Costing a 2020 Target of 15% Renewable Electricity for South Africa

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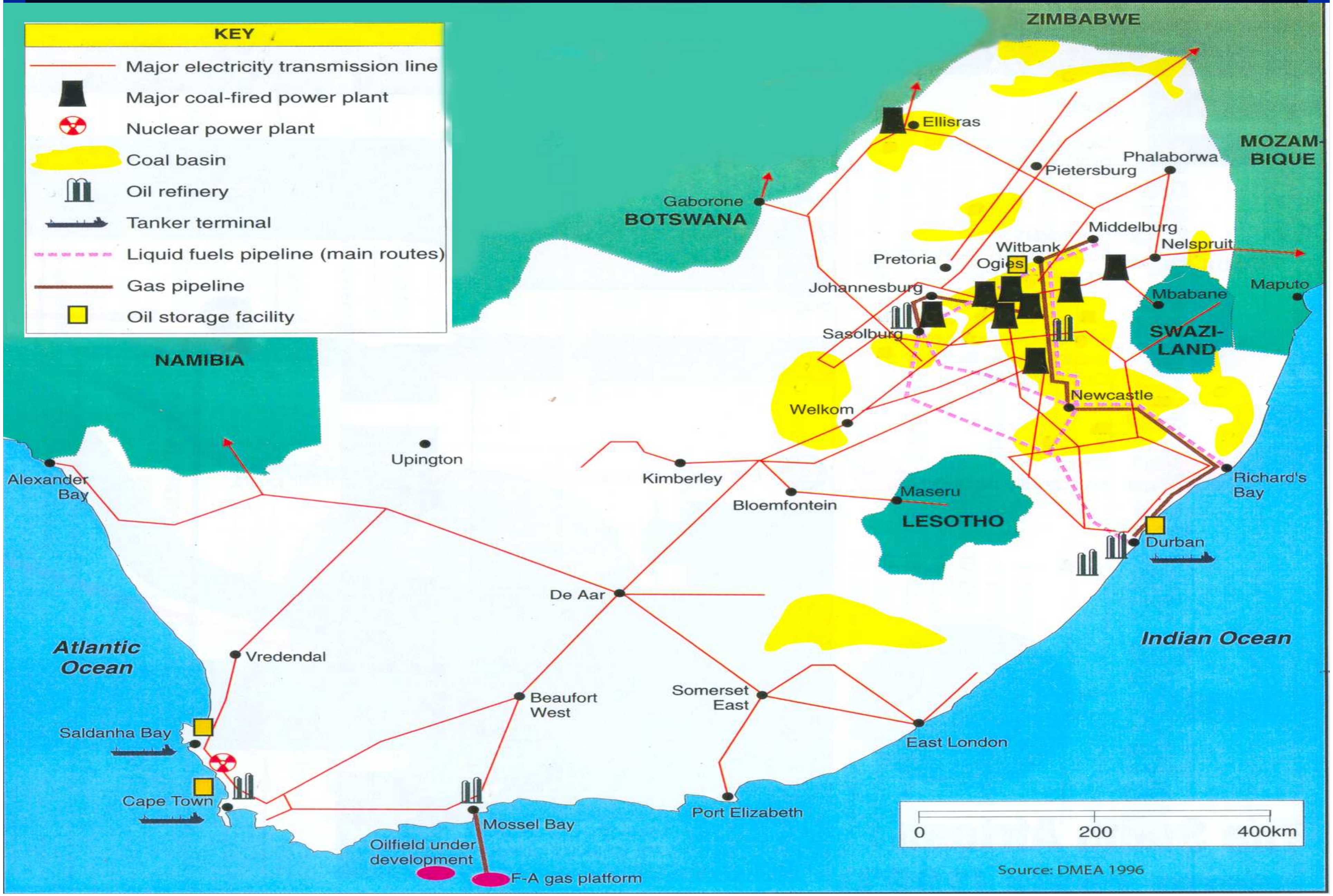
Introduction

