

Smoothing out the Volatility of South Africa's Wind and PV Energy Resources for an Increased share of Renewables

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Agenda

Background

Objectives of the wind and PV resource aggregation study

Study progress to-date and Port Elizabeth case study

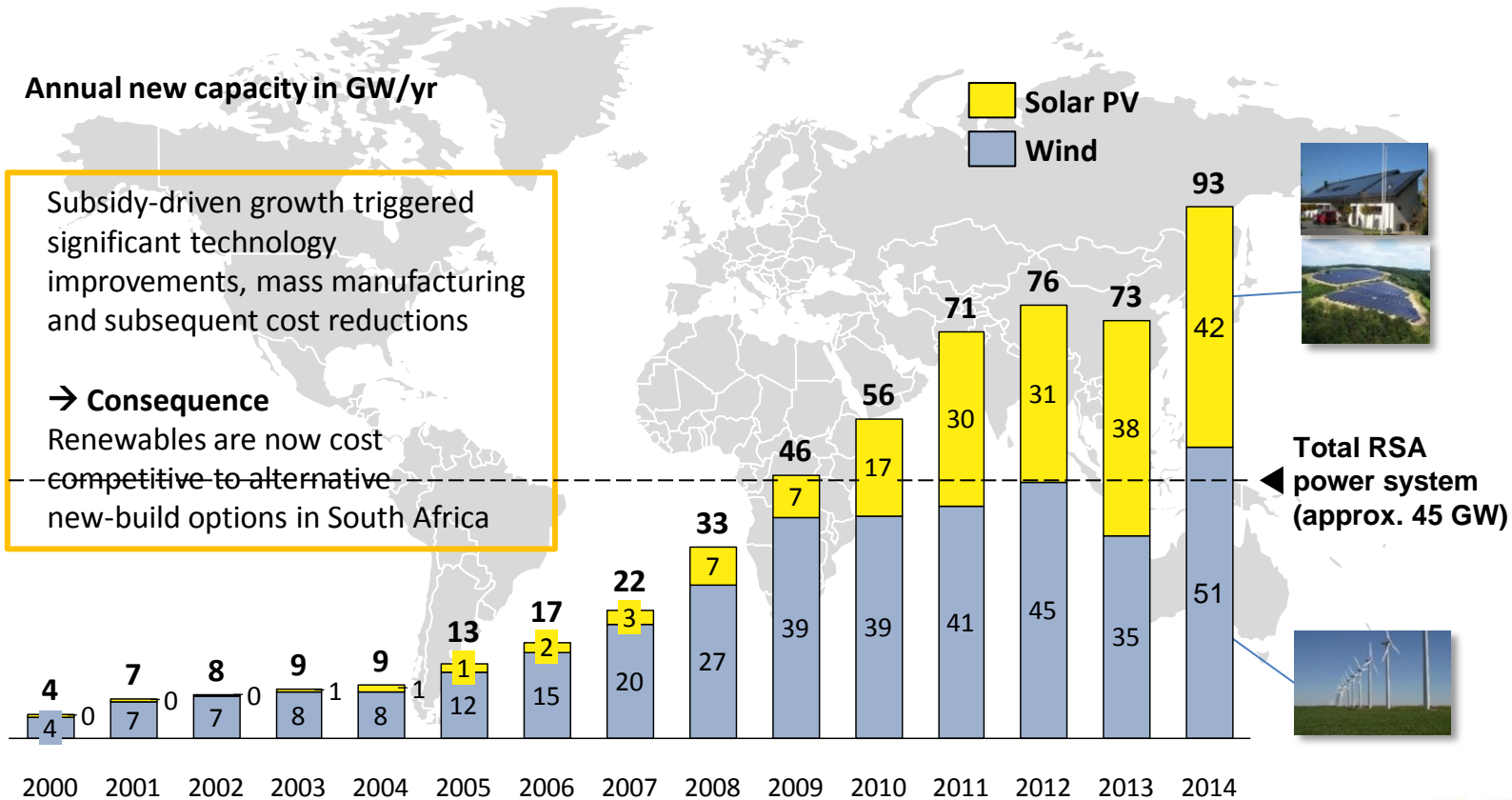
Animated/interactive GUI (wind/PV/Residual load) in the proposed REDZ

Acknowledgements and collaborations

Next steps

Conclusion

Last year alone, 93 GW of wind and solar PV were installed globally



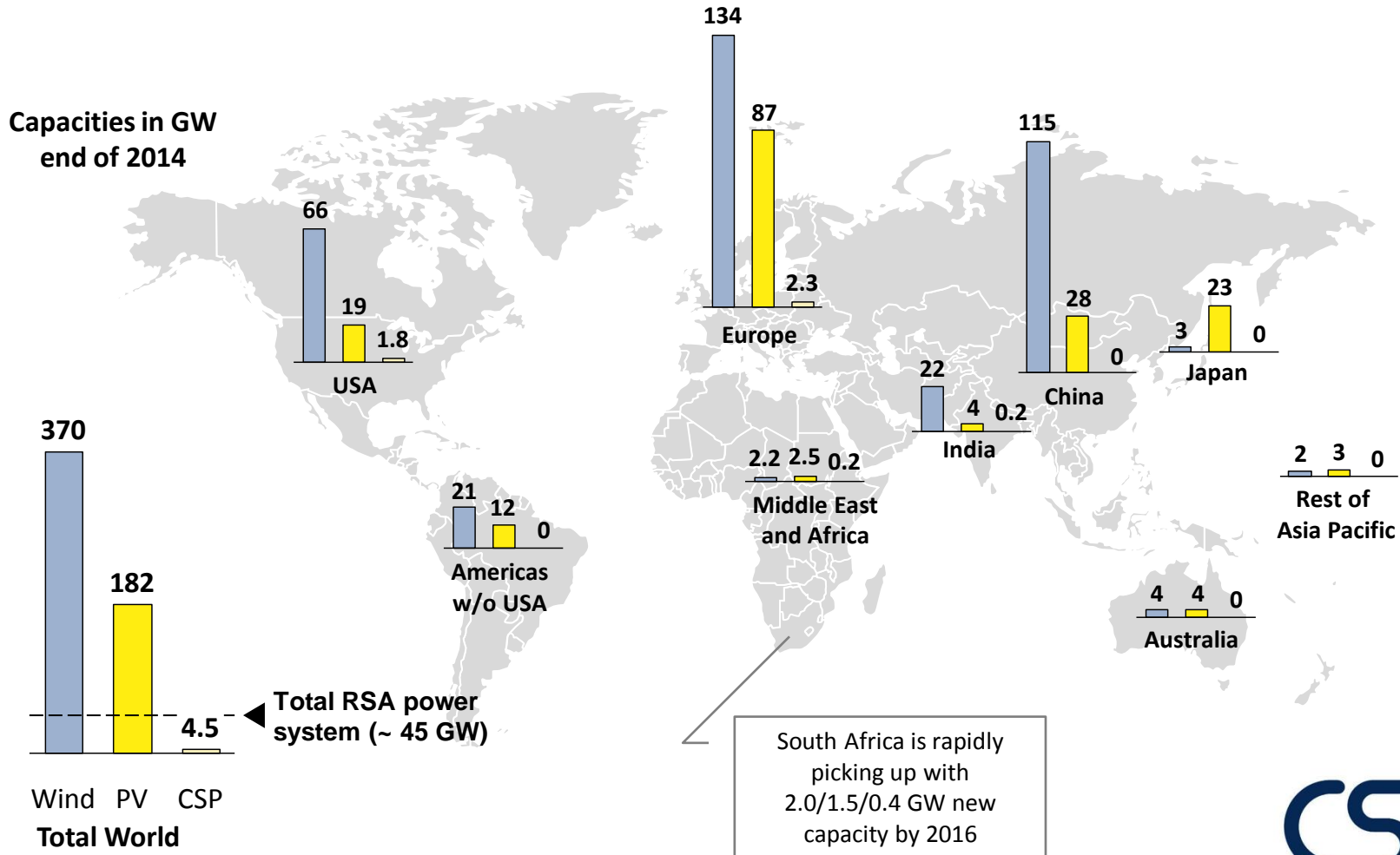
Subsidy-driven growth triggered significant technology improvements, mass manufacturing and subsequent cost reductions

→ **Consequence**
Renewables are now cost competitive to alternative new-build options in South Africa

This is all very new: Almost 90% of the globally existing PV capacity was installed during the last five years alone!

