Financial Costs and Benefits of Renewables in South Africa in 2014

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Author Contact Details: Prof Dr Tobias Bischof-Niemz, Centre Manager: Energy, CSIR, TBischofNiemz@csir.co.za, +27 83 403 1108

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Executive Summary

This study found that renewable energy from South Africa's first wind and solar photovoltaic (PV) projects created R0.8 billion more financial benefits to the country than they cost during 2014.

The benefits earned were two-fold. The first benefit, derived from diesel and coal fuel cost savings, is pinned at R3.64 billion. This is because 2.2 TWh (terawatt-hours) of wind and solar energy replaced the electricity that would have otherwise been generated from diesel and coal (1.05 TWh from diesel-fired open-cycled gas turbines and 1.12 TWh from coal power stations).

The second benefit of R1.67 billion is a saving to the economy derived from 117 hours of so-called "unserved energy" that were avoided thanks to the contribution of the wind and solar projects. During these hours the supply situation was so tight that some customers' energy supply would have had to be curtailed ("unserved") if it had not been for the renewables.

Therefore, renewables contributed benefits of R5.3 billion in total (or R2.42 per kWh of renewable energy), while the tariff payments to independent power producers of the first wind and photovoltaic (PV) projects were only R4.5 billion (or R2.07 per kWh of renewable energy), leaving a net benefit of R0.8 billion.

The CSIR Energy Centre developed a methodology to quantify these financial benefits. The methodology was fed with cost data from publicly available sources, such as Eskom's interim financial results 2014 for coal and diesel costs, or the Department of Energy's publications on the average tariffs of the first renewables projects, or the Integrated Resource Plan on the cost of unserved energy.

Because the study is an "outside-in" analysis of the system operations, conservative assumptions for the system effects and for the costs of coal were chosen. The actual cost savings that renewable energy sources brought during 2014 are therefore presumably higher than shown by the study.

Generally speaking, the pure fuel-saver effect of renewables that was quantified in this study always grossly underestimates the total financial value of renewable energy. The fuel-saver logic purely applies in the short-term and measures the effect of renewables on the already existing conventional fleet. In the medium- to long-term, renewables together with relatively speaking inexpensive flexible new-build options need to be compared with alternative non-renewables new-build scenarios.

Hence, this study underestimates the financial value of renewables not only because the methodology and the cost assumptions were chosen conservatively, but more importantly because of the neglected long-term effects of renewables on the power mix. This was however done on purpose, as the study was meant to be based purely on actual data, without making assumptions on future developments. What the study therefore does is it establishes the floor below which the combined short- and long-term value of renewables in South Africa in 2014 will certainly not lie.

In 2014, this floor of minimum renewables value is the above-mentioned R5.3 billion, and it was higher than the costs of the first renewables projects in form of the tariff payments to the Independent Power Producers that own the projects, which was pinned at R4.5 billion, leaving a minimum net financial benefit of R0.8 billion.

1 Introduction and Background

South Africa's power system is primarily based on coal-fired power generators. Those produced approx. 205 TWh of electricity in 2014, which was more than 86% of the entire electric energy sent out into the South African grid. Slightly more than 6% was produced by nuclear. Close to 1% of energy sent out came from new renewables (wind and solar), while the remainder of 7% was made up of non-renewable Independent Power Producers (IPPs), Hydro, Pumped Storage and diesel-fired Open-Cycle Gas Turbines (OCGTs).

The South African power system is currently under severe constraints, with power generators meant to be the "barely-ever-used" safety net for the system (the diesel-fired OCGTs) running at > 15% average annual load factor, producing approx. 1.5% of the electric energy sent out into the South African grid.

South Africa faced one controlled load shedding in early March 2014, and several more in late 2014. It is expected that load shedding will prevail for a number of years.

At the same time, the South African Department of Energy is currently running a procurement programme that started in 2011 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) for all 4 000 MW were 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 and solar photovoltaic (PV) projects had been commissioned and are now feeding energy into the grid. Wind made up approx. 600 MW of commissioned capacity by end of 2014, while solar PV stood for approx. 1 000 MW.

In the short run, without considering any medium- to long-term effects on the structure of the conventional fleet from an increasing penetration with renewables, the energy produced from wind and solar power generators can do one out of two things: Either it replaces a conventional generator and therefore saves fuel (coal or diesel), or, if the system is very constrained in the particular hour during which wind or solar produces, it avoids so-called "unserved energy" – which means curtailment of customer load.

This study quantifies these short-term effects. It determines how much fuel costs the first 1 600 MW of wind and PV saved during the year 2014 (by reducing utilisation of diesel-fired OCGTs and of the expensive part of the coal fleet), and how much of "unserved energy" they have avoided that would have been necessary without them.

2 Data Sources

2.1 Power system operational data

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 raw data of the total power supply is split into the following main supply categories:

- Nuclear
- Coal
- Hydro
- Pumped Storage
- Gas Turbines (OCGTs, diesel-fired)
- IPP Purchases (non-renewables)
- Imports (mainly hydro from Cahora Bassa)
- IPP PV
- IPP Wind

For the illustration 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”.

For each of the 8 760 hours of the year 2014, one data point is available in the raw data for each of the supply categories mentioned above.

The raw data is measured in MWh/hr, i.e. a value of 500 for the category Gas Turbines at timestamp 9h00 means that 500 MWh of electricity from diesel-fired OCGTs were produced between 9h00 and 10h00. A value of 22 500 for the category Coal at timestamp 21h00 means that 22.5 GWh of electricity from the coal fleet was produced between 21h00 and 22h00.

Because the time resolution is 1 hour, the values provided in the raw data can also be interpreted as the average power output of the generators in a certain supply category during that hour. For example, a value of 500 for the category Gas Turbines at timestamp 9h00 also means that on average during the hour from 9h00 to 10h00, the Gas Turbines ran at 500 MW net output.

2.2 Inflation Index

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.

Data source: Statistics South Africa
http://beta2.statssa.gov.za/publications/P0141/CPIHistory.pdf

Type of data: Consumer Price Index (CPI), monthly index numbers

2.3 Cost of Fuels

All cost of conventional fuels (coal and diesel) comes from publicly available sources from Eskom, in form of the company's interim integrated report and its interim financials 2014.

