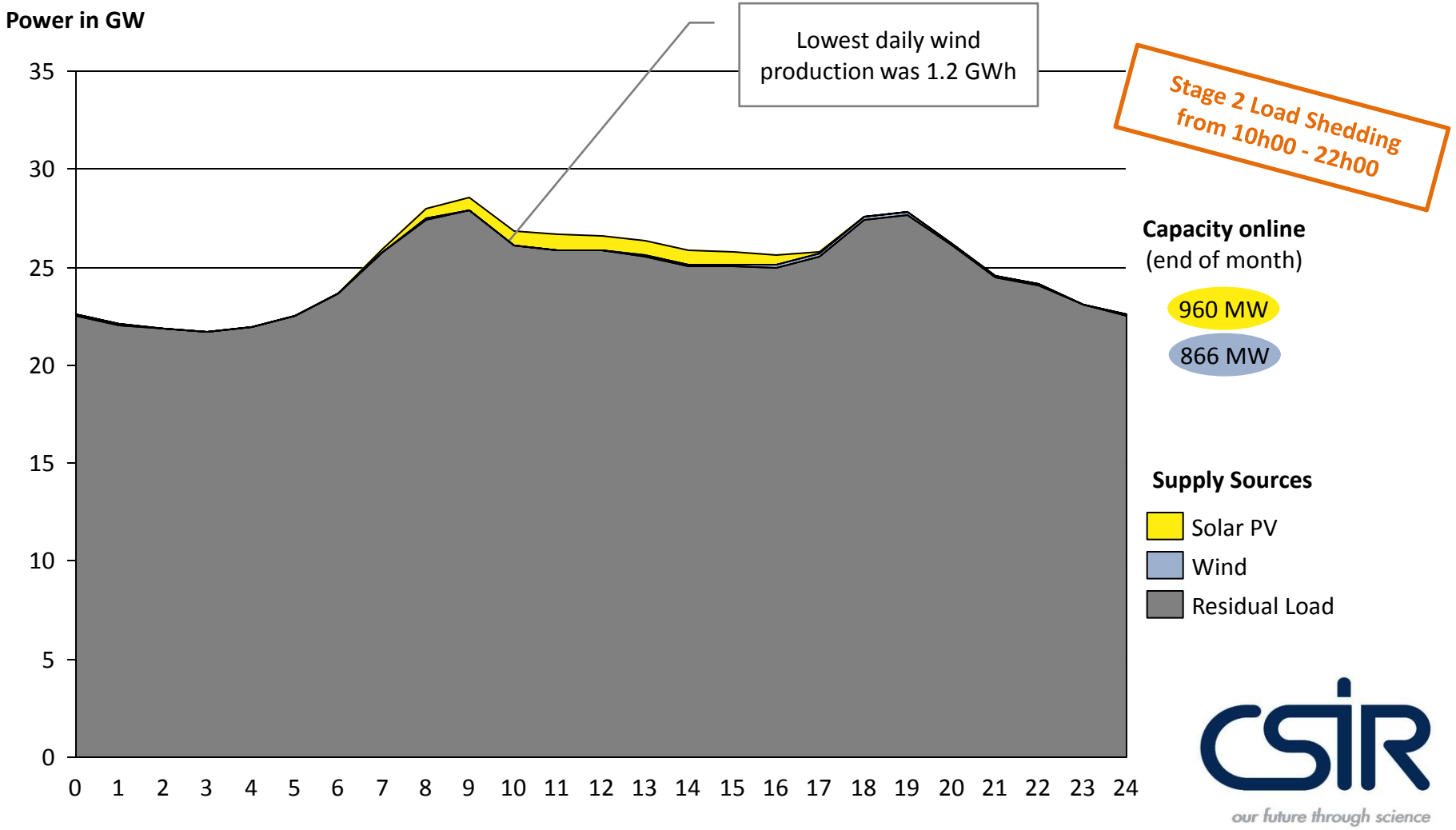


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Lowest wind energy production of 1.2 GWh occurred on 12 Apr 2015

Actual hourly wind and solar PV energy production in South Africa on 12 April 2015 (Sunday)

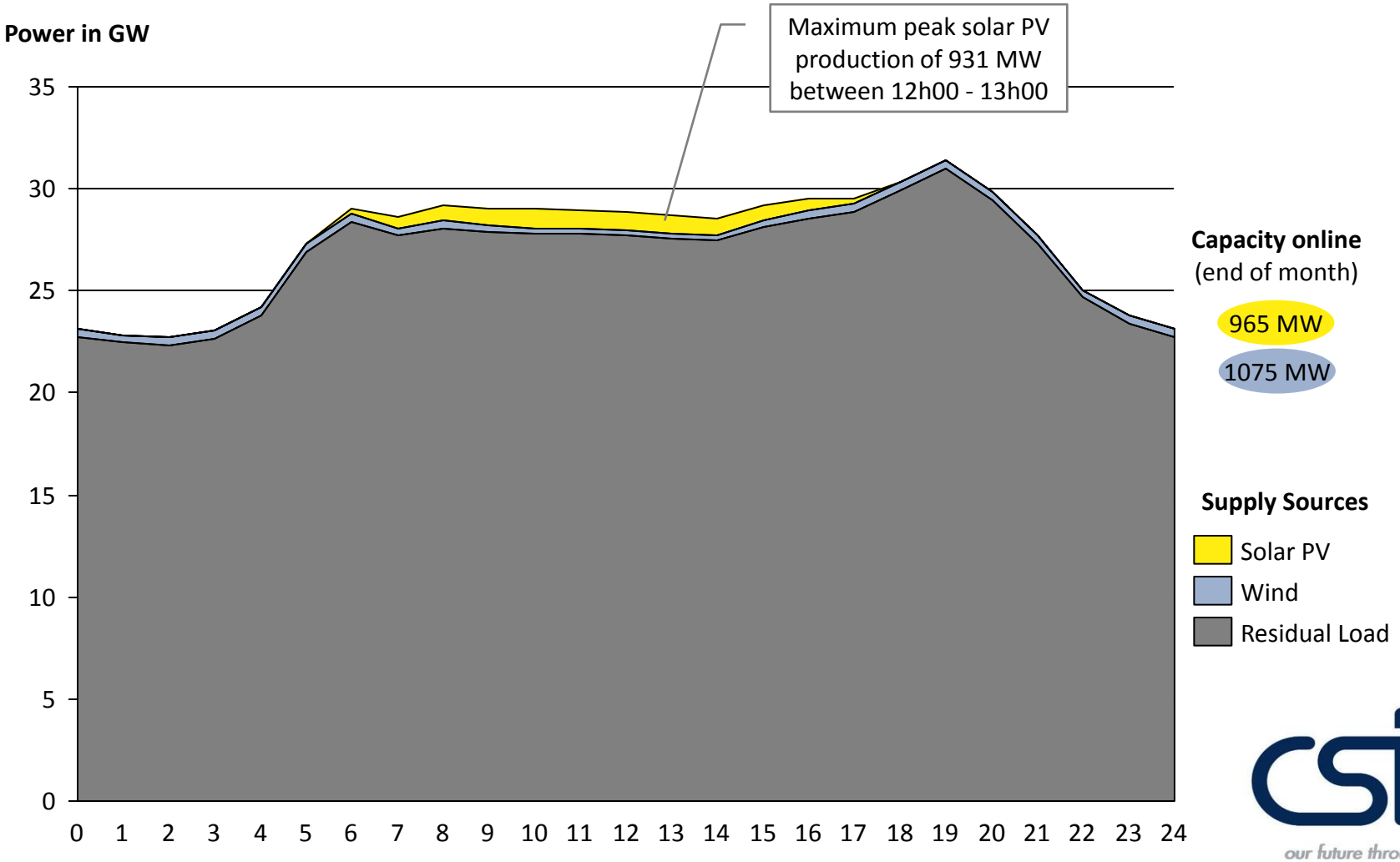


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Maximum solar PV power output of 931 MW occurred on 3 Nov 2015

Actual hourly wind and solar PV energy production in South Africa on 3 November 2015 (Tuesday)

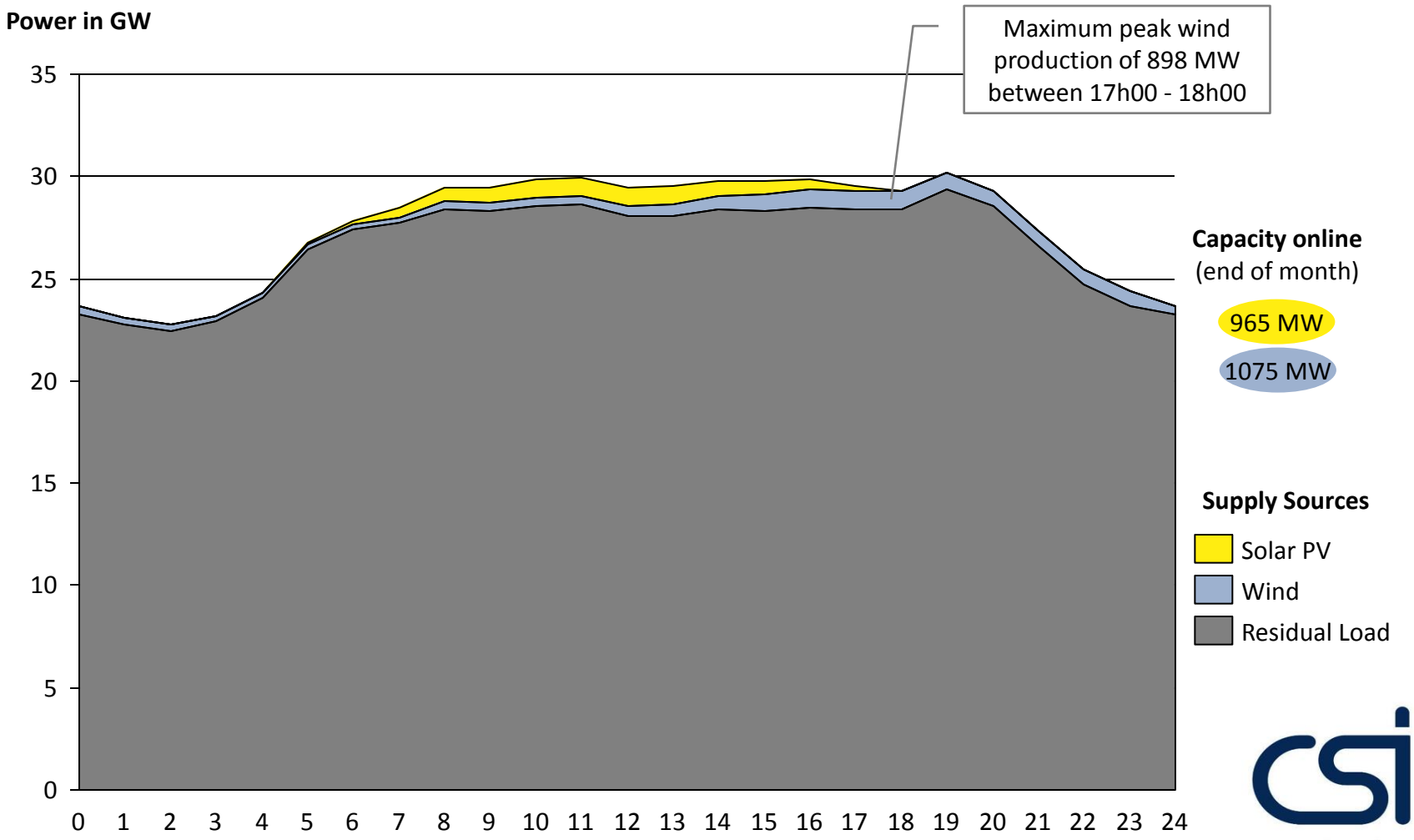


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Maximum wind power output of 898 MW occurred on 26 Nov 2015

Actual hourly wind and solar PV energy production in South Africa on 26 November 2015 (Thursday)

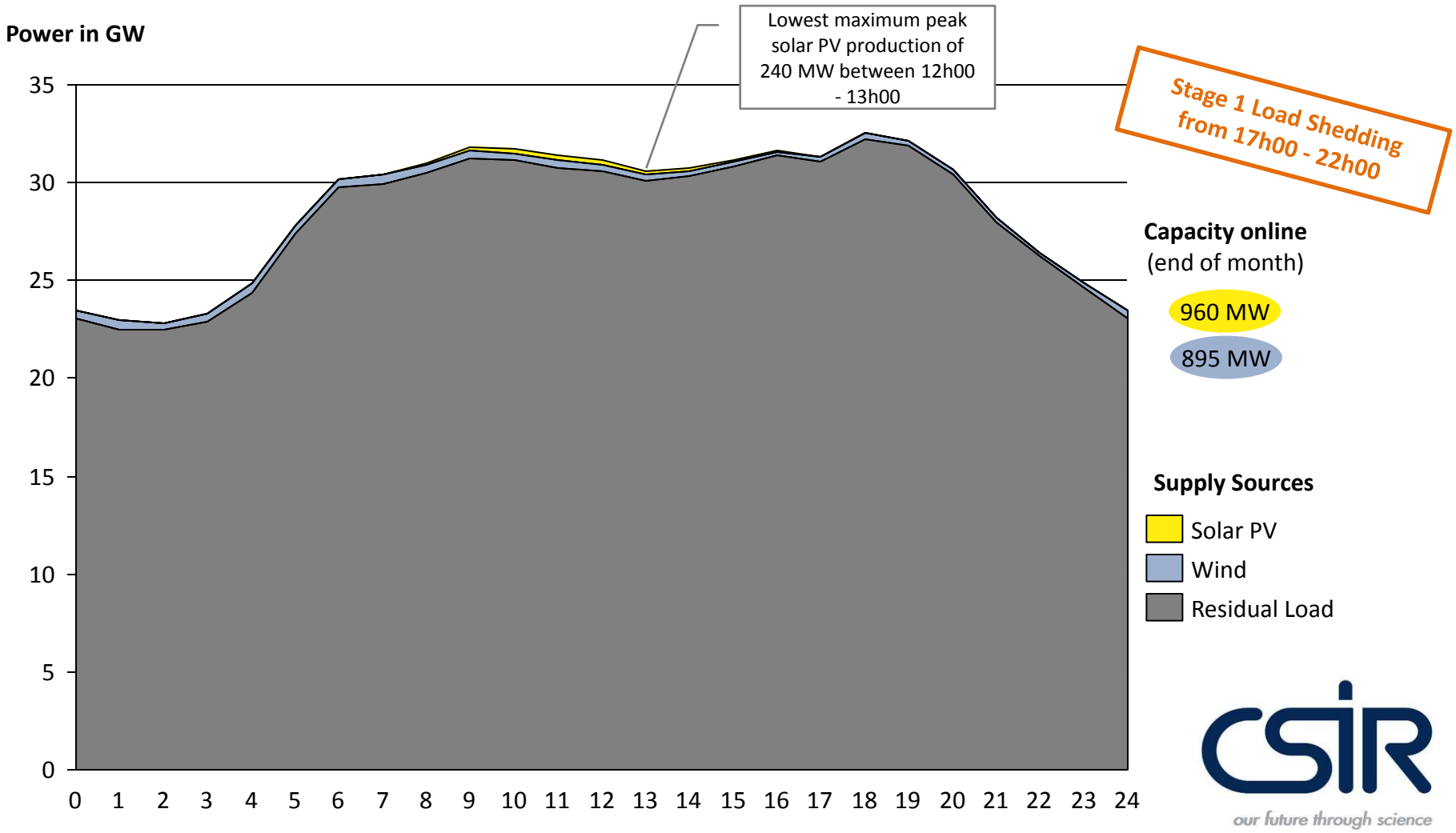


Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Lowest daily peak solar PV power output of 240 MW on 22 Jul 2015

Actual hourly wind and solar PV energy production in South Africa on 22 July 2015 (Wednesday)



Note: Total daily production excludes hyrdo pumping load

Sources: Eskom; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

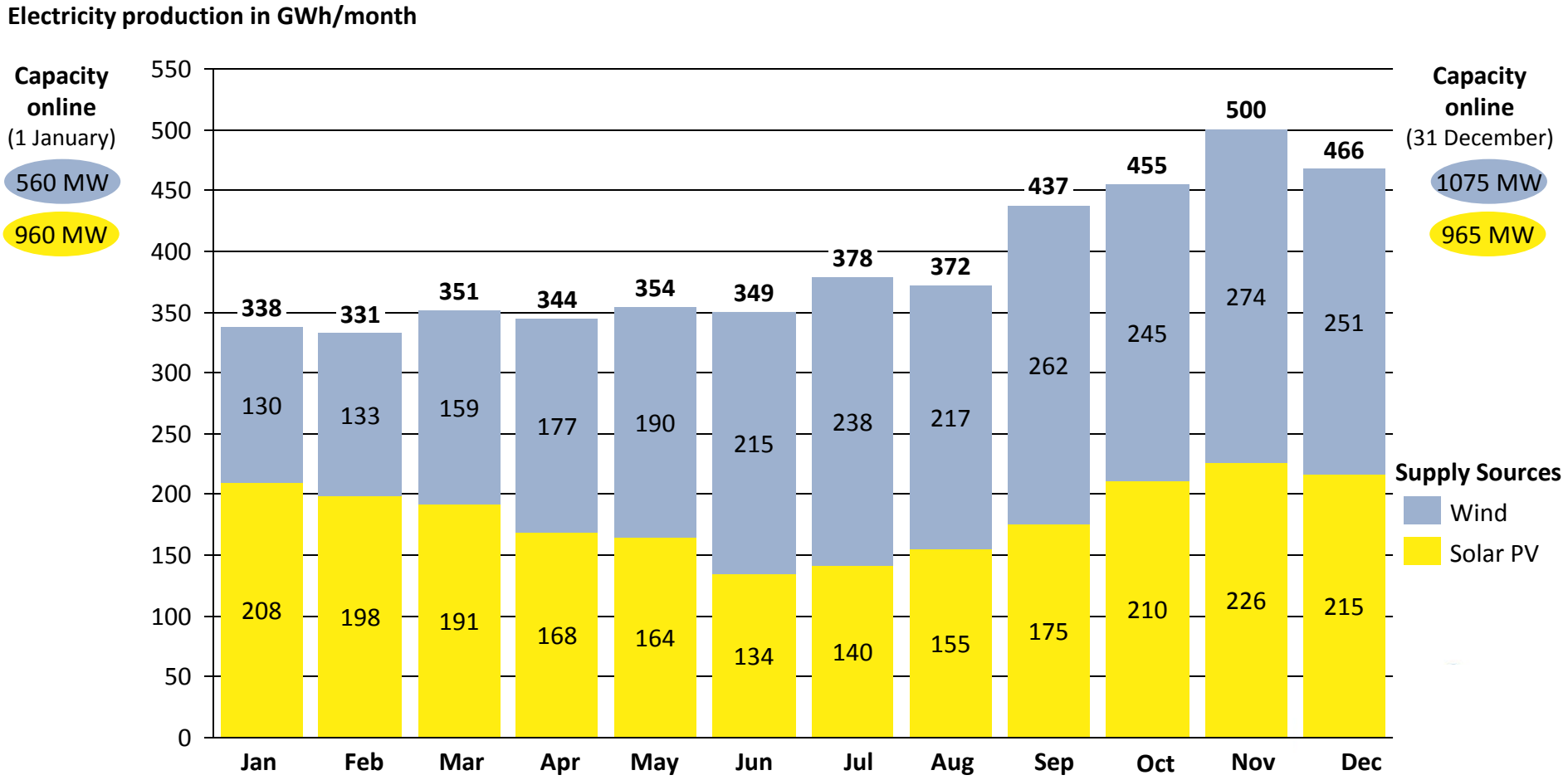
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Monthly electricity production of South African wind and solar PV fleet

Actual monthly production from solar PV and wind plants in South Africa from Jan-Dec 2015

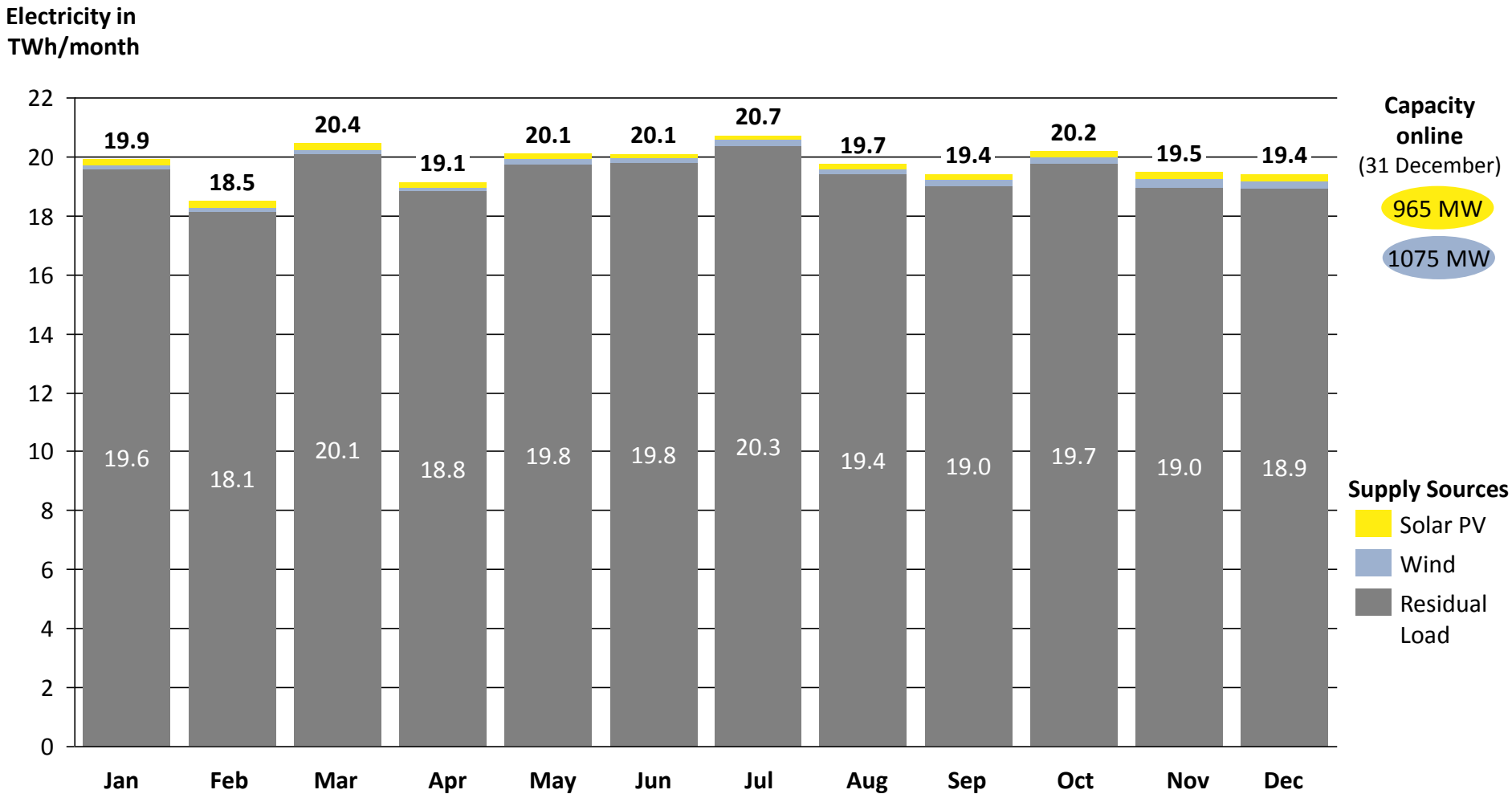


Note: Wind generation includes Eskom's 100 MW Sere wind farm which came online in 2014 and was fully commissioned by 31 March 2015

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Monthly electricity production wind, solar PV and residual load

Actual monthly electricity production for Jan-Dec 2015 from the different supply sources in South Africa

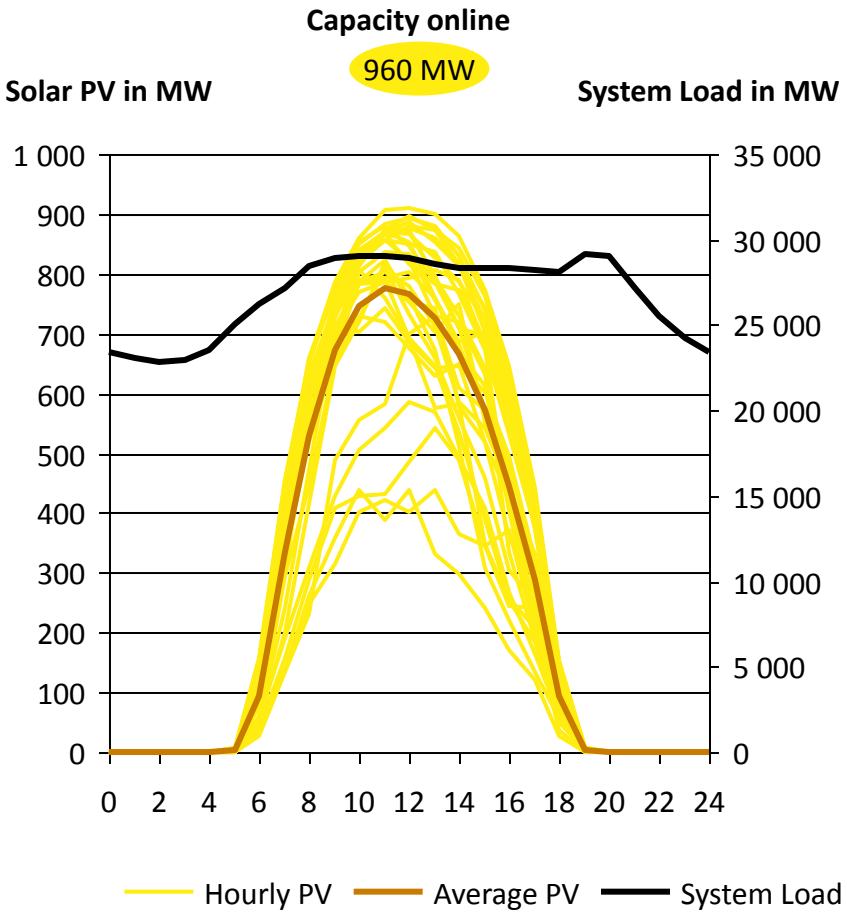


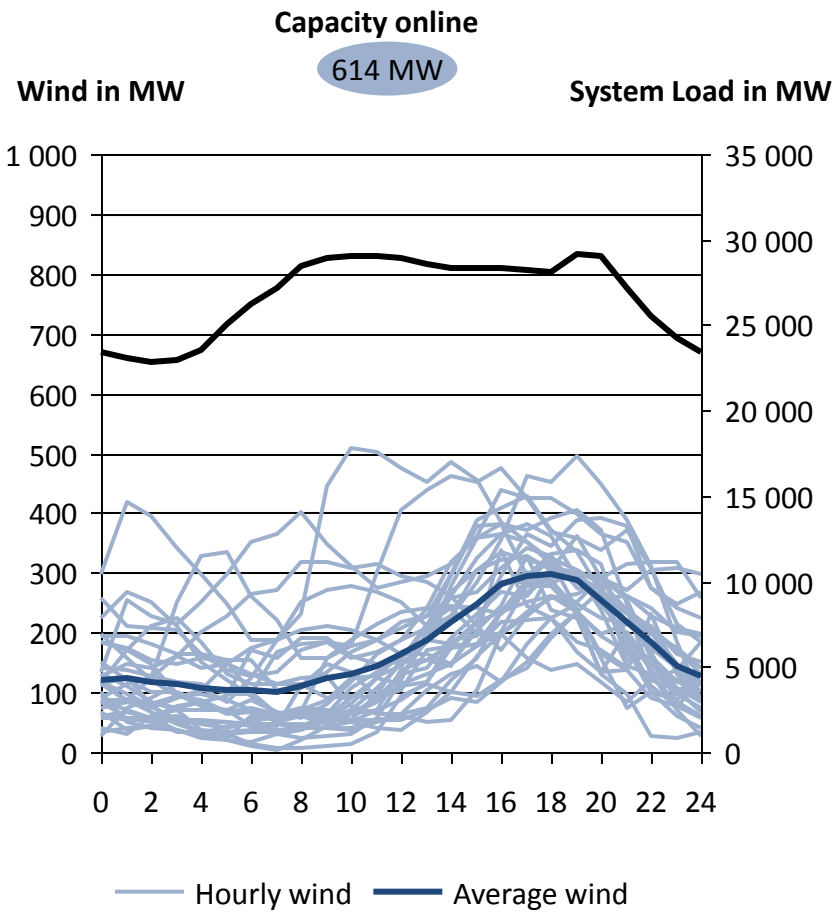
Notes: Pumping load excluded

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Jan 2015 was very stable, wind supplied in evenings

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



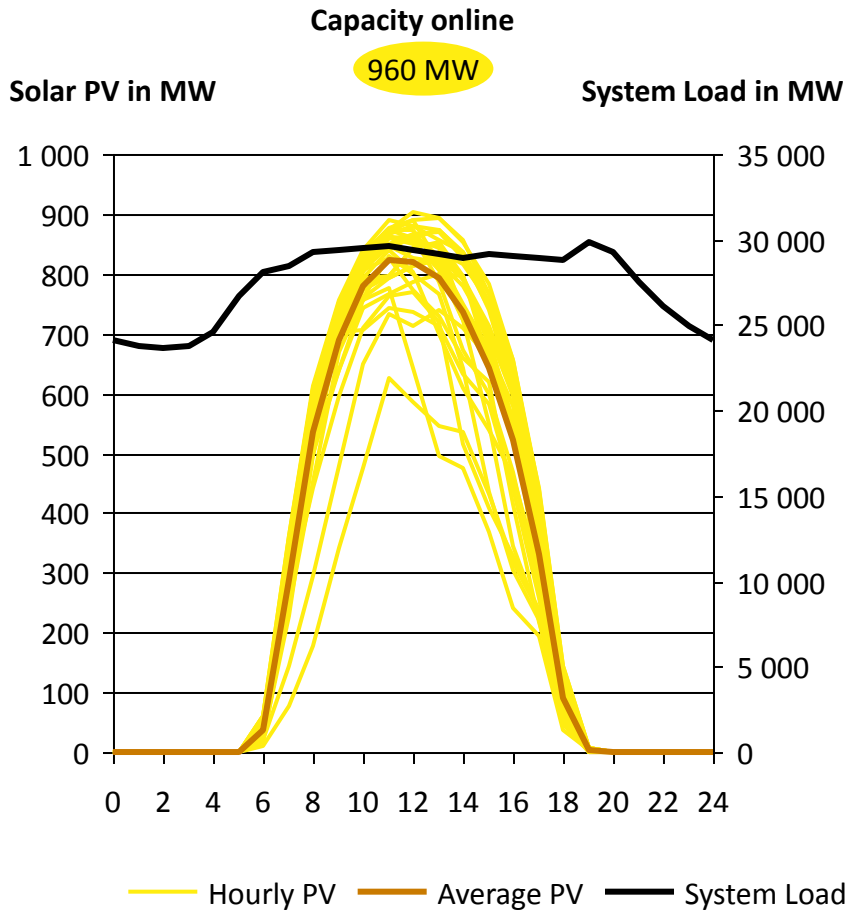


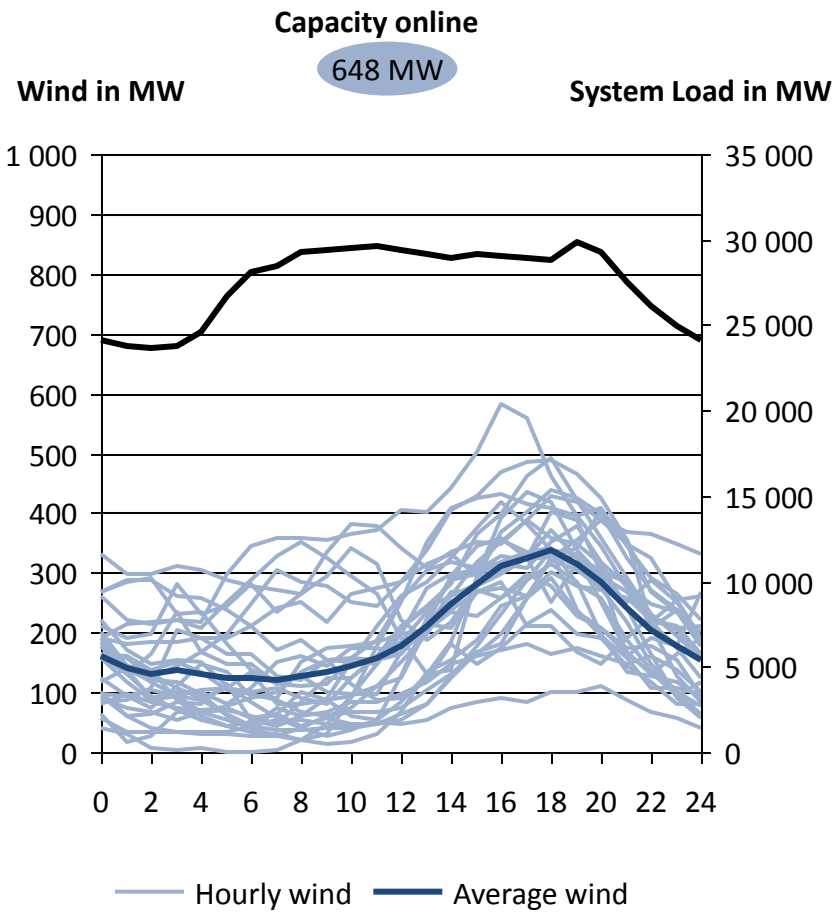
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Feb 2015 was very stable, wind supplied evenings

Hourly solar PV and wind production for all 28 days of Feb 2015 and average system load diurnal course