Sources: International Energy Outlook of the EIA; GWEC; EPIA; CSIR analysis

Until today, renewables were mainly driven by the US, Europe and China – South Africa picking up

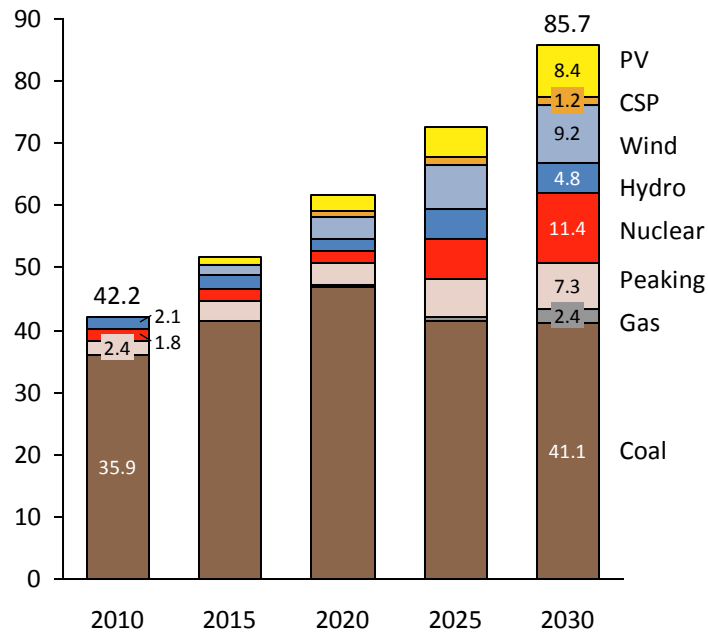


Sources: GWEC; EPIA; CSPToday; CSIR analysis

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

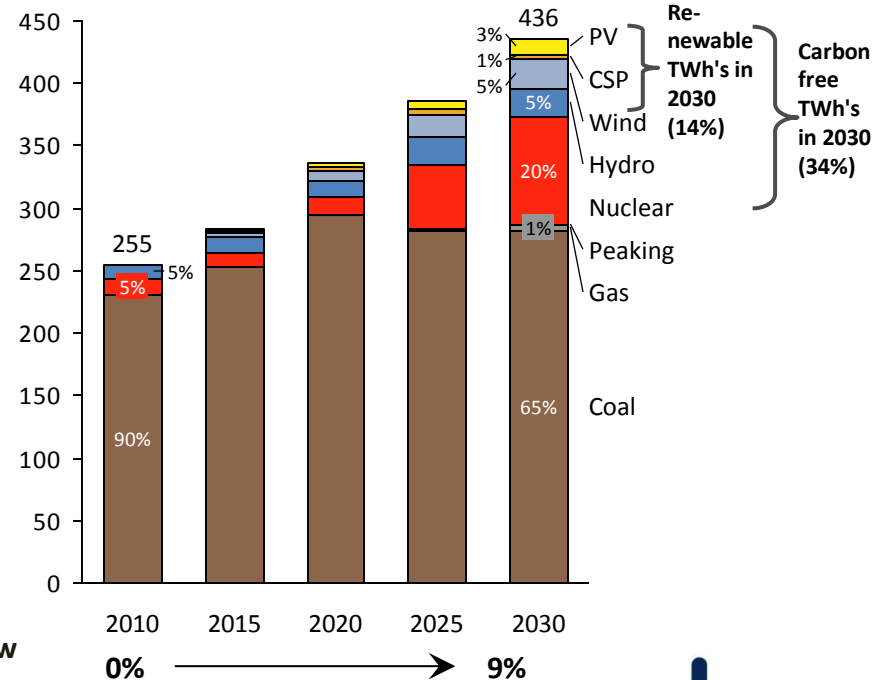
Installed capacity

Total installed net capacity in GW



Energy mix

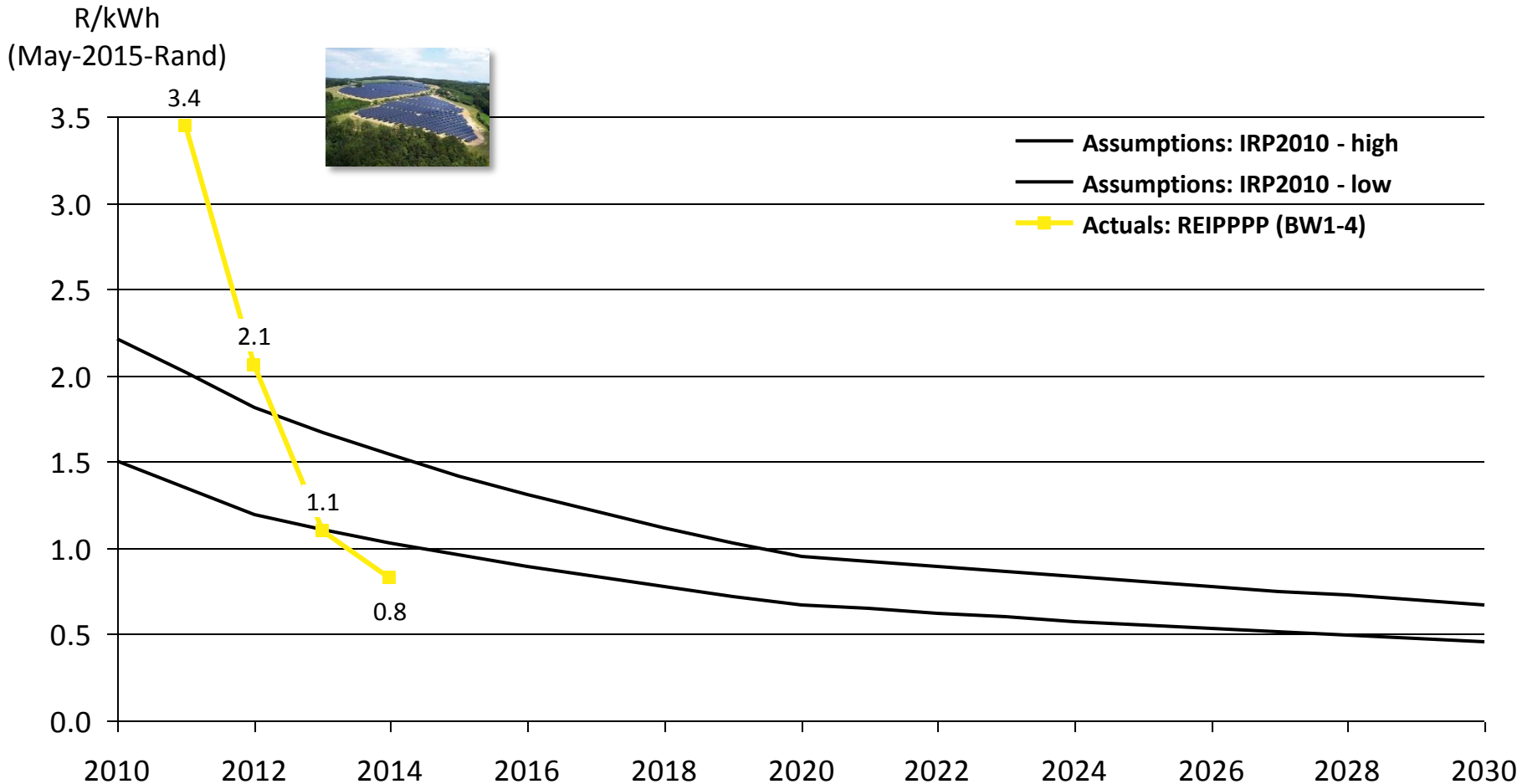
Electricity supplied in TWh per year



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



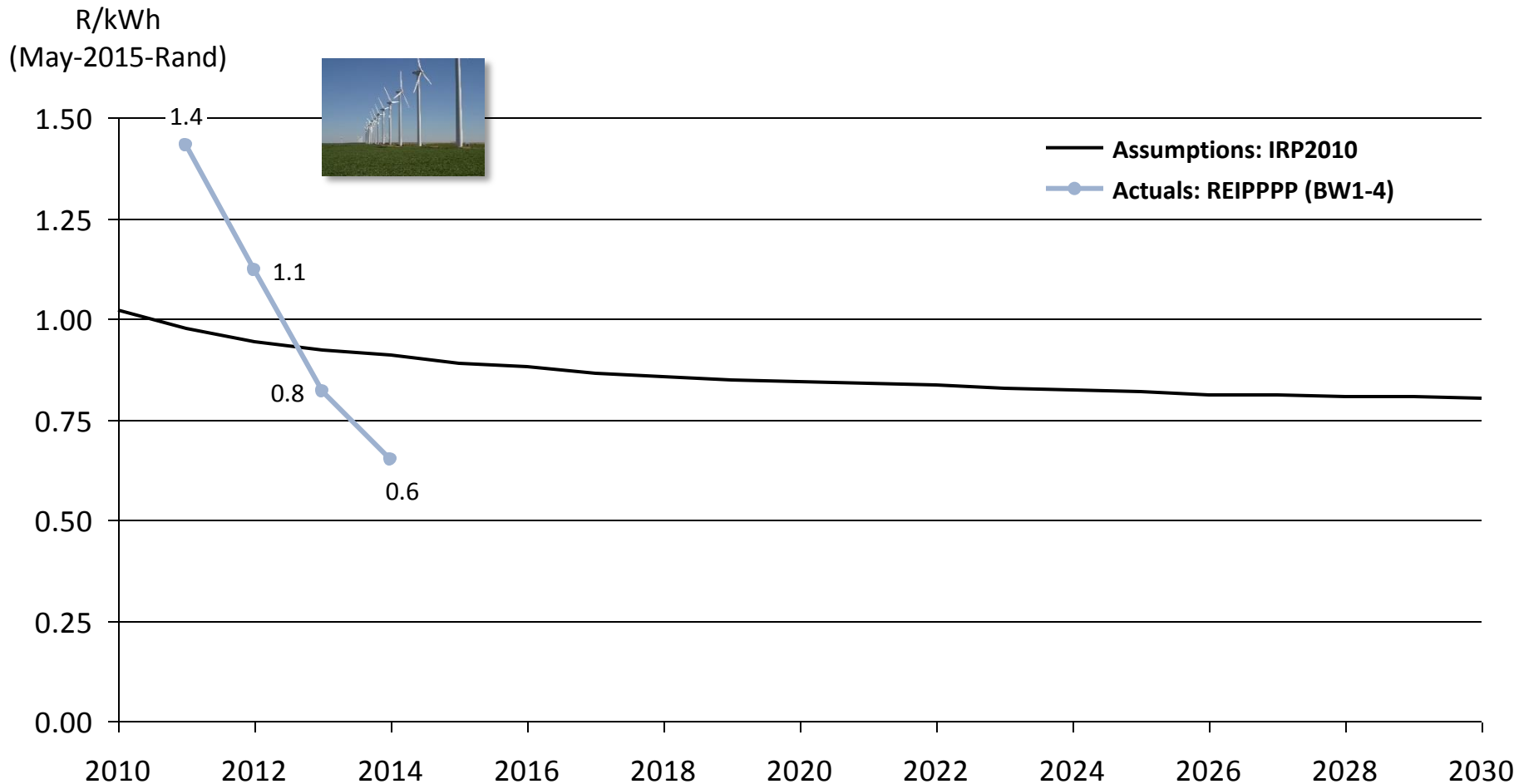
Actual PV tariffs quickly approached IRP cost assumptions in first four bid windows and are now below the lowest cost assumptions of IRP



Assumptions: CPI used for normalisation to May-2015-Rand; LCOE calculated for IRP with 8% discount rate (real), 25 yrs lifetime, cost and load factor assumptions as per relevant IRP document; "IRP Tariff" then calculated assuming 80% of total project costs to be EPC costs, i.e. divide the LCOE by 0.8 to derive at the "IRP Tariff"

Sources: IRP 2010; IRP Update; <http://www.ipprenewables.co.za/gong/widget/file/download/id/279>; CSIR Energy Centre analysis