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: Total spent on diesel fuel from April 2014 to September 2014
Total spent on coal/nuclear fuel from April 2014 to September 2014

2.4 Cost of Unserved Energy

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 macroeconomic value is taken from the Integrated Resource Plan in its updated version (IRP Update).

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)

2.5 Cost and Procured Capacity of Renewables

The cost of renewables to the power system are measured in terms of the tariffs that the power system (Eskom as the off-taker) pays to the Independent Power Producers per kWh of renewable energy that is fed into the grid.

Data source: South African Department of Energy
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 Independent Power Producers (IPPs) for the different technologies (wind and PV) and different bid windows of the Renewable Energy IPP Procurement Programme (REIPPPP)
Procured capacity per technology and bid window

The average tariffs and capacities for wind and PV as per the Department of Energy's publication are as follows:

Wind	**Bid Window 1**	**Bid Window 2**	**Bid Window 3**
Bid submission date *Financial close date*	*4 November 2011* *5 November 2012*	*5 March 2012* *9 May 2013*	*19 August 2013* *11 December 2014*
Capacity procured	*634 MW*	*562 MW*	*787 MW*
Average tariff (Apr-2011-Rand)	1.14 R/kWh	0.90 R/kWh	0.66 R/kWh
Average tariff (Apr-2013-Rand)	1.28 R/kWh	1.01 R/kWh	0.74 R/kWh
Average tariff (Apr-2014-Rand)[1]	1.36 R/kWh	1.07 R/kWh	0.78 R/kWh

[1] Own calculation; base values inflated as per official Consumer Price Index (CPI) of Statistics South Africa

PV	Bid Window 1	Bid Window 2	Bid Window 3
Bid submission date *Financial close date*	*4 November 2011* *5 November 2012*	*5 March 2012* *9 May 2013*	*19 August 2013* *11 December 2014*
Capacity procured	*632 MW*	*417 MW*	*435 MW*
Average tariff (Apr-2011-Rand)	2.76 R/kWh	1.65 R/kWh	0.88 R/kWh
Average tariff (Apr-2013-Rand)	3.10 R/kWh	1.85 R/kWh	0.99 R/kWh
Average tariff (Apr-2014-Rand)[1]	3.29 R/kWh	1.96 R/kWh	1.05 R/kWh

3 Methodology and Assumptions

3.1 Methodology

Financial benefits of renewables

For each hour of the year, the presence of wind/PV can in principle have one of two effects:

- Wind/PV replace a conventional power generator and therefore save fuel costs
  - 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)

The assumed effect of wind and PV on the operation of the conventional fleet, and subsequent fuel savings and avoided "unserved energy", is defined as follows:

- It is assumed that the only two power generator categories that changed their operating regime due to wind and PV in 2014 are coal and OCGTs (i.e. it is assumed that the operations of all other generators were not affected by wind and PV)
- 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 "day-time" 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 methodology is considered conservative (i.e. underestimates the financial value of renewables), because it assumes that during hours in which the OCGTs were non-operational, renewables only saved coal fuel, and therefore the "taking away" of wind and PV capacity in this hour would not have led to the need to switch on the OCGTs (which means wind and PV would have saved more valuable diesel).

It is furthermore considered conservative because it assumes in-principle full availability of the Pumped Storage and of the OCGTs at any given hour of the year in order to calculate the remaining reserve of these power generators. This is a simplifying assumption that leads to an underestimation of the total amount of unserved energy and is therefore conservative.

The following figure explains in an illustrative manner the CSIR-developed methodology.

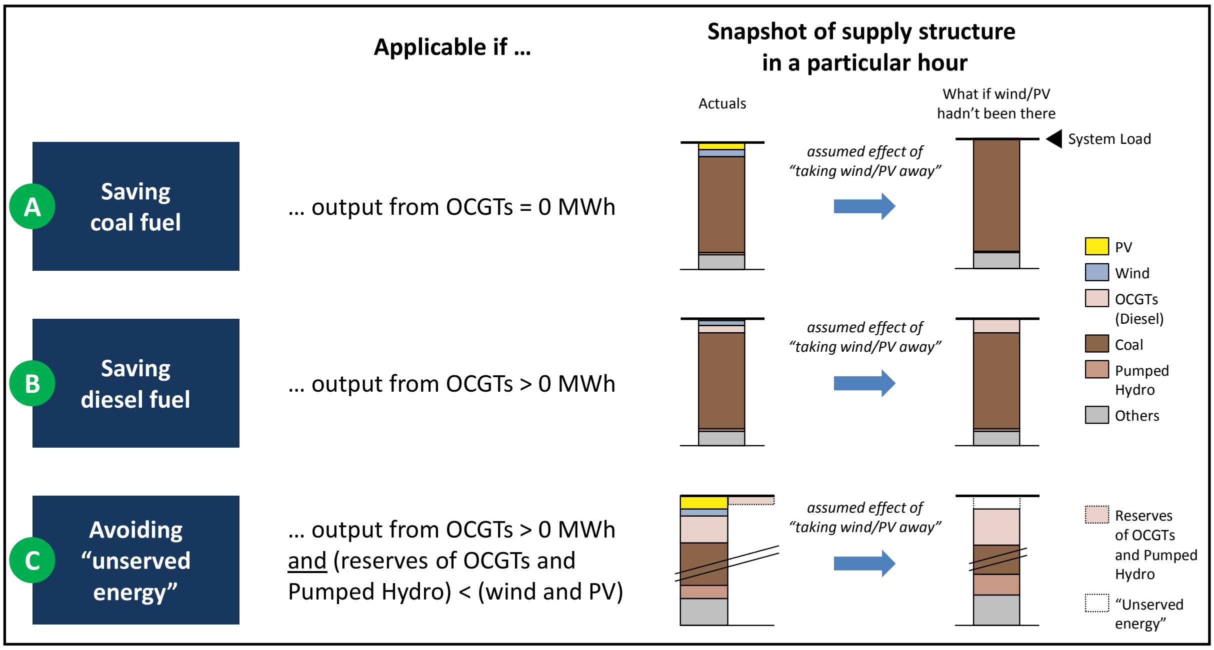

Figure 1: CSIR Methodology to derive the effect of wind and PV onto the conventional fleet

The results for the entire year 2014 (i.e. methodology applied for 8760 hours) are the amount of replaced electricity from coal- and diesel-fired power stations for the wind and for the 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 and with the value of unserved energy give the total financial benefit from renewables in 2014.