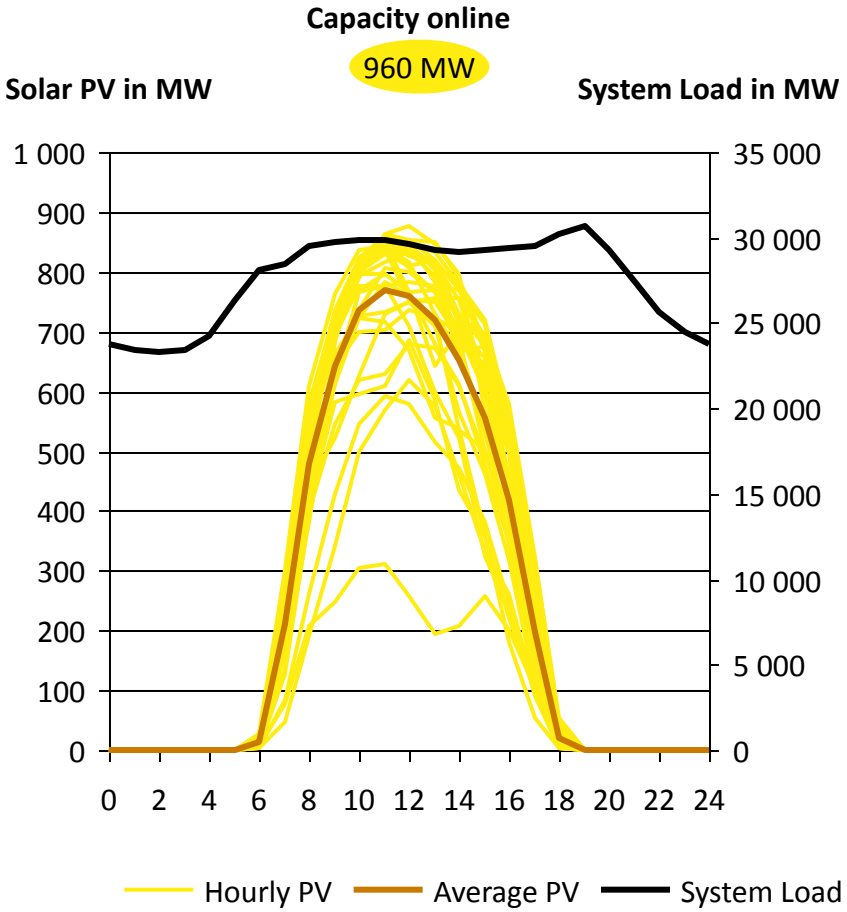


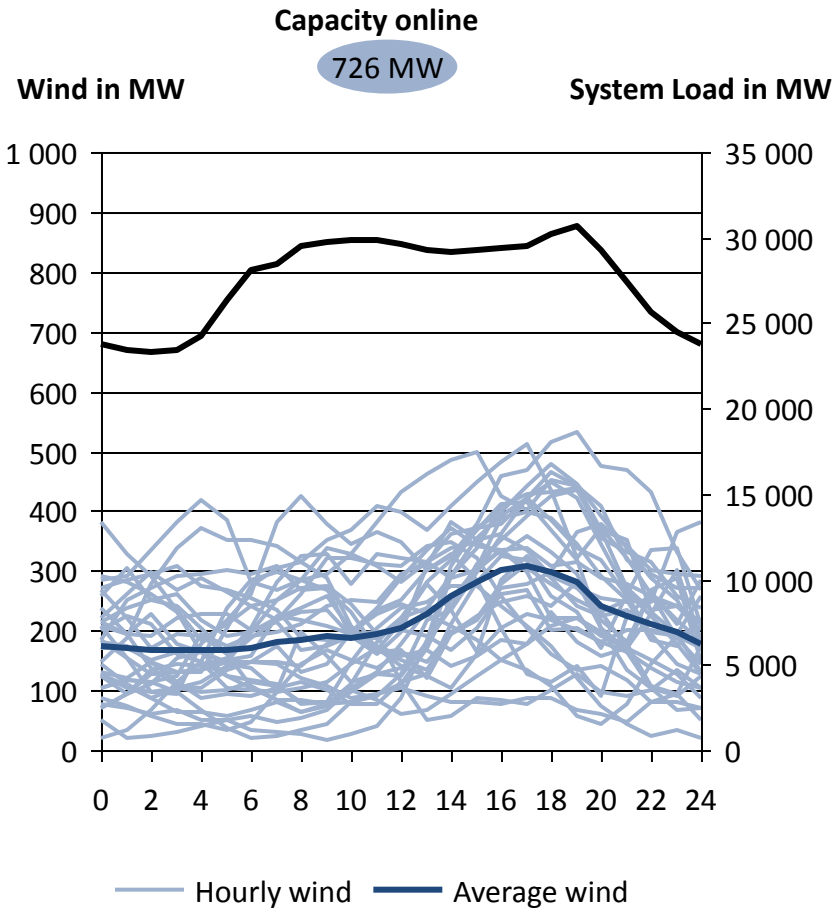
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Mar 2015 very stable, wind fluctuated day-to-day

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



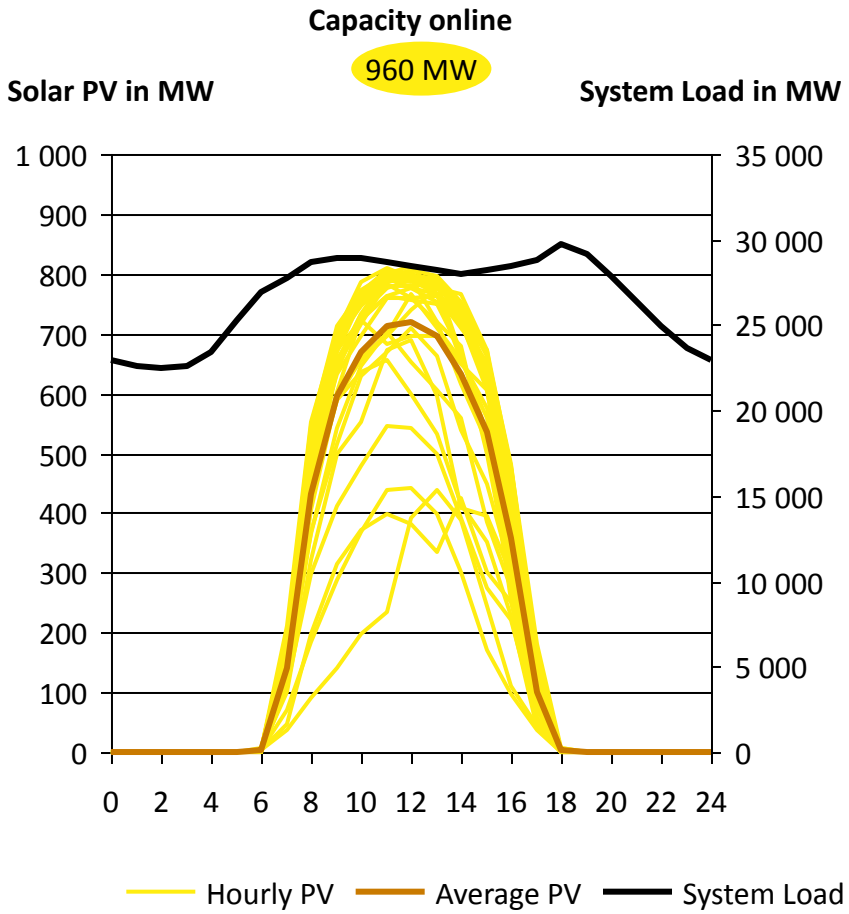


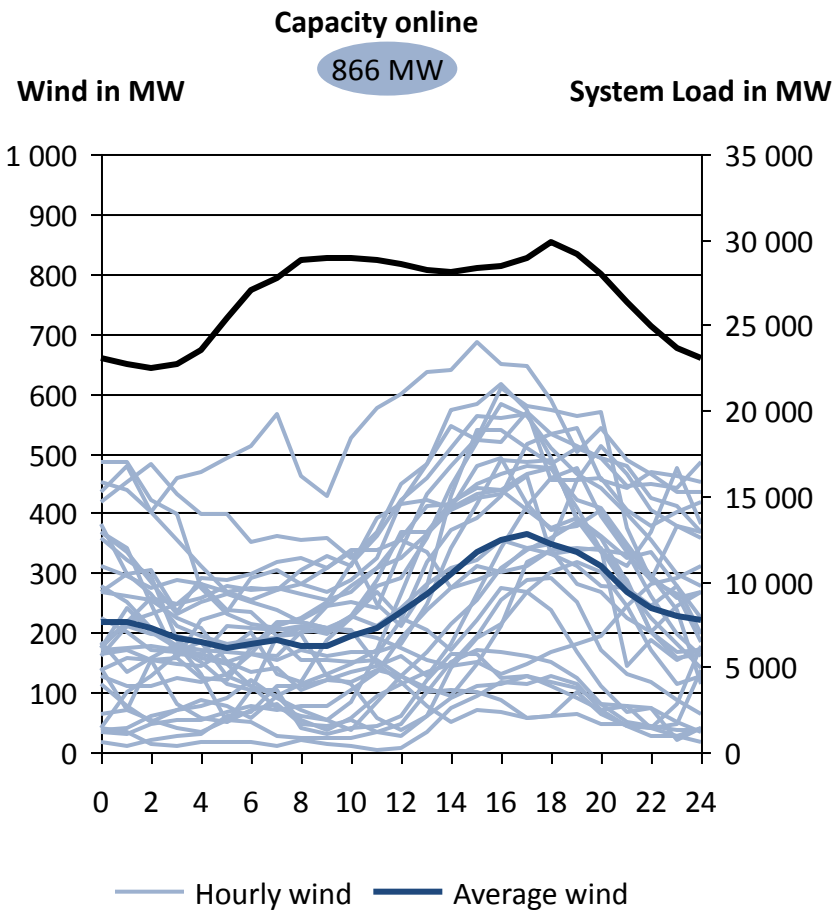
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Apr 2015 very stable, wind fluctuated day-to-day

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



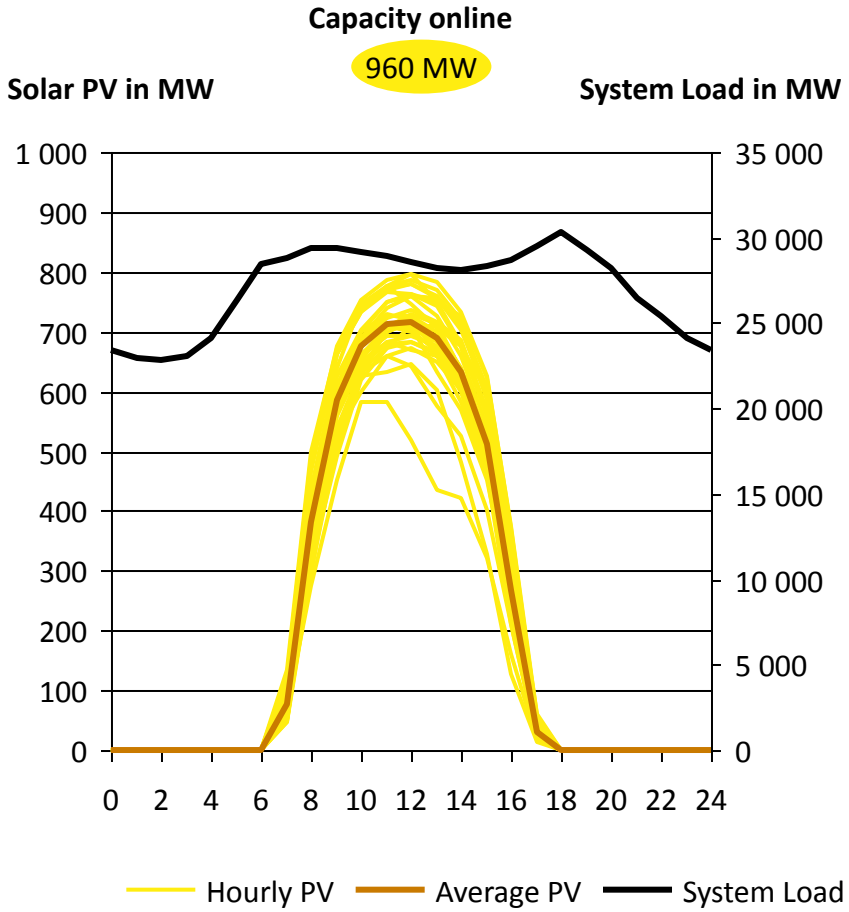


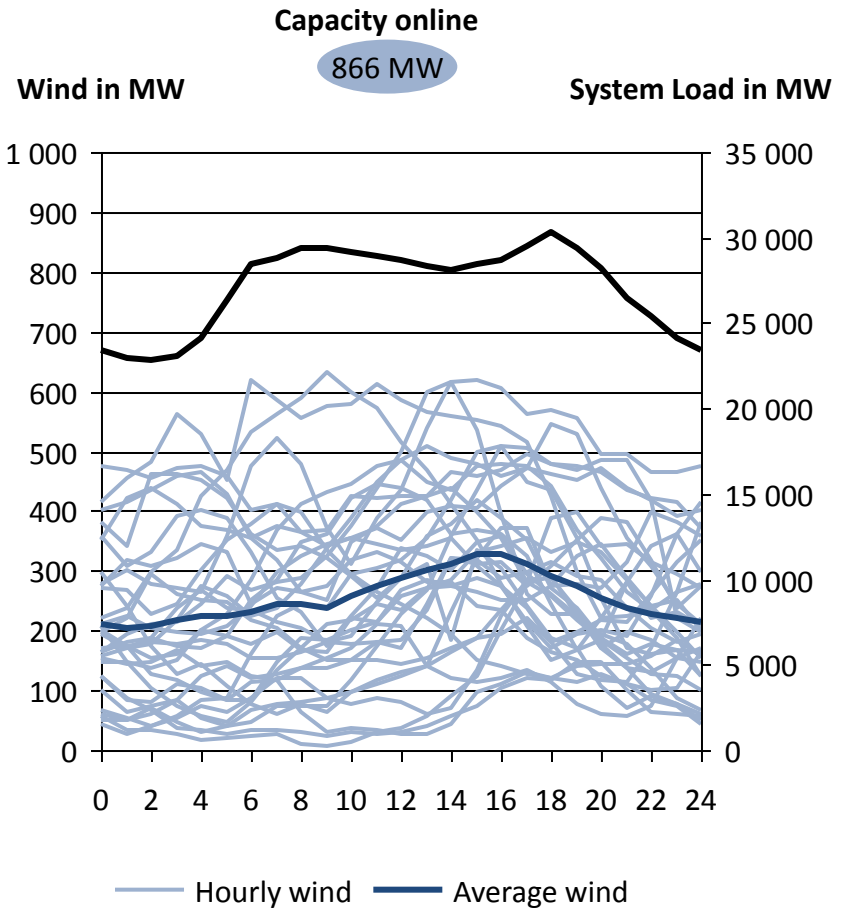
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

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

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



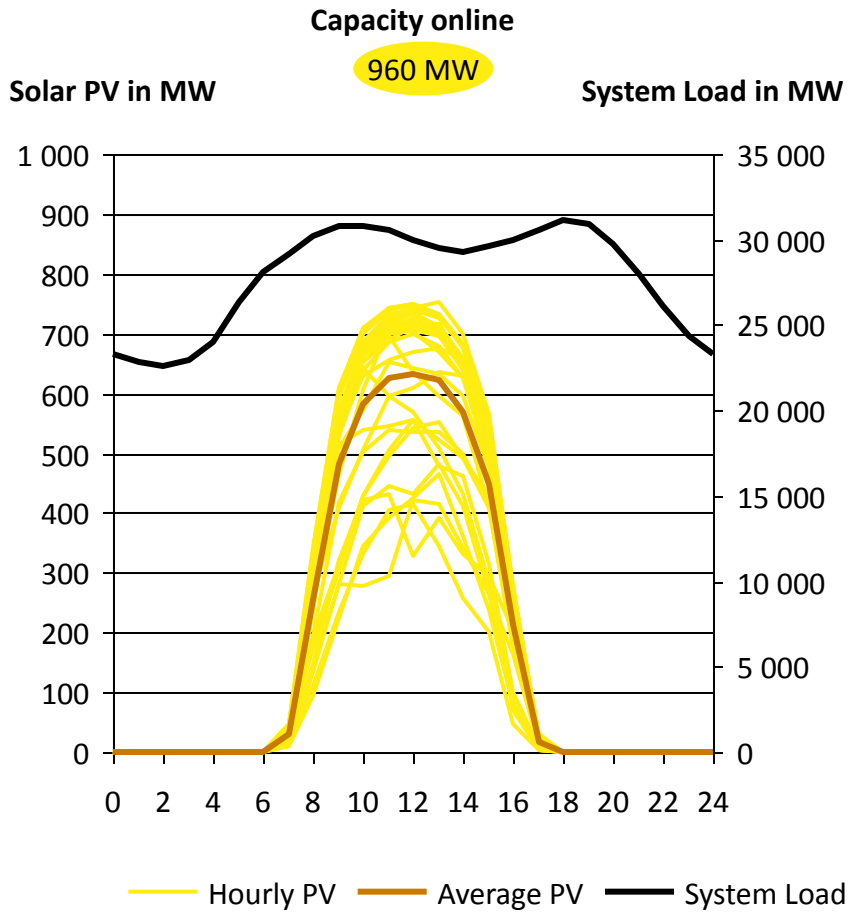


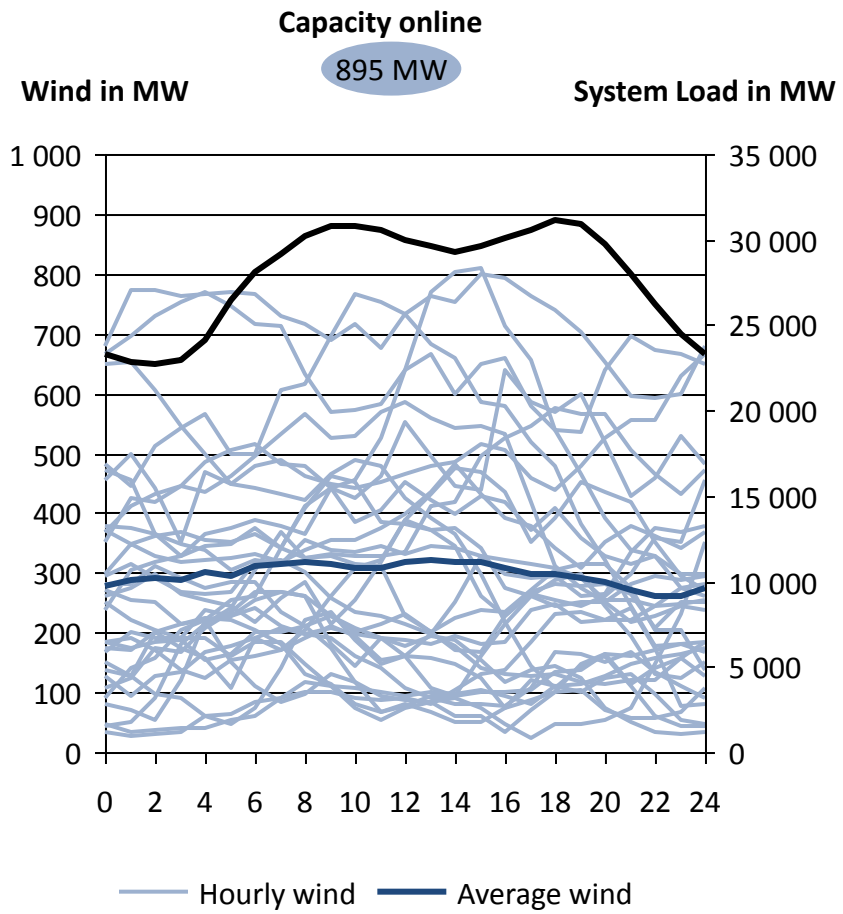
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Jun 2015 very stable, wind fluctuated day-to-day

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



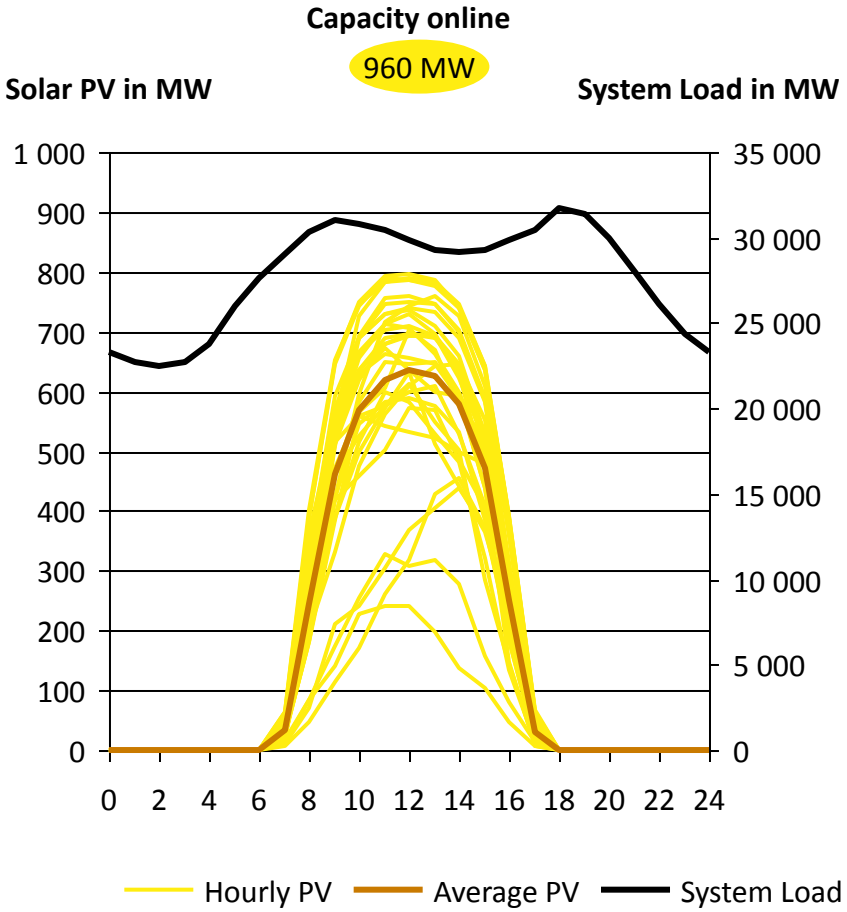


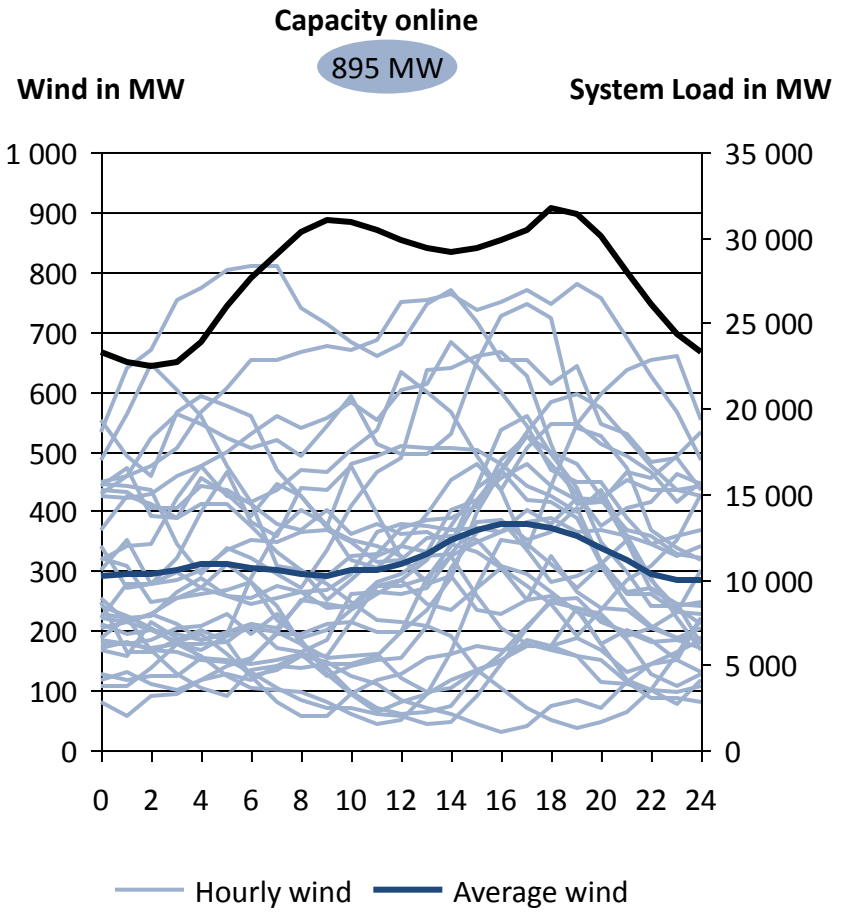
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Jul 2015 very stable, wind fluctuated day-to-day

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



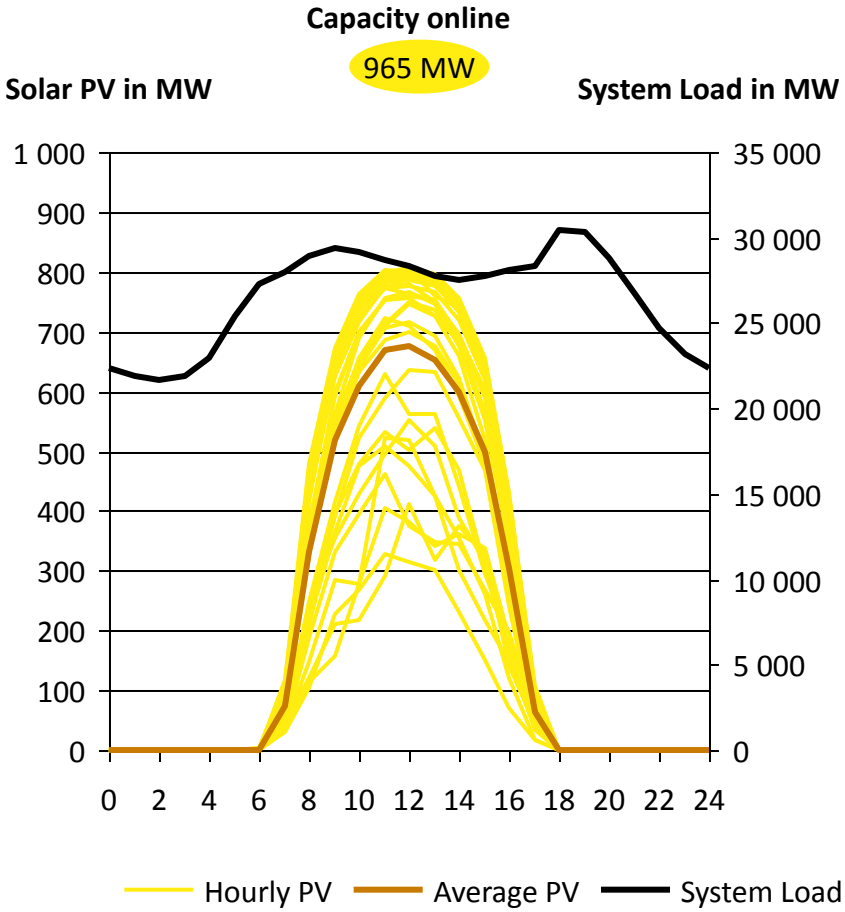


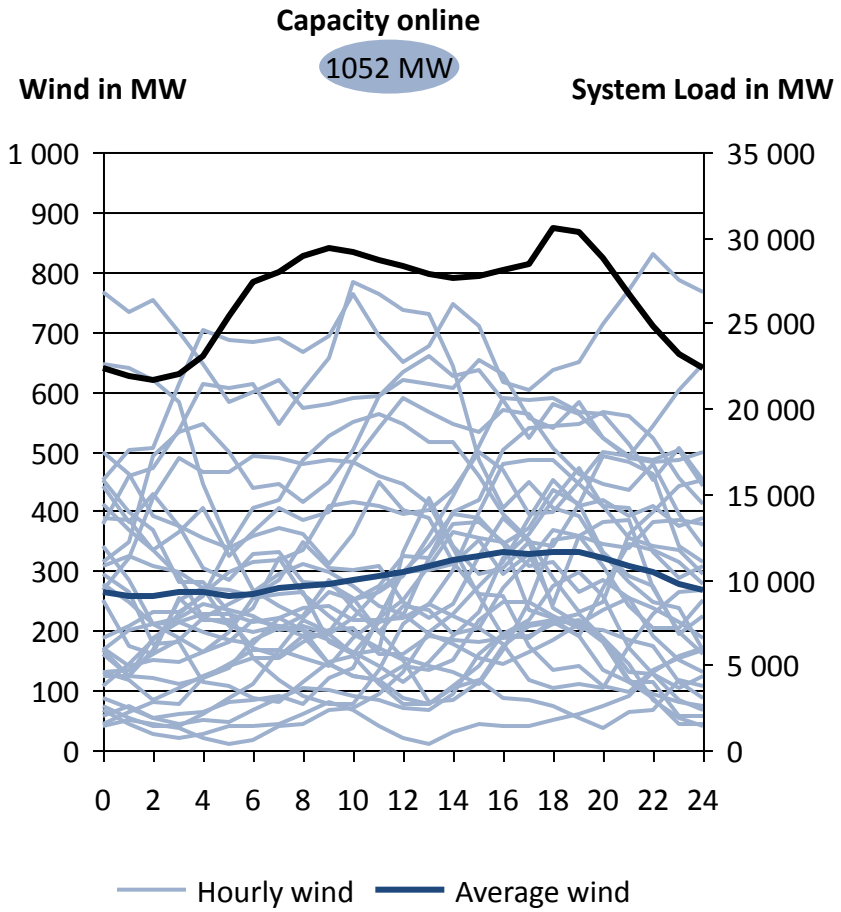
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Aug 2015 very stable, wind fluctuated day-to-day

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



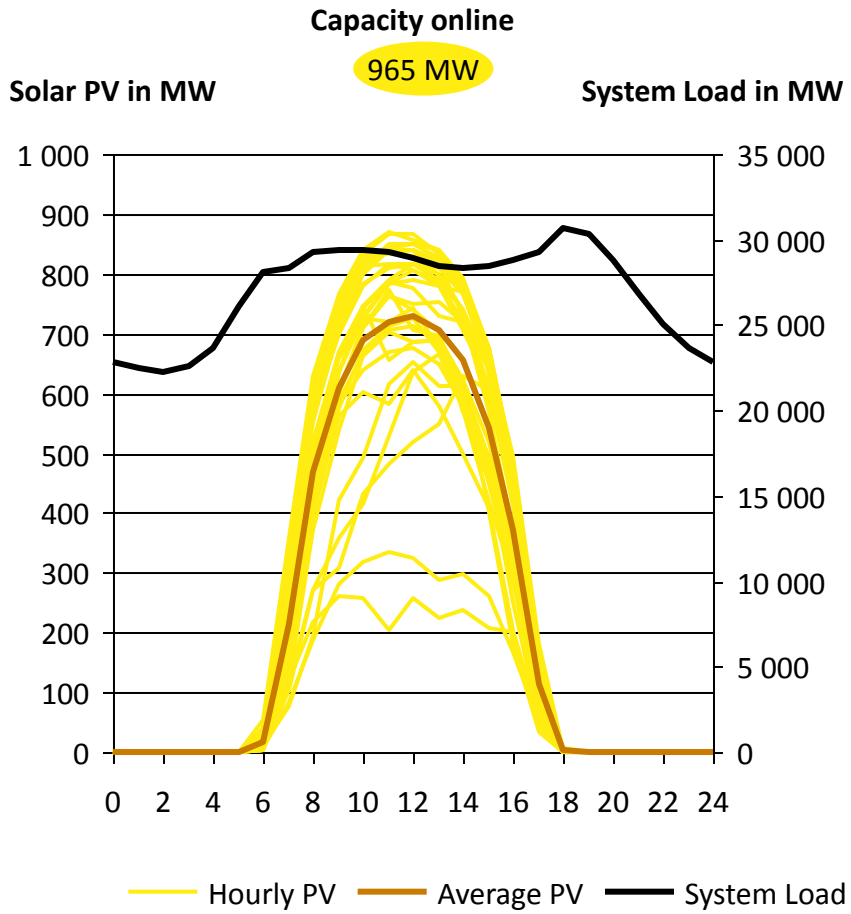


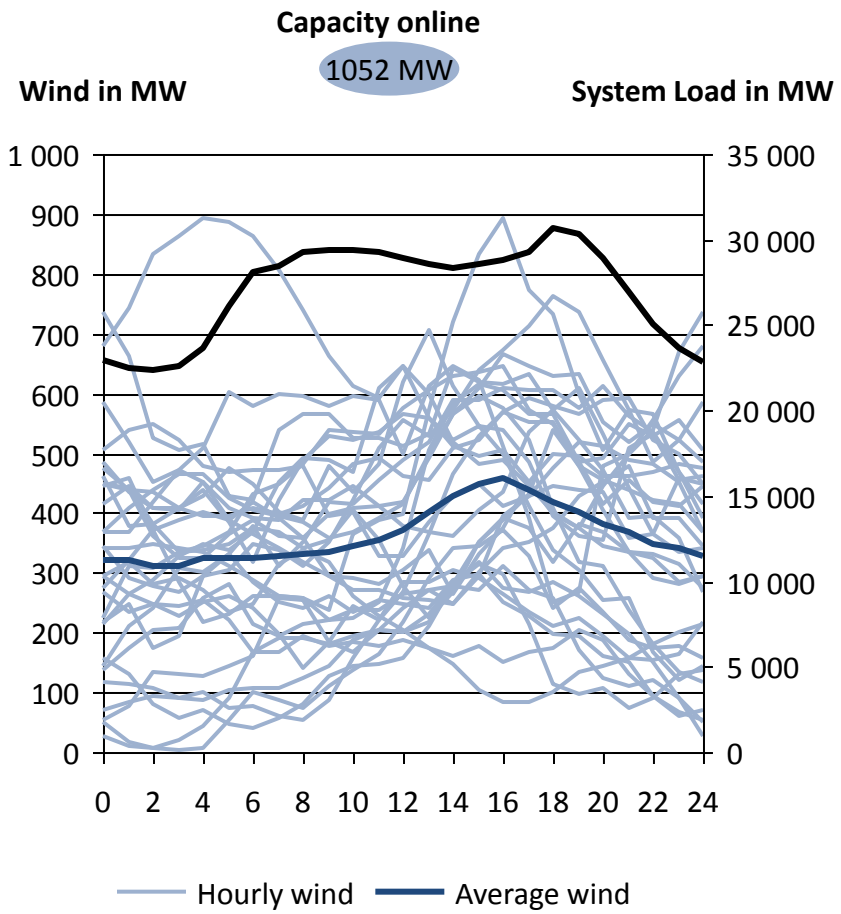
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Sep 2015 very stable, wind fluctuated day-to-day