The problem was to assess the national cost of South Africa achieving a target of 15% of electricity generated from renewable sources by 2020, in the following context:

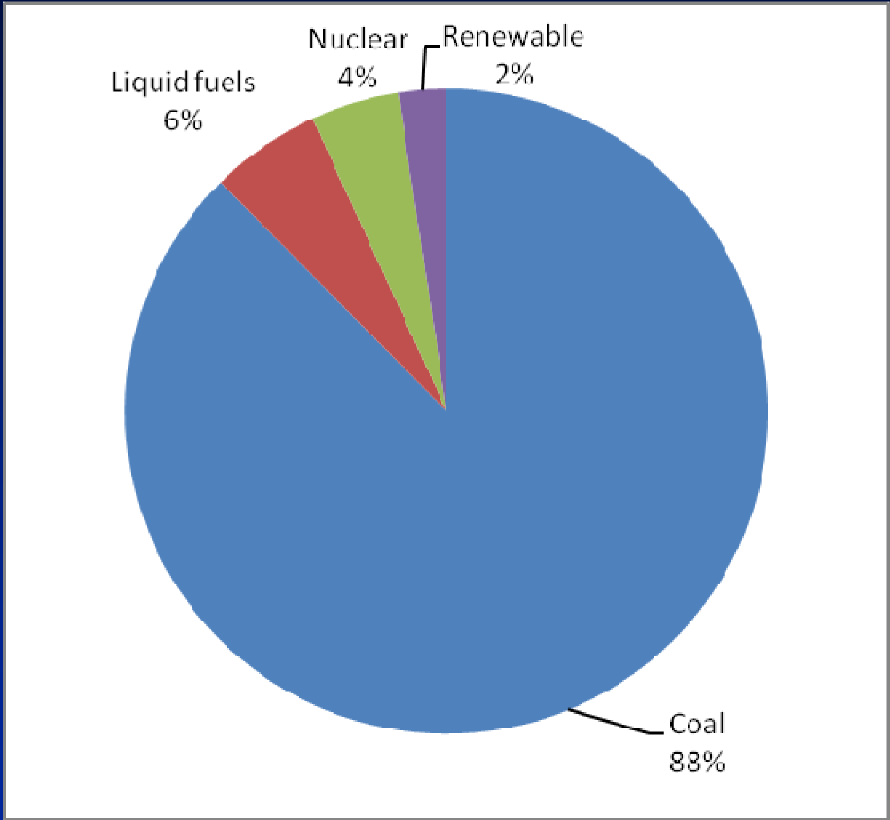
- Most South African electricity is generated from coal (93.3% from coal, and 1.4% from renewables in 2009), but potential for renewables is high (solar and wind, and possibly wave).
- South Africa's electricity is the cheapest in the world (EIA, based on available data), because of a) cheap coal, b) overcapacity in the 1980s (no new powerplants – electricity price is below long-run marginal cost).
- South Africa has relatively high per capita GHG emissions for a developing country, and our President recently committed the country to an emissions path that will peak in the 2020s and then decline substantially by 2050. South Africa's recently-completed Long-Term Emissions Scenarios indicated that the power sector should be a critical focus for mitigation.