Applicability of the methodology

It should be mentioned and highlighted that this methodology is only applicable in the short run to assess the effects of newly introduced renewables capacities on the existing conventional fleet. It is not made to assess effects in the medium- and long-term of renewables on the structure of the conventional new-build fleet! This is important as the pure "fuel-saver" logic as applied in this study is the "worst case" from a renewables perspective and therefore defines the absolute minimum value of renewables that is purely derived from saving conventional fuel.

In the medium- to long-term, renewables have not only fuel-saver value, but must be compared as a new-build scenario in a mix with flexible back-up sources to alternative new-build options.

3.2 Assumptions

Fuel costs of the gas turbines (diesel-fired OCGTs)

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, measured per kWh of electricity produced.

Fuel costs of the coal fleet

Eskom's coal fleet produced 105.6 TWh of electricity from April to September 2014. Its nuclear power station produced 7.0 TWh, i.e. a combined 112.6 TWh. These numbers are derived from the hourly supply data.

For these 112.6 TWh, as per Eskom's interims financial 2014 (page 14), operating costs of R28.415 billion were incurred during the period from April to September 2014. These operating costs are mainly coal, uranium and diesel fuel.

The fuel costs of the OCGTs need to be subtracted from this number. The combined coal/nuclear fleet therefore incurred fuel costs of R28.415 billion minus R3.623 billion = R24.792 billion. On average, this means that the fuel costs of for the average coal/nuclear fleet per kWh of electricity are R24.792 billion/112.6 TWh = 0.22 R/kWh, measured per kWh of electricity produced.

Nuclear fuel costs are generally lower than coal fuel costs. The average fuel costs of the coal fleet alone 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, while the average 0.23 R/kWh are the pure fuel cost for the marginal, most expensive coal-fired power station at night.

Cost of unserved energy

As per the IRP Update (page 68), the cost of unserved energy are 75 R/kWh, measured in January-2012-Rand, which translates into 87 R/kWh in Jul-2014-Rand.

Wind and PV costs

By the end of 2014, approx. 600 MW of wind projects, and another 1 000 MW of PV projects were online and fed energy into the South African power grid. These are assumed values derived from the maxima of the actual hourly power production data for both wind and PV.

It is assumed that the 600 MW of wind projects are the projects from bid window 1, because bid window 1 had a total wind allocation of 634 MW. It is furthermore assumed that the 1 000 MW of PV projects are the projects from both bid window 1 and 2, because bid windows 1 and 2 had a total PV allocation of 1 049 MW.

For the energy from wind projects, the costs in 2014 are therefore the average tariff of bid window 1 (procured at 1.14 R/kWh in Apr-2011-Rand). This tariff is 1.28 R/kWh translated into Apr-2013-Rand, and is applicable for the months from January to March 2014, while the tariff translated into Apr-2014-Rand is applicable for the months from April to December 2014. These are the escalation rules of the REIPPPP.

For the energy from PV projects, the costs in 2014 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 3.10 R/kWh in Apr-2013-Rand, and procured at 1.85 R/kWh in Apr-2013-Rand). This weighted average is is 2.60 R/kWh in Apr-2013-Rand. Similarly to wind, it is applicable for the months from January to March 2014, while the weighted average tariff translated into Apr-2014-Rand is applicable for the months from April to December 2014.

The following table gives an overview of the applicable tariffs for the two technologies wind and PV in the different months of the year 2014.

Applicable tariff in R/kWh	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec 2014
Wind	1.28	1.28	1.28	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
PV[2]	2.60	2.60	2.60	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76

Wind projects produced a total of 1.07 TWh in 2014, while PV projects produced 1.12 TWh in the same year (2.19 TWh of renewable energy). This is broken down into the months of the year in the table below.

Electricity production in GWh	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec 2014
Wind	26	31	43	37	60	104	123	113	104	147	148	130
PV	23	26	44	47	53	66	85	98	131	169	168	213

[2] The assumed applicable PV tariff is the capacity-weighted average for bid window 1 and bid window 2.

Applying the monthly tariffs to the electricity production per month, total payments of R1.44 billion to wind IPPs and R3.08 billion to PV IPPs in 2014 result (i.e. R4.53 billion total payments to wind/PV IPPs).

The production-weighted average costs of the combined wind and PV fleet in 2014 were therefore 2.07 R/kWh of renewable energy, 1.35 R/kWh for the average wind project and 2.75 R/kWh for the average PV project.

4 Results

4.1 Statistics of Actual Production Data in 2014

The figure below shows the breakdown of the South African electricity supply in 2014. 237.1 TWh were sent out into the grid from all power stations in South Africa that are accounted for in Eskom's wholesaler accounting system (i.e. exclusive of self-consumed electricity of embedded customer plants). "Sent out" is measured after subtraction of electricity generated that is used within power stations for auxiliaries (pumps, conveyor belts, etc.). Sent out electricity is therefore in principle available within the South African grid.

Of that, 227.1 TWh were produced by Eskom (incl. electricity from Eskom's Pumped Storage), and 9.9 TWh were produced by Independent Power Producer (both conventional and renewables).