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



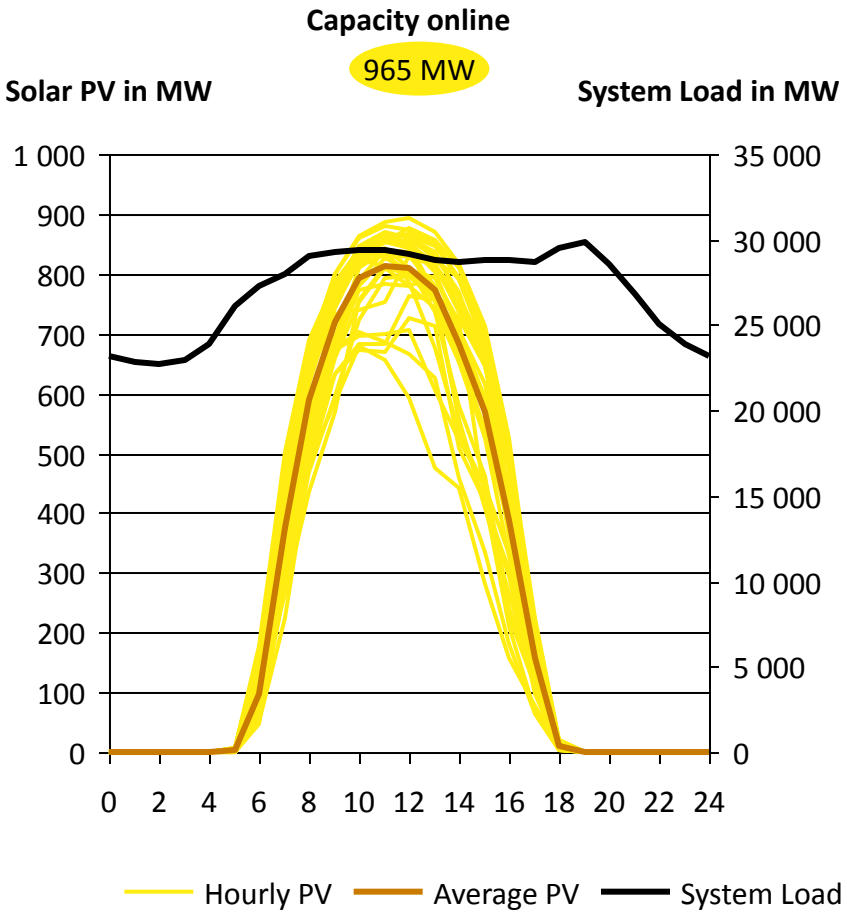


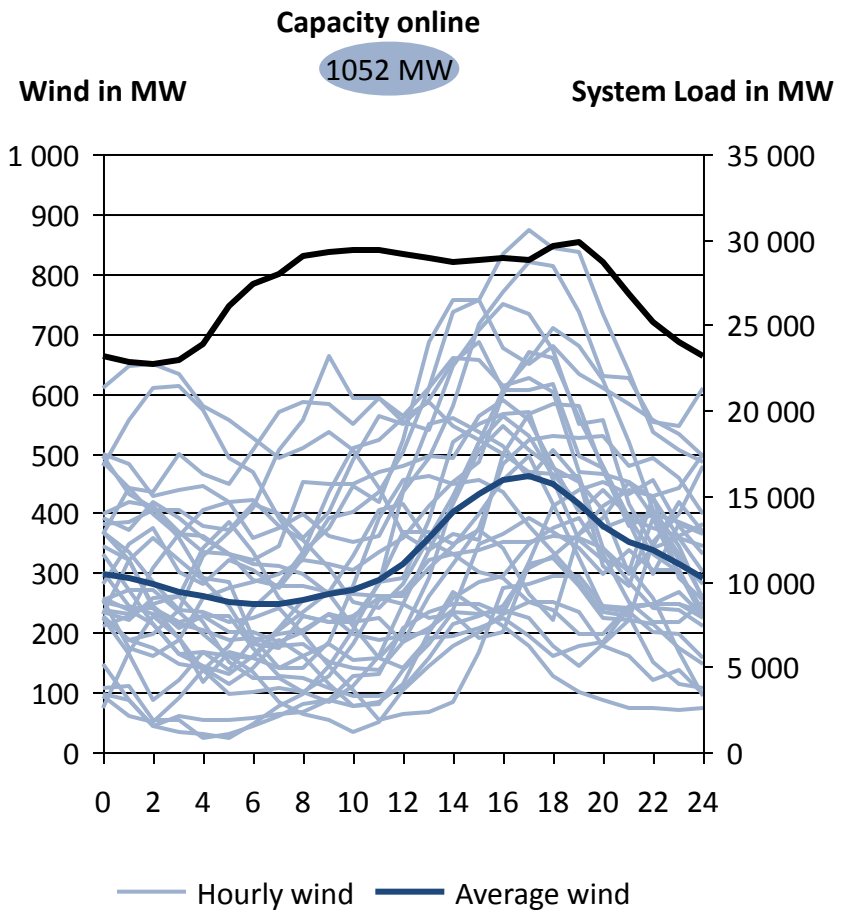
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Oct 2015 very stable, wind supplied more evenings

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



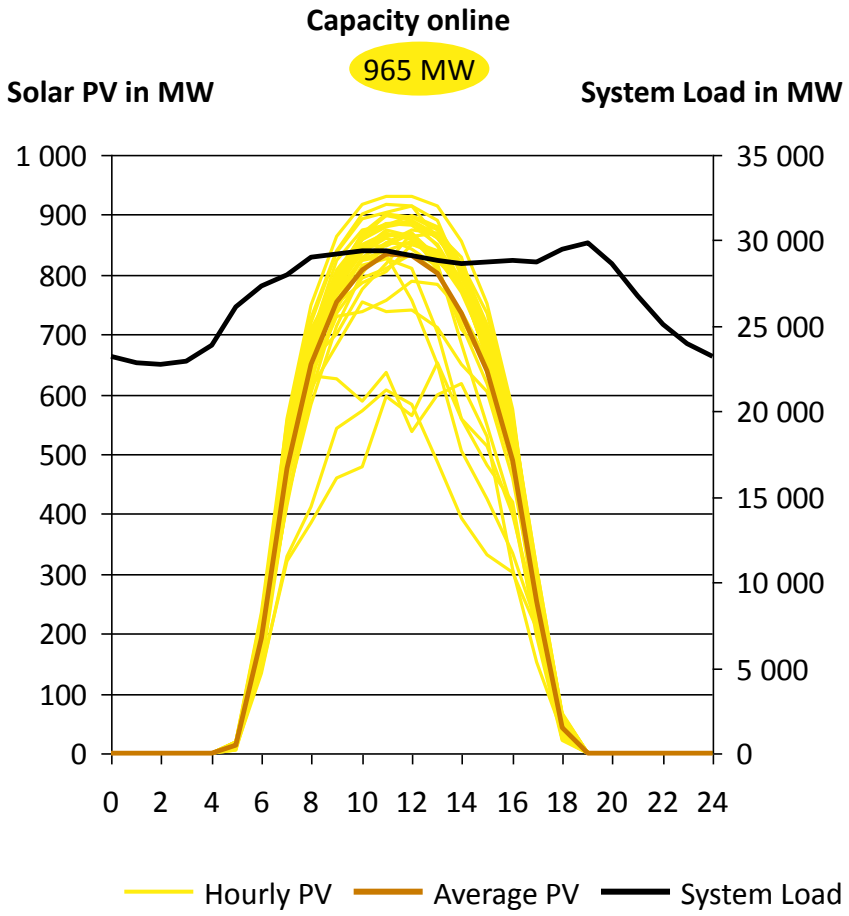


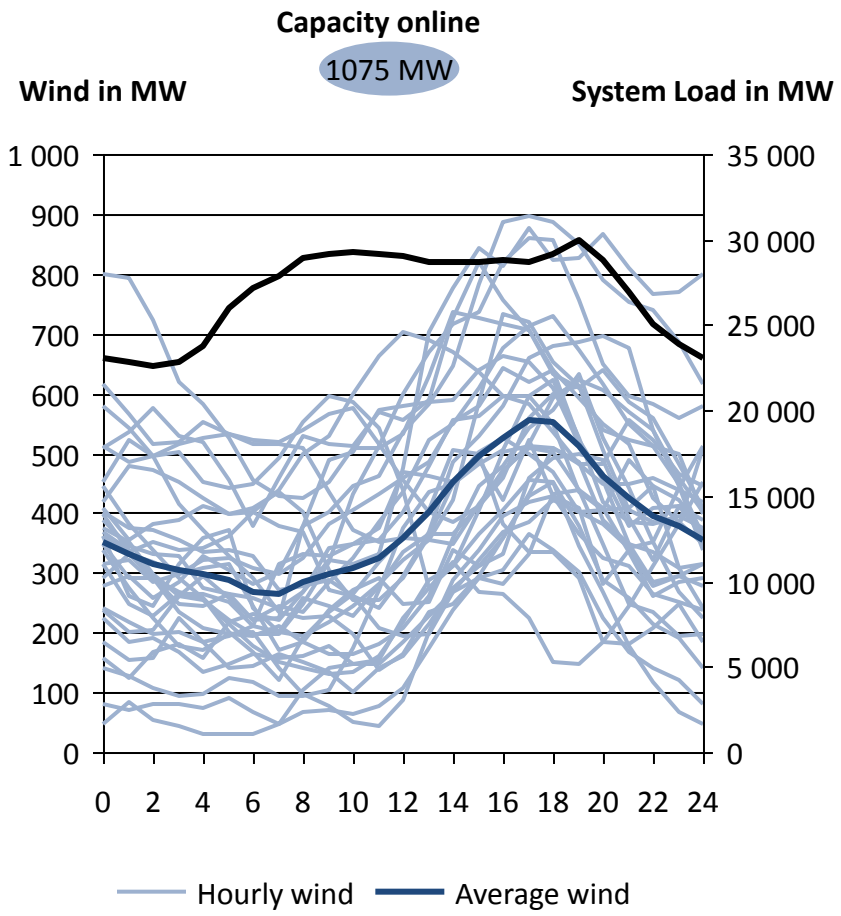
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Nov 2015 very stable, wind supplied more evenings

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



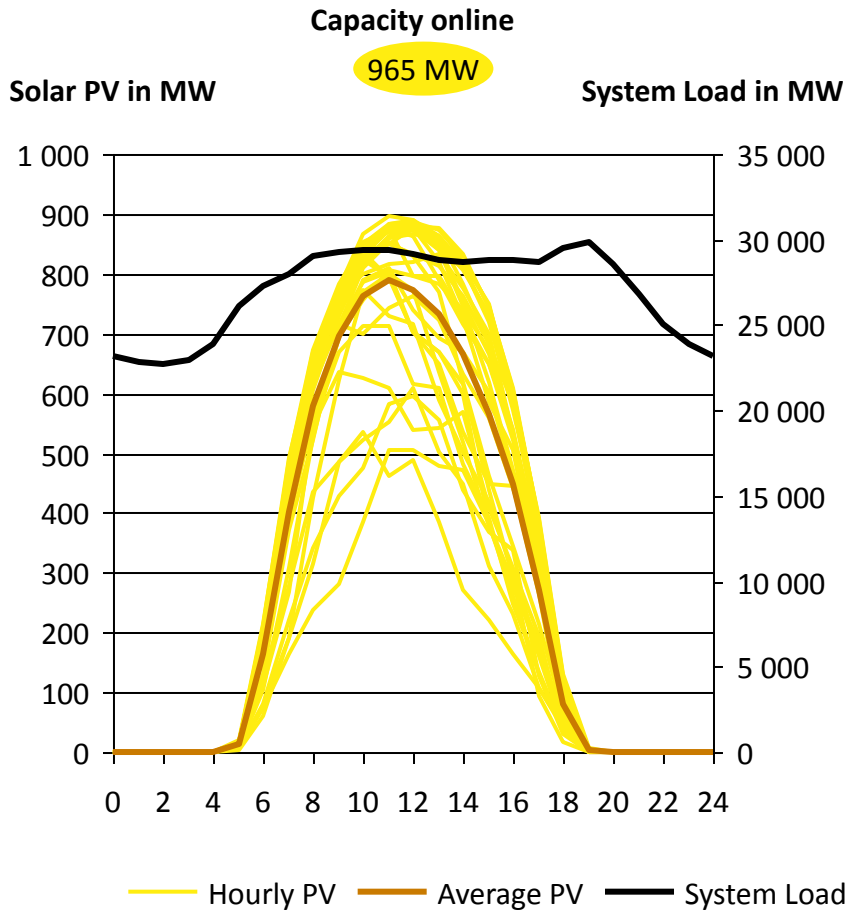


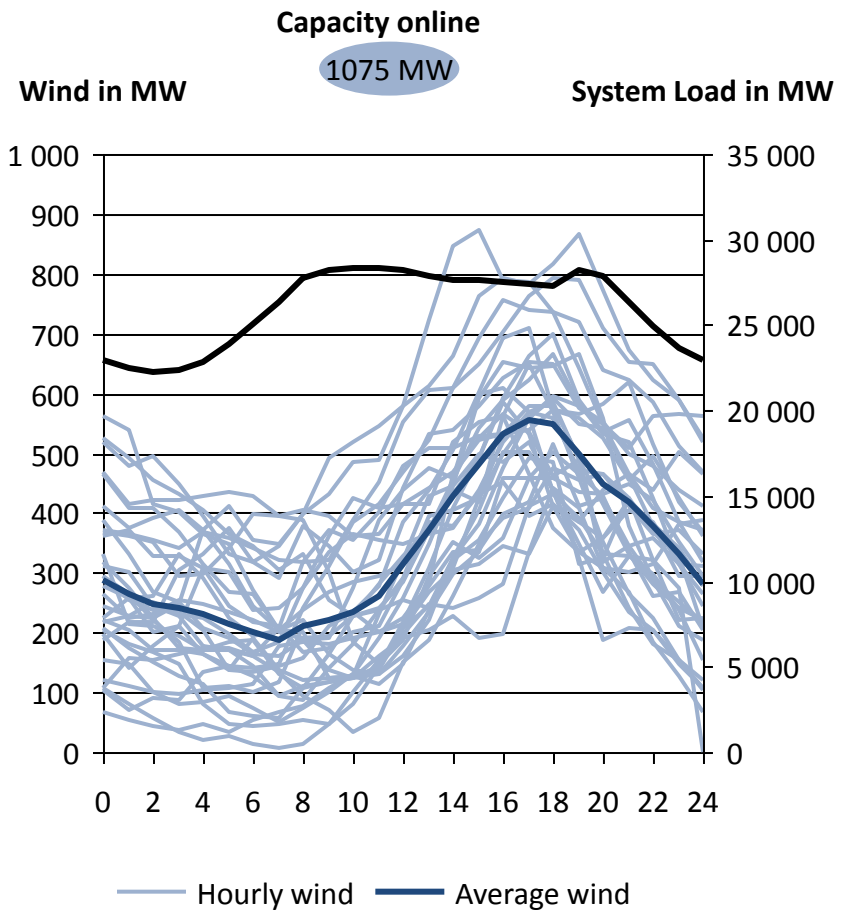
Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Solar PV supply in Dec 2015 very stable, wind supplied more evenings

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





Note: System load excludes hydro pumping load

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

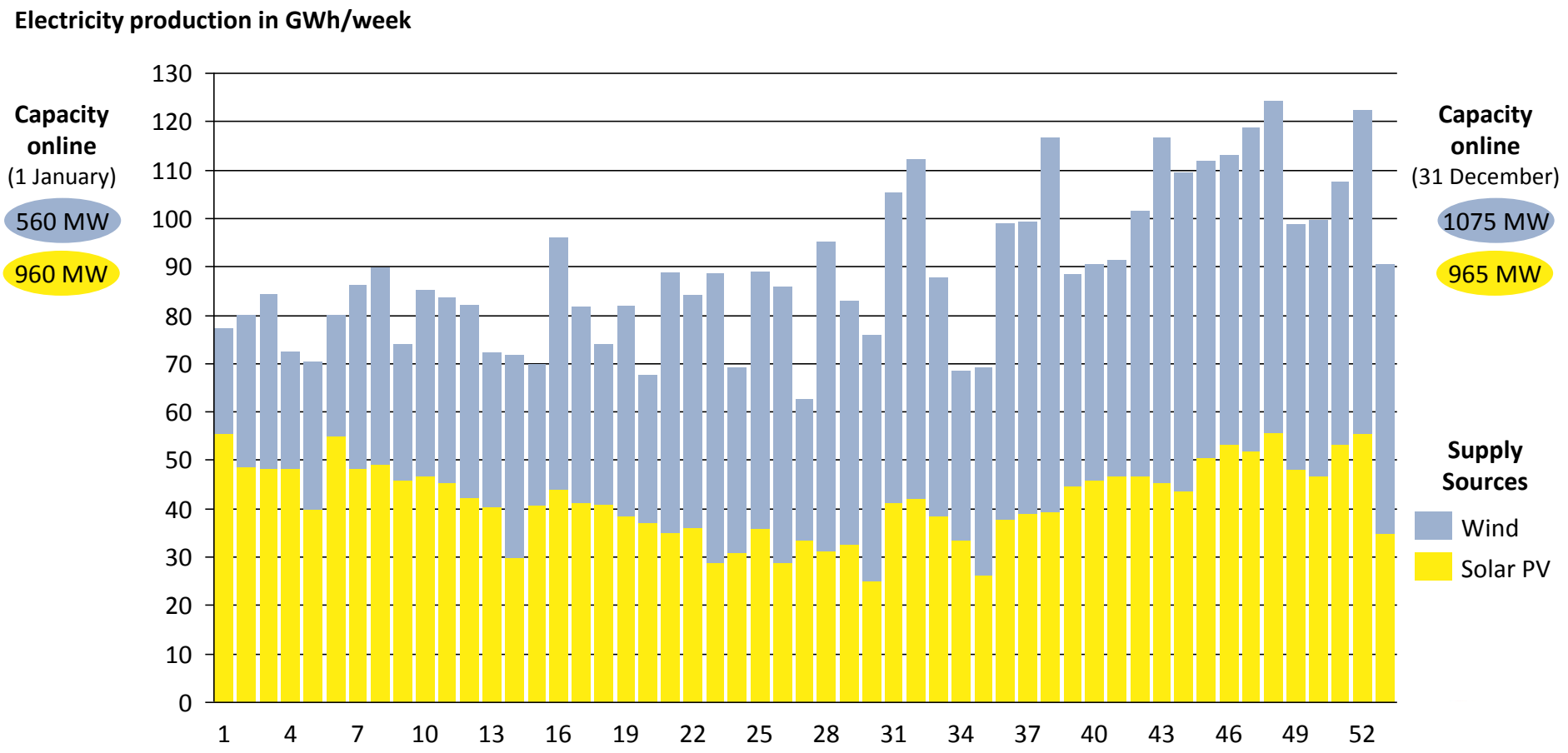
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Weekly electricity production of South African wind & solar PV fleet

Actual weekly production from large-scale solar PV and wind plants under the REIPPPP from Jan-Dec 2015

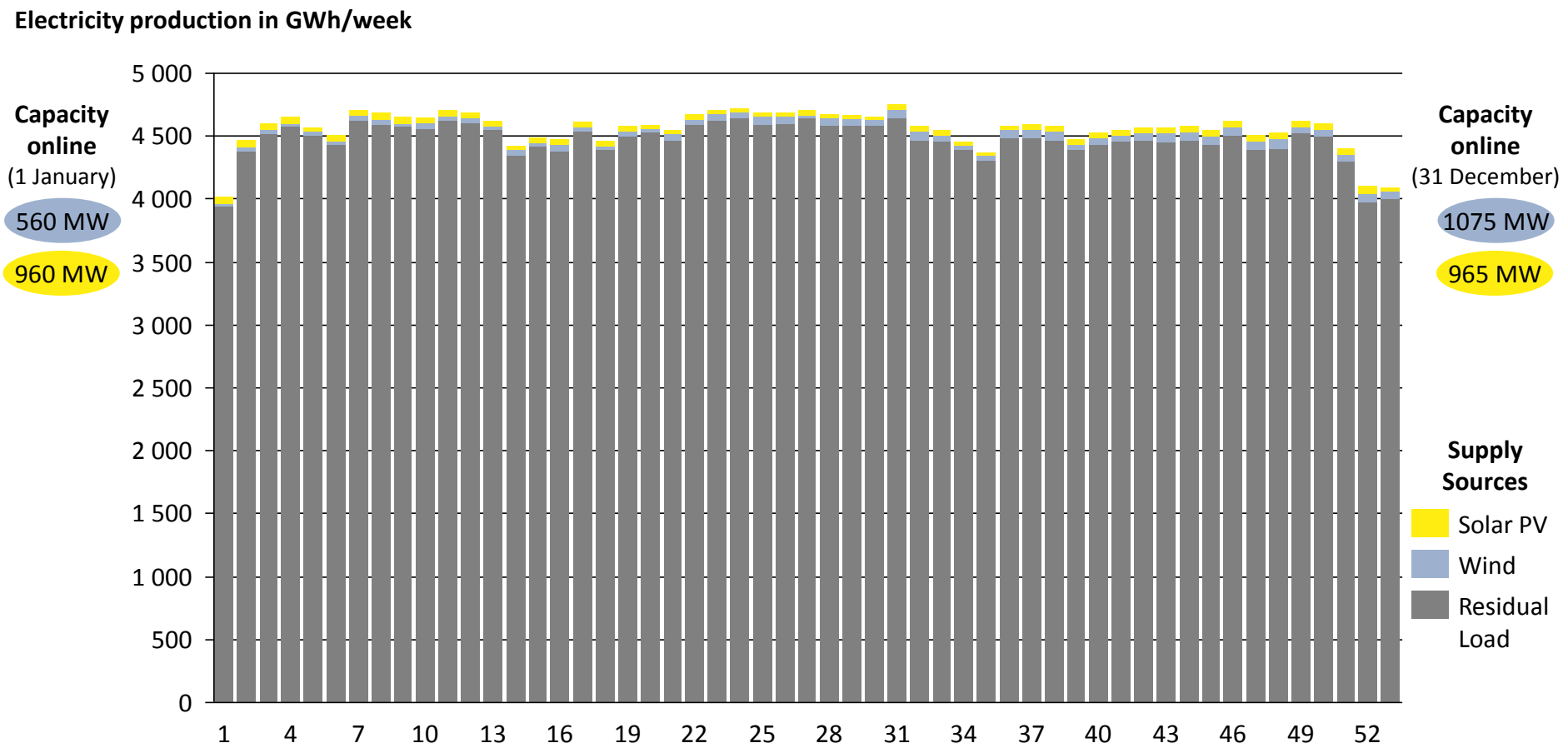


- Maximum wind + solar PV weekly production of 124 GWh in week 48
- Minimum wind + solar PV weekly production of 62 GWh in week 27

Note: Design as per Fraunhofer ISE. Week 1 and week 53 adjusted/scaled to 7 day week.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Weekly electricity production wind, solar PV and residual load

Actual weekly production: conventional fleet, wind & solar PV plants under REIPPPP from Jan-Dec 2015



Note: Design as per Fraunhofer ISE. Week 1 and week 53 adjusted/scaled to 7 day week. Pumping load excluded

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

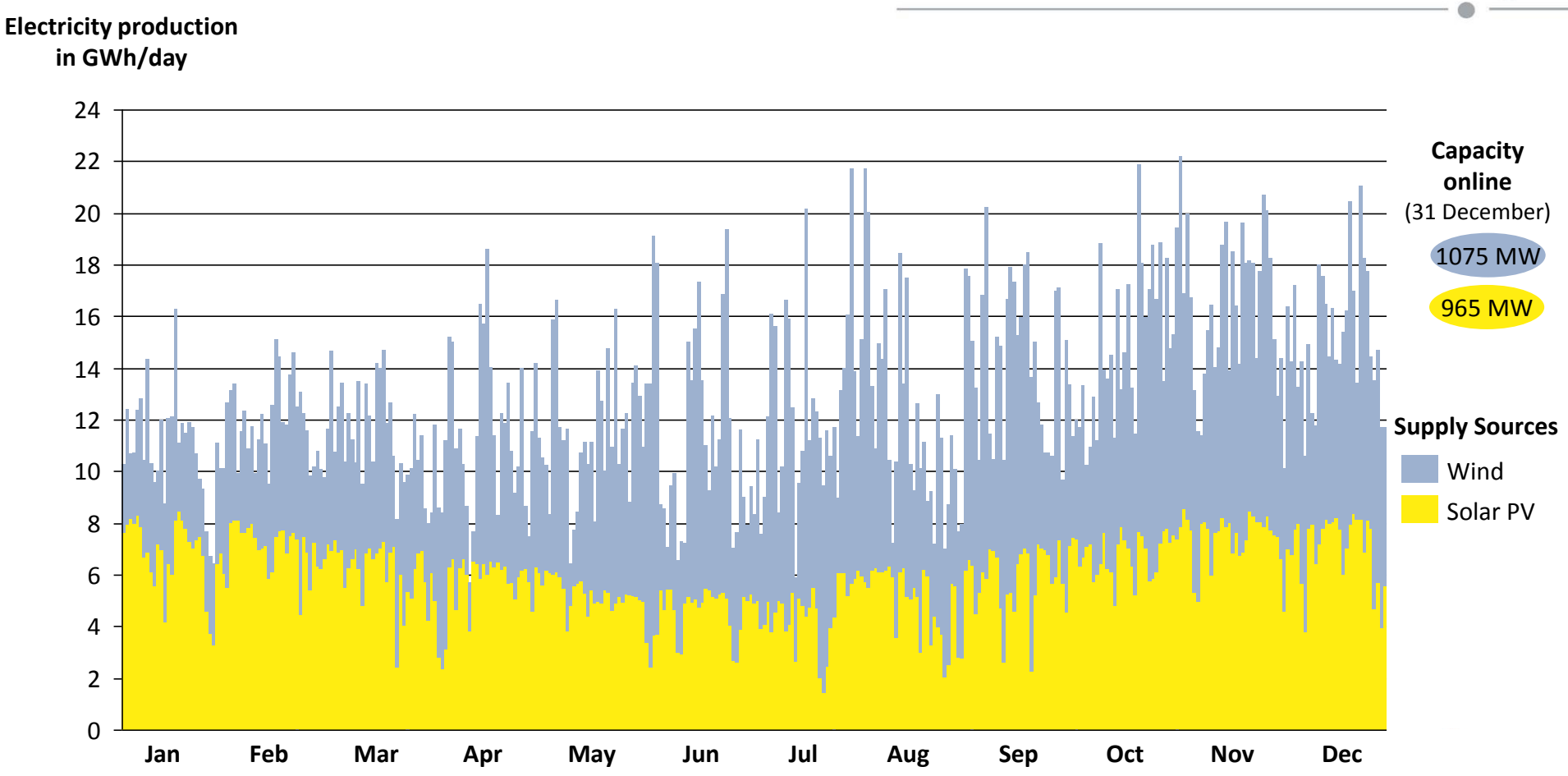
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Daily electricity production wind and solar PV fleet Jan to Dec 2015

Actual daily production from large-scale solar PV and wind plants under the REIPPPP from Jan-Dec 2015



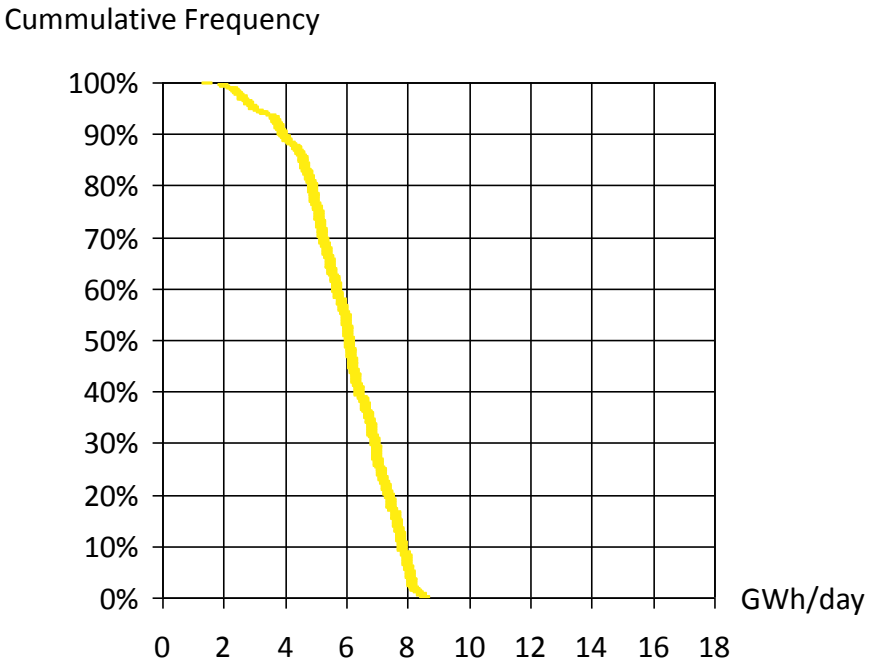
- Maximum daily production of 22.2 GWh on 3 Nov 2015.
- Minimum daily production of 5.7 GWh on 11 Apr 2015.