Actual wind tariffs in bid window three were already at the level that was assumed for 2030 in the IRP, bid window four is significantly below



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

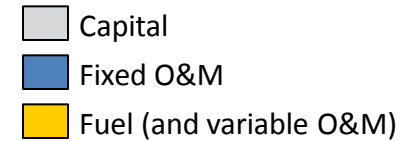
Sources: IRP 2010; IRP Update; <http://www.ipprenewables.co.za/gong/widget/file/download/id/279>; CSIR Energy Centre analysis

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

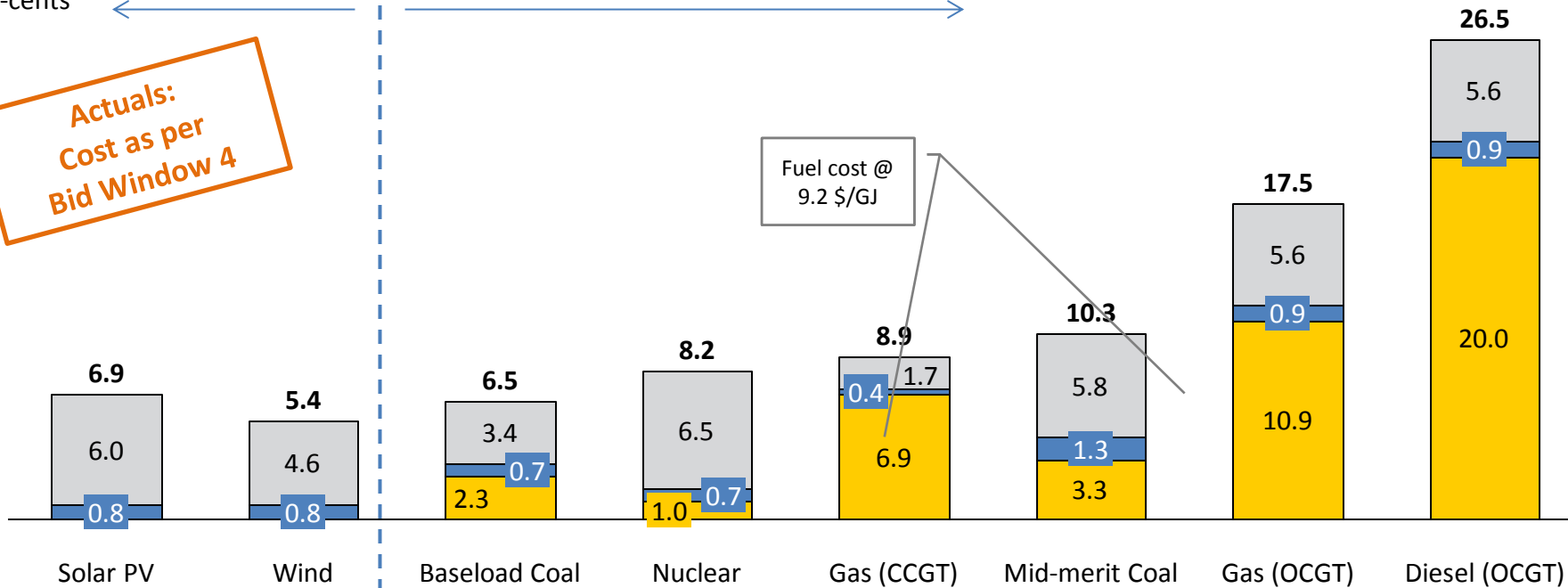
Lifetime cost per energy unit 

US-\$-cents ← Renewables

Conventional new-build options →



**Actuals:
Cost as per
Bid Window 4**



Assumed load factor →



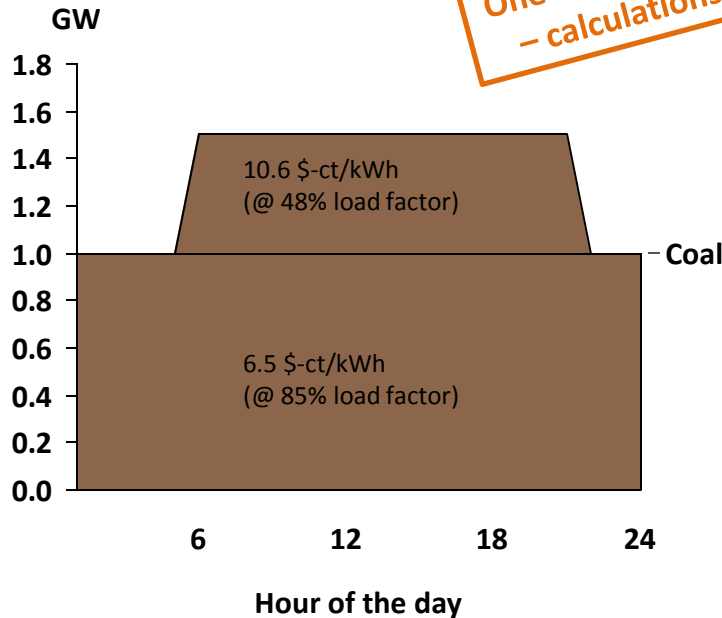
Note: Changing full-load hours for conventionals drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per MWh); Assumptions: average efficiency for CCGT = 50%, OCGT = 35%; coal = 37%; nuclear = 33%; IRP cost from Jan 2012 escalated with CPI to May 2015; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; CSP: 50% annual load factor and full utilisation of the five peak-tariff hours per day assumed to calculate weighted average tariff from base and peak tariff