Of the 237.1 TWh, 4.2 TWh were used to pump water in the Pumped Storage power stations of Eskom. 232.9 TWh were therefore "net sent out". These were complemented with 11.4 TWh of imported electricity (mainly from Cahora Bassa), and 13.8 TWh were exported to neighbouring countries (according to Statistics South Africa). Therefore, in 2014 230.4 TWh of electricity were available for distribution in South Africa.[3]

[3] These numbers might differ slightly from those published by Statistics South Africa due to differing raw-data sources. http://beta2.statssa.gov.za/wp-content/uploads/2015/02/Electricity_Dec2014_Infographic.png

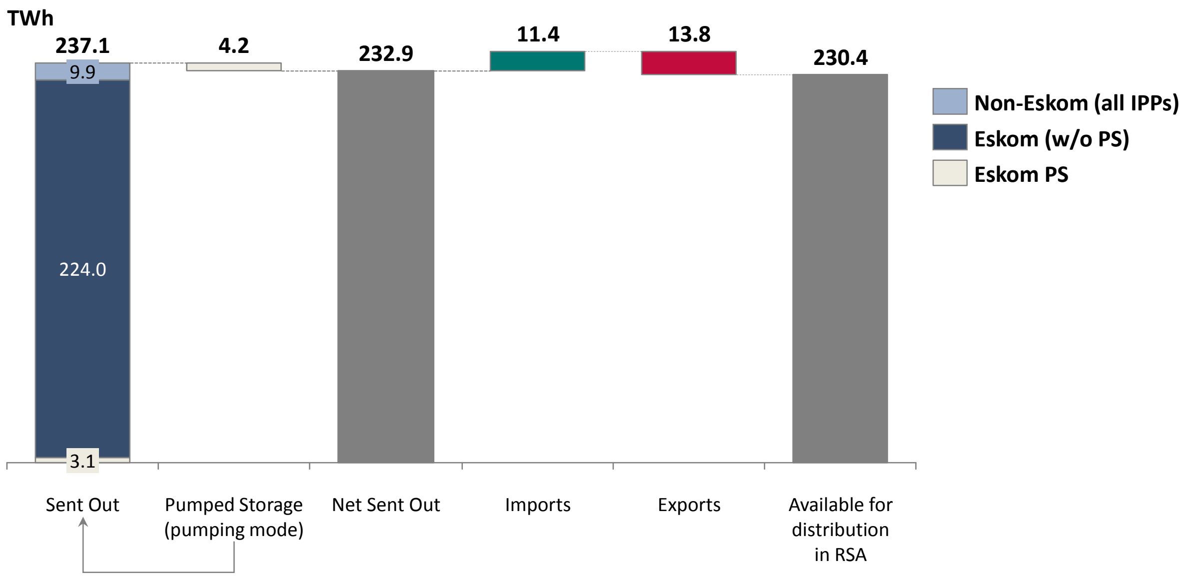

Figure 2: Actual electricity generated in South Africa and exports/imports in 2014

The following figure shows how the 237.1 TWh domestically sent out broke down to the different power generator categories in 2014.

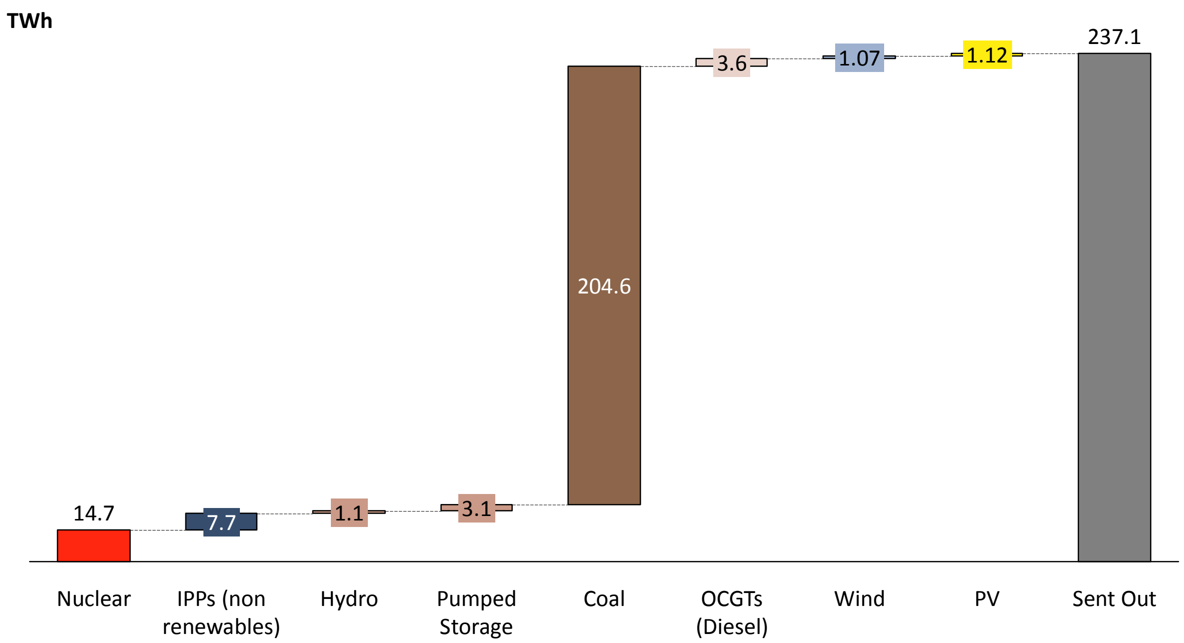

Figure 3: Breakdown of domestic electricity generation to different generator categories in 2014

The following figure shows how the 1.07 TWh from wind projects and the 1.12 TWh from PV projects in 2014 distributed over the 12 months of the year. One can clearly see the ramp-up of capacities and subsequent increasing electricity generated month-on-month from wind and PV.