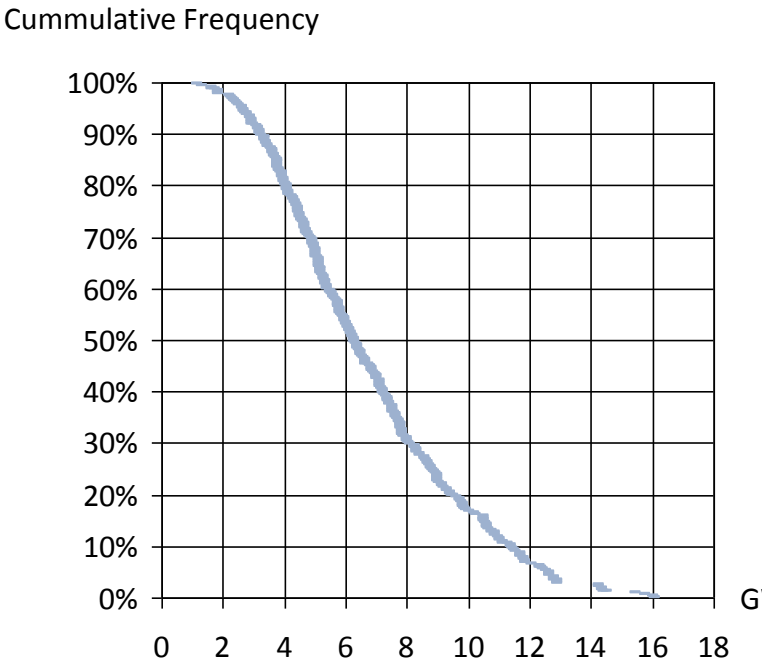
Note: Design as per Fraunhofer ISE

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

On 90% of the days in 2015, solar PV and wind had a daily energy production of 4 GWh and 3 GWh or more, respectively

Frequency distribution of daily solar PV and wind electricity production in 2015





Capacity online
(31 December)

1075 MW

965 MW

Supply Sources

Wind

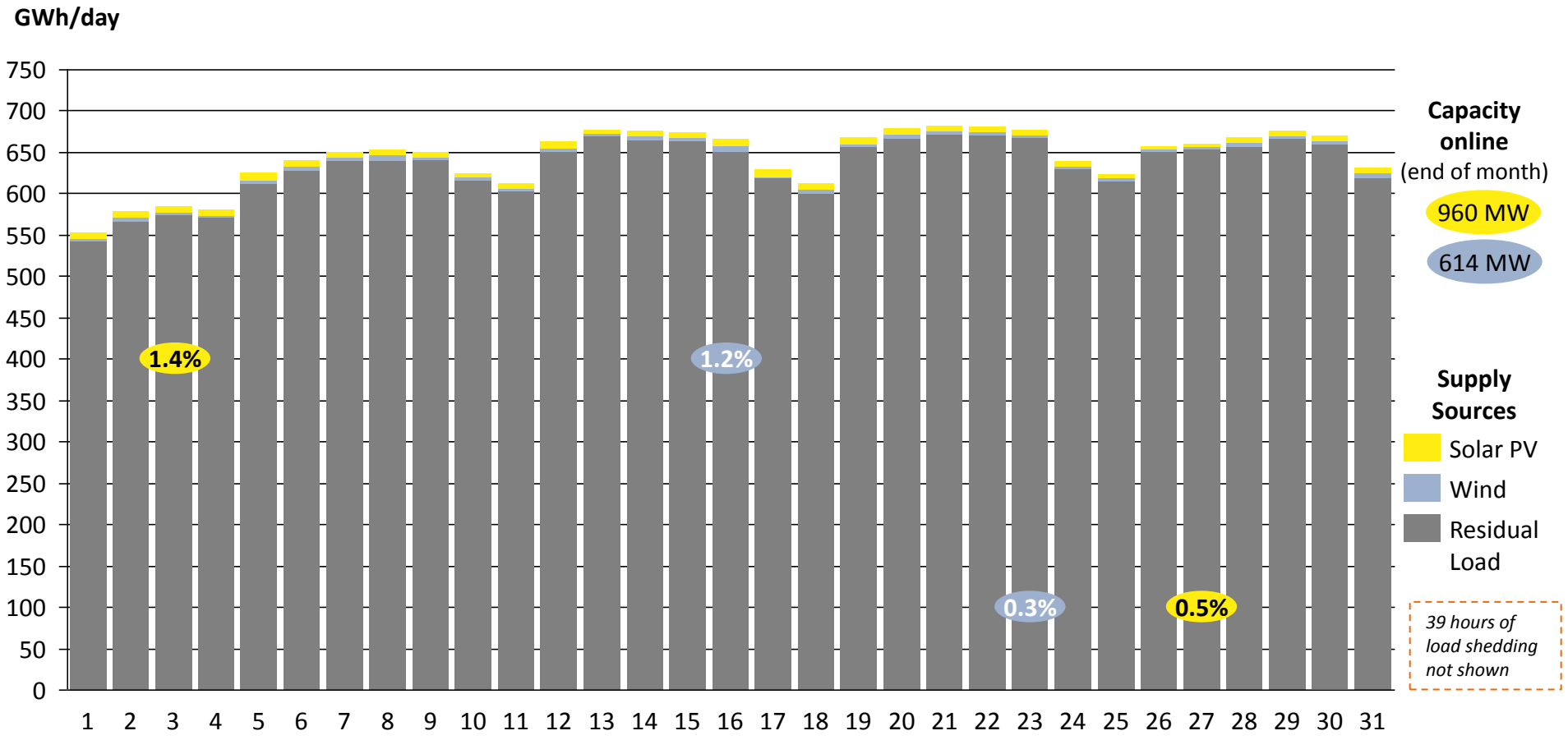
Solar PV

CSIR
our future through science

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 552-682 GWh in Jan 2015

Actual daily production from all power supply sources in South Africa for January 2015

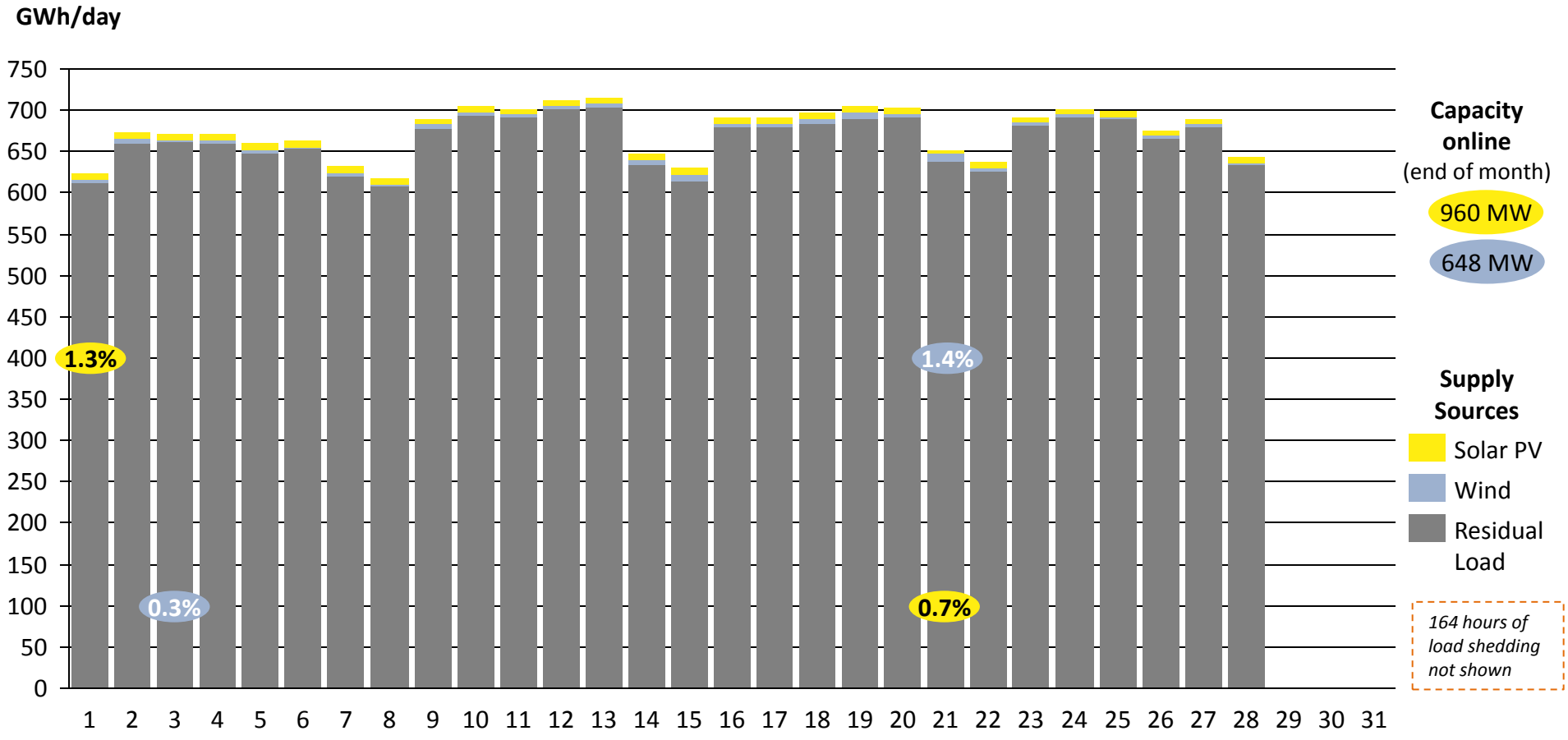


- Maximum daily production of 682 GWh on 21 Jan 2015 (Wednesday)
- Minimum daily production of 552 GWh on 1 Jan 2015 (Thursday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 606-701 GWh in Feb 2015

Actual daily production from all power supply sources in South Africa for February 2015

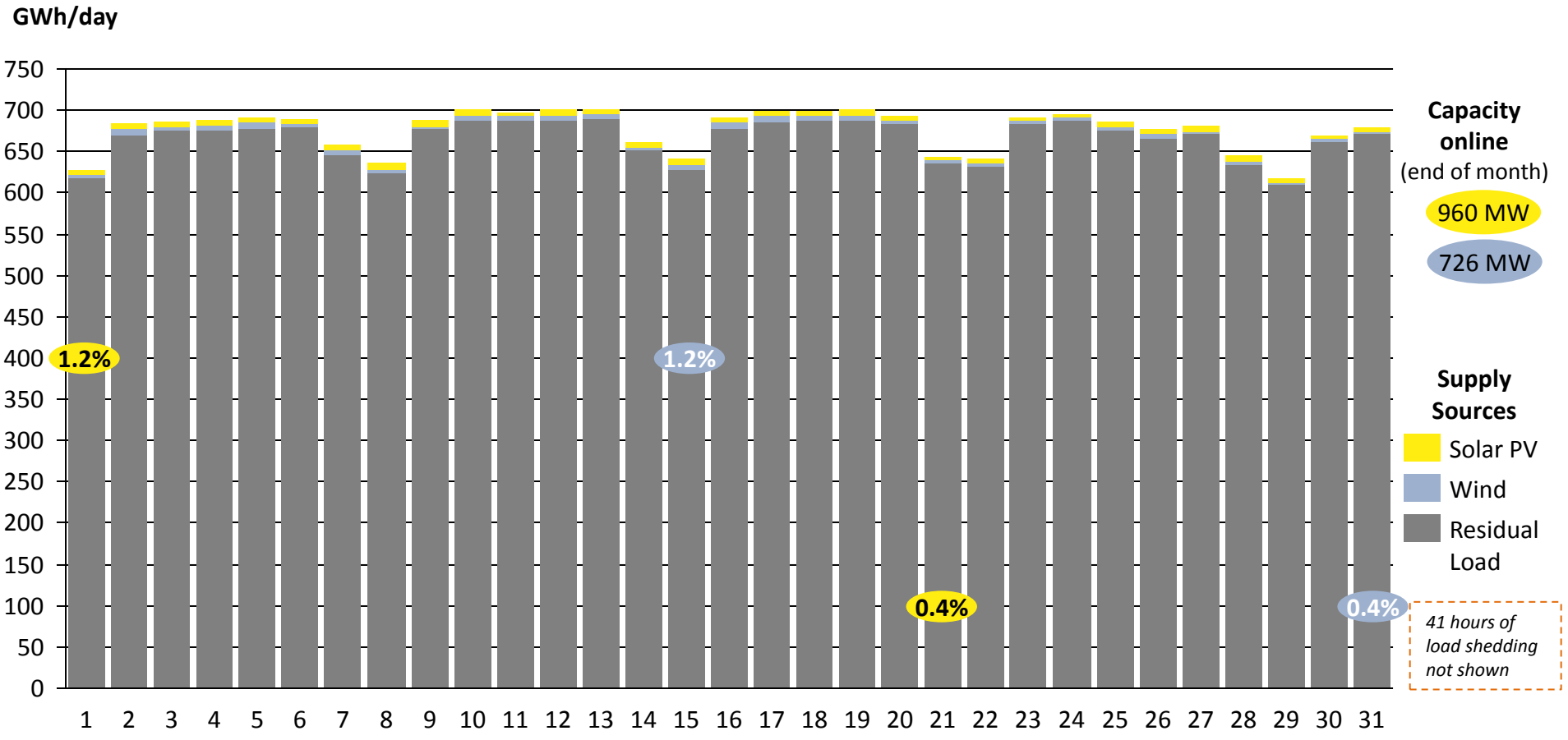


- Maximum daily production of 701 GWh on 13 Feb 2015 (Friday)
- Minimum daily production of 606 GWh on 8 Feb 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 608-689 GWh in Mar 2015

Actual daily production from all power supply sources in South Africa for March 2015

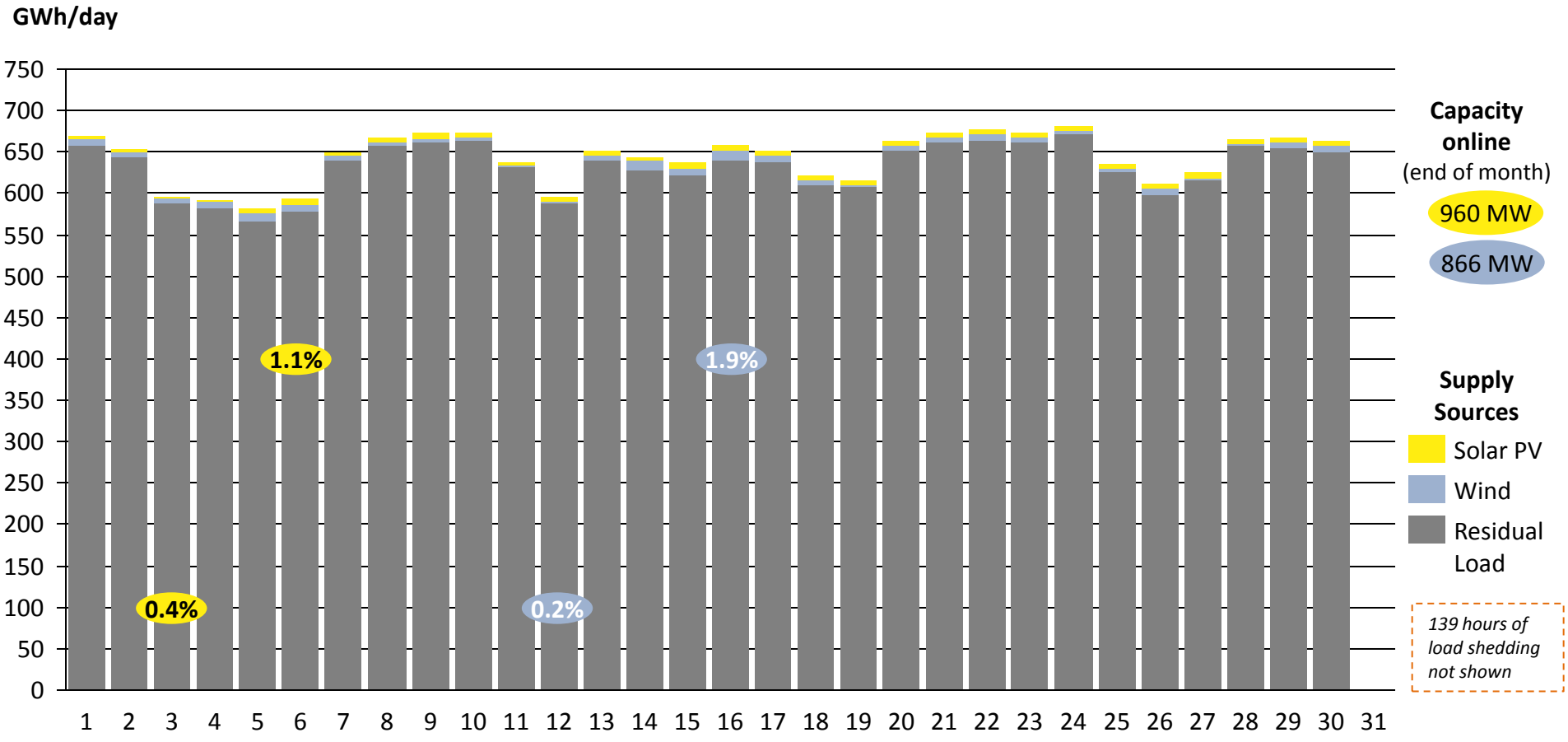


- Maximum daily production of 689 GWh on 13 Mar 2015 (Friday)
- Minimum daily production of 608 GWh on 29 Mar 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 565-671 GWh in Apr 2015

Actual daily production from all power supply sources in South Africa for April 2015

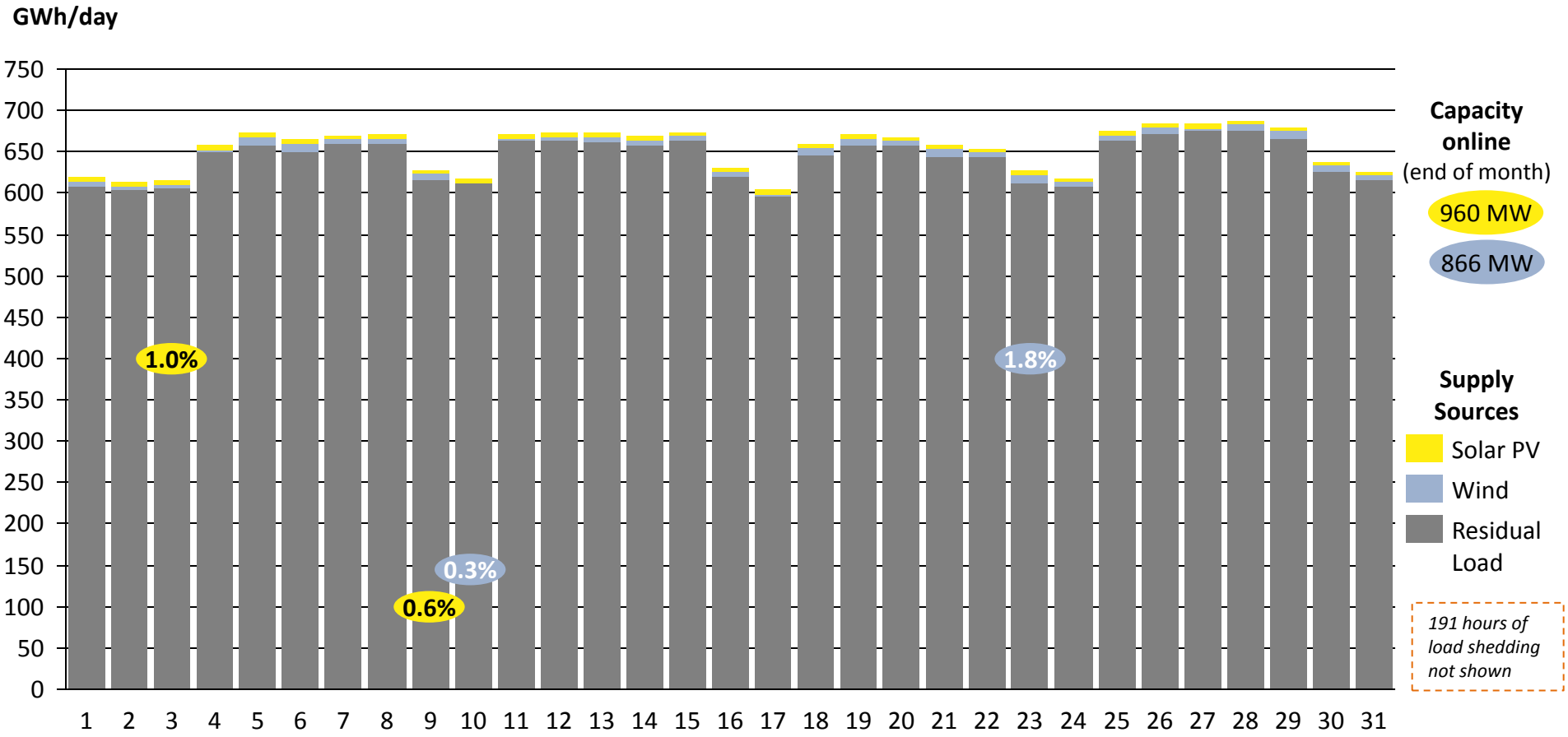


- Maximum daily production of 671 GWh on 24 Apr 2015 (Friday)
- Minimum daily production of 565 GWh on 5 Apr 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 594-674 GWh in May 2015

Actual daily production from all power supply sources in South Africa for May 2015

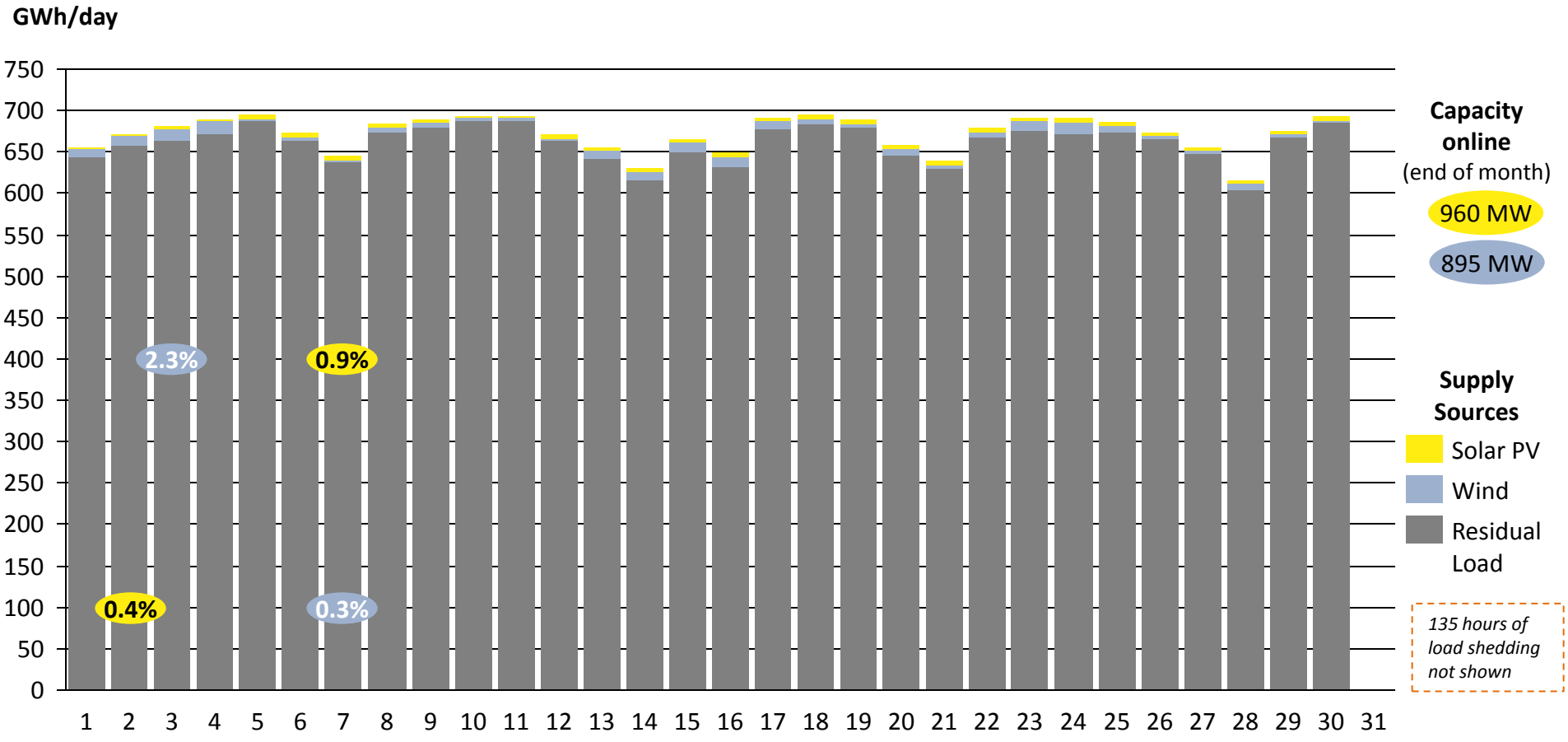


- Maximum daily production of 674 GWh on 27 May 2015 (Wednesday)
- Minimum daily production of 594 GWh on 17 May 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 602-686 GWh in Jun 2015

Actual daily production from all power supply sources in South Africa for June 2015

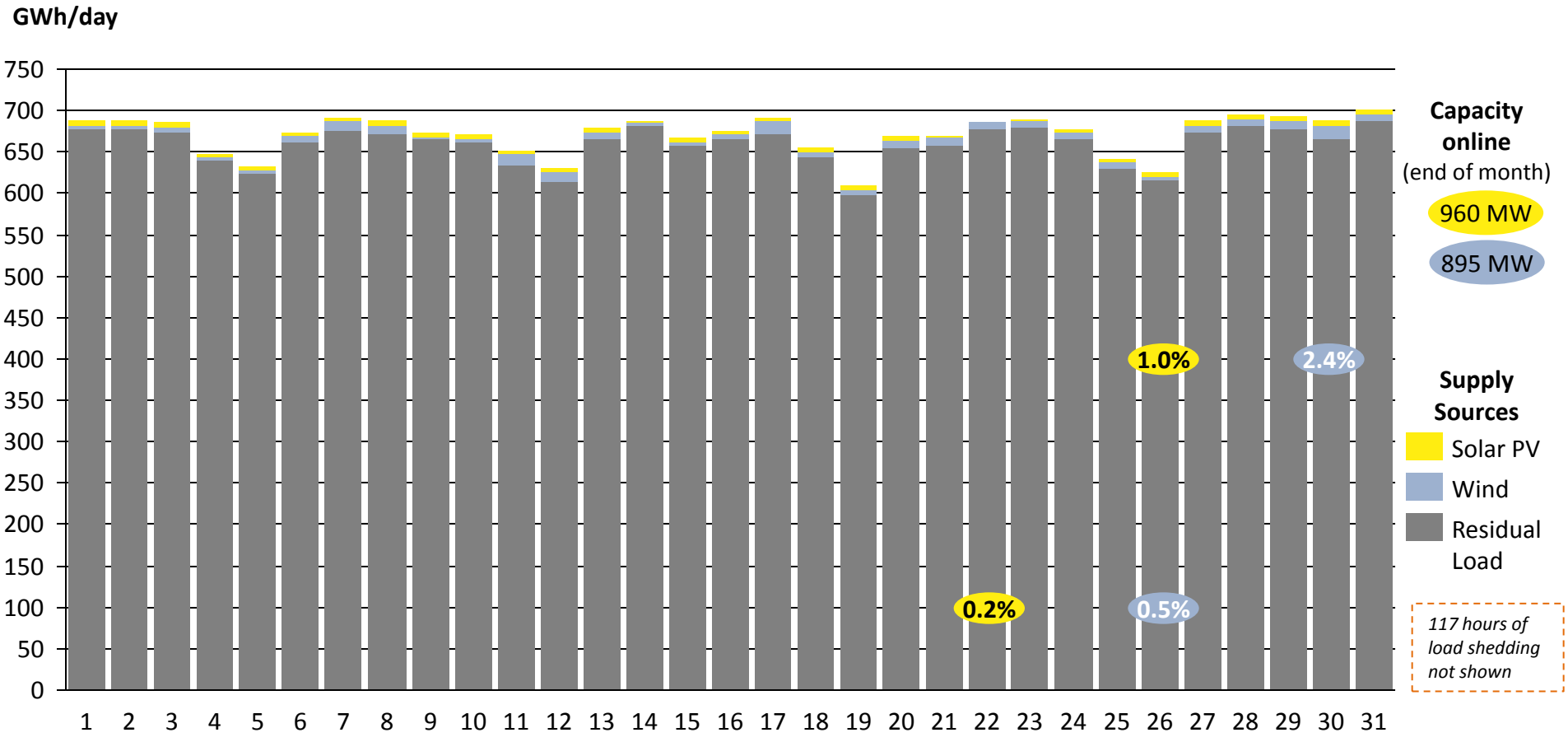


- Maximum daily production of 686 GWh on 10 Jun 2015 (Wednesday)
- Minimum daily production of 602 GWh on 28 Jun 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 596-687 GWh in Jul 2015

Actual daily production from all power supply sources in South Africa for July 2015

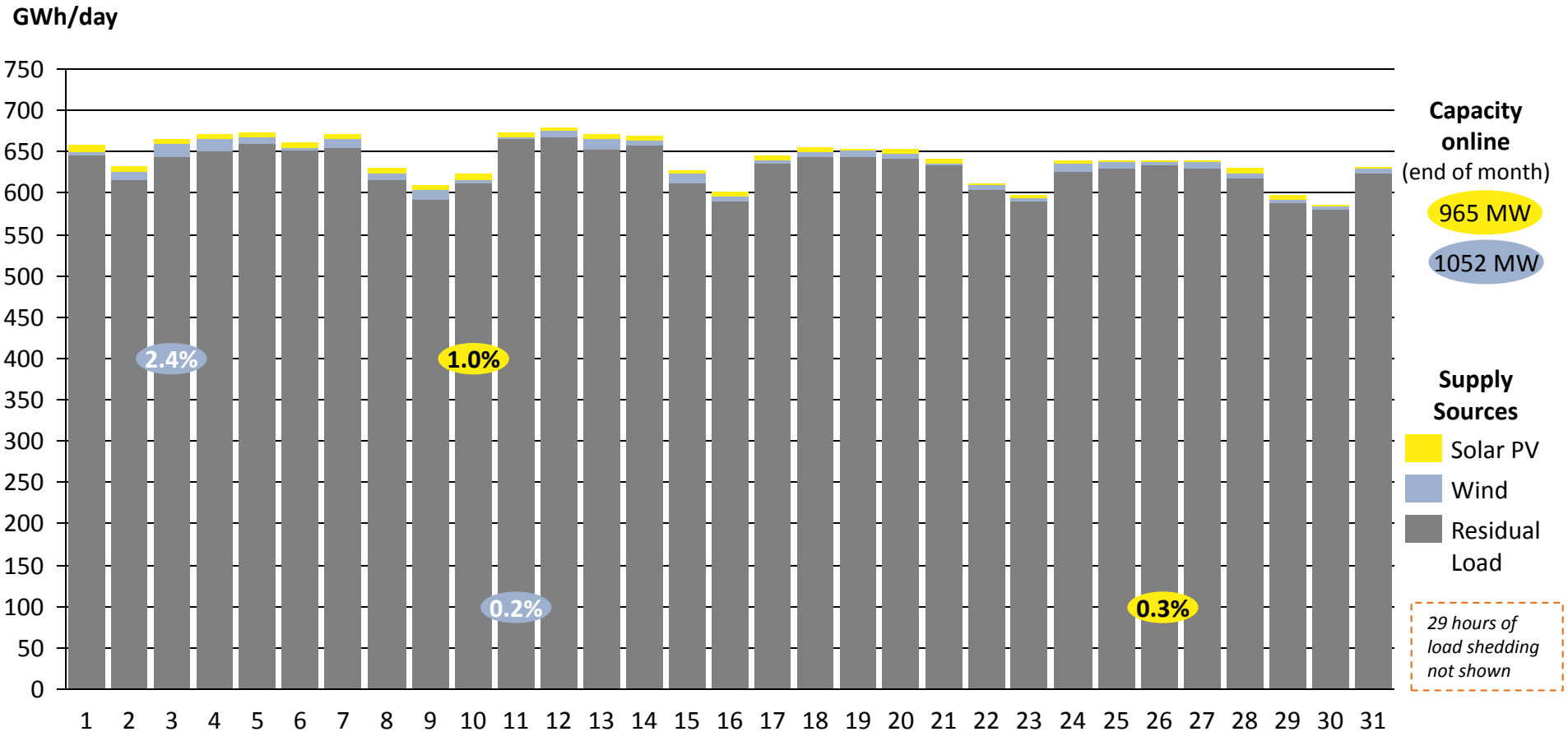


- Maximum daily production of 687 GWh on 31 Jul 2015 (Friday)
- Minimum daily production of 596 GWh on 19 Jul 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 578-667 GWh in Aug 2015

Actual daily production from all power supply sources in South Africa for August 2015

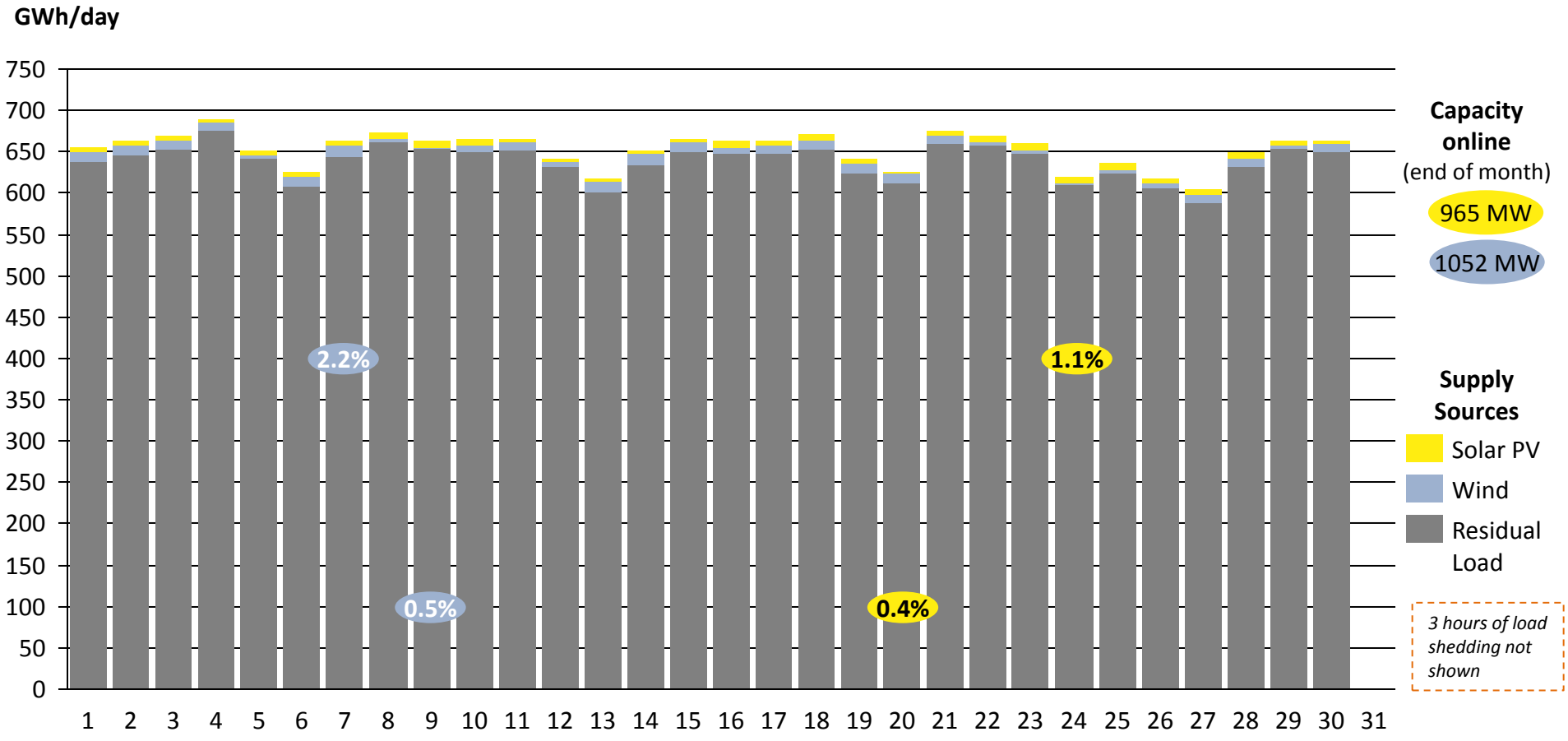


- Maximum daily production of 667 GWh on 12 Aug 2015 (Wednesday)
- Minimum daily production of 578 GWh on 30 Aug 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 586-675 GWh in Sep 2015

Actual daily production from all power supply sources in South Africa for September 2015

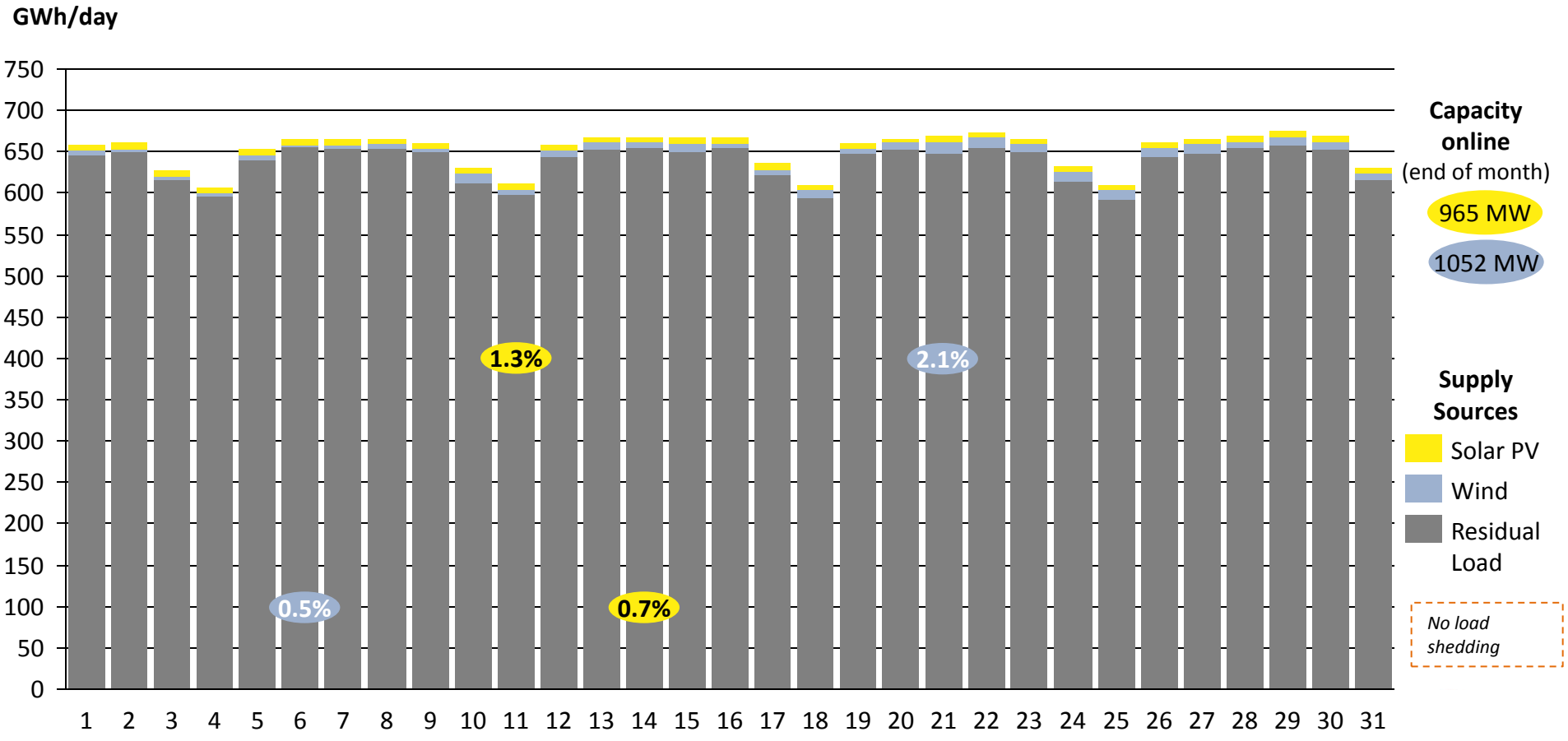


- Maximum daily production of 675 GWh on 4 Sep 2015 (Friday)
- Minimum daily production of 586 GWh on 27 Sep 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 591-656 GWh in Oct 2015