Sources: IRP Update; REIPPPP outcomes; StatsSA for CPI; Eskom financial reports on coal/diesel fuel cost; CSIR analysis

By 2020, a mix of PV, wind and flexible gas (LNG-based) costs the same as new coal, even without any value given to excess wind/PV energy



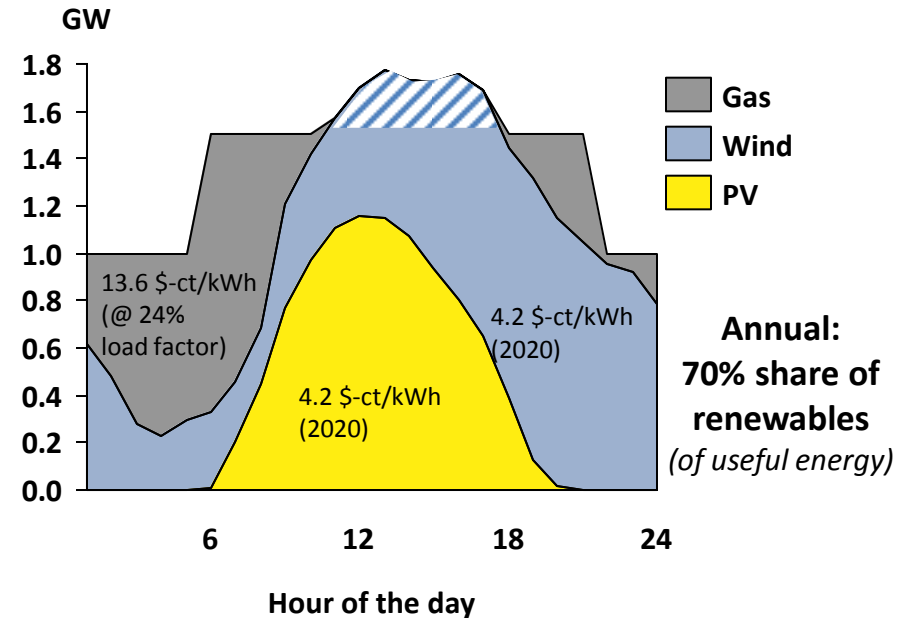
One illustrative winter day in display
 - calculations done for a full year



Technology: Coal base / coal mid-merit
Size: 1.18 / 0.56 GW
Energy: 11.1 TWh/yr

Weighted cost: 7.3 \$-ct/kWh

CO2: ~0.95 kg/kWh



Technology: PV / wind / gas
Size: 1.5 / 2.0 / 1.61 GW
Energy (useful): 11.1 TWh/yr
Energy (total): 3.6 / 5.3 / 3.2 TWh/yr = 12.1 TWh/yr

Weighted cost: 7.3 \$-ct/kWh
 (per useful energy, i.e. no value given to excess)

CO2: ~0.18 kg/kWh (per useful energy)

Annual:
 70% share of
 renewables
 (of useful energy)

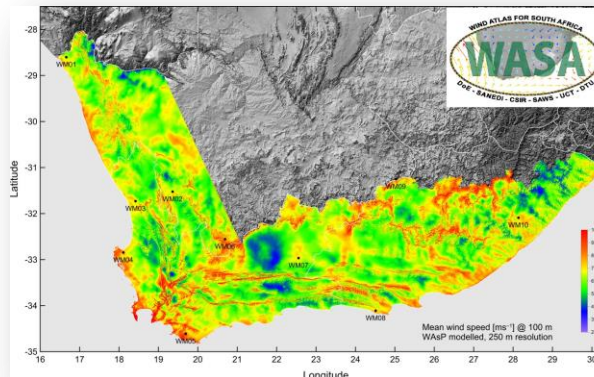
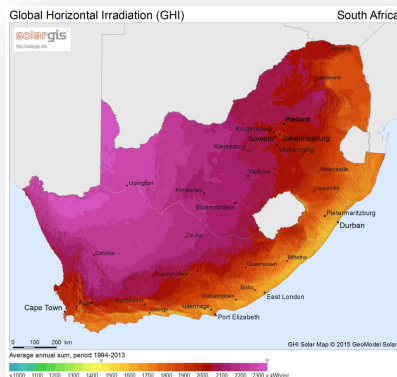
South Africa has abundant solar and wind resources

South Africa has some of the world's best solar and excellent wind resources, that until today are largely untapped

The Integrated Resource Plan 2010 plans for 8.4 GW of PV and 9.2 GW of wind by 2030 in South Africa

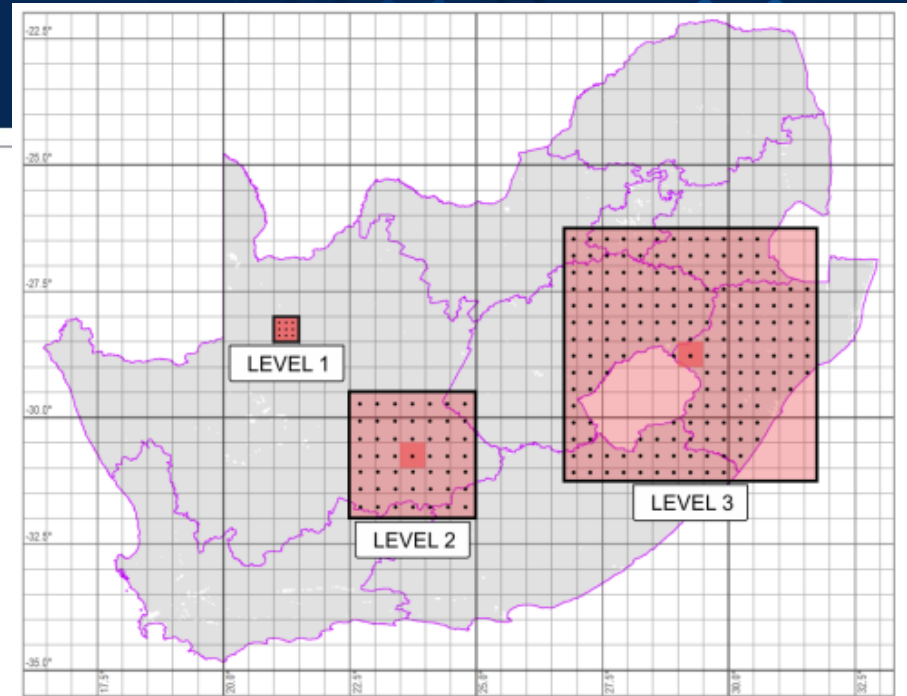
These targets which were developed five years ago are far below potential

Cost not a barrier anymore: new wind now costs 0.6 R/kWh (< 5 \$ct/kWh) and new solar PV costs 0.8 R/kWh (6 \$ct/kWh), based on actual PPA tariffs