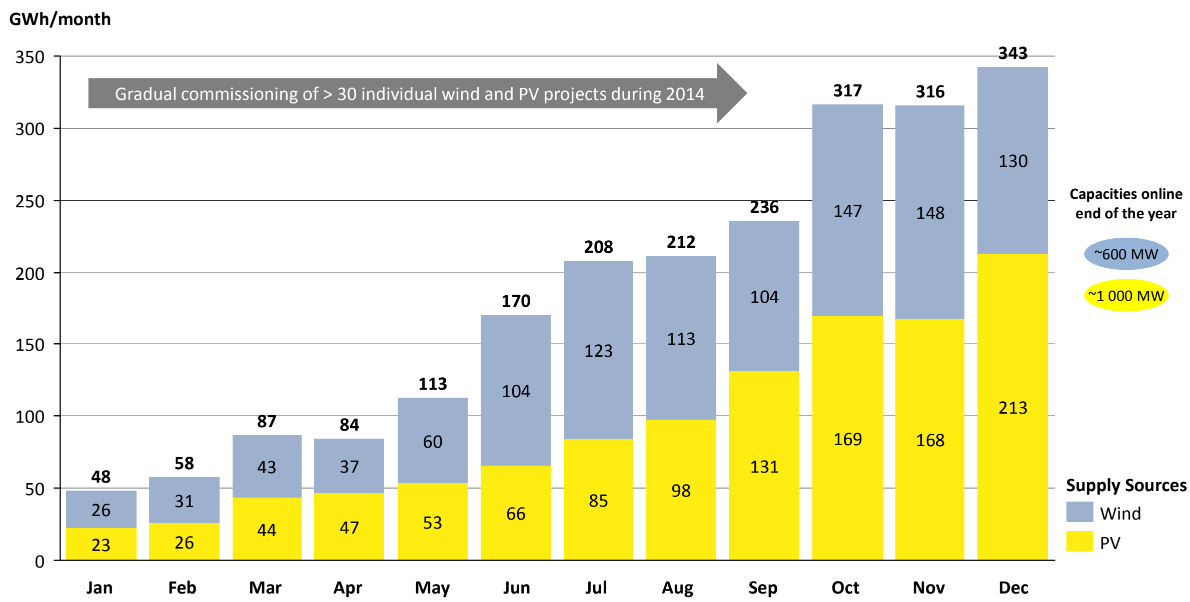

Figure 4: Actual monthly electricity generation from wind and PV in 2014 (ramp up of wind and PV capacities)

The next figure shows the actual monthly average diurnal courses for the power supply structure in South Africa in 2014. Because the hours of a day are averaged for an entire month, one cannot see differences between weekdays and weekends, and one can also not see the effect per day of wind and PV on the conventional fleet. But one can see that on average PV supplied a significant part of the morning peak, and that wind supplied part of the evening peak.

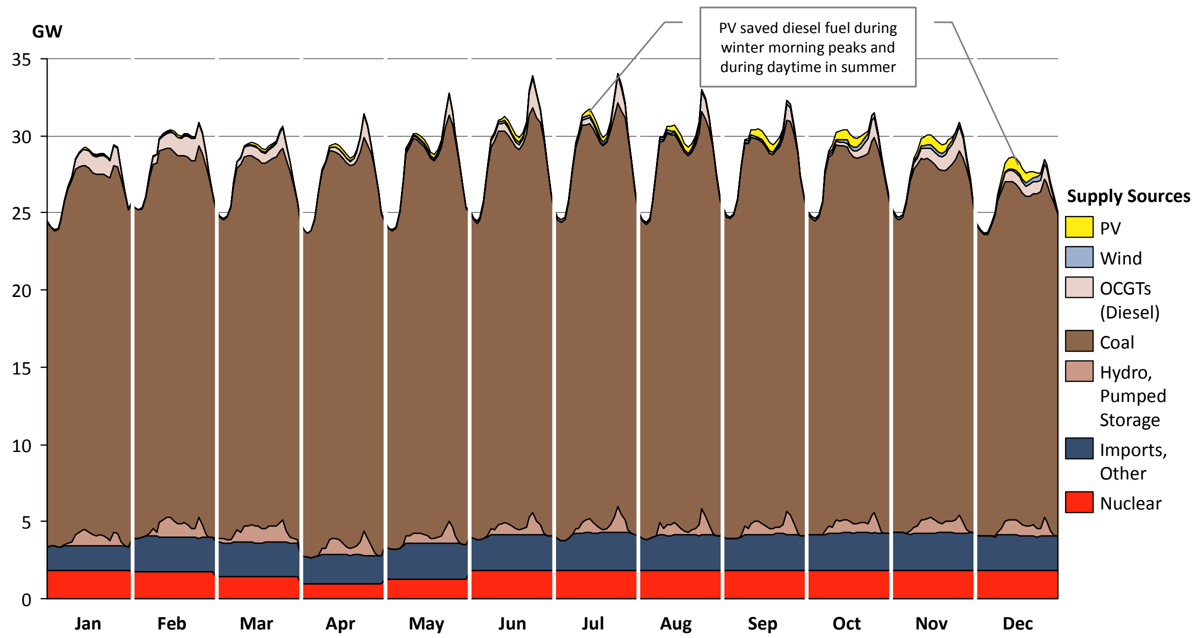

Figure 5: Average monthly diurnal courses of the electricity generation structure in South Africa in 2014

This can be seen even clearer in the following figure, which shows the entire hourly and the average PV and wind supply for the month of December 2014, with the average diurnal system load overlaid on a second axis on top.

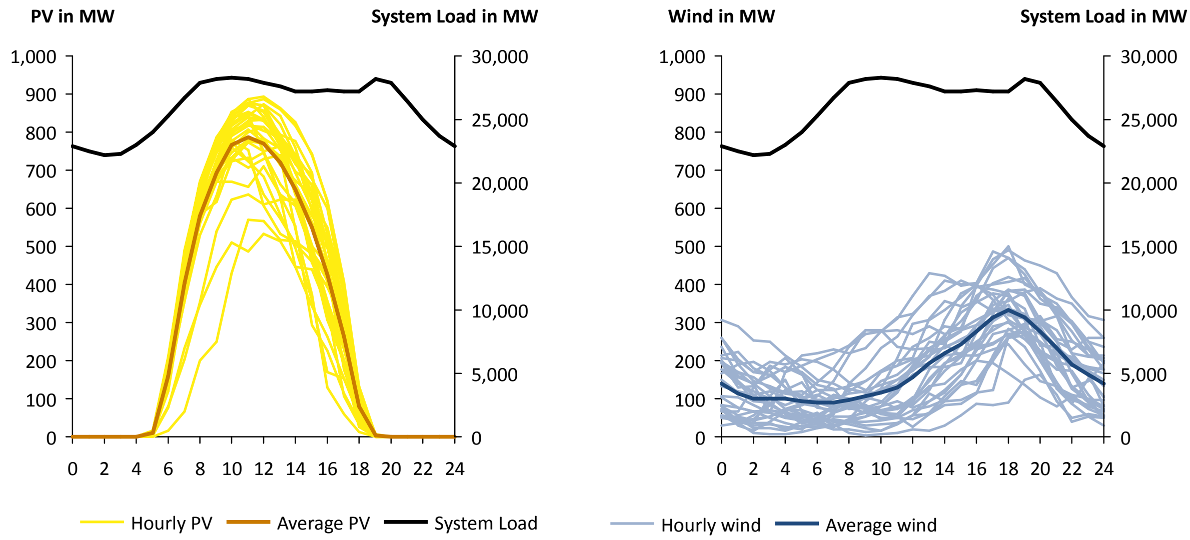

Figure 6: Actual hourly and average wind and PV generation data during the month of December 2014, and average diurnal system load