The South African electricity system

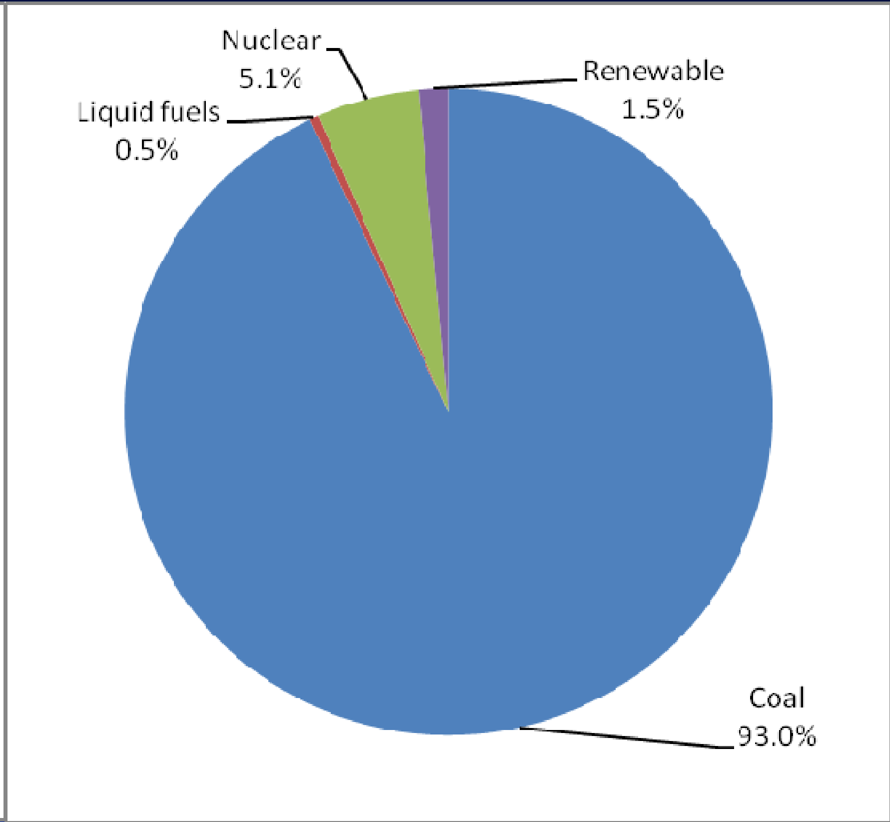


The South African electricity system

Installed capacity by energy type



Electricity sent out by energy type



What a 15% by 2020 target means

- Current electricity demand is around **250,000 GWh**. Projected electricity demand in 2020 is around **375 000 GWh - 15**% of this is **56 000 GWh**
- Production of this amount of electricity would require:
  - Slightly more than two of South Africa's current coal plants, OR
  - **116** 100MW solar thermal plants (55% availability), OR
  - **213** 100MW wind farms (30% availability)
- Additional system requirements would vary (to meet peak demand reliably)

How much will it cost?

Five different cost indicators:

1. Levellised plant costs
2. Total system costs, used to assess the cost of mitigation (discounted incremental system costs/emissions reductions)
3. Comparative investment requirements per year
4. Total annual electricity production costs – calculated using annualised capital costs
5. Annual average cost of producing electricity – an indicator of the effect on the electricity price, and calculated from (4)

The last indicator was also used to calculate the impact of carbon financing (e.g. the CDM)

Modelling Approach

1. Technologies – focus on wind and solar technologies – large-scale commercialised technologies with well-known resource bases in South Africa.
2. We assumed technology learning takes place.
3. We compared the cost of electricity from individual power plants using Levellised Electricity Costs.
4. Comparing the costs of alternative electricity systems:
   - We used a bottom-up, partial equilibrium MARKAL model of the South African energy system (originally developed for South Africa's Long-Term Mitigation Scenarios) to model the electricity system, which allowed us to model supply options, as well the impact of demand-side options.
   - We then applied a reliability check, to check that all the cases we modelled had adequate and comparable reliability (due to low resolution of MARKAL load curve, and the potentially high incidence of wind), and adjusted the MARKAL runs accordingly.