Definition of aggregation levels

Regularly distributed power plants
Equally-sized

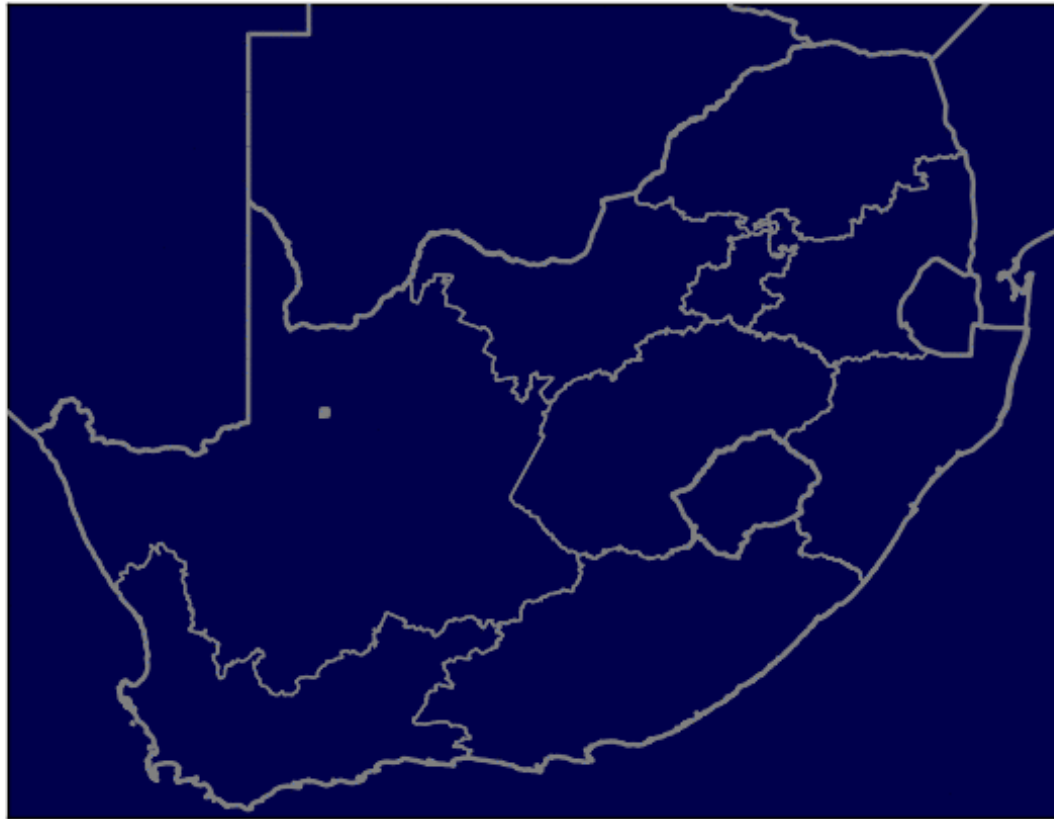


Aggregation level	Size of square		Number of power plants
	Arc-degrees in the database	Approximation in km	
Level 0	0.05°	5 x 5	1
Level 1 (reference)	0.5°	50 x 50	9 (3 x 3)
Level 2	2.5°	250 x 250	49 (7 x 7)
Level 3	5.0°	500 x 500	225 (15 x 15)

Cloud impact on PV: a single PV plant's power output has very high fluctuations

23 Jan 2012 04:15 SAST

Global tilted irradiance



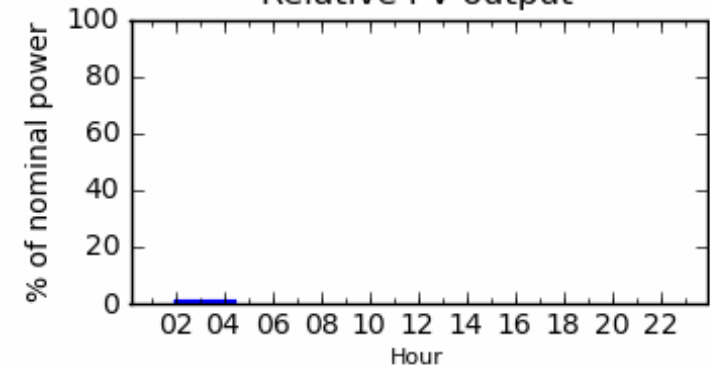
Upington area

Aggregation level: 0

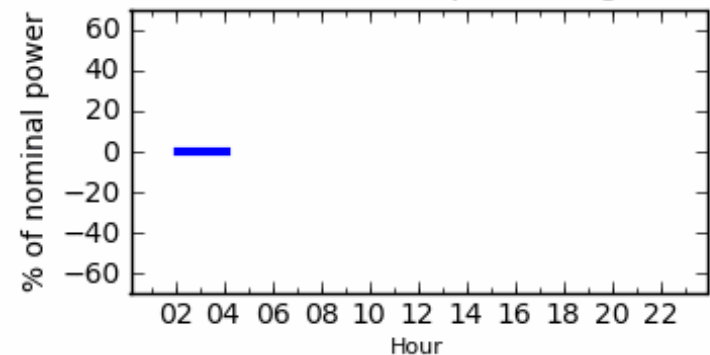
Aggregation area: 5 km x 5 km

Number of PV power plants: 1

Relative PV output



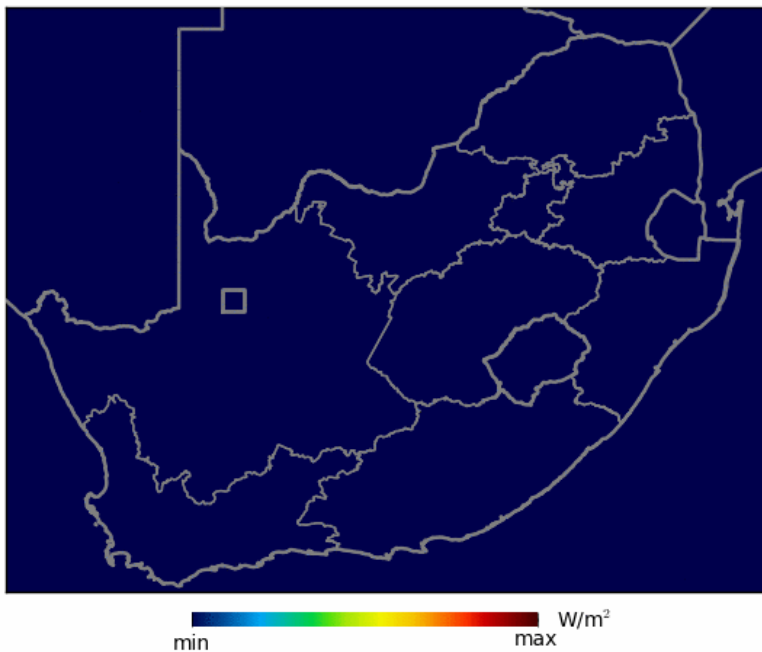
Relative PV output change



Aggregating 9 PV plants in a relatively small area already reduced fluctuations significantly

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Global tilted irradiance

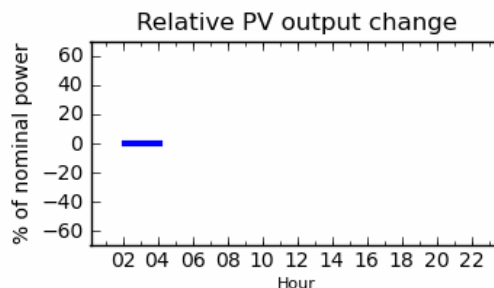
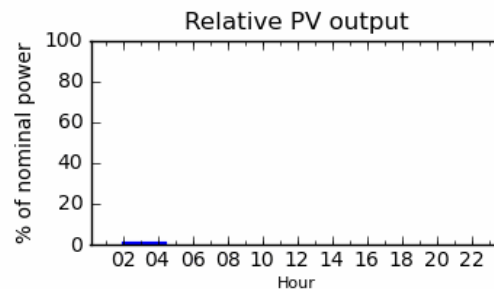


Upington area

Aggregation level: 1

Aggregation area: 50 km x 50 km

Number of PV power plants: 9

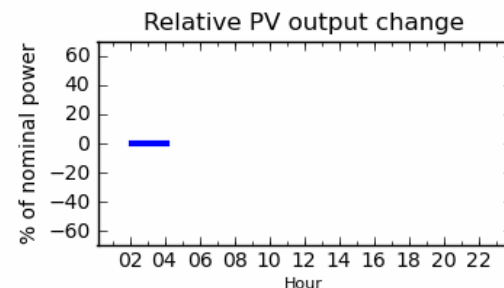
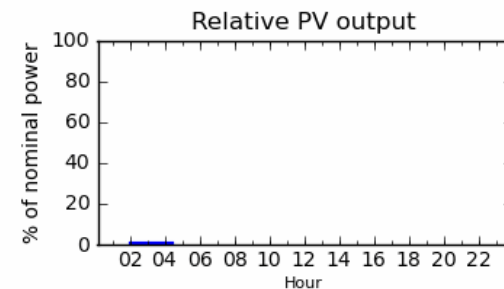