4.2 Financial Benefits of Wind and PV in 2014

Applying the methodology as described in the previous chapter to all 8 760 hours of the year 2014, the following results are obtained.

in TWh	... of electricity from coal	... of electricity from diesel	... "unserved energy"	**Total**
Electricity from wind replaced/avoided...	0.56 (0.27 / 0.29)[4]	0.49	0.01	**1.07**
Electricity from PV replaced/avoided...	0.56 (0.0 / 0.56)[4]	0.56	0.01	**1.12**
Total	**1.12**	**1.05**[5]	**0.02**	**2.19**

[4] "night-time" coal from 22h00 to 6h00 / "daytime" coal from 6h00 to 22h00

[5] In a previous version of this study, the 0.02 TWh of avoided unserved energy were counted as replaced electricity from diesel, and in the financial evaluation this was made up with a reduced value of unserved energy to avoid double-counting. The methodology was now slightly adjusted to reflect better the fact that OCGTs are not able at certain times to meet the electricity demand anymore, and all three accounts "coal", "diesel" and "unserved energy" are now accounted for individually.

Wind projects generated 1.07 TWh of electricity in 2014, which replaced 0.56 TWh of electricity from coal, 0.49 TWh of electricity from diesel and it avoided 9 GWh (0.01 TWh) of so-called "unserved energy". PV projects generated 1.12 TWh of electricity in 2014, which replaced also 0.56 TWh of electricity from coal, 0.56 TWh of electricity from diesel and it avoided 10 GWh of unserved energy.

The value per category of derived benefits from renewables is summarised in the table below.

	Replaced electricity from "night-time" coal	Replaced electricity from "day-time" coal	Replaced electricity from diesel	Avoided unserved energy
Value in R/kWh	0.23	0.35	3.11	87

The resulting value of replaced electricity from conventional coal- and diesel-fired power stations and the value of the avoided unserved energy is summarised in the table below.

in million Rand	… of cash spent on coal	… of cash spent on diesel	**Subtotal** *(fuel savings)*	Value of avoiding "unserved energy"	**Total**
Electricity from wind saved...	165 (63 / 102)[6]	1 541	**1 705**	794	**2 499**
Electricity from PV saved...	194 (0 / 194)[6]	1 736	**1 930**	876	**2 806**
Total	**359**	**3 276**	**3 635**[7]	**1 670**[7]	**5 305**

[6] "night-time" coal from 22h00 to 6h00 / "daytime" coal from 6h00 to 22h00

[7] In a previous version of this study, R60 millions of value from avoided unserved energy were counted as diesel savings. The methodology was now slightly adjusted, leaving the total financial benefits however unchanged.

The value of wind and PV projects per energy unit produced is shown in the table below.

	Value per energy unit from fuel savings	Economic value per energy unit from avoided unserved energy	Total value per renewables energy unit
Wind	1.60 R/kWh	0.74 R/kWh	2.34 R/kWh
PV	1.72 R/kWh	0.78 R/kWh	2.50 R/kWh
Average	**1.66 R/kWh**	**0.76 R/kWh**	**2.42 R/kWh**

4.3 Costs of Wind and PV in 2014

The tariff payments to Independent Power Producers are estimates as per the methodology and assumptions described in previous chapters.

Wind and PV projects in 2014 produced 2.19 TWh of electricity, which cost on average 2.07 R/kWh in tariff payments to the Independent Power Producers. That made a total of R4.53 billion in tariff payments to the IPPs. The detailed breakdown of these payments is shown in the table below.

	Total tariff payments to IPPs in 2014	Average tariff paid to IPPs
Wind	R1 444 million	1.35 R/kWh
PV	R3 084 million	2.75 R/kWh
Total / Average	**R4 529 million**	**2.07 R/kWh**

4.4 Statistics of Avoided Unserved Energy in 2014

During 117 hours in the year 2014 did the amount of electricity supplied by wind and PV exceed the remaining combined reserves of Pumped Storage and the diesel-fired OCGTs. As per the methodology, it was assumed that during these hours unserved energy was avoided due to the presence of wind and PV.

These 117 hours of avoided unserved energy were distributed over 48 days in 2014. Statistics about how much unserved energy was avoided during these 48 days is shown in the table below.

Category	**Number of days**	**Amount of unserved energy avoided**	**Number of hours with avoided unserved energy**
>= 1 000 MWh per day	*9 December 2014*	*3 059 MWh*	*10 hours*
	16 December 2014	*2 062 MWh*	*4 hours*
	11 November 2014	*1 399 MWh*	*8 hours*
	6 June 2014	*1 169 MWh*	*4 hours*
	8 December 2014	*1 158 MWh*	*7 hours*
	2 December 2014	*1 062 MWh*	*8 hours*
	3 December 2014	*1 000 MWh*	*6 hours*
	7 days	**10 908 MWh**	**47 hours**
>= 500 MWh and < 1 000 MWh per day	*30 October 2014*	*932 MWh*	*5 hours*
	10 November 2014	*929 MWh*	*4 hours*
	4 November 2014	*802 MWh*	*5 hours*
	29 October 2014	*704 MWh*	*3 hours*
	28 November 2014	*658 MWh*	*3 hours*
	5 days	**4 024 MWh**	**20 hours**
>= 100 MWh and < 500 MWh per day	**17 days**	**3 512 MWh**	**30 hours**
< 100 MWh per day	**19 days**	**724 MWh**	**20 hours**
TOTAL	**48 days**	**19 168 MWh**	**117 hours**

Therefore, most of the unserved energy was avoided during a relatively small number of days. During 12 days in 2014 (the ones explicitly mentioned in the table above), close to 15 GWh of unserved energy was avoided – which is almost 80% of the total avoided unserved energy in 2014.

