Response to questions around the CSIR methodology to quantify the fuel-saver effect of new power generators in the South African power system

11 January 2017

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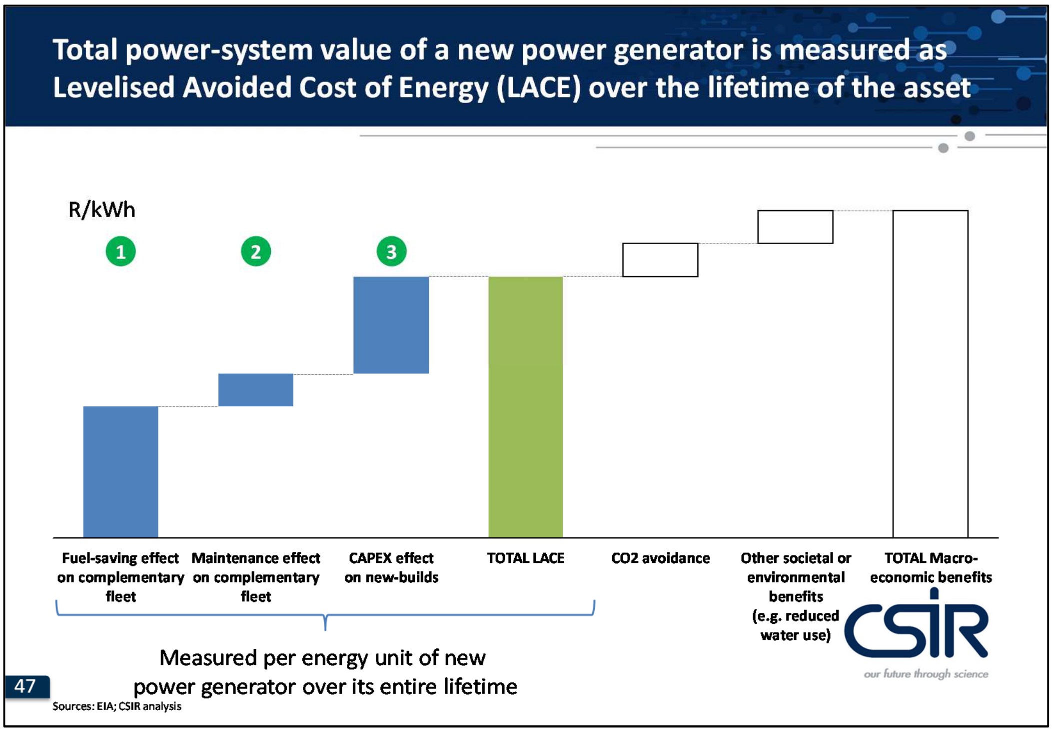
This document serves as a response to a media statement issued by Eskom on 10 January 2017, which makes reference to a methodology that was developed by the CSIR in 2015 to assess the fuel-saving effect of a new power generator in a constrained power system.

http://www.eskom.co.za/news/Pages/Jann9.aspx; https://www.csir.co.za/csir-energy-centre

Value of a new power generator

Introducing a new power generator into the power system has following effects over the lifetime of the new power generator:

1) The energy produced by the new power generator reduces the burning of fuel by the complementary fleet of power generators in the power system (today in RSA: This is mostly coal with some diesel. In future, this could be gas or other fuels that are saved).
2) The operation of the new power generator can increase or reduce the operating and maintenance costs of the complementary fleet of power generators in the power system.
3) The operation of the new power generator can increase or reduce the capital cost of building new power generators when existing power generators are decommissioned, there is additional demand or a combination of the two.



Items 1) and 2) have immediate cash effects on the existing fleet of power generators, and they affect the fuel and maintenance cost of this existing fleet and new power generators that are built over the lifetime of the new power generator investment. Item 3) is a long-term effect that stems from the change in required structure of complementary new power generators to meet expected demand when a single new power generator investment is introduced. This general logic is aligned with a number of publications that are often referenced in this discussion:

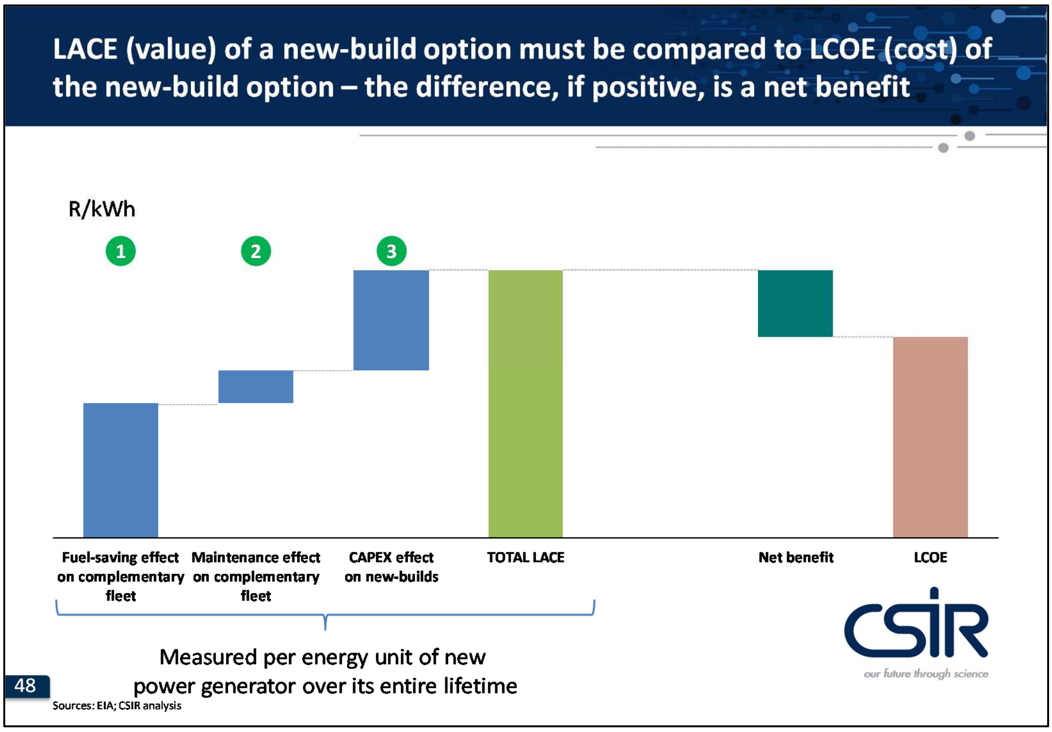
[1] Agora Energiewende, The Integration Costs of Wind and Solar Power, 2015, Available Online: https://www.agora-energiewende.de/fileadmin/Projekte/2014/integrationskosten-wind-pv/Agora_Integration_Cost_Wind_PV_web.pdf

[2] International Energy Agency (IEA), Next Generation Wind and Solar Power, 2016, Available Online: https://www.iea.org/publications/freepublications/publication/Next_Generation_Windand_Solar_PowerFrom_Cost_to_ValueFull_Report.pdf

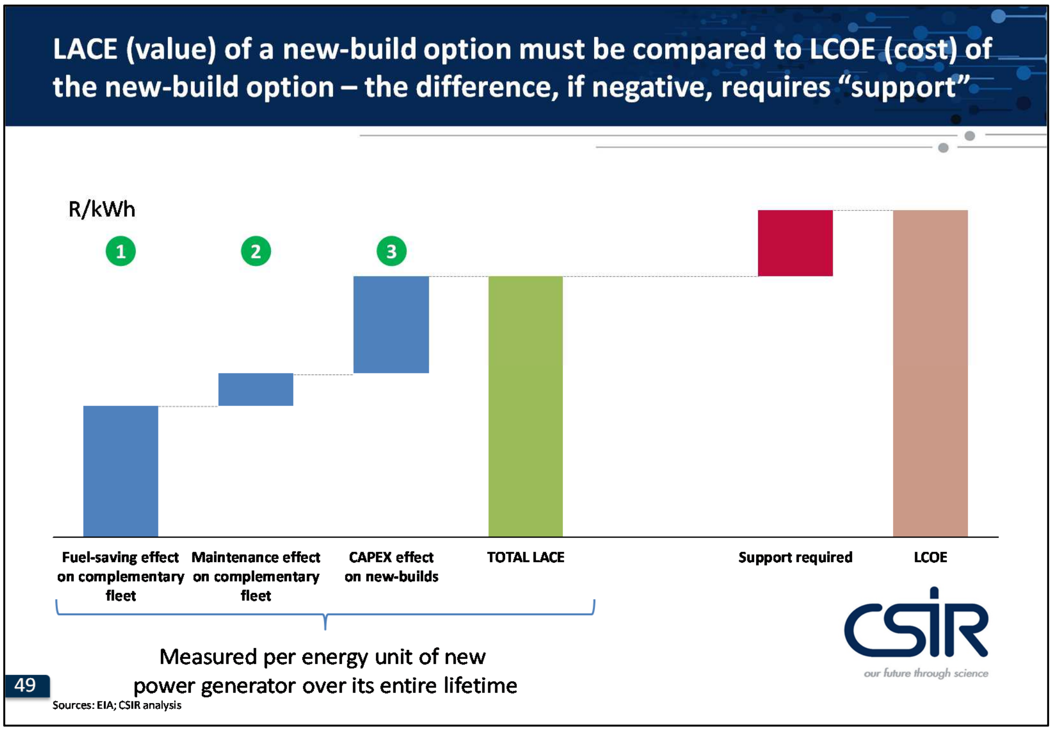
[3] U.S. Energy Information Agency (EIA), Levelized Cost of Electricity and Levelized Avoided Cost of Electricity Methodology Supplement, Technical Report, 2013,Available Online: http://www.eia.gov/renewable/workshop/gencosts/pdf/methodology_supplement.pdf