Upington area

Aggregation level: 0

Aggregation area: 5 km x 5 km

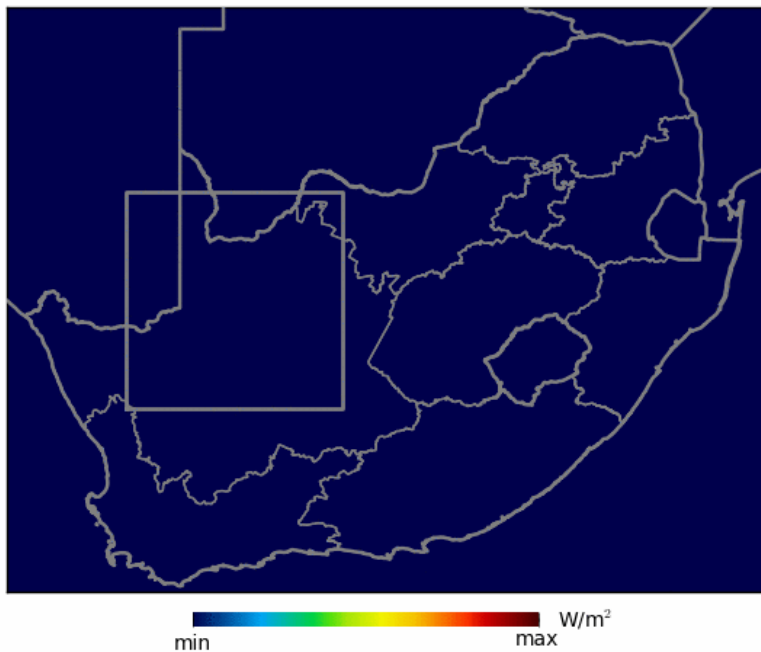
Number of PV power plants: 1



Aggregating 225 PV plants over 500 x 500 km reduces short-term fluctuations to almost zero

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Global tilted irradiance

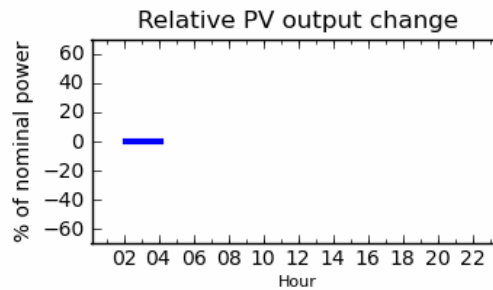
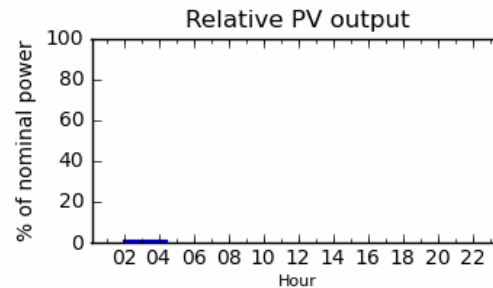


Uppington area

Aggregation level: 3

Aggregation area: 500 km x 500 km

Number of PV power plants: 225

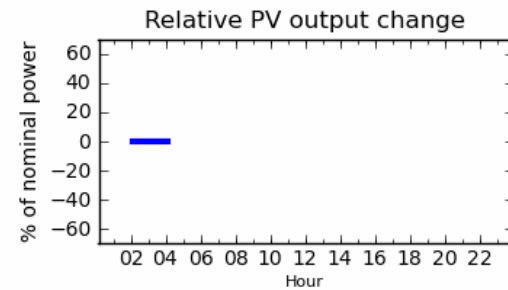
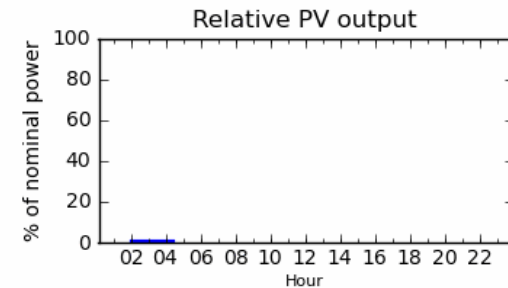


Uppington area

Aggregation level: 1

Aggregation area: 50 km x 50 km

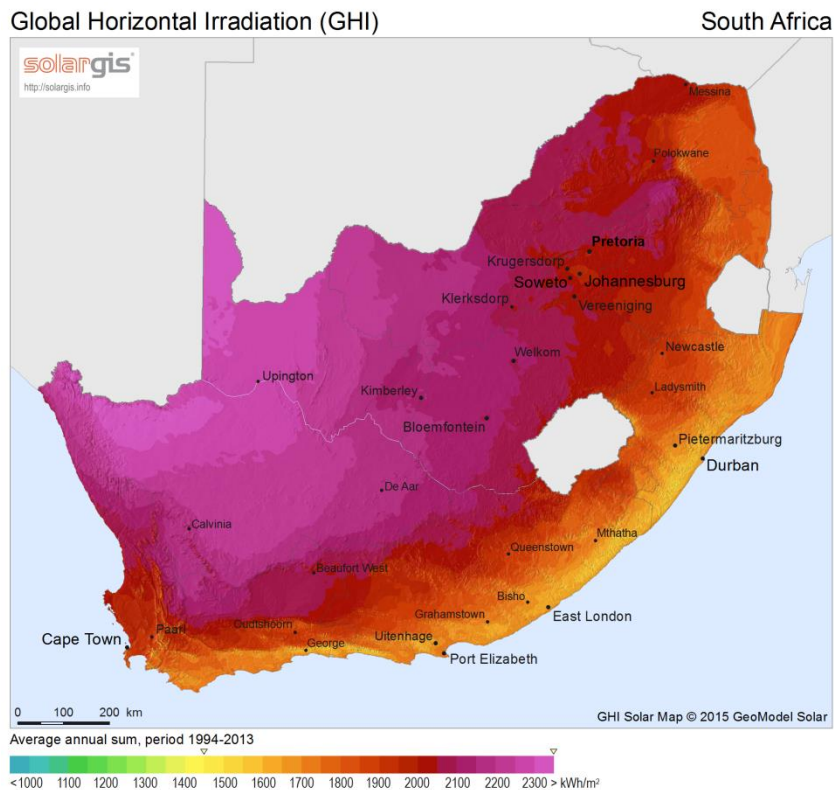
Number of PV power plants: 9



Widespread spatial distribution makes aggregated PV power output very predictable and smooth

South Africa has almost 2-times the solar resource as Germany, where PV is close to cost competitiveness

Solar resource in South Africa...



... as compared to Germany



SA's planned PV capacity by 2030: 8.4 GW
target too low

Germany's status today: almost 40 GW PV
installed capacity (roughly one Eskom)

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Wind and solar aggregation study: Main objective to quantify the effects of spatial distribution on output

Increase the fact base and understanding of aggregated wind and PV power profiles for different spatial distributions in South Africa

Generate data sets that can be used for various studies (IEP, IRP, TDP, SEA etc.)