The figure below shows the relationship between cumulative avoided unserved energy and the number of days during which unserved energy was avoided.

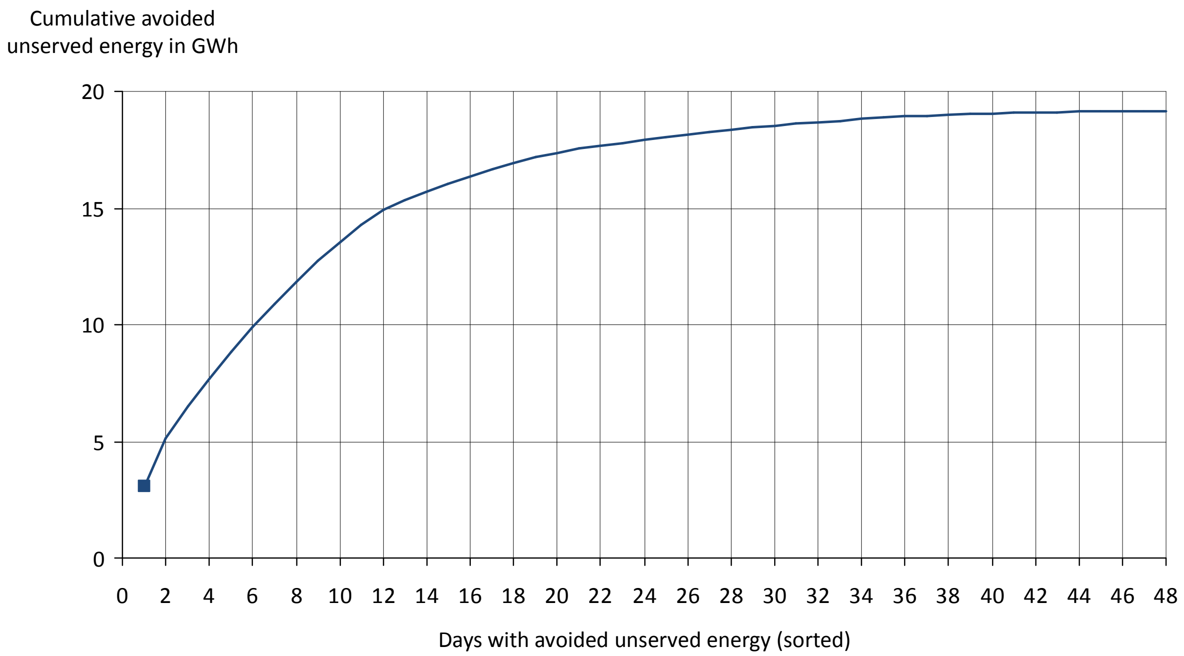

Figure 7: Cumulative avoided "unservered energy" for 48 days in 2014

The figure below shows for the 12 days that made up almost 80% of the entire avoided unserved energy in 2014 the distributed of that avoided unserved energy over the course of the day. All hourly values are in MWh, and the column to the right indicates the total avoided unserved energy for that day.

	Hour of the day -->																								Total
Date	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MWh
09/12/2014	0	0	0	0	0	0	0	0	0	0	201	413	415	210	68	468	620	376	166	122	0	0	0	0	3 059
16/12/2014	0	0	0	0	0	0	0	0	0	345	575	629	514	0	0	0	0	0	0	0	0	0	0	0	2 062
11/11/2014	0	0	0	0	0	0	0	0	0	0	0	81	443	13	106	313	278	0	122	44	0	0	0	0	1 399
06/06/2014	0	0	0	0	0	0	0	0	0	146	395	367	260	0	0	0	0	0	0	0	0	0	0	0	1 169
08/12/2014	0	0	0	0	0	0	0	45	258	306	10	175	0	0	0	191	175	0	0	0	0	0	0	0	1 158
02/12/2014	0	0	0	0	0	0	0	0	0	0	0	83	252	97	90	224	150	79	0	86	0	0	0	0	1 062
03/12/2014	0	0	0	0	0	0	0	0	0	0	102	229	236	182	104	146	0	0	0	0	0	0	0	0	1 000
30/10/2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	430	380	40	74	0	0	0	0	0	932
10/11/2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	203	250	255	221	0	0	0	0	929
04/11/2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	238	169	108	177	0	0	0	0	802
29/10/2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	221	318	165	0	0	0	0	0	0	704
28/11/2014	0	0	0	0	0	0	0	0	0	106	246	307	0	0	0	0	0	0	0	0	0	0	0	0	658

Figure 8: Hourly pattern of avoided unserved energy of the 12 days in 2014 with the most avoided unserved energy

5 Conclusions

5.1 Summary of Cost-Benefit Analysis

The net benefits (financial benefits minus costs) of the first wind and PV projects in South Africa in 2014 are pinned at approx. R0.8 billion. The total fuel savings are R3.64 billion, the economic value of having avoided 19.2 GWh of unserved energy is R1.67 billion, which makes a total financial benefit to the country of R5.31 billion in 2014.

That is against tariff payments to the wind and PV Independent Power Producers of R4.53 billion in 2014. That leaves a net financial benefit of R780 million.