Actual daily production from all power supply sources in South Africa for October 2015

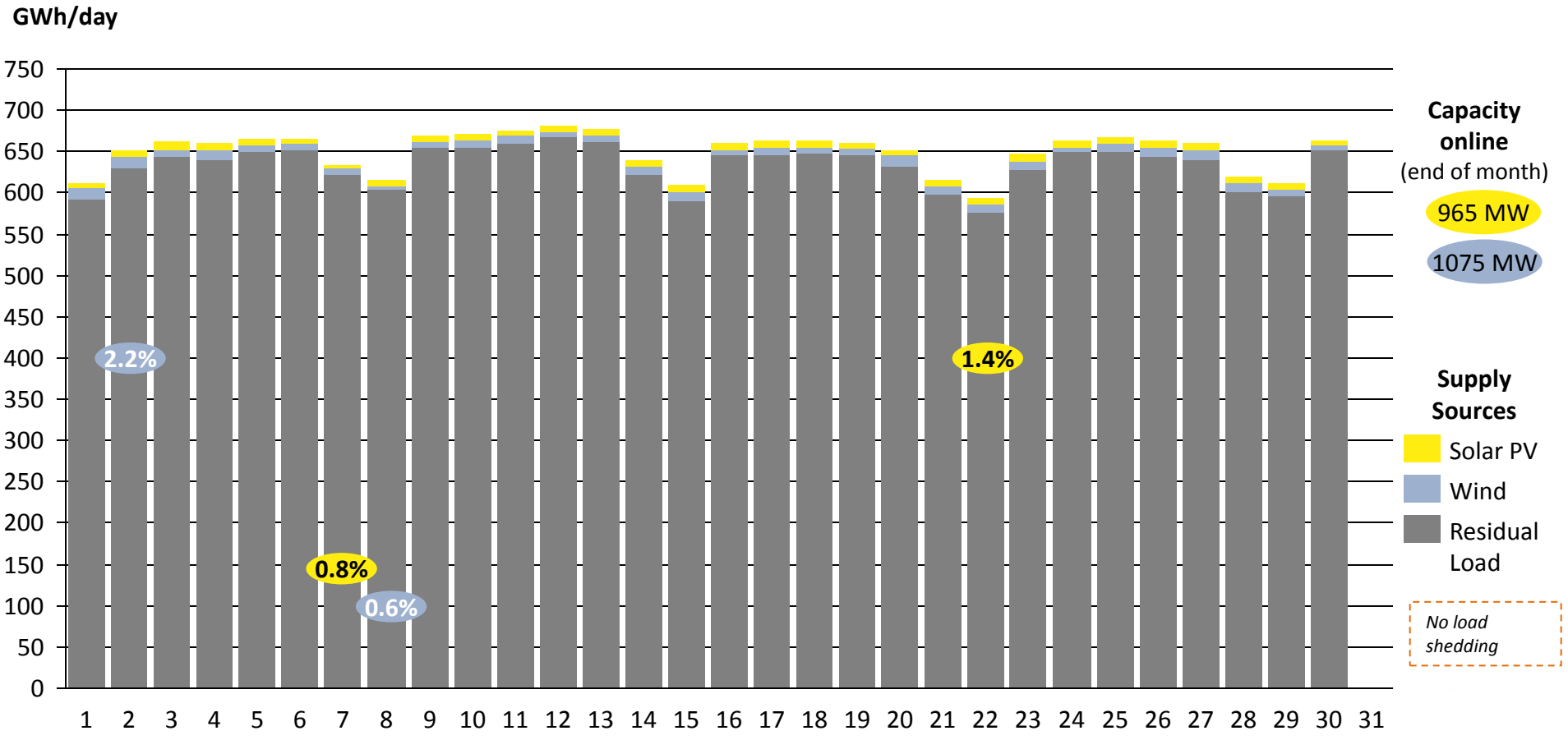


- Maximum daily production of 656 GWh on 29 Oct 2015 (Thursday)
- Minimum daily production of 591 GWh on 25 Oct 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 593-680 GWh in Nov 2015

Actual daily production from all power supply sources in South Africa for November 2015

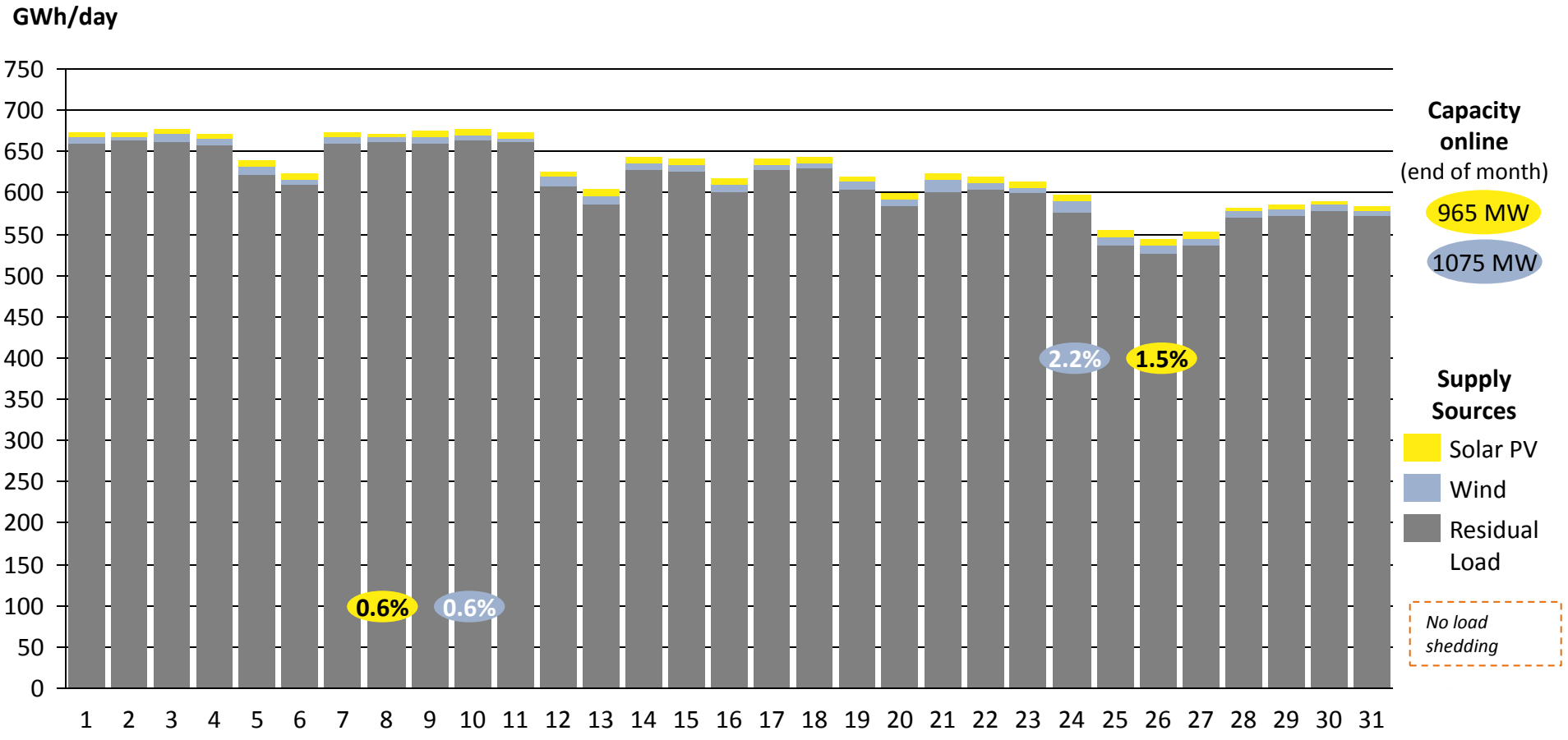


- Maximum daily production of 680 GWh on 12 Nov 2015 (Thursday)
- Minimum daily production of 593 GWh on 22 Nov 2015 (Sunday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Daily electricity production of between 542-677 GWh in Dec 2015

Actual daily production from all power supply sources in South Africa for December 2015



- Maximum daily production of 677 GWh on 3 Dec 2015 (Thursday)
- Minimum daily production of 542 GWh on 26 Dec 2015 (Saturday)

Note: Design as per Fraunhofer ISE. Total daily production excludes pumping load.Days with highest/lowest relative solar PV/wind contribution highlighted (as % of total supply on that day)
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

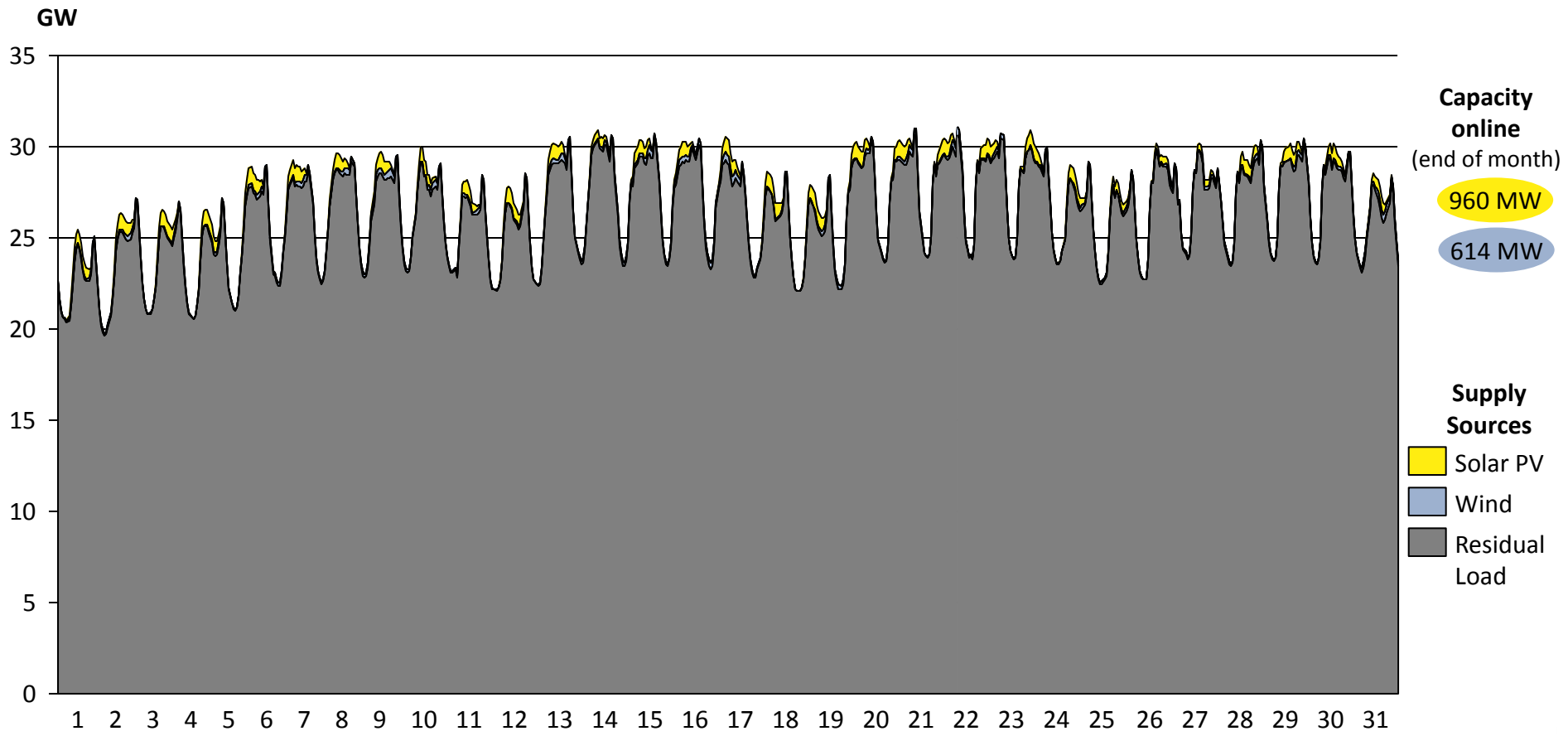
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Hourly electricity production in Jan 2015

Actual hourly production from all power supply sources in RSA for January 2015

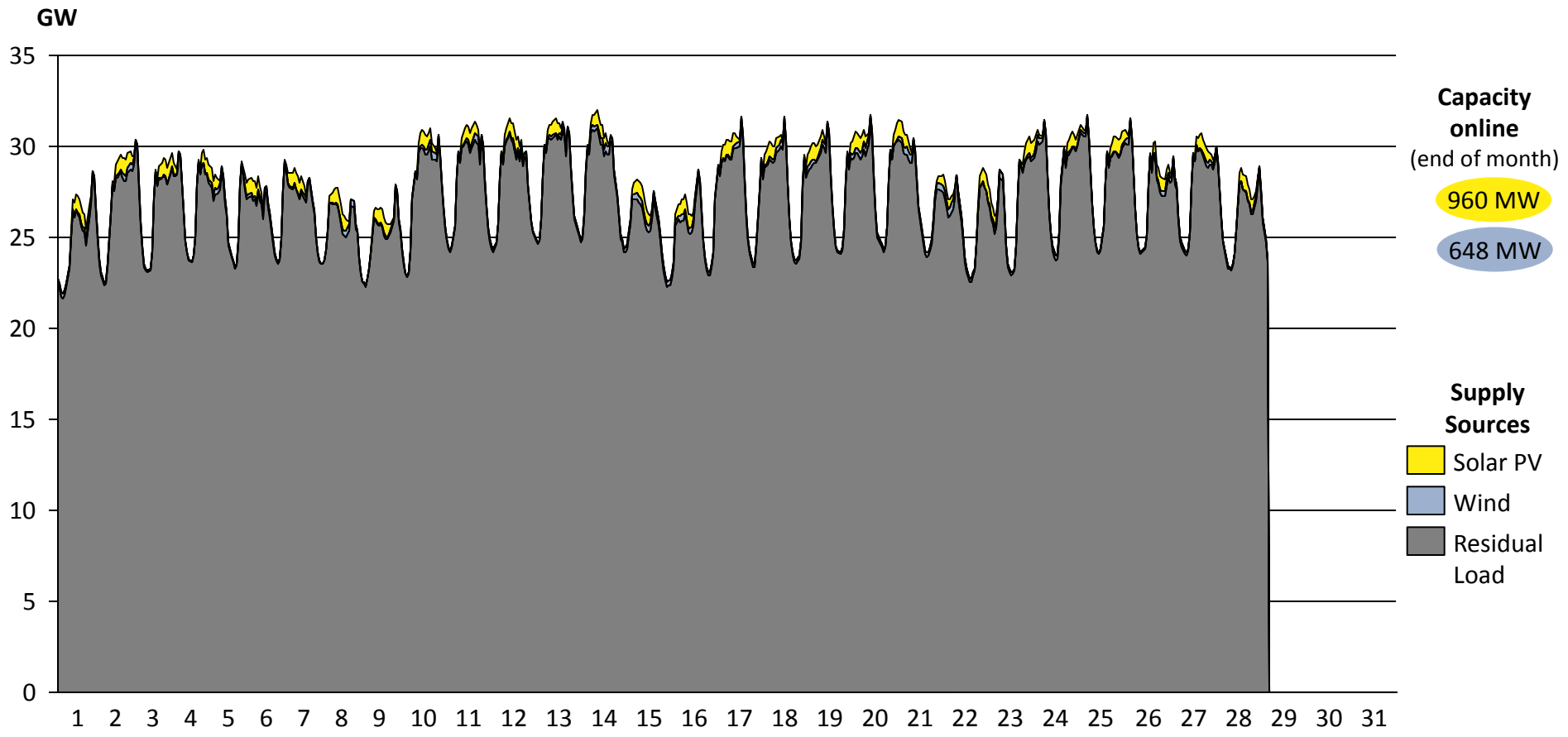


- Maximum power of 31 GW between 19h00 and 20h00 on 21 Jan 2015
- Minimum power of 20 GWh between 02h00 and 03h00 on 2 Jan 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Feb 2015

Actual hourly production from all power supply sources in RSA for February 2015

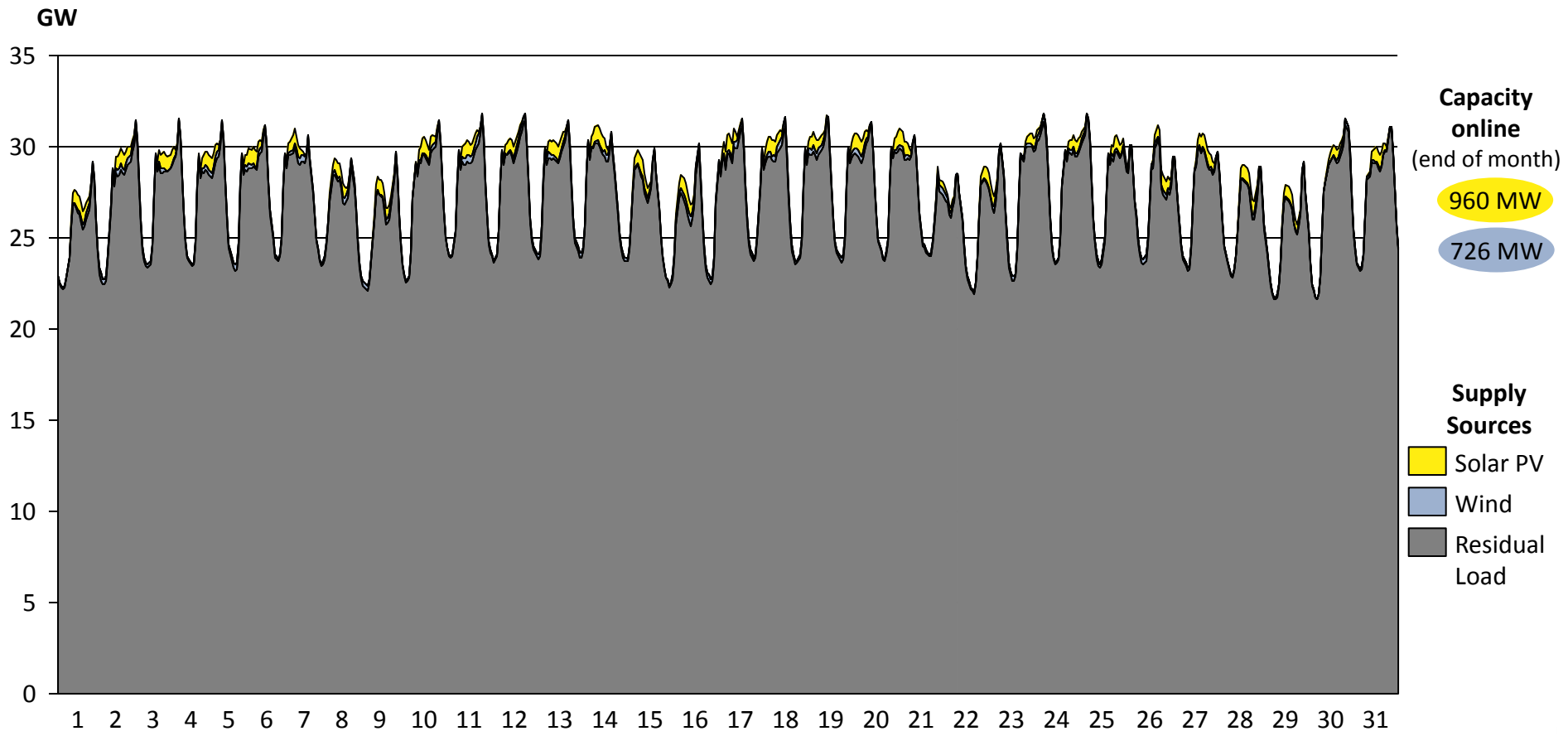


- Maximum power of 32 GW between 11h00 and 12h00 on 13 Feb 2015
- Minimum power of 22 GWh between 03h00 and 04h00 on 1 Feb 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Mar 2015

Actual hourly production from all power supply sources in RSA for March 2015

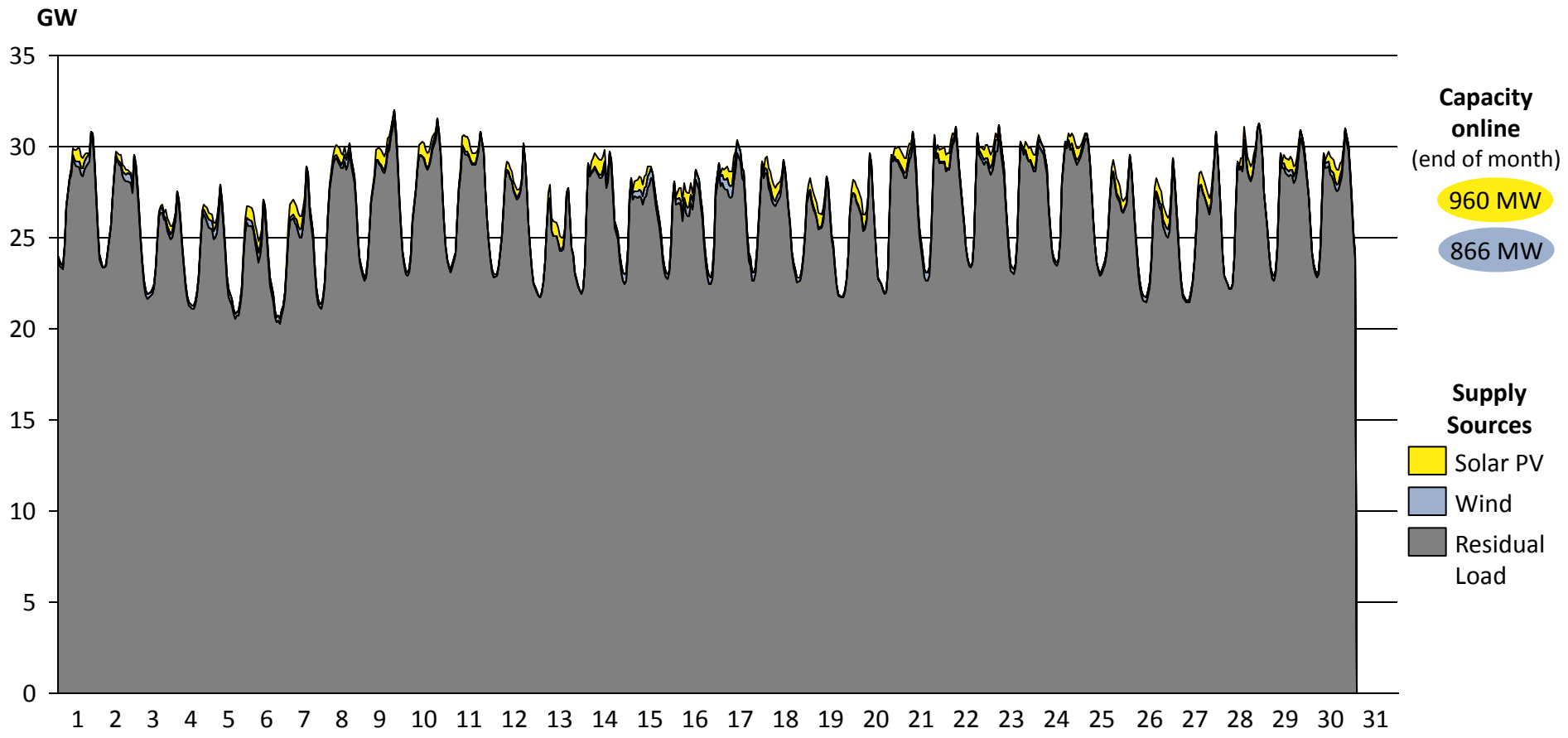


- Maximum power of 31 GW between 19h00 and 20h00 on 3 Mar 2015
- Minimum power of 22 GWh between 02h00 and 03h00 on 30 Mar 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Apr 2015

Actual hourly production from all power supply sources in RSA for April 2015

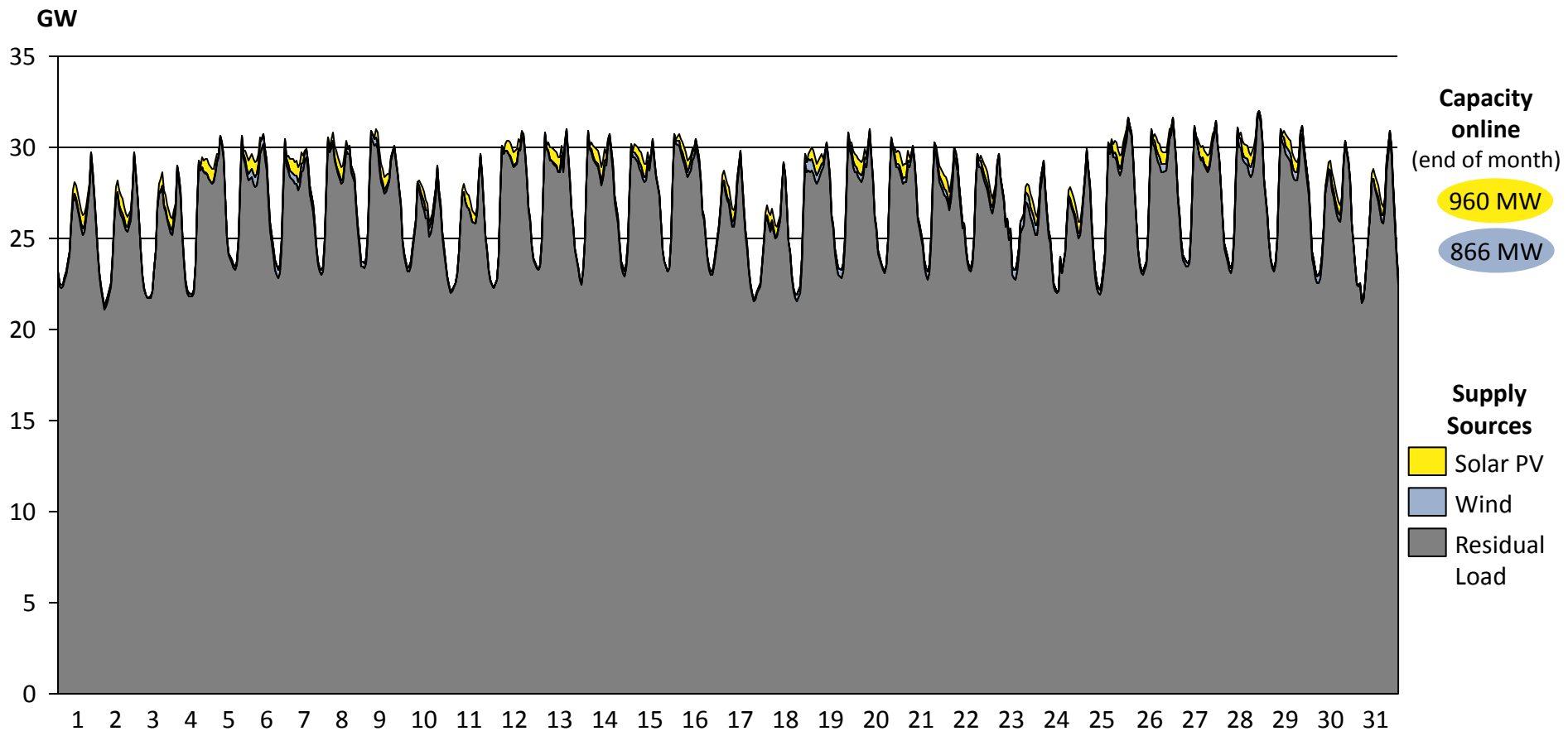


- Maximum power of 32 GW between 18h00 and 19h00 on 8 Apr 2015
- Minimum power of 21 GWh between 03h00 and 04h00 on 6 Apr 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in May 2015

Actual hourly production from all power supply sources in RSA for May 2015

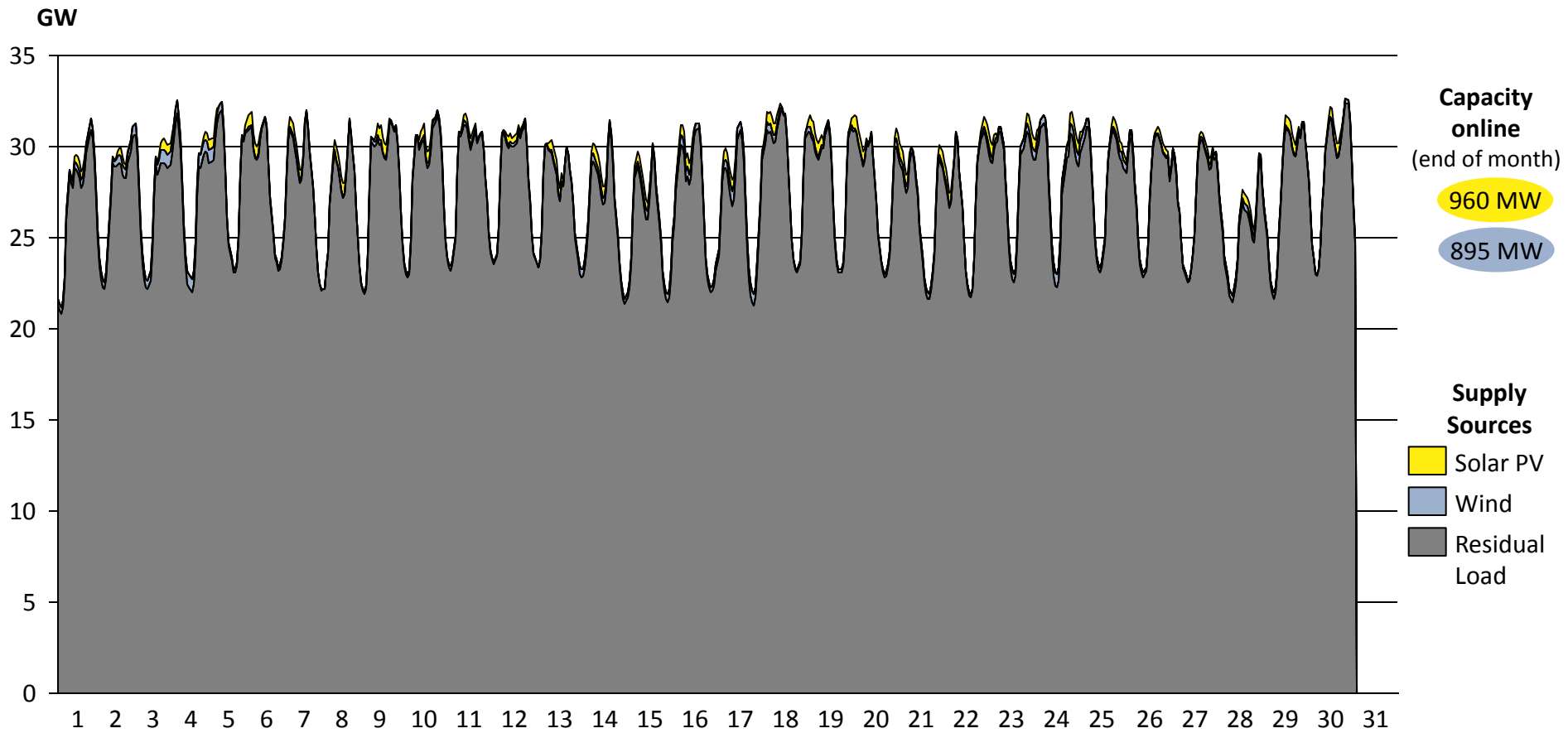


- Maximum power of 32 GW between 18h00 and 19h00 on 28 May 2015
- Minimum power of 21 GWh between 02h00 and 03h00 on 2 May 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Jun 2015