Resulting in:

- Confidence in integrating higher renewables shares
- Optimal mix of wind and PV, to minimise cost and maintain grid stability easier

Transfer of knowledge and skills on utilising wind data in energy-planning activities

The study is currently being conducted for South Africa

- Wind and solar data sets covering the entire country
- 5x5 km spatial resolution, 10-minute time resolution, 5 years of data
- Spatial load data for the entire country

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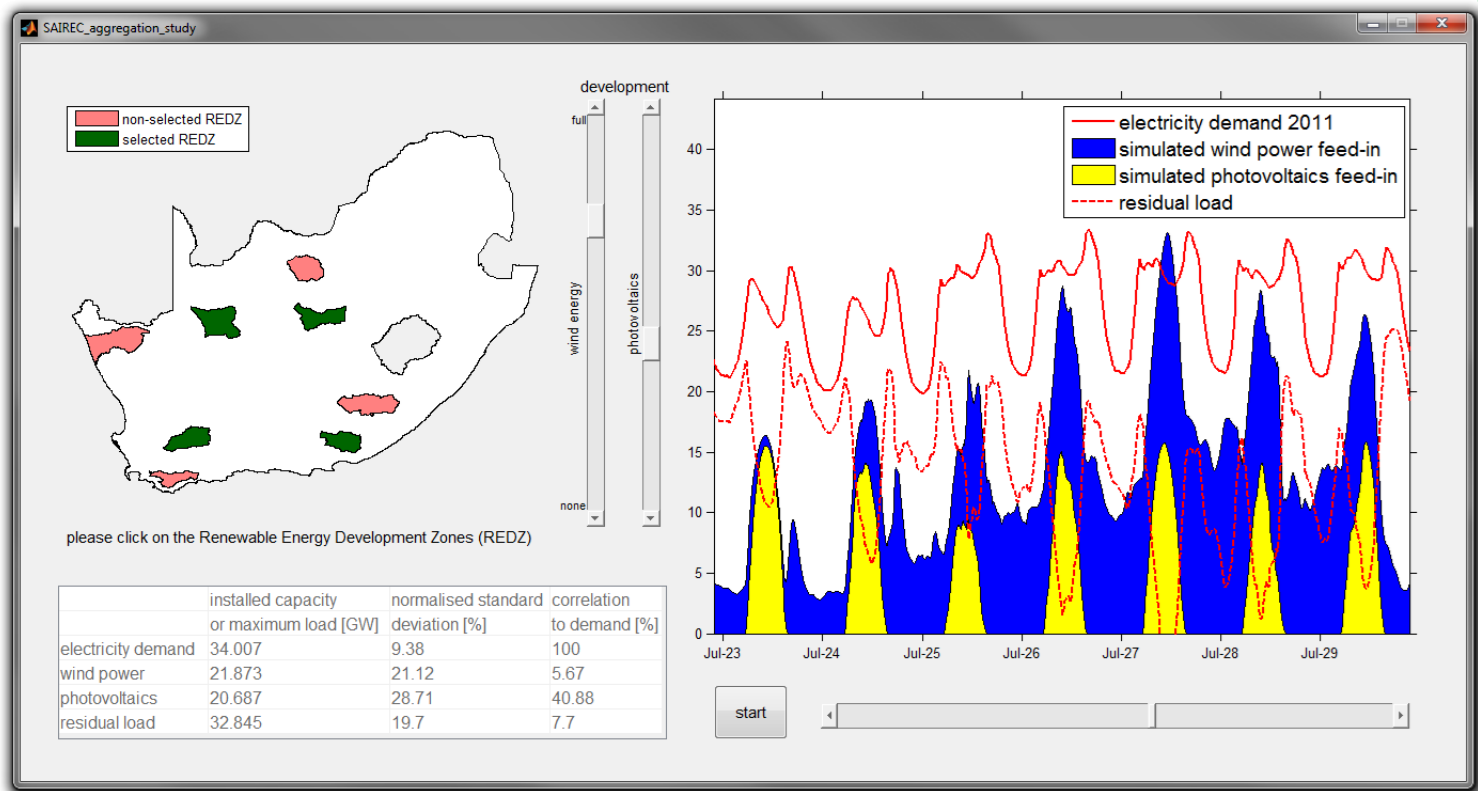
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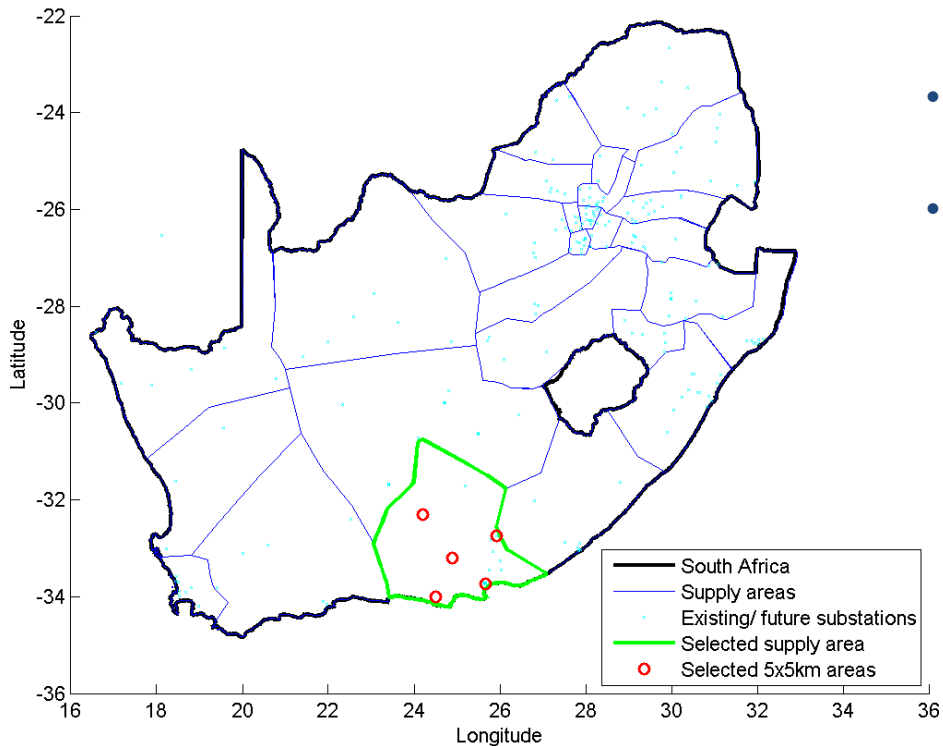
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Animated graphical user interface

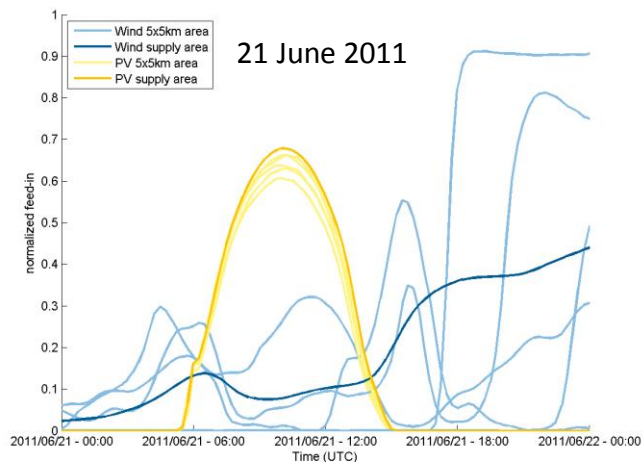
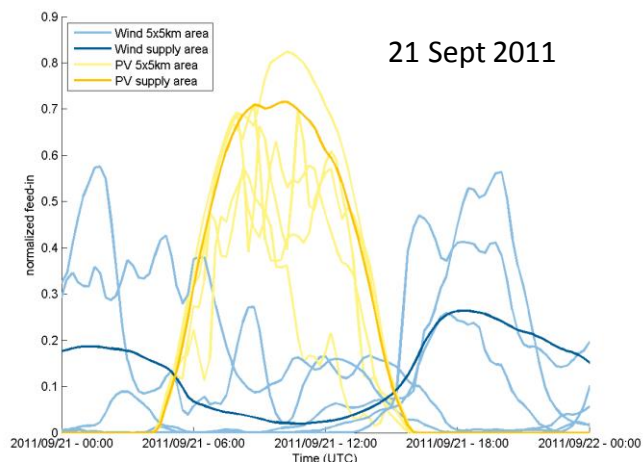


Preliminary study for the Port Elizabeth area



- Five areas/sites (5x5km each) selected as generation sources
- 2011 Wind (WASA) and solar PV profiles (Geomodel Solar) used

First results show on two specific days how volatility of wind and solar reduces with spatial aggregation



- Individual plants have high ramp rates
- Individual plant power output very volatile; low predictability
- Area (aggregated) output is much smoother with low ramp rates
- Aggregated plant output is more predictable
- PV is output high during the day and Wind high during in the evening – good synergy (true for most areas)