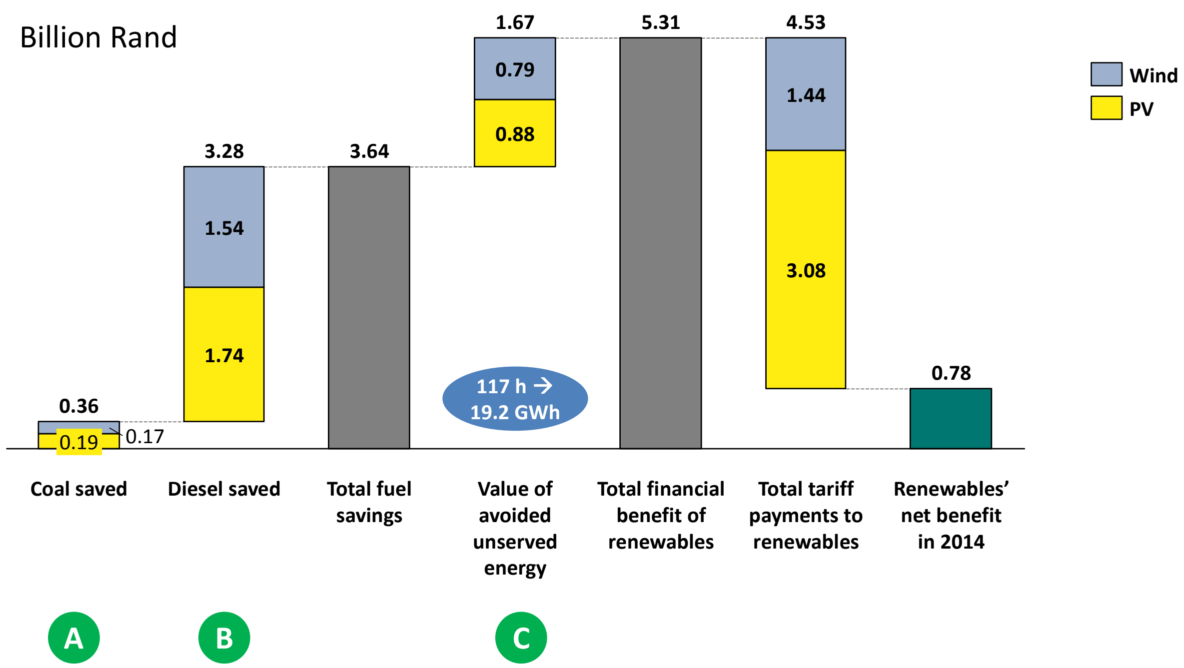

Figure 9: Financial costs and benefits of wind and PV in South Africa in 2014

5.2 Next Steps

The wind and PV projects that came online during the year 2014 were those of bid window 1 for wind and those of bid windows 1 and 2 for PV. The current average tariff for new wind and PV projects (0.74 R/kWh in April-2013-Rand for wind and below 1 R/kWh for PV) lies significantly below that of these first projects. Wind projects saw a reduction in cost of more than 40% from bid window 1 to bid window 3, while PV projects' costs reduced by almost 70%. This is illustrated in the figure below.

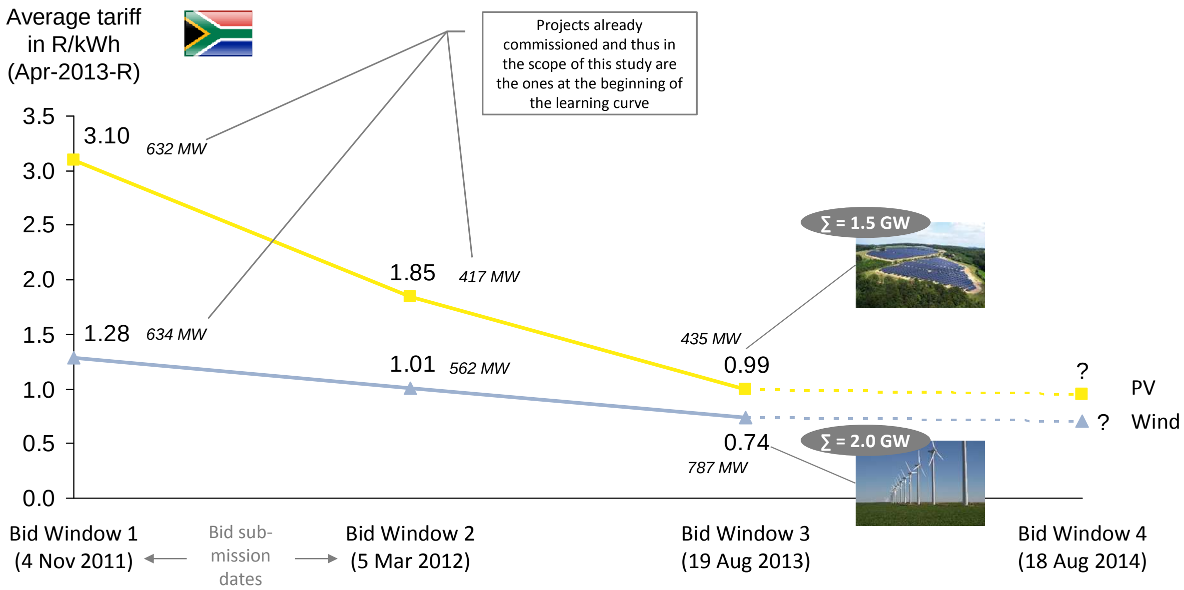

Figure 10: Results (average tariffs and allocated capacities) of the first three bid windows of the South African Department of Energy's Renewable Energy Independent Power Producer Procurement Programme

Going forward, two effects will therefore have to be considered on the pure fuel-saver logic:

- Any additional wind and PV project will on average save less fuel costs than the first projects, because with every additional MW from wind and PV the amount of saved cheap coal will go up while the amount of saved expensive diesel will eventually stay constant. That reduces gradually the value of each renewable kWh from a pure fuel-saver logic.
- On the other hand, any <u>new</u> MW from wind and PV that comes online will generate electricity at significantly lower average tariffs than the first projects that came online during 2014 and therefore were in the scope of this study.

In a second phase, the CSIR Energy Centre will therefore develop a methodology to predict the expected fuel savings for new renewables capacities in a 12-24 months forward-looking time horizon.

In the medium- to long-term, the pure fuel-saver logic falls flat, because renewables in a mix with flexible power generators need to be compared with alternative <u>new-build options</u>.

With more and more wind and PV projects coming online, the shape of the residual load (system load minus wind supply minus PV supply) changes and therefore the requirements on the conventional new-build fleet also. The benefit of this is that these flexible power generators (e.g. gas-fired engines, open-cycle gas turbines, or combined-cycle gas turbines) that need to be newly built are generally cheaper per installed capacity (R/kW) than less flexible power generators (e.g. coal-fired steam turbines).

The medium- to long-term financial benefit of renewables is therefore much more than just savings of fuel. Renewables allow a cheaper conventional fleet (per installed capacity) to be built.

In a third phase, the CSIR Energy Centre will therefore develop a methodology to assess the medium- to long-term effects of a higher renewables penetration on the structure of the conventional fleet and therefore on the cost requirements for the conventional new-build fleet.