The U.S. Energy Information Administration (EIA) calls the lifetime value of a new power generator per energy unit "Levelised Avoided Cost of Energy (LACE)". The total lifetime cost of a new power generator is expressed as "Levelised Cost of Energy (LCOE)".

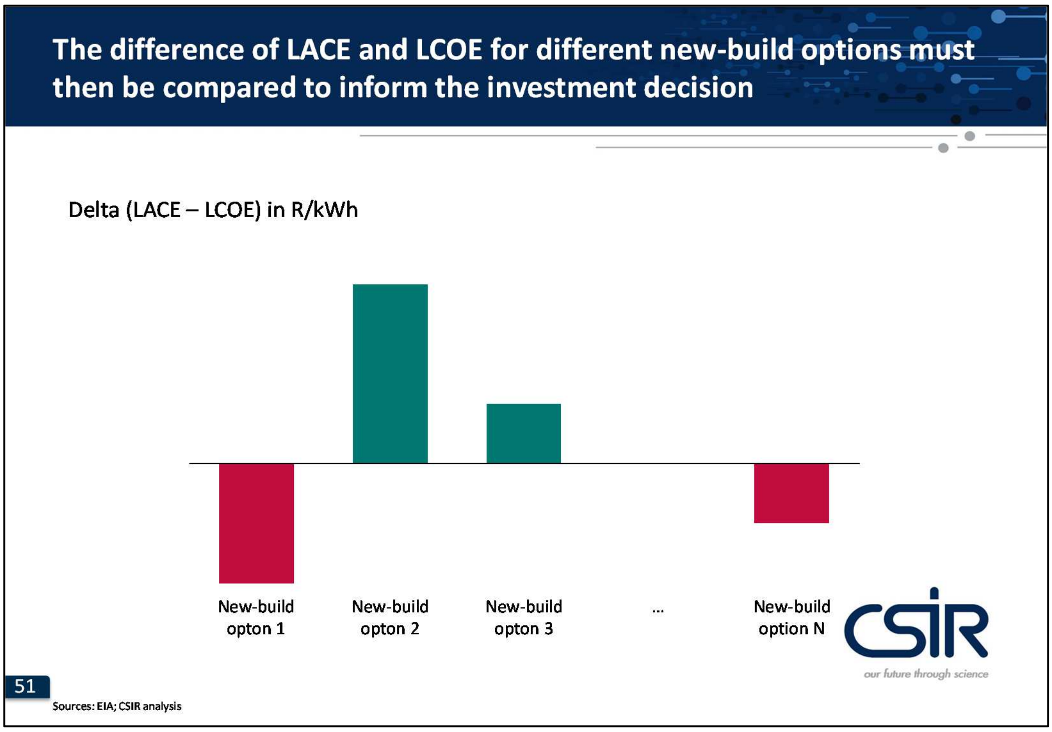
If the lifetime value (measured as LACE in R/kWh) of a new power generator is greater than its lifetime cost (measured as LCOE in R/kWh), then the new power generator can finance itself from within the power system (tariffs will stay constant or can even decrease).



If the lifetime value (measured as LACE in R/kWh) of a new power generator is lower than its lifetime cost (measured as LCOE in R/kWh), then the new power generator cannot finance itself from within the power system at current tariffs and needs support (through tariff increases or from outside the power system in the form of tax-based subsidies).



The difference between LACE and LCOE for different new-build options must then be compared in order to make a decision which new power generator to build.



It is worth noting that introducing any new power generator into an existing power system that has very low existing operating costs (which can be the case for historic reasons, if the system is based on fully depreciated, old plant that is cheap to operate, like coal or hydro) will require support, i.e. increasing electricity tariffs. That is because a new power generator simply cannot compete with an existing, fully depreciated fleet that carries basically only fuel cost. This is true for any new power generator introduced into such a system, whether it is coal, renewables, nuclear or something else.