Actual hourly production from all power supply sources in RSA for June 2015

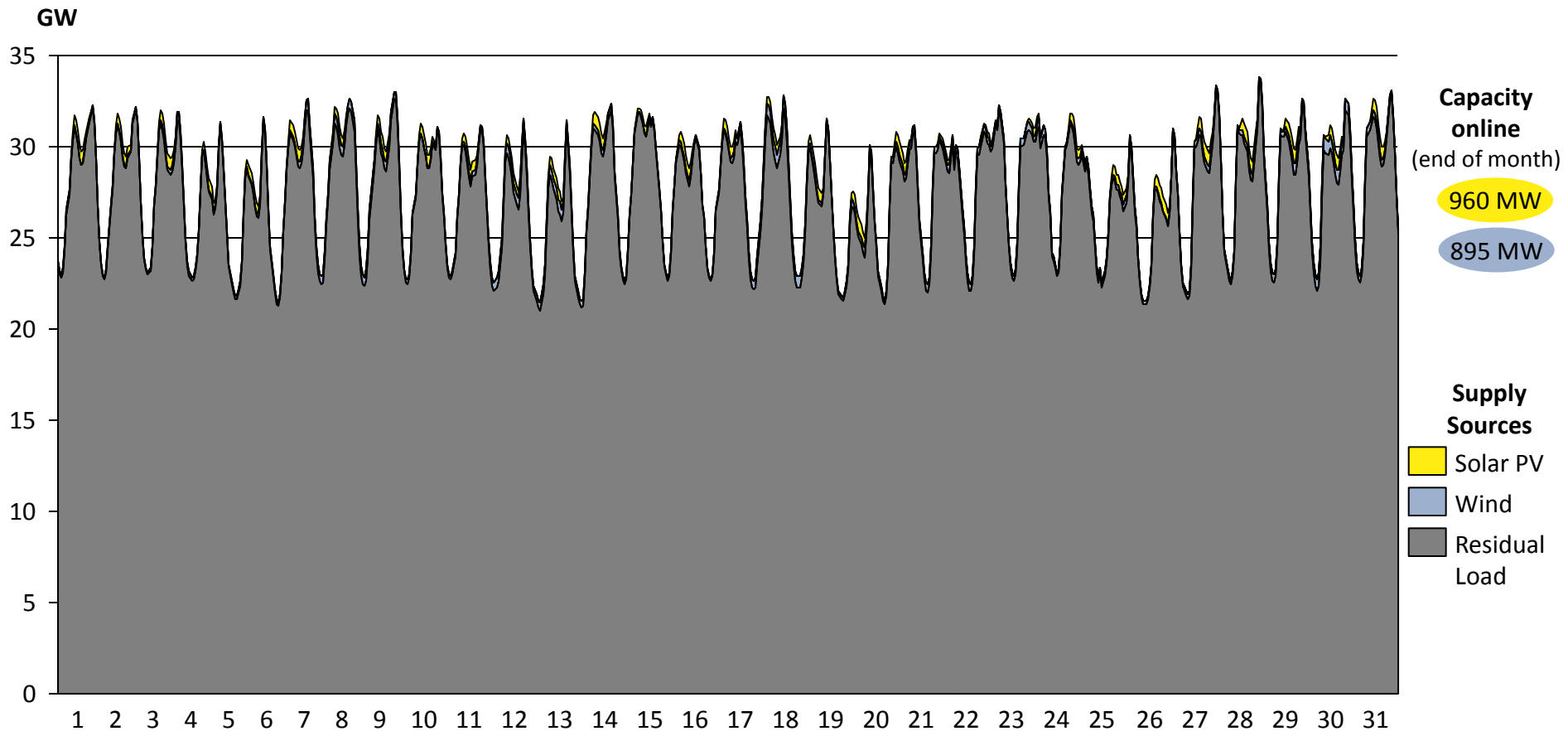


- Maximum power of 33 GW between 18h00 and 19h00 on 30 Jun 2015
- Minimum power of 21 GWh between 02h00 and 03h00 on 1 Jun 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Jul 2015

Actual hourly production from all power supply sources in RSA for July 2015

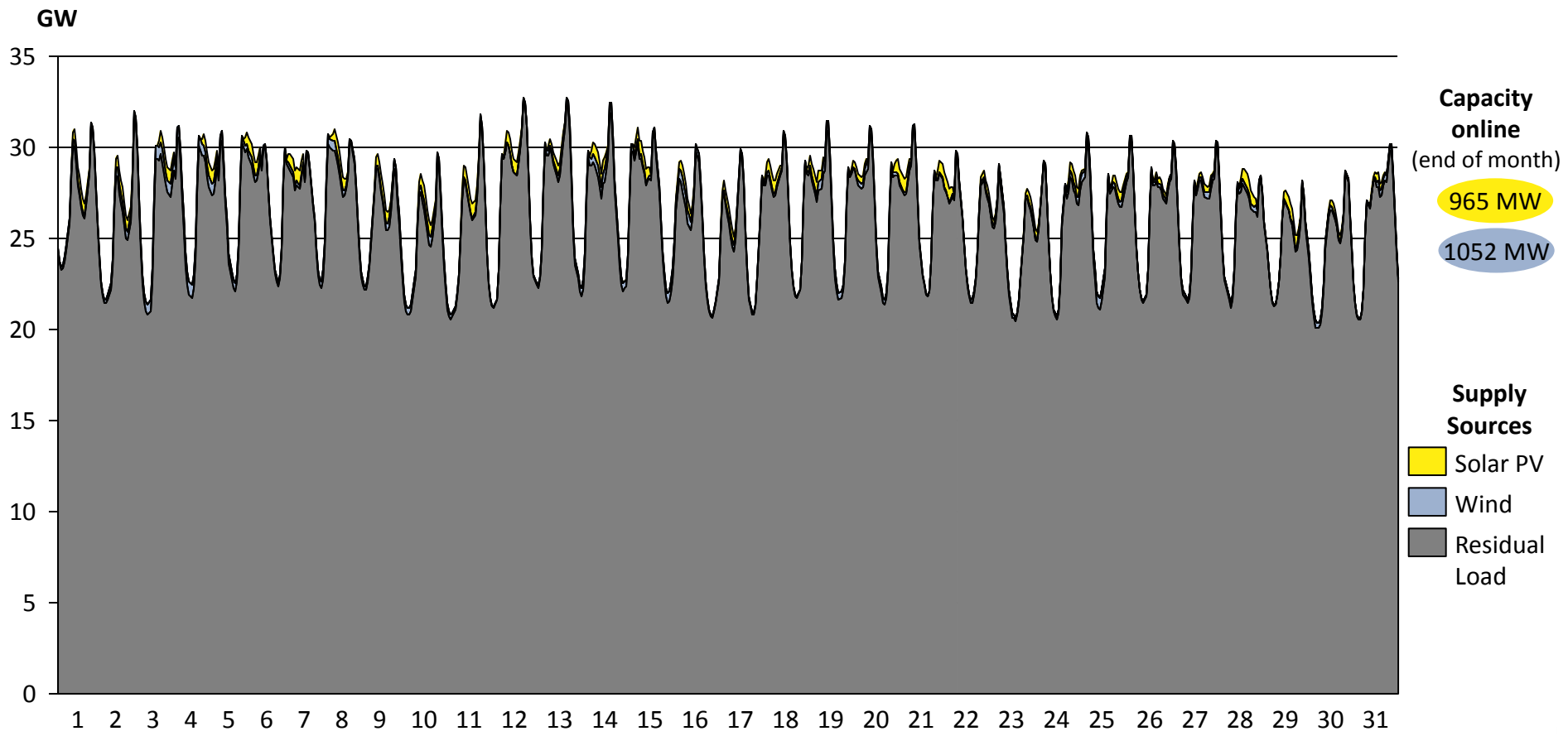


- Maximum power of 34 GW between 18h00 and 19h00 on 28 Jul 2015
- Minimum power of 21 GWh between 02h00 and 03h00 on 6 Jul 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Aug 2015

Actual hourly production from all power supply sources in RSA for August 2015

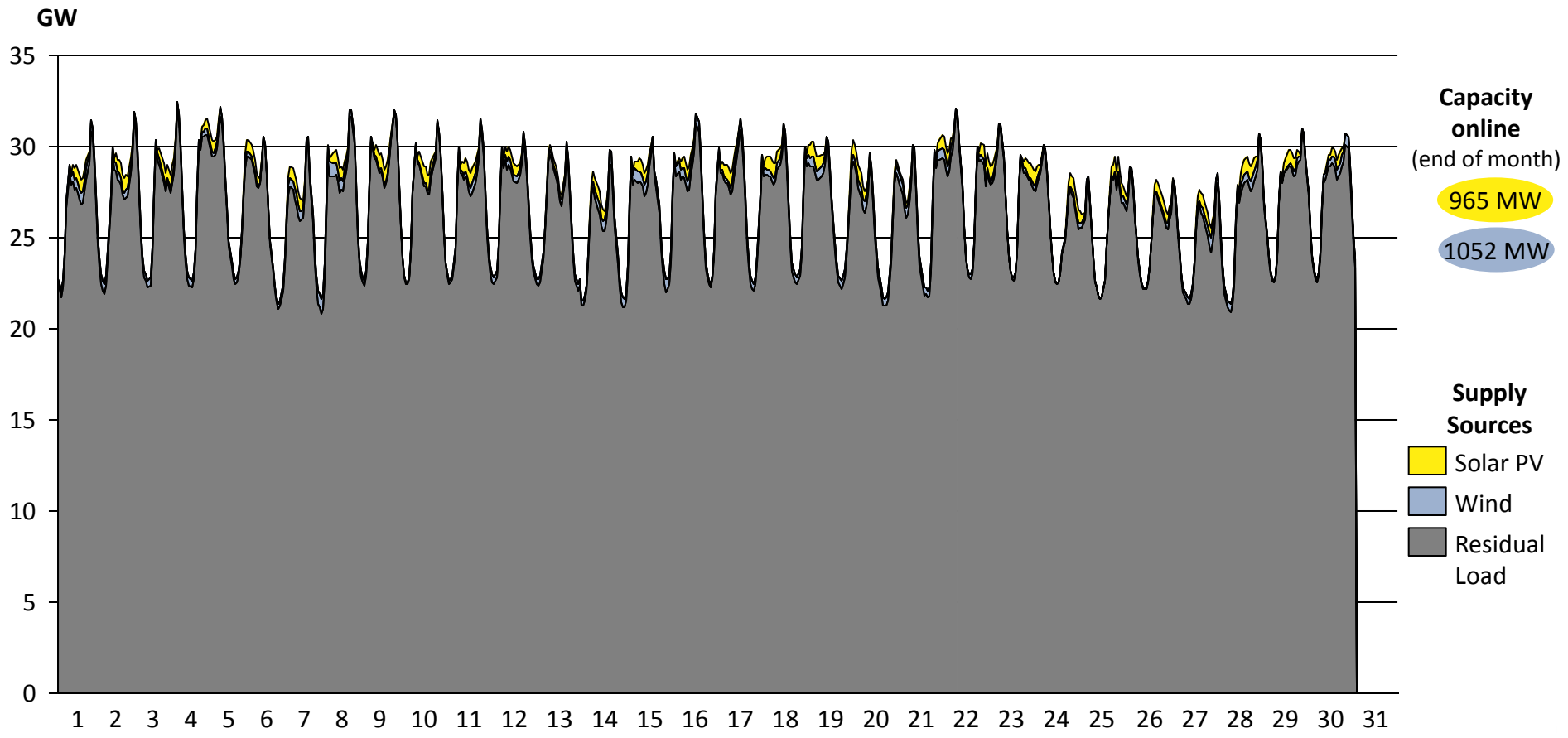


- Maximum power of 33 GW between 18h00 and 19h00 on 11 Aug 2015
- Minimum power of 20 GWh between 03h00 and 04h00 on 30 Aug 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Sep 2015

Actual hourly production from all power supply sources in RSA for September 2015

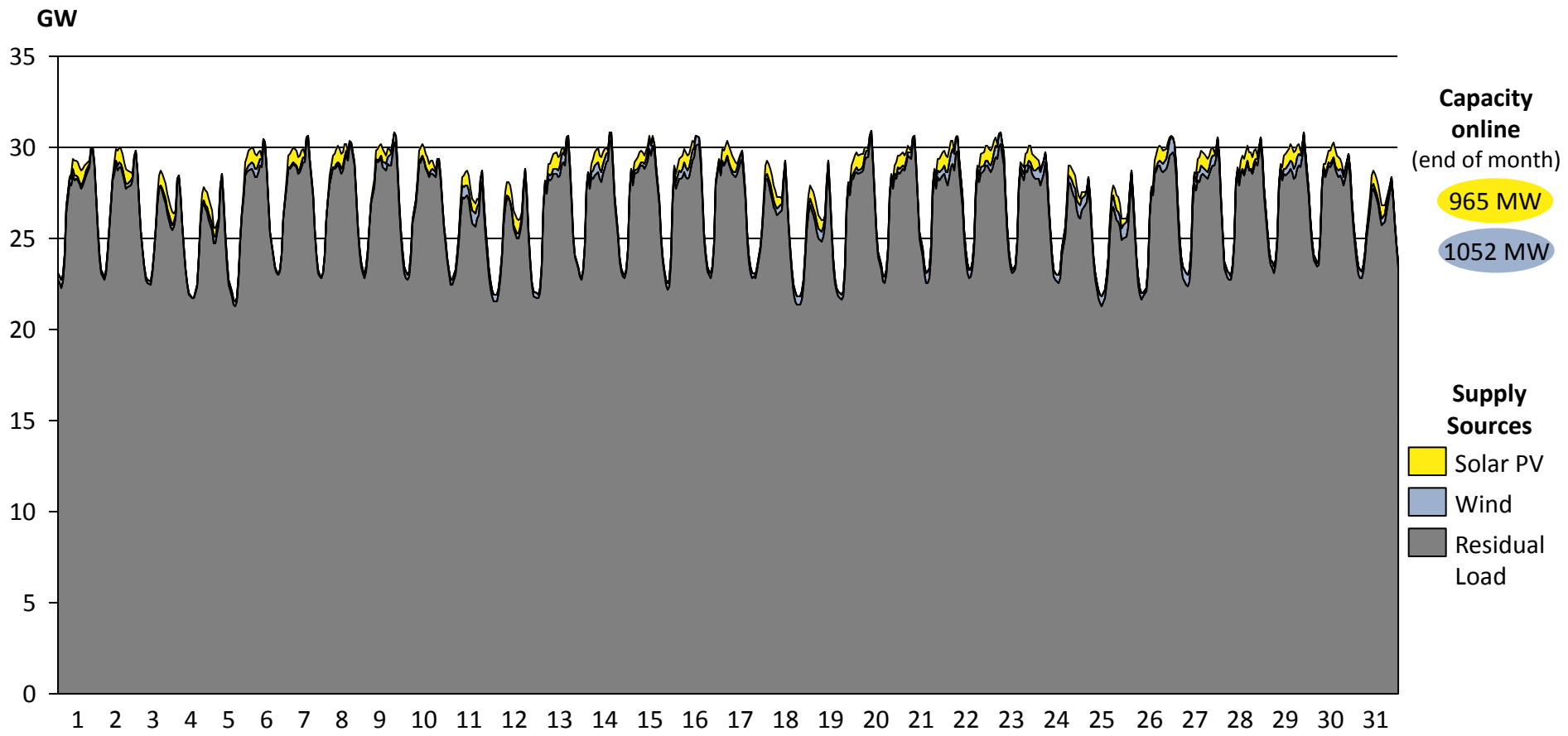


- Maximum power of 32 GW between 18h00 and 19h00 on 3 Sep 2015
- Minimum power of 21 GWh between 02h00 and 03h00 on 13 Sep 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Oct 2015

Actual hourly production from all power supply sources in RSA for October 2015

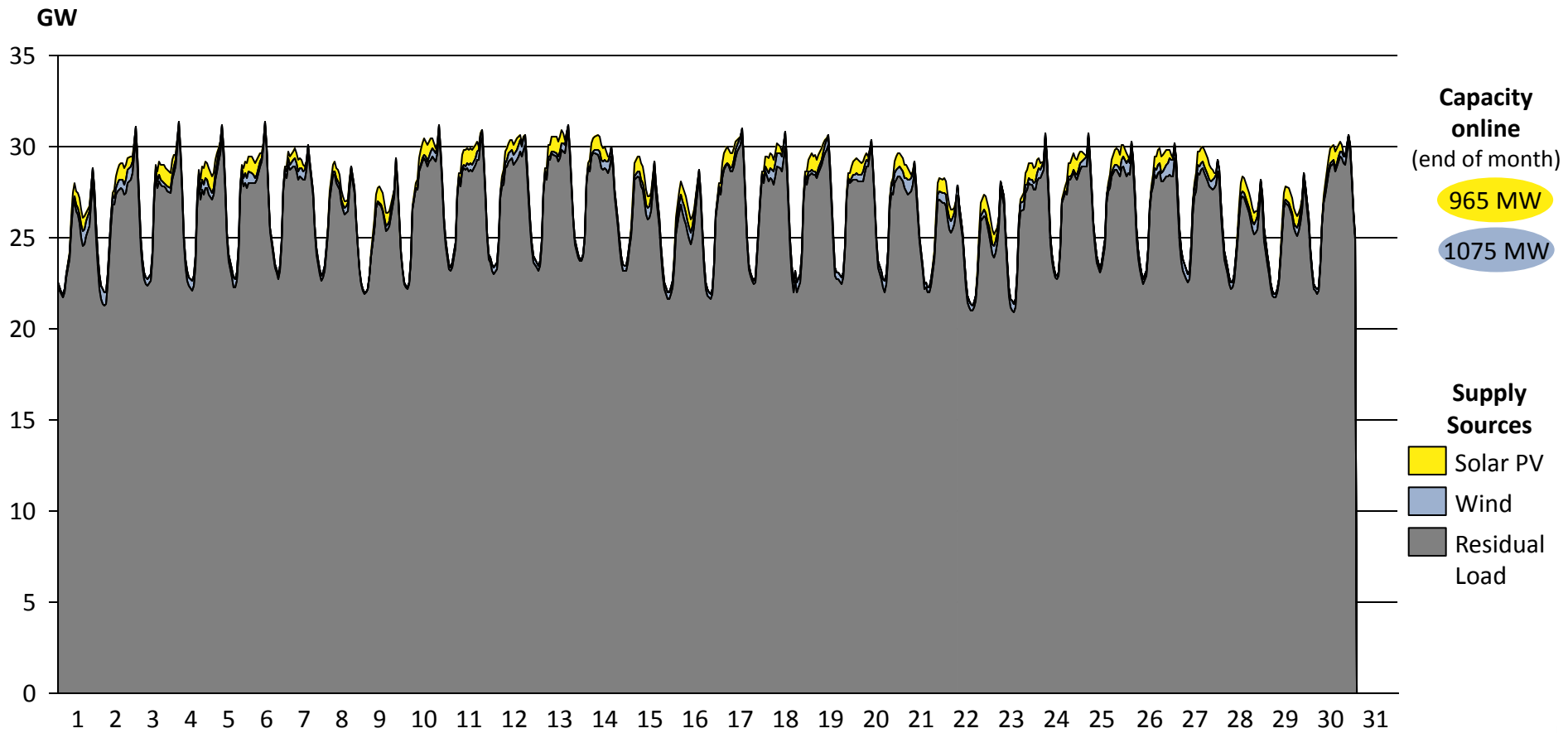


- Maximum power of 31 GW between 19h00 and 20h00 on 19 Oct 2015
- Minimum power of 22 GWh between 02h00 and 03h00 on 5 Oct 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Nov 2015

Actual hourly production from all power supply sources in RSA for November 2015

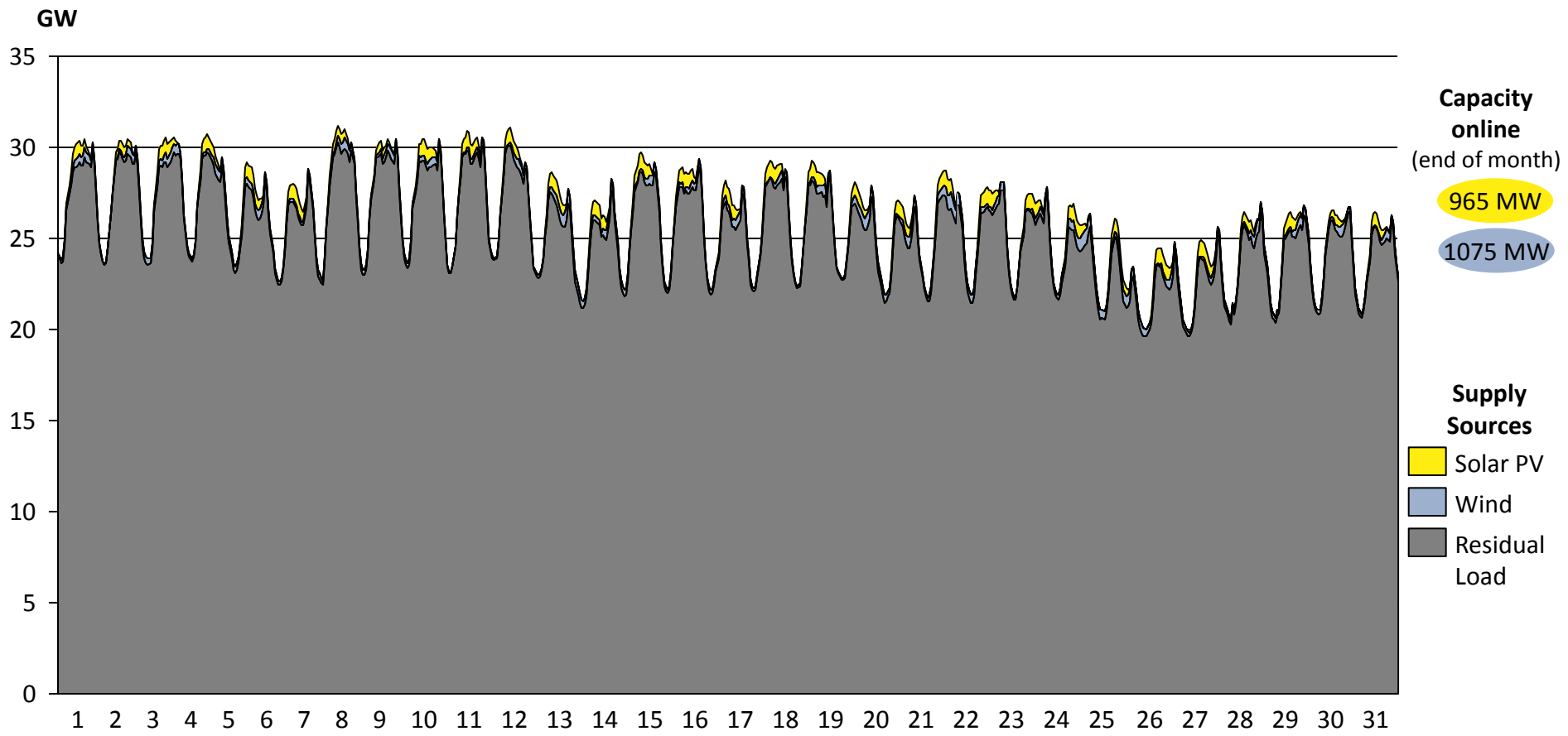


- Maximum power of 31 GW between 19h00 and 20h00 on 3 Nov 2015
- Minimum power of 21 GWh between 03h00 and 04h00 on 22 Nov 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Hourly electricity production in Dec 2015

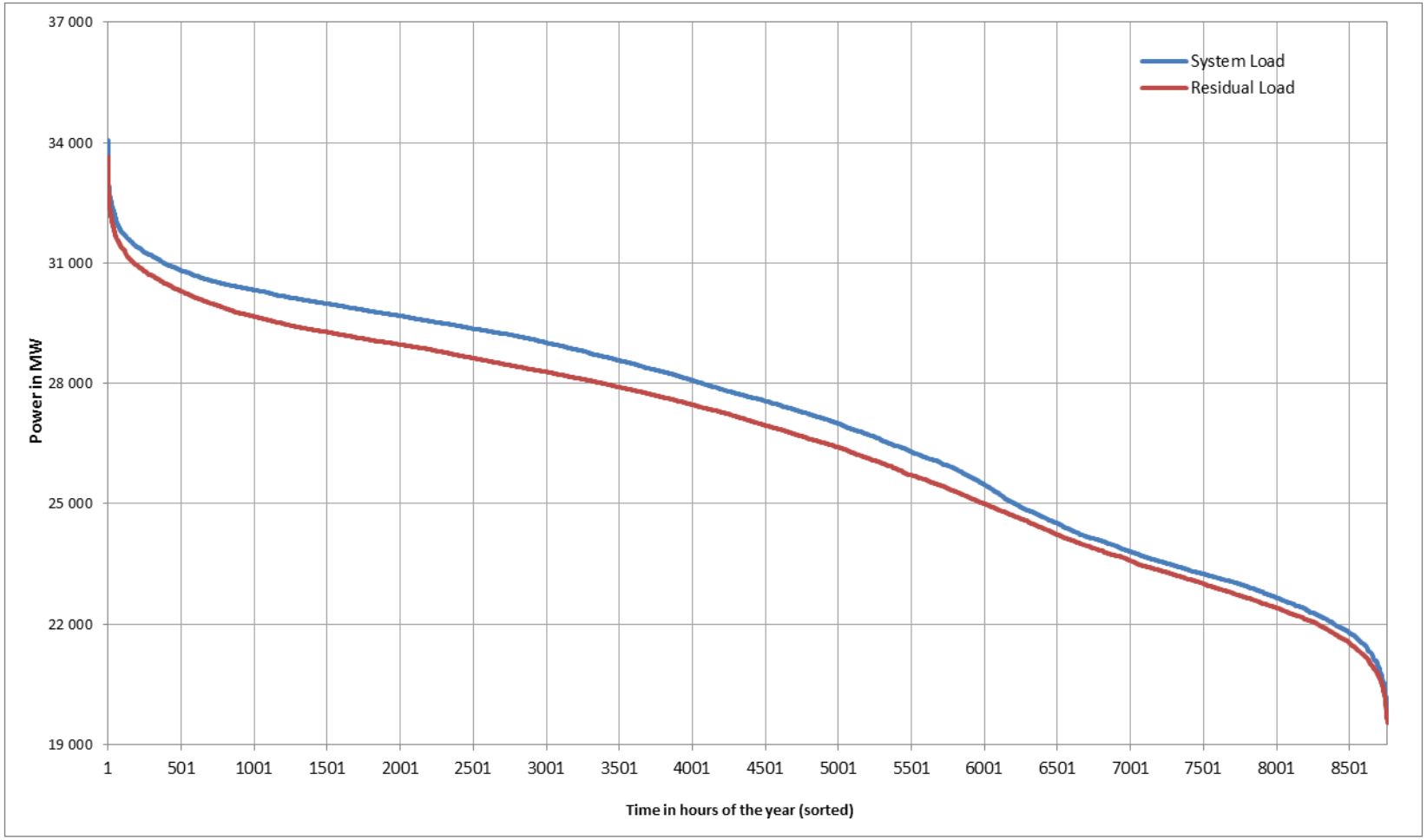
Actual hourly production from all power supply sources in RSA for December 2015



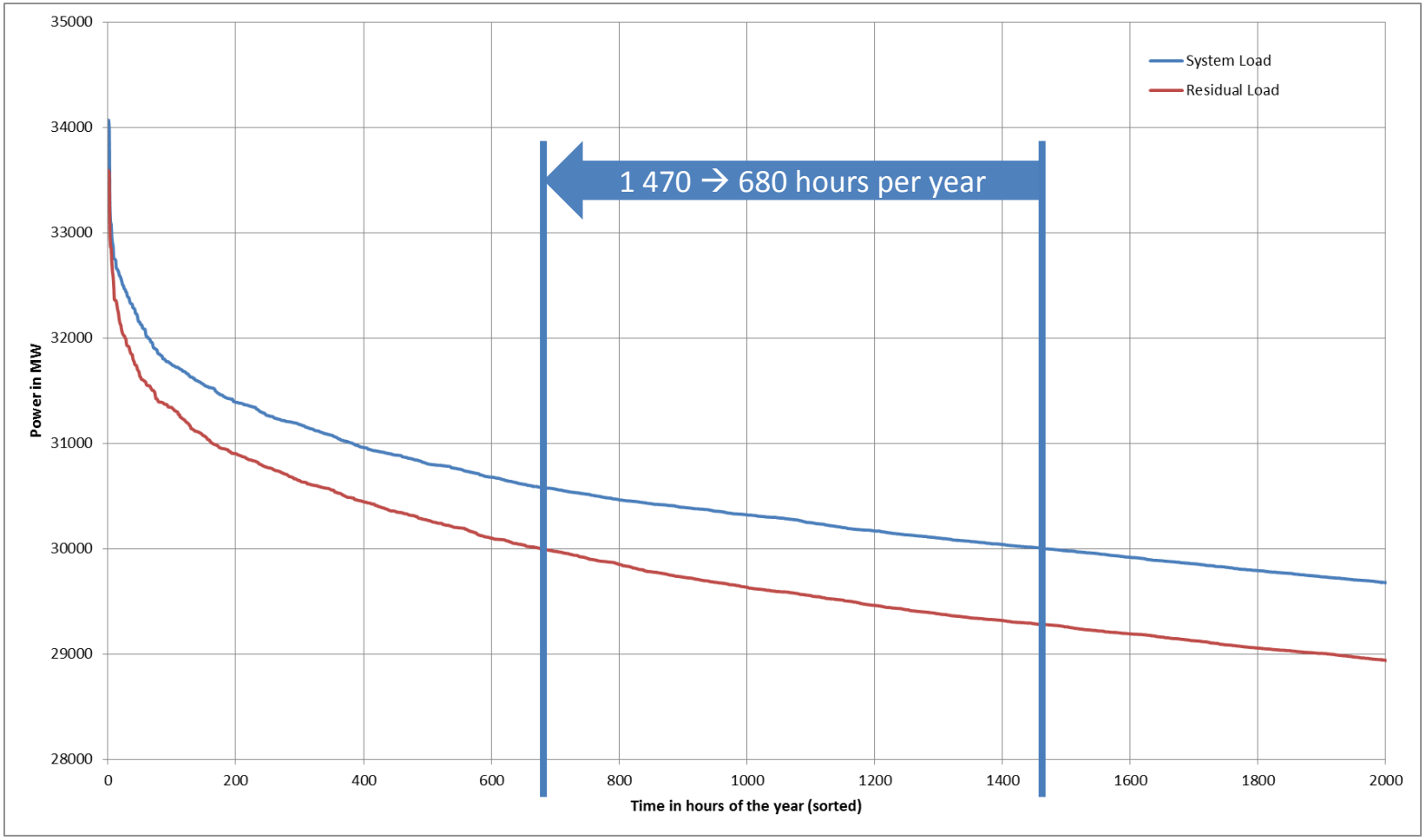
- Maximum power of 31 GW between 11h00 and 12h00 on 7 Dec 2015
- Minimum power of 20 GWh between 03h00 and 04h00 on 27 Dec 2015

Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

2015 system and residual load duration curves



In 2015, wind and solar PV reduced the number of hours with more than 30 000 MW total load from 1470 to 680 (almost 800 hours less)



Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Monthly average wind and photovoltaic electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

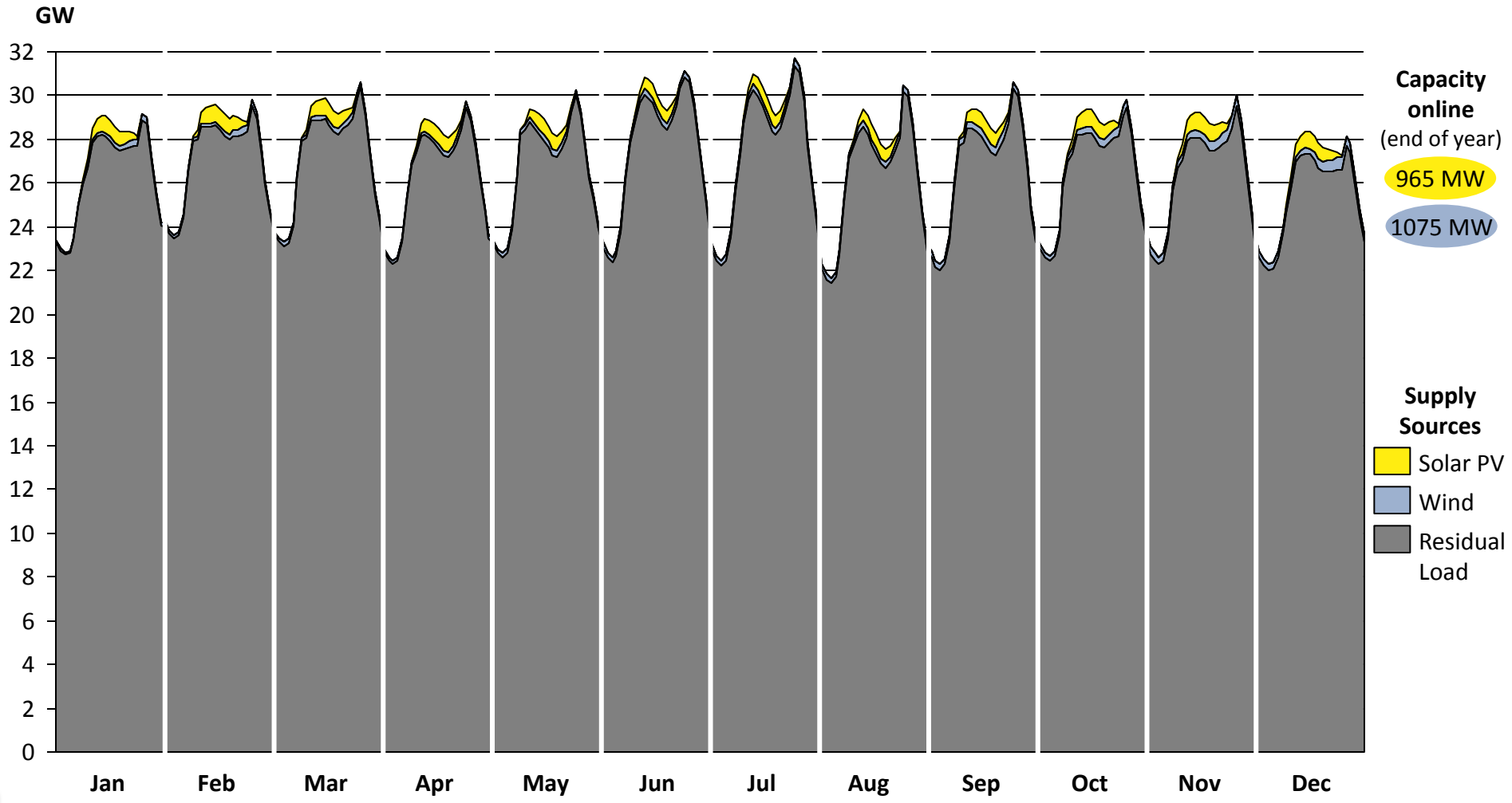
Diurnal courses

Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Diurnal Courses

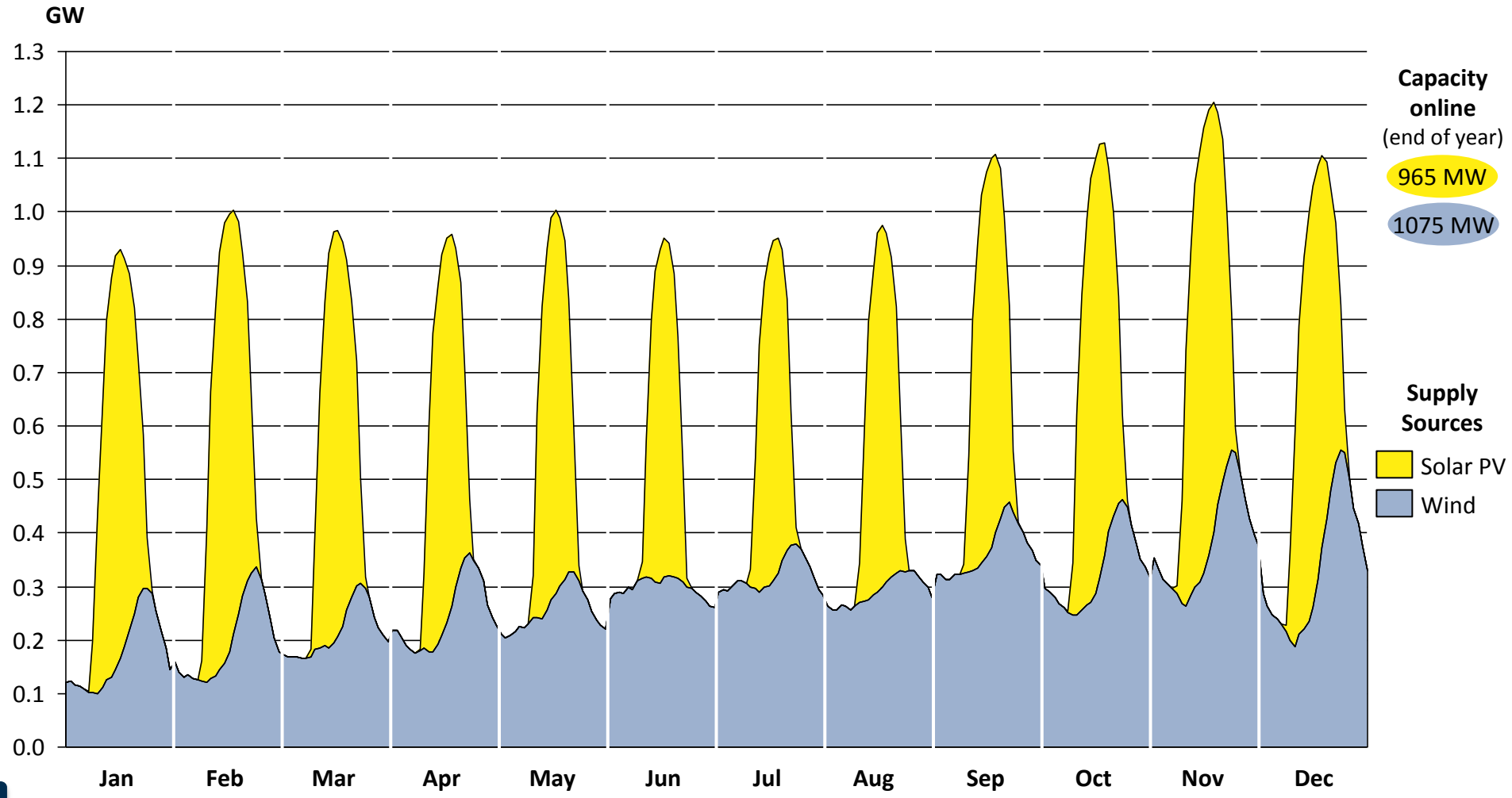
Actual monthly average diurnal courses of the total power supply in RSA for the months from Jan-Dec 2015