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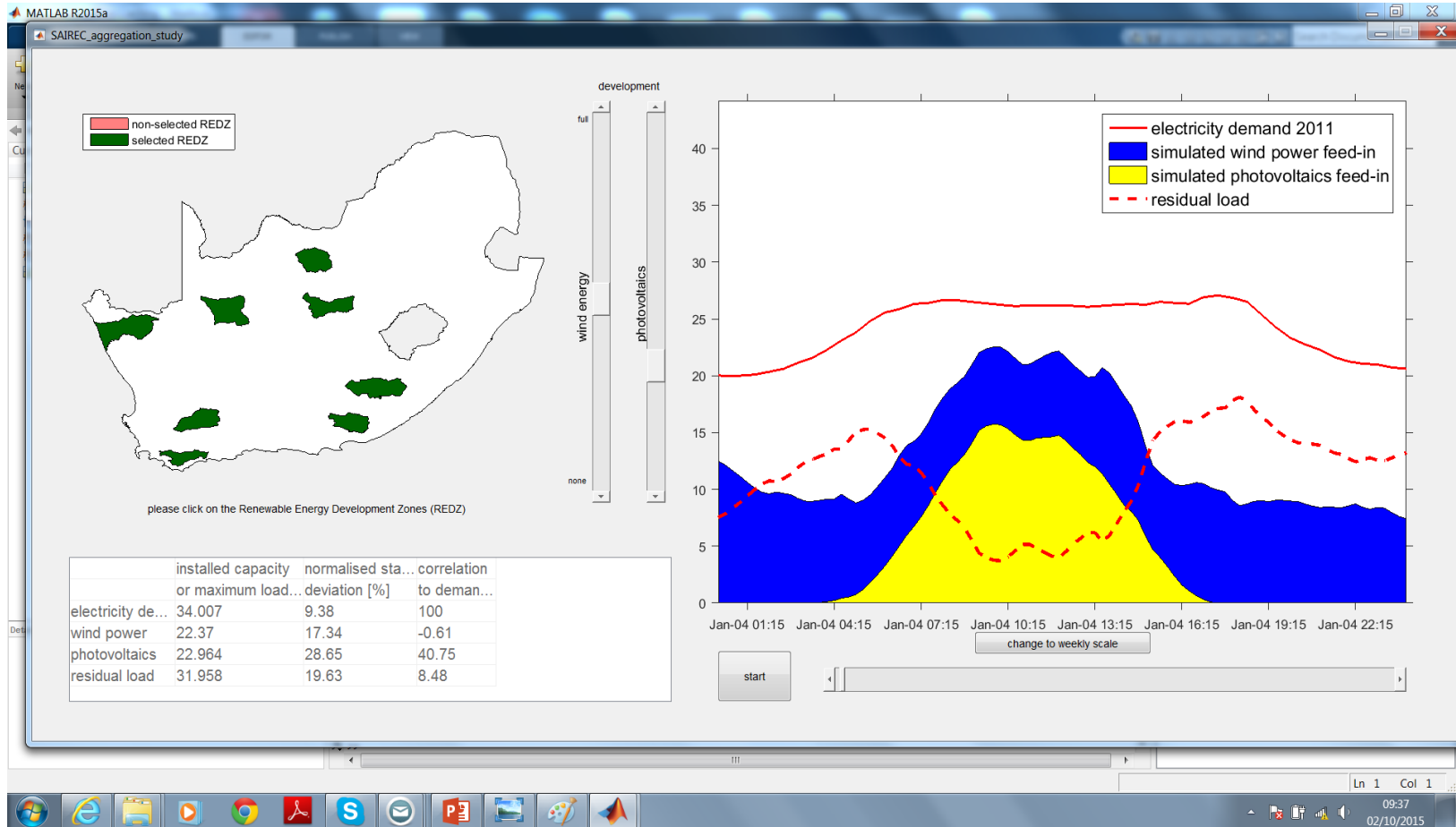
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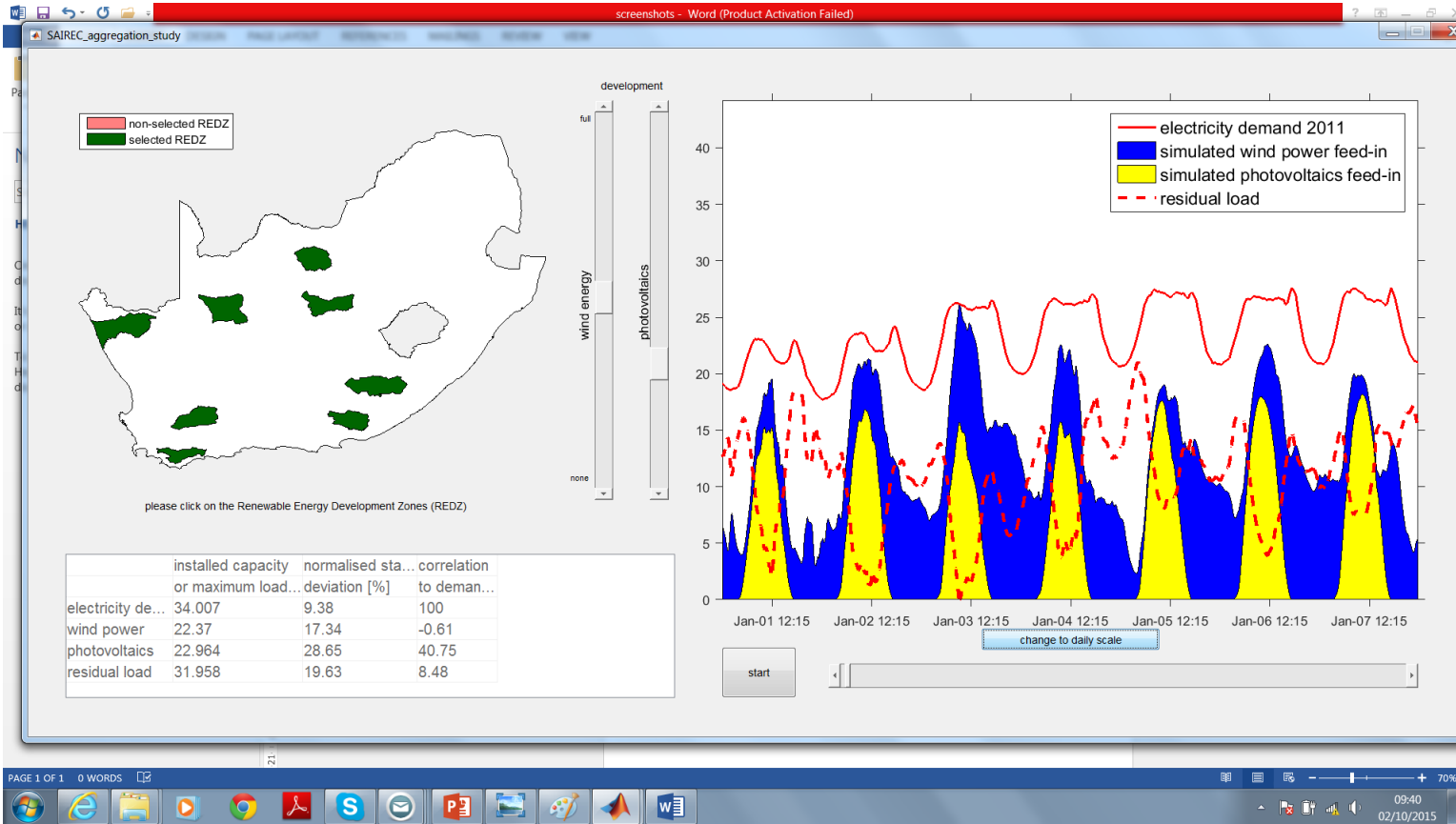
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Animated graphical user interface



Animated graphical user interface



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Acknowledgements and contribution



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Next steps

Analysis for the for 27 load areas covering the whole country

Include the load profile in the analysis to determine the residual load (Load – PV – Wind) – Done!

Estimate the resource potential

Country wide analysis for different shares of wind and PV

Determine residual metrics that can be used to determine the capability of conventional plants

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The true success of the RE IPPPP lies in the fact that wind and PV are cost competitive

Acceleration of the future rounds is critical as all the barriers have been removed; delays are costly, and there are economic and social development spins

Start where there is grid capacity; Eskom and DEA already doing strategic plans for future grid to expedite wind and PV integration – support and contribute to this initiative

Spatially aggregate wind and PV as part of IRP planning

With combined (wind and PV) spatial aggregation, it is reasonable to expect an increase in wind and PV capacity in the next IRP, accompanied by complimentary flexible generation

Thank you