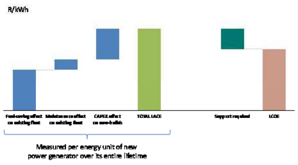
For example, the LCOE of Medupi and Kusile are between 1.05 R/kWh and 1.17 R/kWh, the tariff for the recently procured baseload coal IPP project is 1.03 R/kWh. All of these numbers are higher than the pure fuel cost of the existing Eskom fleet. The fuel saving value will therefore be lower than the LCOE, and very likely for that exact reason the full LACE will also be lower than LCOE. As a consequence, electricity tariffs have to increase. The question is which new-build decision lets the electricity tariffs increase the least.

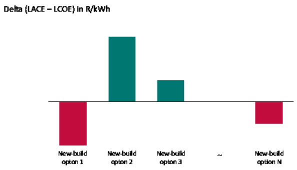
The logic is the same as to why a new car purchase cannot compete with the pure fuel cost of an old car. If a new power generator needs to be built regardless, either because demand increases or because existing plants are due to be decommissioned, i.e. supply decreases, then the fact that LACE is lower than LCOE is irrelevant. A new power generator has to be built. The power generator for which the difference between LACE and LCOE is least negative needs to be built in such a case.

In South Africa, fortunately, complicated LACE vs. LCOE considerations to assess individual investment decisions do not need to be made, because the country has embarked on an Integrated Resource Plan (IRP) approach to determine which and how many new power generators are cost optimal. An IRP optimises the entire new-build portfolio in one shot, as opposed to LACE vs. LCOE which assesses one individual investment decision and its effects on the power system over its lifetime.

Remember: all this (LACE vs. LCOE) is implicitly done in a proper IRP

LACE/LCOE concept to assess an <u>individual</u> investment decision





IRP to optimise the entire <u>portfolio</u> of new-build options "in one shot"

Integrated Resource Plan

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Sources: EIA; CSIR analysis

CSIR Fuel-Saving Methodology

Scope of the methodology

Effect 1) is relatively easy to quantify if the appropriate hourly production data is available on aggregated level (i.e. per fuel type). Effect 2) is more difficult to quantify, because the rescheduling of the existing fleet in a world with vs. a world without the new power generator must be assessed. Generally effect 2) is relatively small though. Effect 3) is the most difficult to quantify because it requires a prediction over the entire lifetime of the new power generator in terms of its effect on the type of new power generators that need to be built.

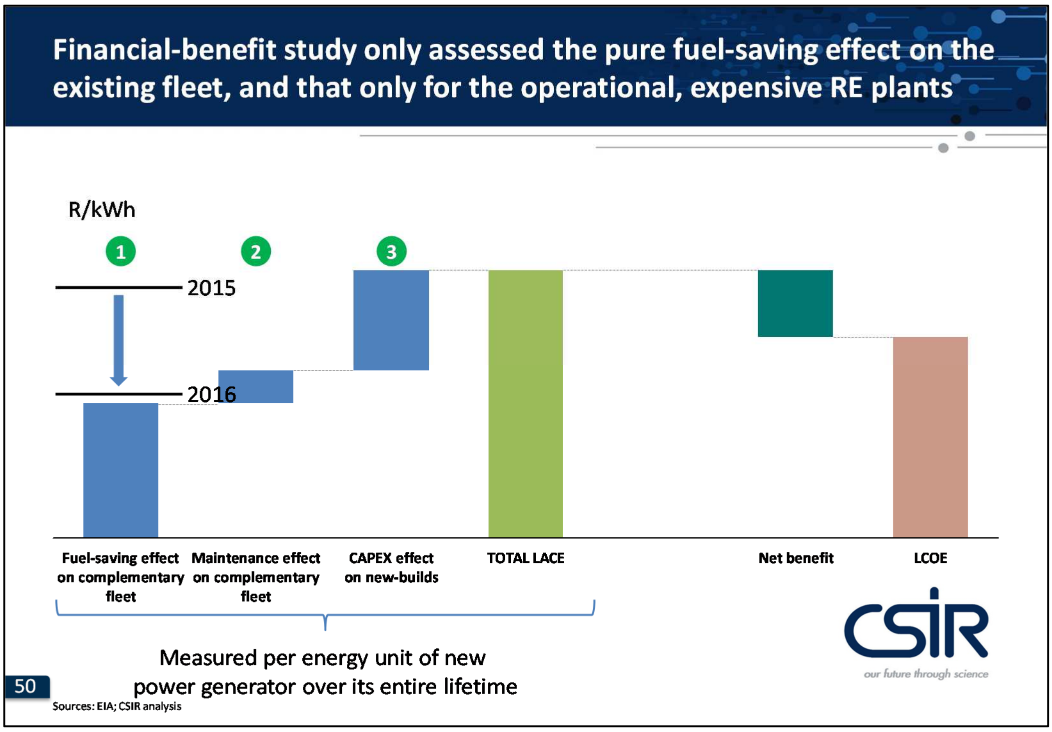
The CSIR methodology quantified only effect 1). In doing so, the absolute minimum and undisputable value of the new power generator (solar PV and wind in this case) was calculated. This was clearly stated in the initial report:

"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."

-- CSIR, Financial Costs and Benefits of Renewables in South Africa in 2014, page 4, 10 February 2015[1]

[1] https://www.csir.co.za/sites/default/files/Documents/Financial%20benefits%20of%20Wind%20and%20PV%20in%202014-%20CSIR%20-%2010Feb2015_FINAL%20-%20report.pdf



Applicability of the methodology in a less constrained power system

In addition, the CSIR methodology furthermore only reliably calculates fuel-saving values in a constrained power system. This is because it is conducted as an outside-in analysis without knowledge about the remaining reserve capacity of the existing coal fleet within a certain hour. The methodology therefore assumes that whenever the Eskom diesel turbines are not operational, renewables saved coal and only coal. However, in a less constrained system, during many hours the diesel turbines will not be operational, but the renewables actually prevented them from being switched on in the first place, i.e. the use of diesel turbines was avoided. This is not measured by the CSIR methodology – hence it underestimates the diesel savings.

This is acceptable in a constrained power system situation (like 2015), because the number of hours without diesel usage is small, but in a less constrained power system (like 2016), the methodology must be expanded to measure the effect of diesel turbines not being switched on because of renewables.

Type of renewable power generators that were assessed by the methodology

Finally and most importantly, the operational renewable power generators in South Africa are those of Bid Windows (BW) 1 and 2 for solar PV and wind (and some BW 3 projects that became operational recently). BW 1 and 2 for solar PV and wind are by far the most expensive BWs that South Africa will ever see for these type of power generators.

This directly results in a high average tariff paid to solar PV and wind in 2016 of 2.03 R/kWh (as per Eskom's media statement of 10 January 2017: R12.2 billion / 6.0 TWh = 2.03 R/kWh). The weighted average tariff for new solar PV and wind in BW4 and BW4 Additional is roughly 0.80 R/kWh or 60% less. The weighted average tariff for new solar PV and wind in BW4 Expedited is 0.62 R/kWh or 70%

less (all in April-2016-Rand). This is summarised in the table below and based on information from the Department of Energy.[2]

In summary: Results of the Department of Energy's IPP Procurement Programme

All tariffs in R/kWh	Base Month / Year	REIPPPP BW 1	REIPPPP BW 2	REIPPPP BW 3	REIPPPP BW 4	REIPPPP BW 4 additional	Coal IPP BW 1	REIPPPP BW 4 expedited
Bid submission		*4 Nov 2011*	*5 Mar 2012*	*19 Aug 2013*	*18 Aug 2014*	*18 Aug 2014*	*2 Nov 2015*	*11 Nov 2015*
Financial close		*5 Nov 2012*	*9 Mar 2013*	*11 Dec 2014*				
Solar PV		632 MW	417 MW	435 MW	415 MW	398 MW		520 MW
	April 2014	3.29	1.96	1.05	0.79	0.85		0.56
	April 2015	3.44	2.05	1.10	0.82	0.89		0.58
	April 2016	3.65	2.18	1.17	0.87	0.95		0.62
Wind		634 MW	563 MW	787 MW	676 MW	686 MW		650 MW
	April 2014	1.36	1.07	0.78	0.62	0.72		0.56
	April 2015	1.42	1.12	0.82	0.65	0.75		0.58
	April 2016	1.51	1.19	0.87	0.69	0.80		0.62
Coal							863 MW	
	April 2014						0.93	
	April 2015						0.97	
	April 2016						1.03	