Note: Design as per Fraunhofer ISE. Pumping load excluded.
Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Diurnal Courses

Actual monthly average diurnal courses of wind and solar PV in RSA for the months from Jan-Dec 2015

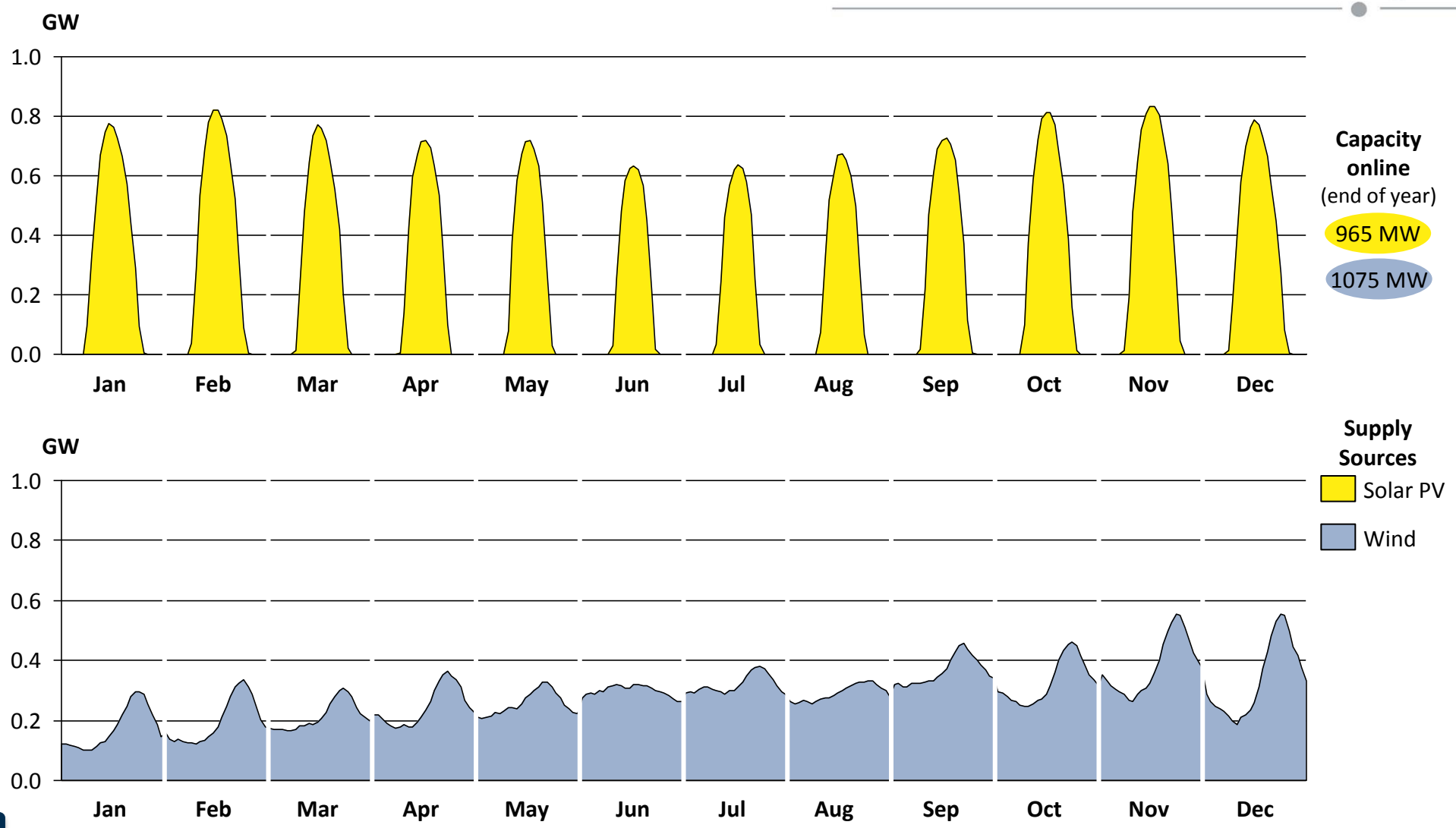


Note: Design as per Fraunhofer ISE

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Diurnal Courses

Actual monthly average diurnal courses of wind and solar PV in RSA for the months from Jan-Dec 2015



Note: Design as per Fraunhofer ISE

Sources: Eskom; DoE IPP Office; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

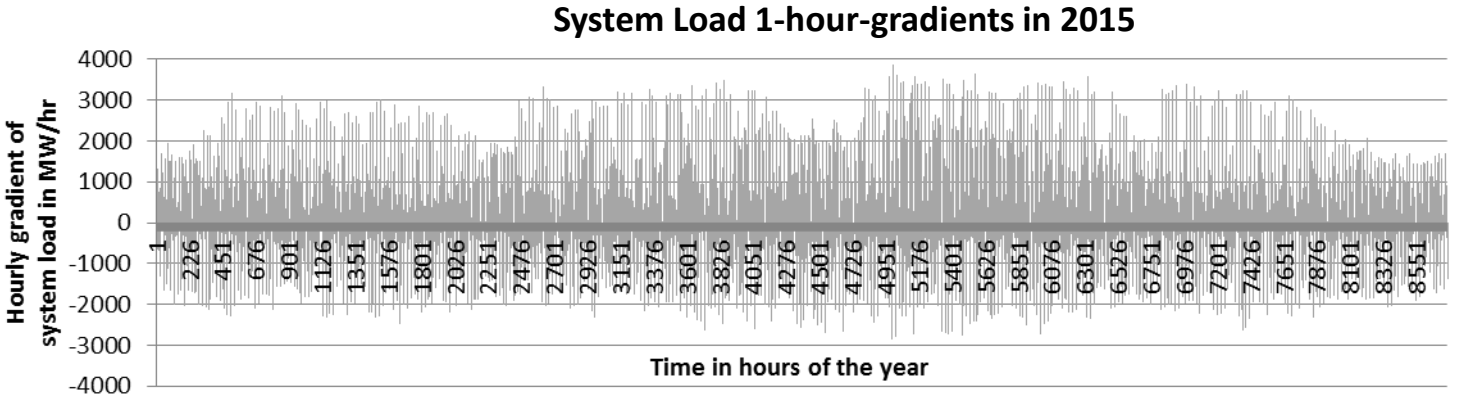
Hourly electricity production

Diurnal courses

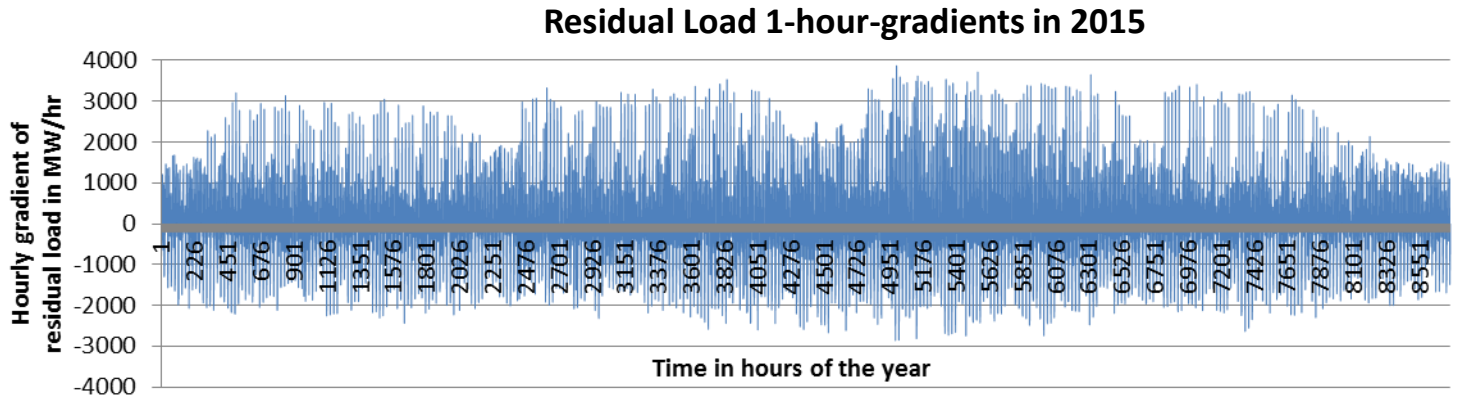
Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Maximum 1-hour gradient was not affected by 2 GW wind & solar PV



- Max gradient of 3 886 MW on 28 July 2015 between 05h00 and 06h00
- Min gradient of -2 848 MW on 27 July 2015 between 22h00 and 23h00



- Maximum gradient of 3 873 MW on 28 July 2015 between 05h00 and 06h00
- Minimum gradient of -2 861 MW on 27 July 2015 between 22h00 and 23h00

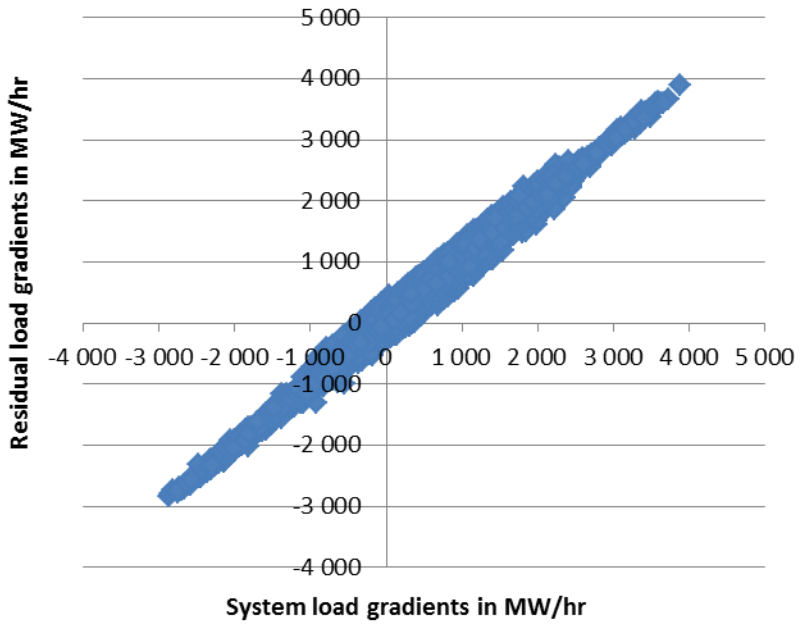
- Residual load = System load – Solar PV – Wind

Notes: System and Residual load excludes pumping load for all data points throughout the year. $Load\ gradient_t = load_t - load_{t-1}$

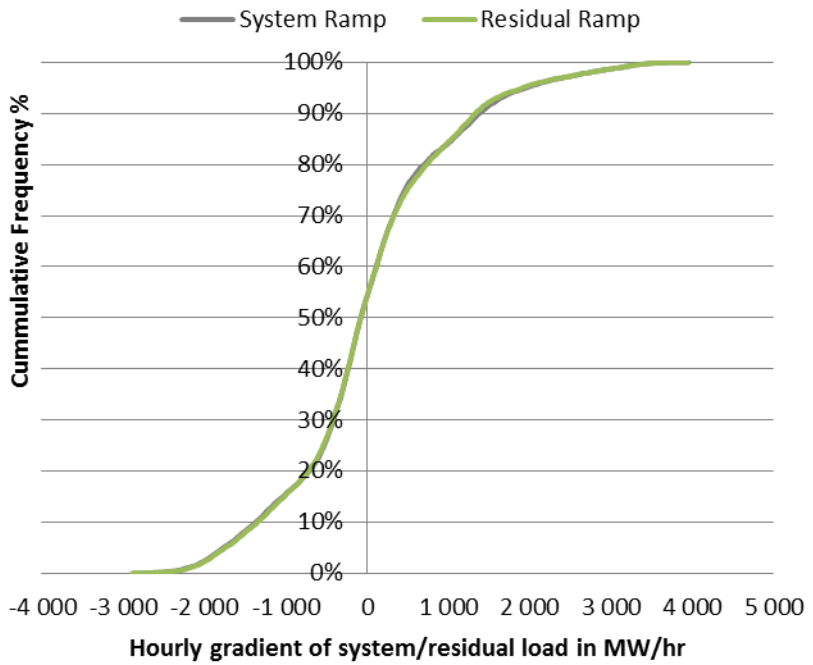
Sources: Eskom; CSIR Energy Centre analysis

1-hour gradients did not increase due to 2 GW of wind and solar PV

System load 1-hour gradients vs. residual load 1-hour gradients for all hours from Jan – Dec 2015

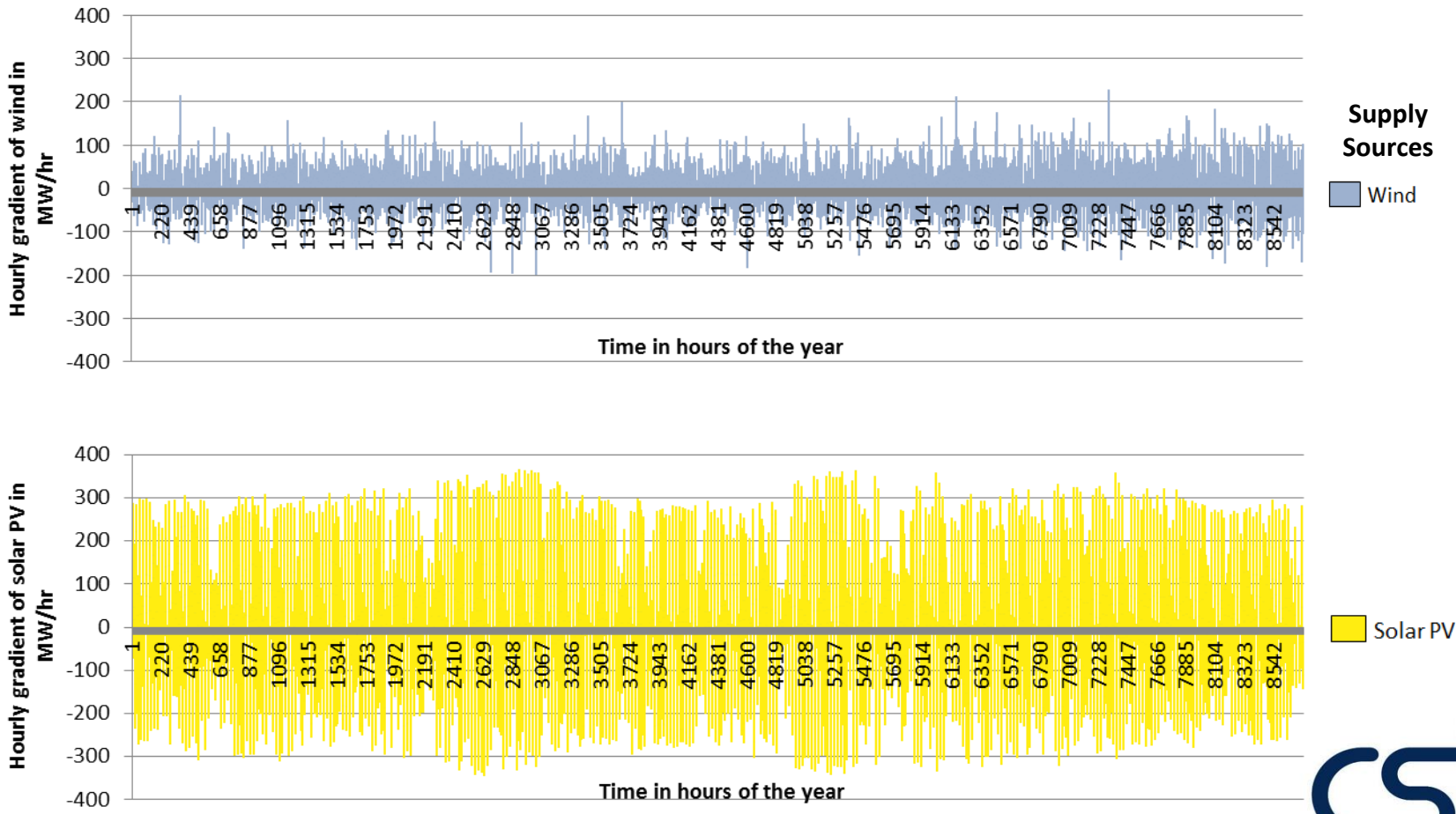


Cumulative frequency distribution of 1-hour gradients for all hours from Jan – Dec 2015



Notes: System and Residual load excludes pumping load for all data points throughout the year.
Sources: Eskom; CSIR Energy Centre analysis

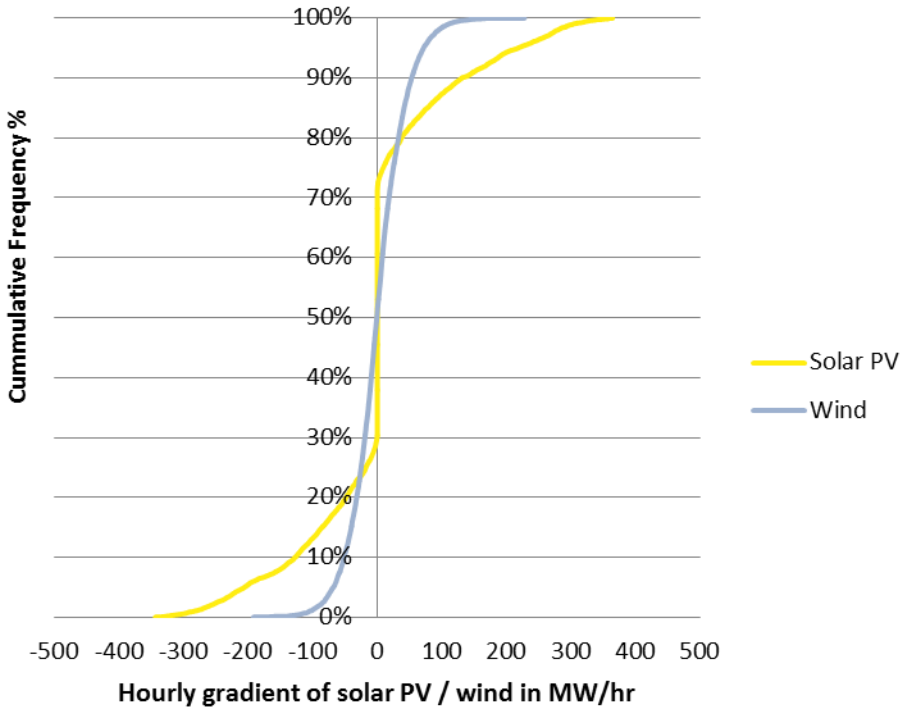
2015 1-hour gradients of wind and solar PV supply



Sources: Eskom; CSIR Energy Centre analysis

2015 wind and solar PV frequency distribution of 1-hour gradients

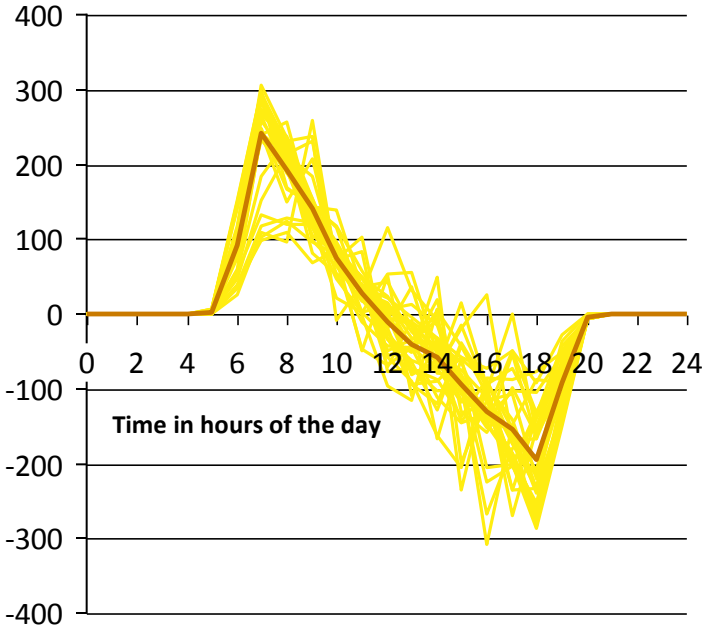
- Cumulative frequency distribution of 1-hour gradients for all hours from Jan – Dec 2015



Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in January 2015

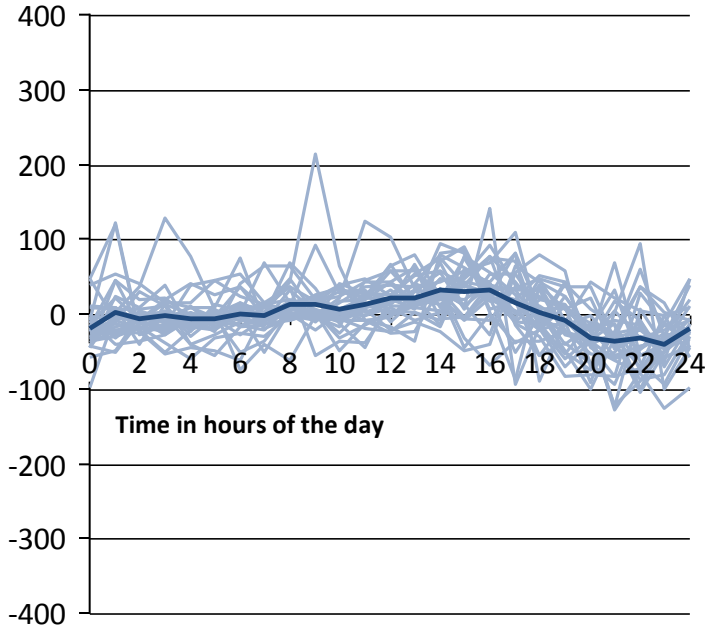
Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr

Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr



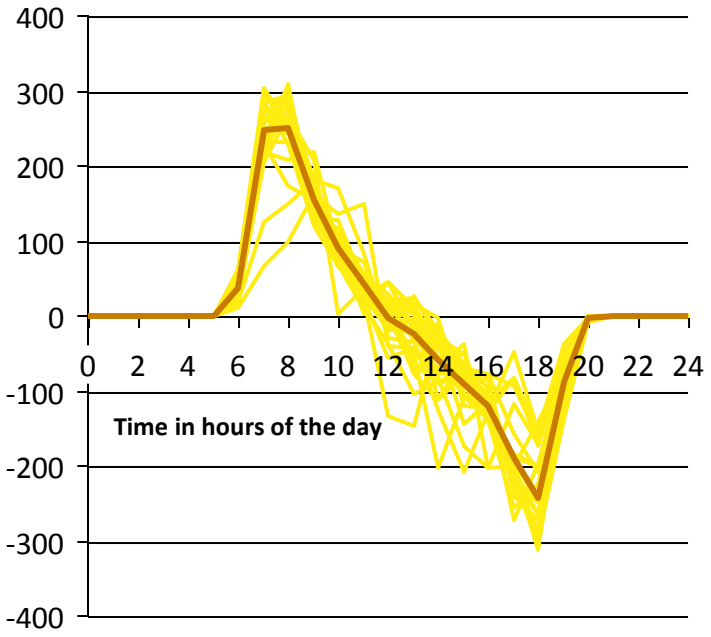
Wind hourly gradients in MW/hr

Average hourly wind gradients in MW/hr

Sources: Eskom; CSIR Energy Centre analysis

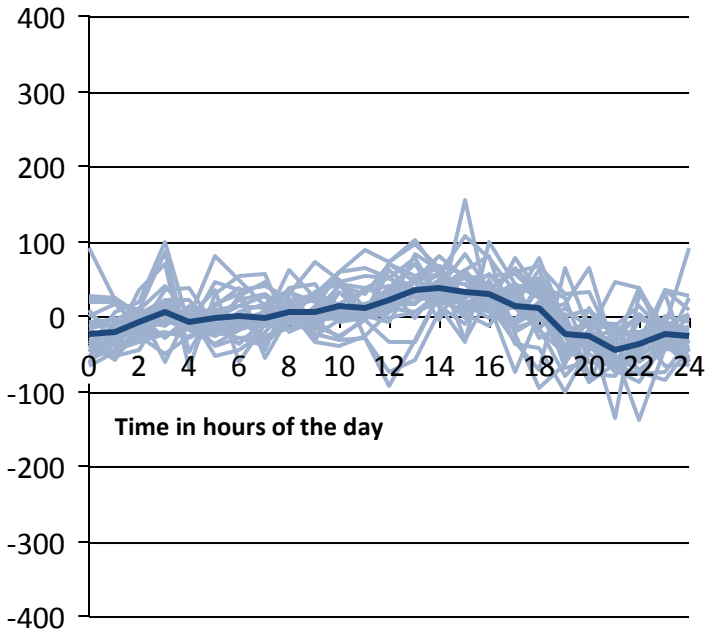
Solar PV and wind 1-hour gradients in February 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

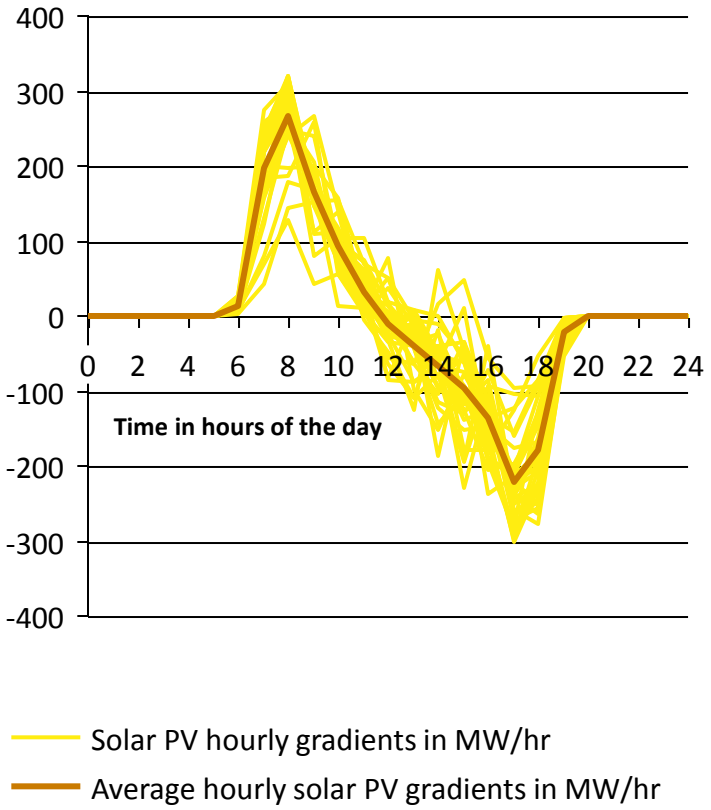


Wind hourly gradients in MW/hr
Average hourly wind gradients in MW/hr

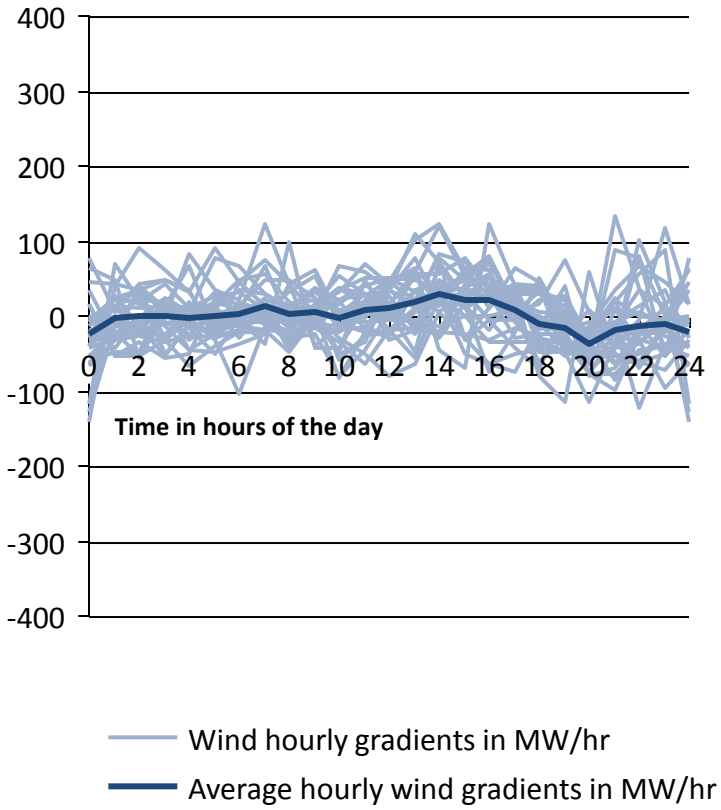
Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in March 2015

Solar PV hourly gradients in MW/hr



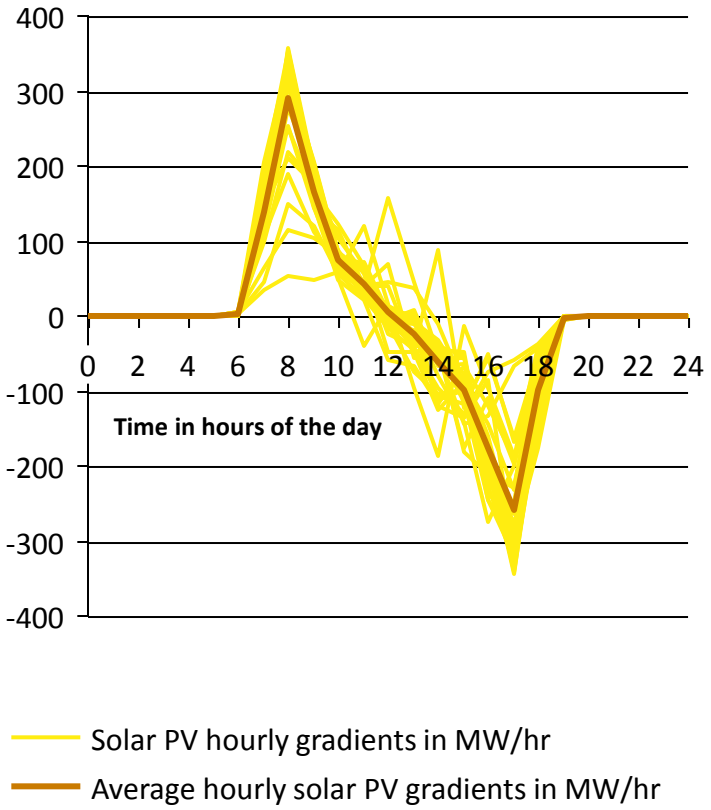
Wind hourly gradients in MW/hr



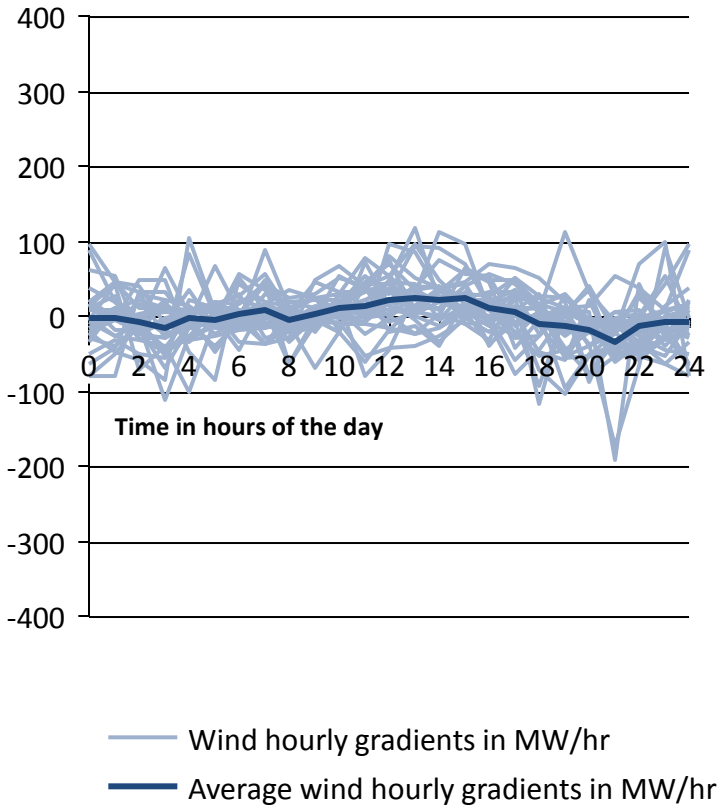
Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in April 2015