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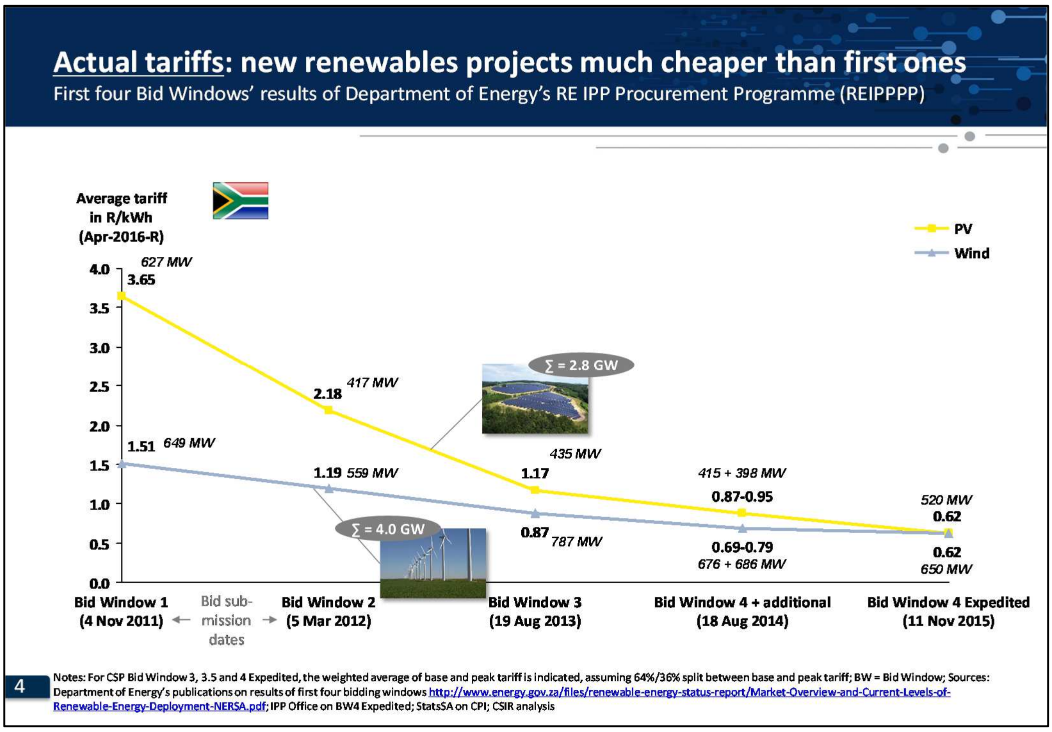
Sources: South African Department of Energy IPP Office; StatsSA for CPI (http://beta2.statssa.gov.za/publications/P0141/CPIHistory.pdf); CSIR analysis



[2] http://www.energy.gov.za/files/renewable-energy-status-report/Market-Overview-and-Current-Levels-of-Renewable-Energy-Deployment-NERSA.pdf

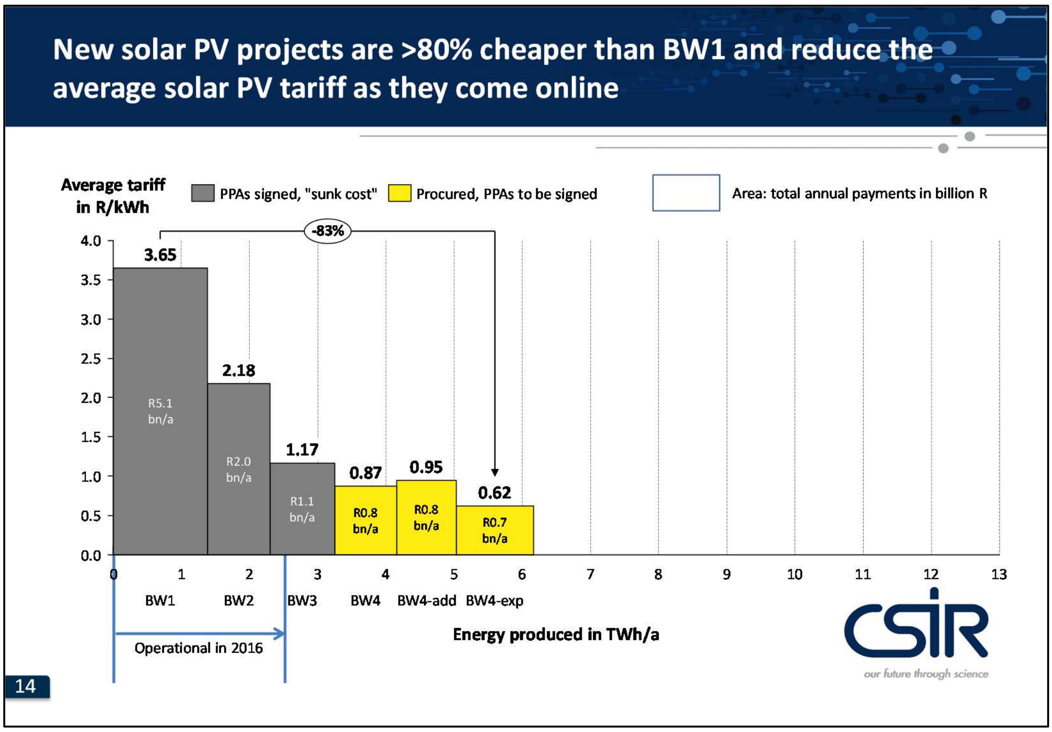
Sunk cost of operational power generators vs. new investment decisions

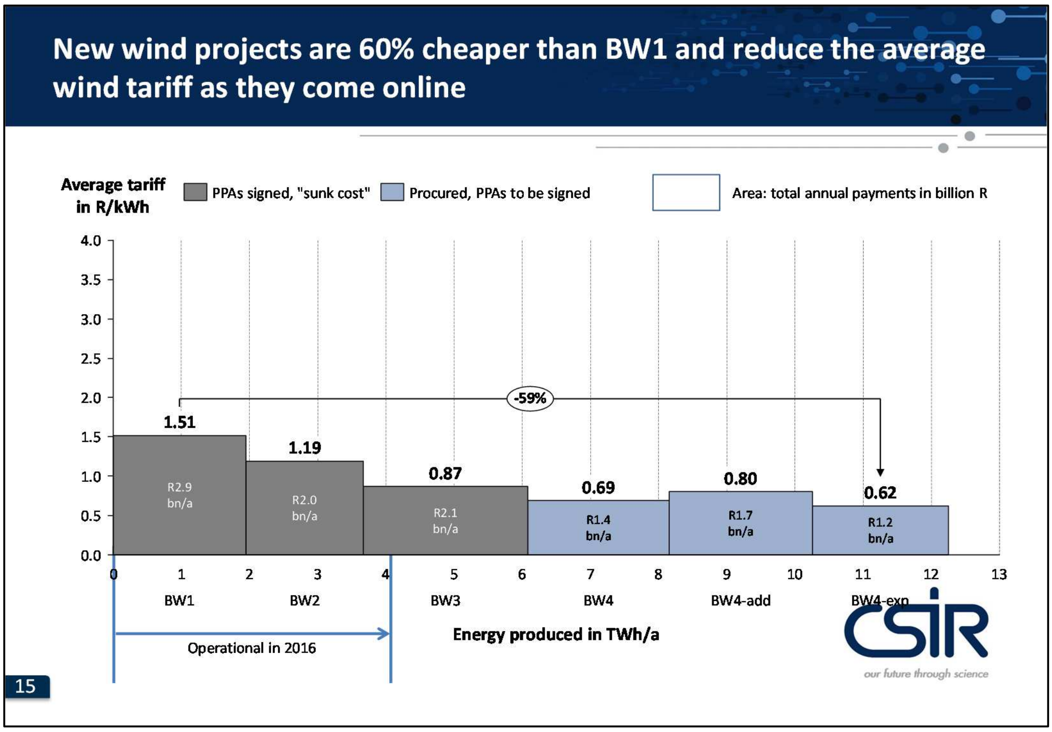
The Power Purchase Agreements (PPAs) for BWs 1, 2 and 3 are signed by both parties, an Independent Power Producer (IPP) on the one side (as the seller) and Eskom's Single Buyer Office (SBO) on the other (as the off-taker). These contracts have a 20-year lifetime, and although these tariffs are high, they need to be treated as "sunk costs" and are essentially the school fees that had to be paid in order to achieve the very low solar PV and wind tariffs of BW4 forward.

Clearly the decision on whether or not new solar PV or wind (or any other power generator for that matter) should be implemented must not be taken on the basis of sunk cost, but on the basis of a comparative analysis of different new-build options (which is what an IRP does).

While the operational solar PV and wind projects (of BWs 1 and 2) triggered tariff payments of roughly R12 billion in 2016 and produced roughly 6 TWh in the same year, the entire BW4 solar PV and wind projects (BW4, BW4 Additional and BW4 Expedited) will trigger tariff payments of merely R6.6 billion per year while they will produce more than 9 TWh/yr. That means 45% less annual payments for 50% more energy compared to the currently operational solar PV and wind projects. These new projects will therefore be almost cost neutral from a pure fuel-saving perspective (i.e. the entire cost of the new car is similar to the cost of the fuel only for the existing car).