Solar PV hourly gradients in MW/hr



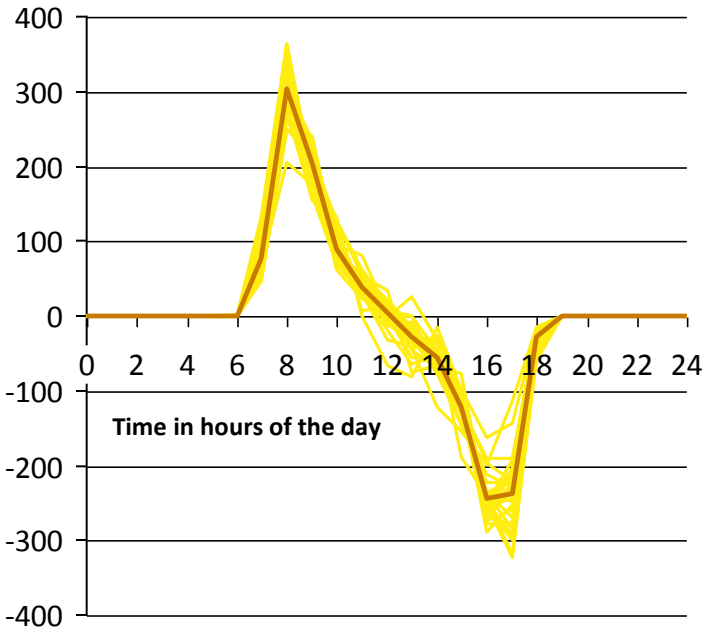
Wind hourly gradients in MW/hr



Sources: Eskom; CSIR Energy Centre analysis

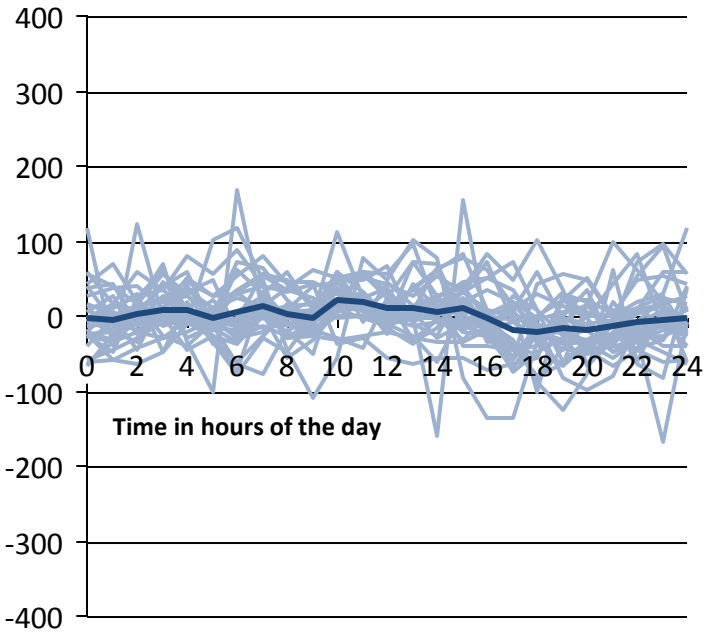
Solar PV and wind 1-hour gradients in May 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

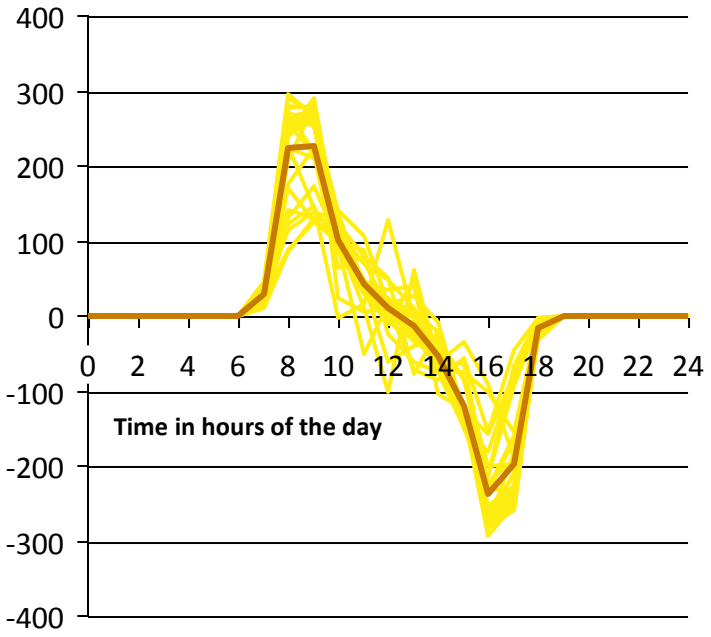


Wind hourly gradients in MW/hr
Average wind hourly gradients in MW/hr

Sources: Eskom; CSIR Energy Centre analysis

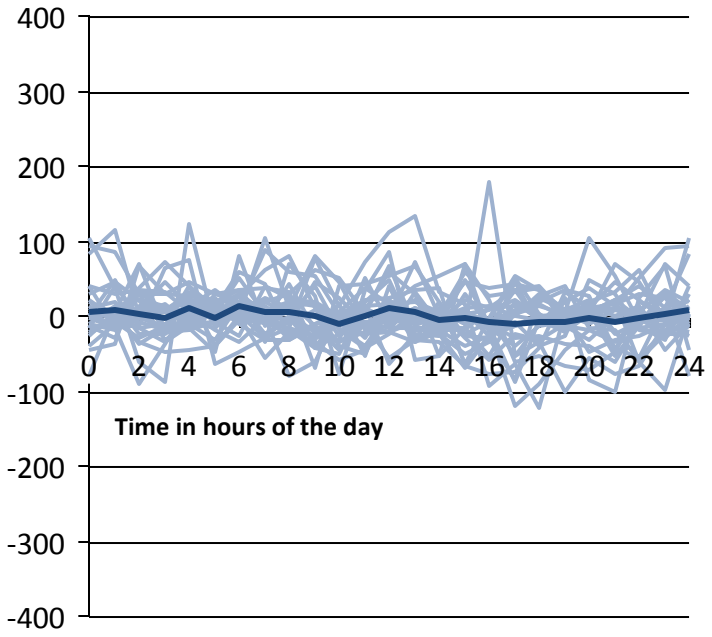
Solar PV and wind 1-hour gradients in June 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

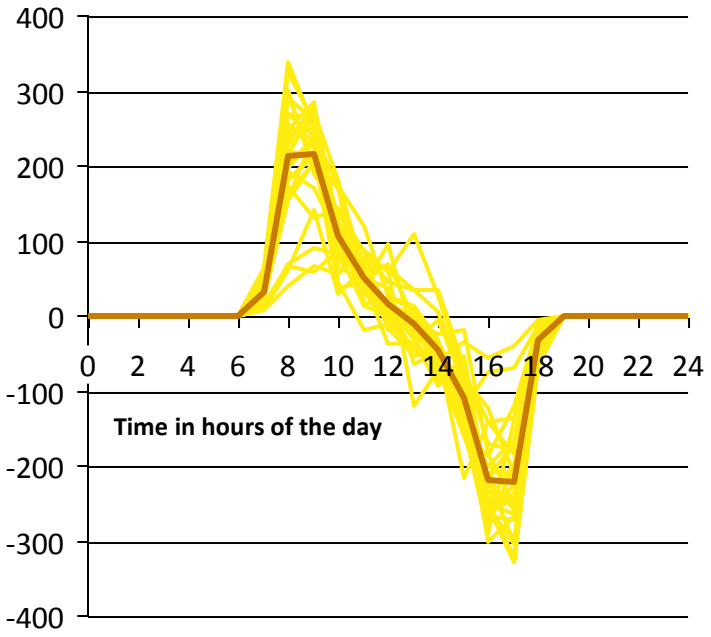


Wind hourly gradients in MW/hr
Average wind hourly gradients in MW/hr

Sources: Eskom; CSIR Energy Centre analysis

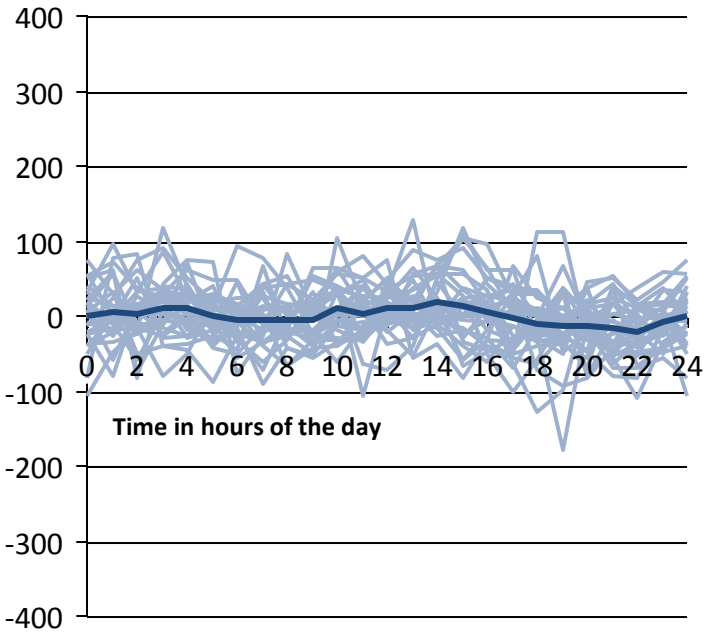
Solar PV and wind 1-hour gradients in July 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

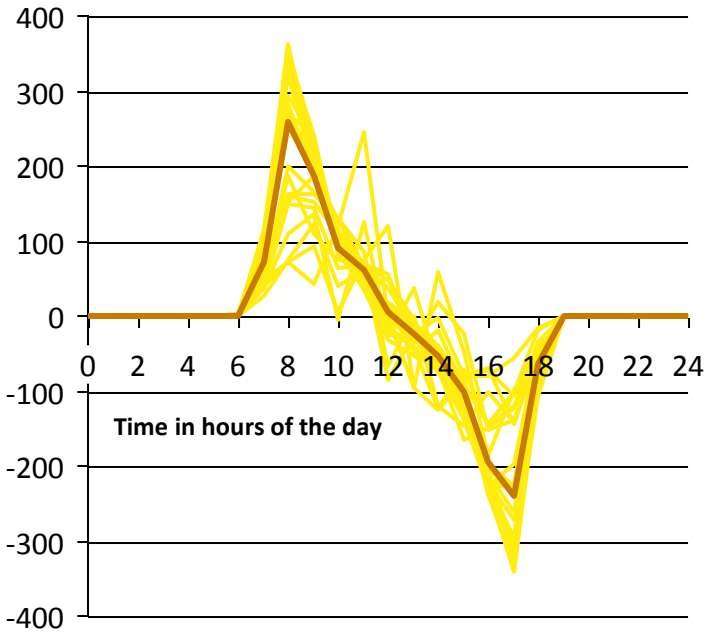


Wind hourly gradients in MW/hr
Average wind hourly gradients in MW/hr

Sources: Eskom; CSIR Energy Centre analysis

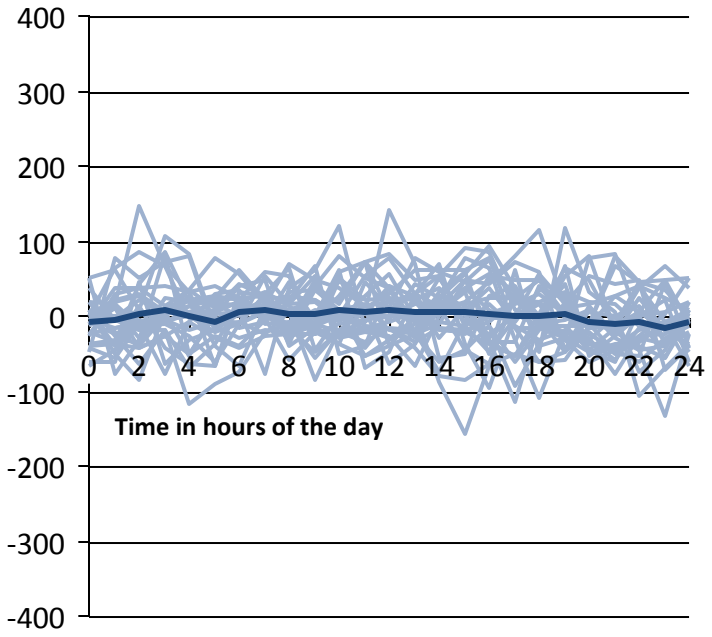
Solar PV and wind 1-hour gradients in August 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

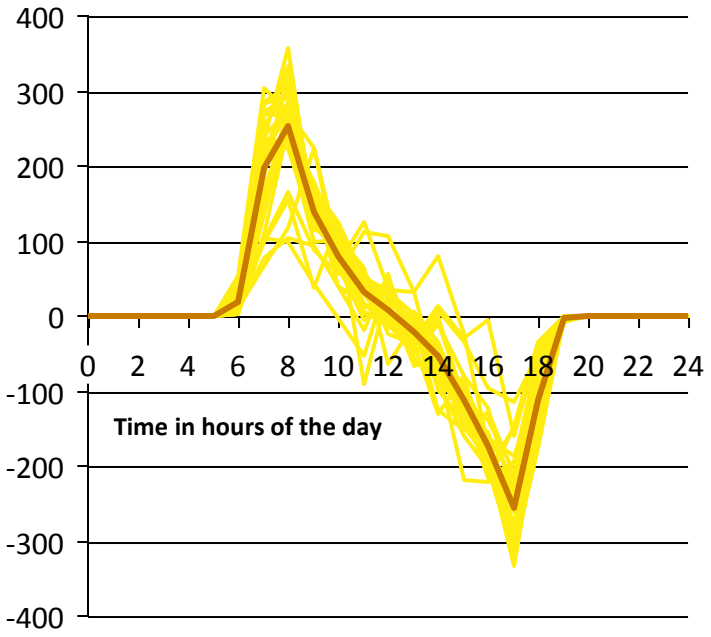


Wind hourly gradients in MW/hr
Average wind hourly gradients in MW/hr

Sources: Eskom; CSIR Energy Centre analysis

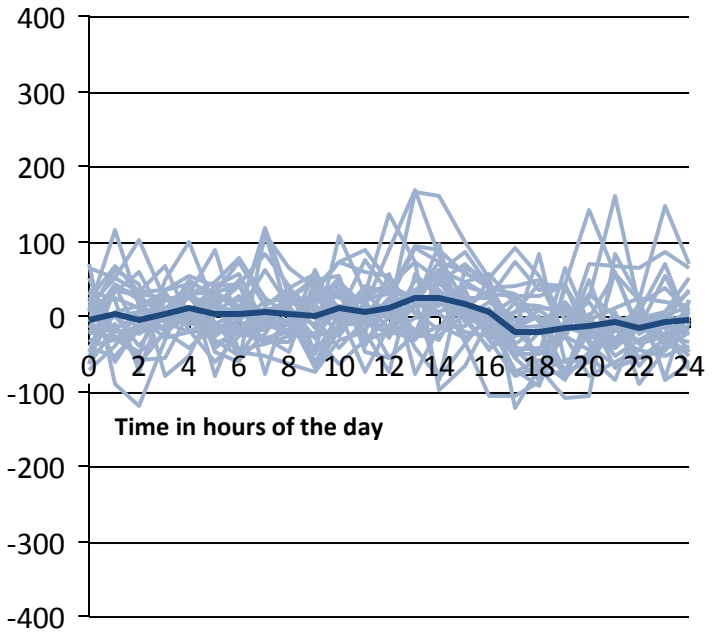
Solar PV and wind 1-hour gradients in September 2015

Solar PV hourly gradients in MW/hr



Solar PV hourly gradients in MW/hr
Average hourly solar PV gradients in MW/hr

Wind hourly gradients in MW/hr

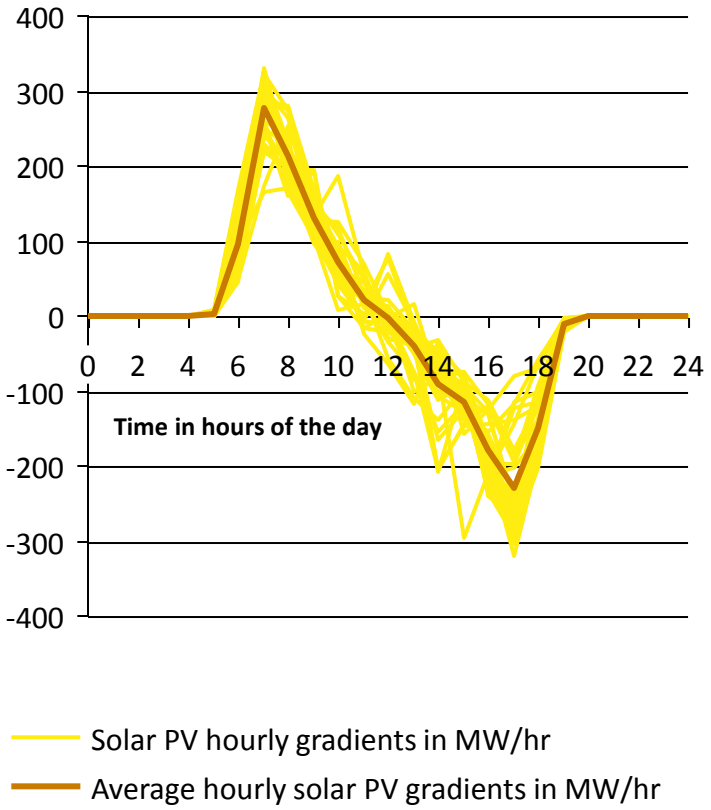


Wind hourly gradients in MW/hr
Average wind hourly gradients in MW/hr

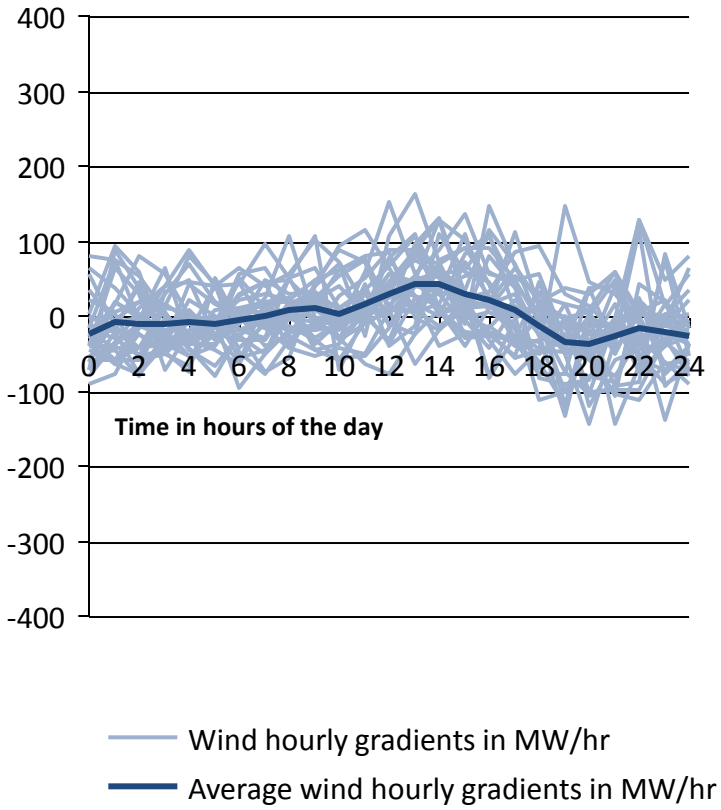
Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in October 2015

Solar PV hourly gradients in MW/hr



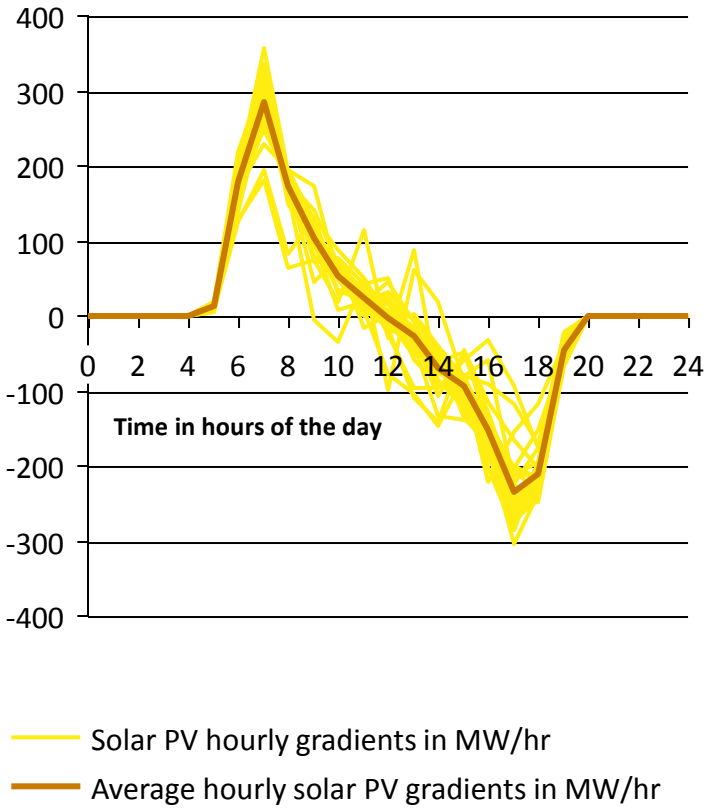
Wind hourly gradients in MW/hr



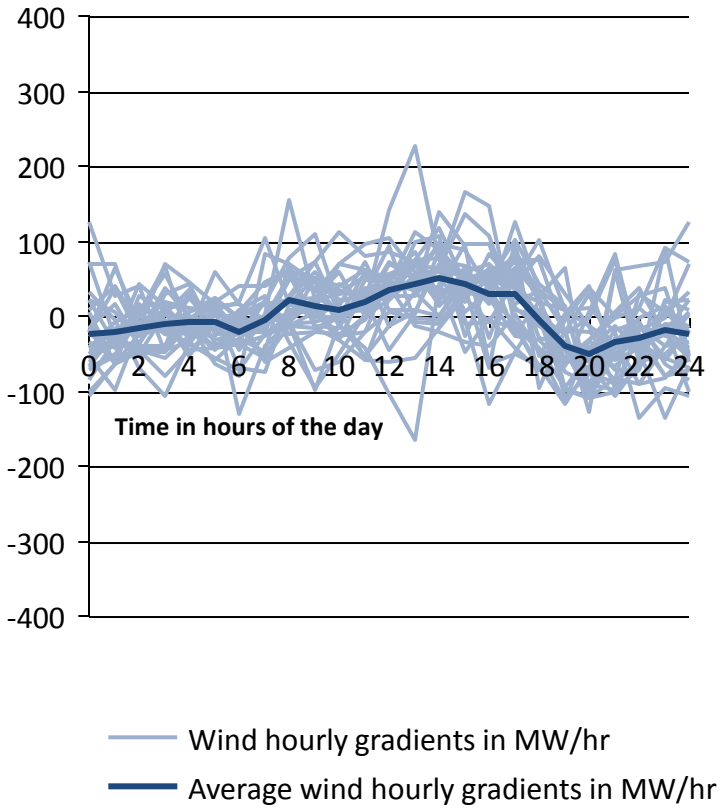
Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in November 2015

Solar PV hourly gradients in MW/hr



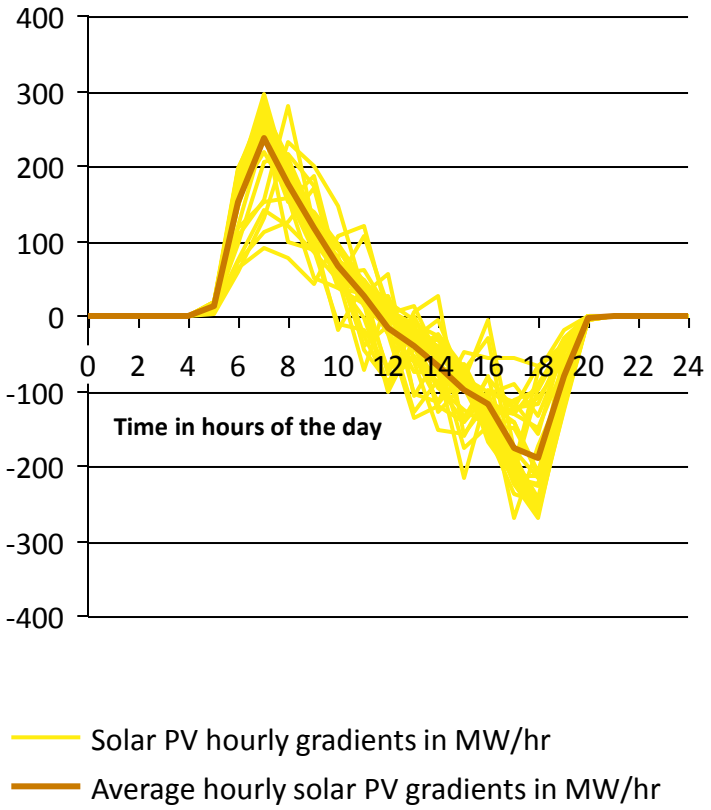
Wind hourly gradients in MW/hr



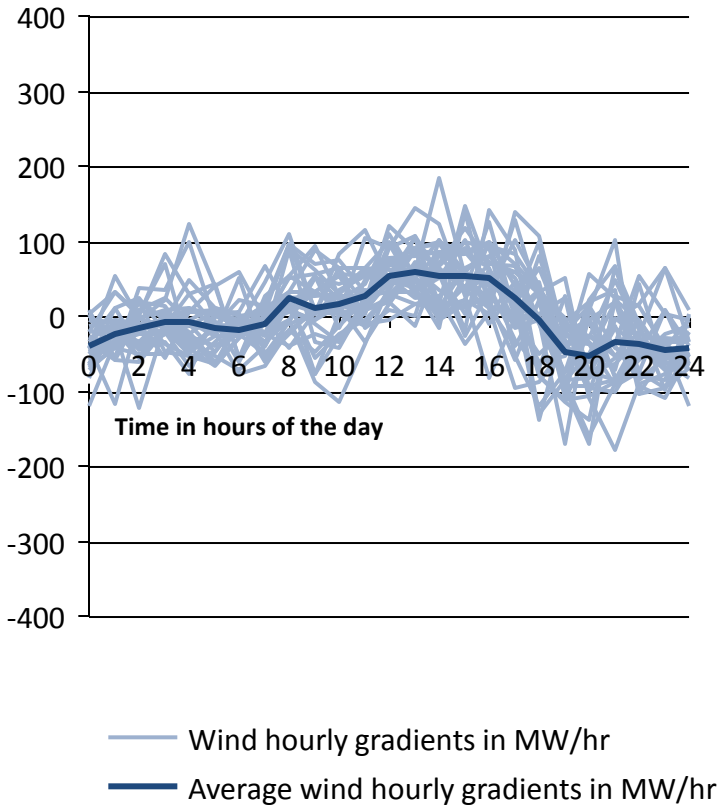
Sources: Eskom; CSIR Energy Centre analysis

Solar PV and wind 1-hour gradients in December 2015

Solar PV hourly gradients in MW/hr



Wind hourly gradients in MW/hr



Sources: Eskom; CSIR Energy Centre analysis

Agenda

Overview actual electricity production data for 2015

Monthly electricity production

Weekly electricity production

Daily electricity production

Hourly electricity production

Diurnal courses

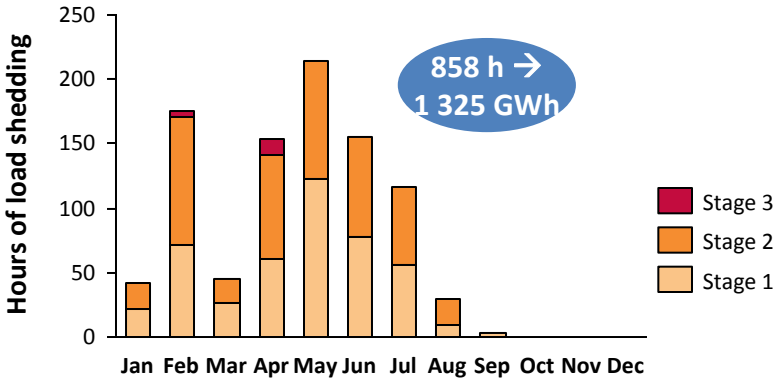
Hourly gradients of wind and photovoltaics

Actual load shedding for Jan-Dec 2015

Actual load shedding occurred on 103 of the 365 days from Jan-Dec 2015

103 days, 858 hours of load shedding

Approx. 1 325 GWh of unserved energy



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

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
Jul	0	0	0	0	0	0	0	0	8	8	8	8	9	9	8	8	8	20	21	21	21	21	0	0	178
Aug	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	9	9	9	9	8	0	0	49
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	3
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	7	11	41	43	56	58	63	63	64	65	93	147	155	156	151	147	5	0	1 325

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

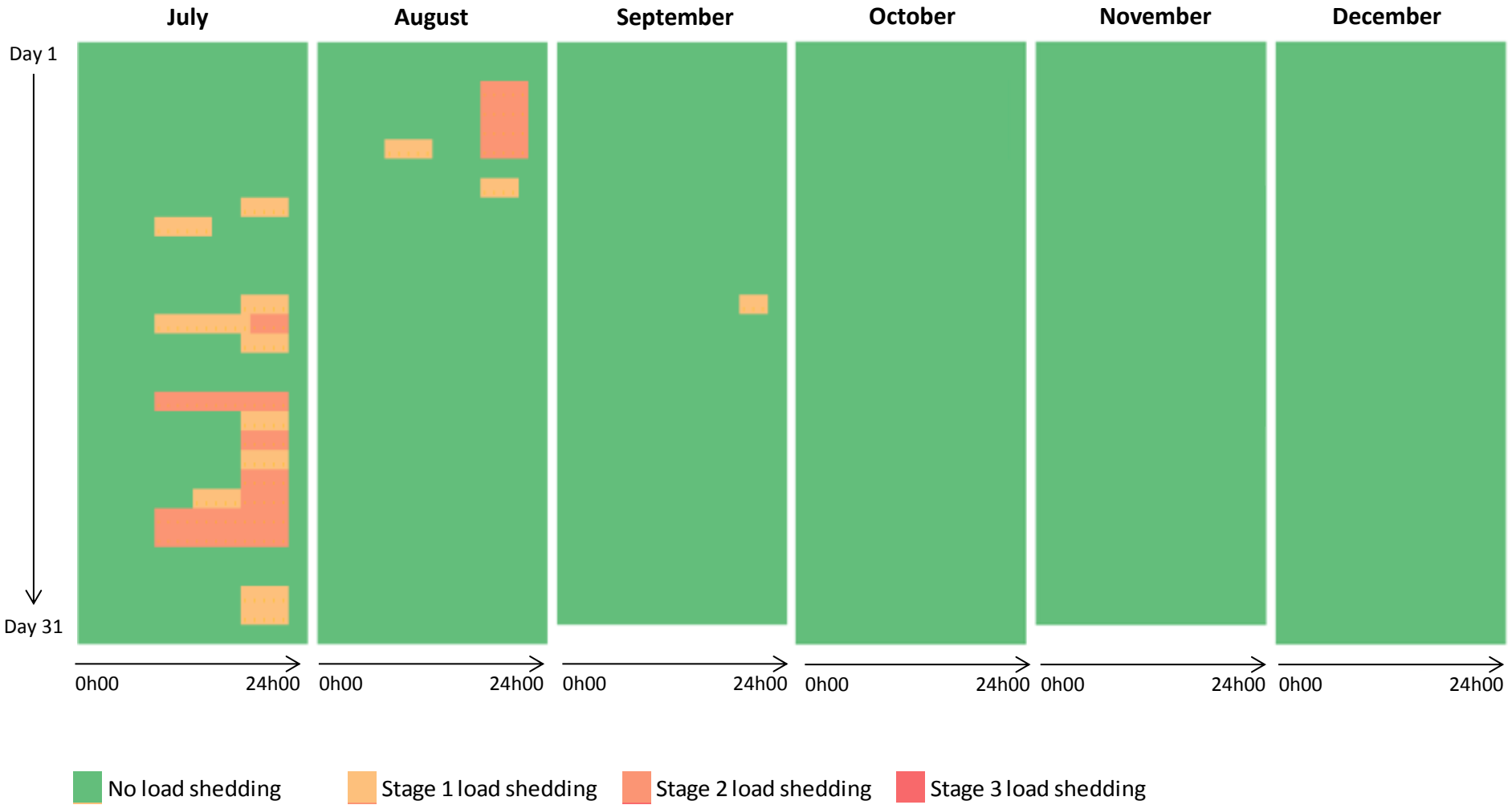
Sources: Eskom Twitter account; CSIR Energy Centre analysis

Hourly distribution of actual load shedding 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

Hourly distribution of actual load shedding July to December 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

Data sources

Data sources

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

- Data source: Eskom
- Type of data: Hourly system supply data for the calendar year 2015 on aggregated level for all installed wind and solar PV
  Total hourly system energy for the calendar year 2015, minus hydro pumping load

Total wind and solar PV capacity online

- Data source: Department of Energy (DoE) IPP Office
- Type of data: Monthly total wind and solar PV IPPs online

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

Re a leboha

Ha Khensa

Enkosi

Siyathokoza

Thank you!

Re a leboga

Ro livhuha

Dankie

Siyabonga