Of the R12 billion in 2016, almost 43% of that (R5.1 billion) was paid for solar PV projects of BW1 alone. These projects produced only 1.4 TWh in 2016, which is 23% of the total 6 TWh. This aspect in itself shows how distorted the current total cost of solar PV and wind are by the very first (expensive) projects. These expensive projects of the first BWs are not representative of the latest procured projects of BW4 and their costing must not inform new investment decisions.




New wind projects are 60% cheaper than BW1 and reduce the average wind tariff as they come online
Average tariff in R/kWh
PPAs signed, "sunk cost"
Procured, PPAs to be signed
Area: total annual payments in billion R
-59%
1.51
1.19
0.87
0.69
0.80
0.62
R2.9 bn/a
R2.0 bn/a
R2.1 bn/a
R1.4 bn/a
R1.7 bn/a
R1.2 bn/a
BW1
BW2
BW3
BW4
BW4-add
BW4-exp
Energy produced in TWh/a
Operational in 2016
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Summary on the applicability of the CSIR fuel-saver methodology and the meaning of the results

1. **CSIR's fuel-saver methodology measures only short-term effects**
   The methodology developed by the CSIR measures only the immediate fuel saving effect on the existing fleet and not the long-term effects on new investments that an IRP will measure. Methodologically it therefore always grossly underestimates the lifetime value of a new power generator.

2. **Even these short-term effects are measured incorrectly if the methodology is applied without adjustments**
   The methodology was developed to be applicable during a time of a constrained power system with high diesel turbine usage and load shedding. When the power system is less constrained and diesel turbines are not operational most of the time, the methodology underestimates the diesel fuel savings. Thus, it needs to be adjusted to give the correct fuel-saving value.

3. **In 2016 only the most expensive solar PV and wind projects were operational**
   Only BW1 and BW2 projects of solar PV and wind were operational in 2016 (and a few BW3 projects for a few months). These are by far the most expensive projects – and they will be for the next 18 years (the residual time period of the 20-year PPAs).
   - South Africa effectively got a "discount" on these expensive projects for the first 2-3 years when the power system was (and partially still is) constrained. This discount stems from both avoided load shedding and from diesel fuel savings.
   - Both effects were not anticipated when the decision was made to implement these expensive projects. South Africa essentially made an investment decision into new power generator technologies, knowing that those of the first rounds are expensive and school fees were being paid in the first few BWs. Because of the coinciding constrained nature of the power system during the time when these power generators came online and worked as an "emergency supplement", the country received a "discount" on the cost of them for the first few years.

4. **The true value of the expensive first BWs lies in the cost reduction they achieved**
   The real value in the projects of BWs 1-3 lies in the fact that without them the country would not have been able to bring the cost for <u>new</u> solar PV and wind down to the latest achieved 0.62 R/kWh – which is 40% cheaper than <u>new</u> coal[3].

5. **New projects of all BW4 are almost cost neutral from a pure fuel-saving perspective**
   While the <u>operational</u> solar PV and wind projects (of BWs 1 and 2) triggered tariff payments of roughly R12 billion in 2016 and produced roughly 6 TWh in the same year, the entire BW4 solar PV and wind projects (BW4, BW 4 Additional and BW4 Expedited) will trigger tariff payments of merely R6.6 billion per year while they will produce more than 9 TWh/yr. That means <u>45% less</u> annual payments for <u>50% more</u> energy compared to the currently operational solar PV and wind projects. These new projects will therefore be almost cost neutral from a pure fuel-saving perspective (i.e. the entire cost of the new car is similar to the cost of the fuel only for the existing car).

[3] http://www.ee.co.za/wp-content/uploads/2016/10/New_Power_Generators_RSA-CSIR-14Oct2016.pdf

Suggestion

It would be very beneficial for the quality of the discussion if Eskom could publish the hourly raw data that underlies the power system analysis, such that researchers can conduct independent peer reviews and additional power system analyses.

This publication of power system data is common practice by Transmission System Operators (TSOs) across the globe. For example, the European Network of Transmission System Operators for Electricity (ENTSO-E) has been publishing (on its transparency platform[4]), in real-time the 15-minute to hourly production and availability data of all power supply sources on an aggregated level (i.e. per fuel type) along with demand and transmission interconnector data in all European countries, markets and balancing areas. Planned and unplanned outages of large units are even reported on unit level[5].Without this transparency about the operational details of the power system it is very difficult to comment on final results of any study for any researcher, market participant and/or decision maker.

[4] https://transparency.entsoe.eu/
[5] https://transparency.entsoe.eu/outage-domain/r2/unavailabilityOfProductionAndGenerationUnits/show