Scenarios modelled

Reference Case – 'business as usual' – assume current plans for new two new coal plants, and thereafter the least-cost option

Renewables Cases:

1. Lower wind resource assumptions – model chooses least-cost way of meeting target
2. Higher wind resource assumptions – model chooses least-cost way of meeting target
3. Higher wind resource assumptions – target split between wind and solar

Nuclear Case modelled for comparison – capacity after planned units is nuclear

All the above also modelled with an energy efficiency programme (1A to 3A)

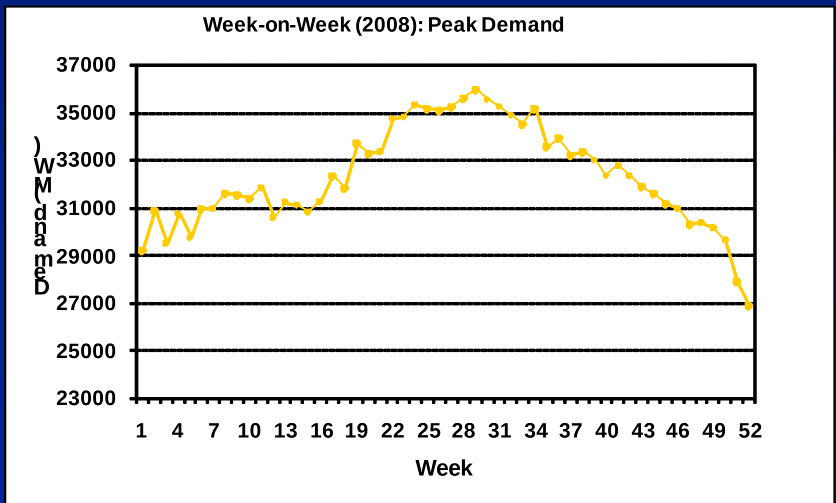
Assumptions and Data

- **Technology learning** – learning rates based on a model developed for the LTMS, and updated from recent literature.
- **Economic growth and structure** – economic growth rates based on South African government projections – quite optimistic, and do not take current crisis into account, although impact on South African economy has been less severe than in other countries. Economic structure assumed to shift gradually towards service sectors, with decline in key sectors (e.g. gold mining).
- **Discount rate** – a **real** discount rate of 7.5%, lower than 10% standard but comparable with Eskom's planning assumption - with South African inflation this equates to a nominal rate of 15-18%.
- **Plant costs** – sourced primarily from IEA ETP, as well as from other sources including US DOE EIA NEMS costs and local integrated resource planning cost assumptions – high degree of uncertainty for nuclear, solar.
- **Fuel costs** – most important fuel price is coal, based on local industry estimates – local coal prices largely delinked from international prices. Gas and oil/liquid fuels prices based on international projections (gas is imported, price is regulated and linked to international gas prices; liquid fuels prices are regulated and based on an import parity price formula).

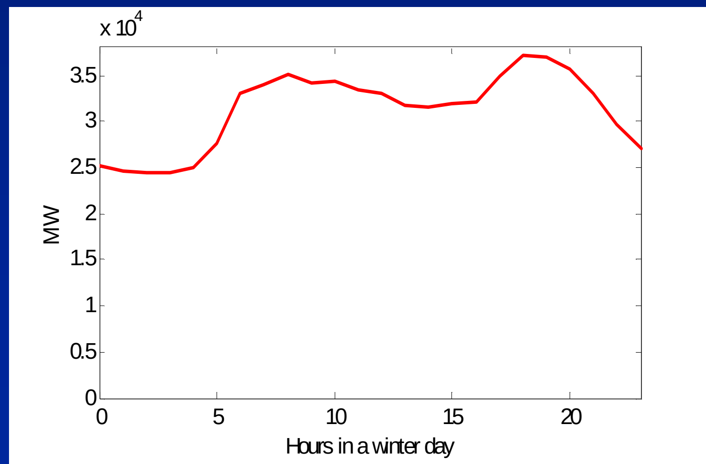
Load characteristics of the South African electricity system

- Load is very 'peaky'
- With ample coal supplies there is no shortage of energy
- SA system is CAPACITY constrained

Week on week peak demand



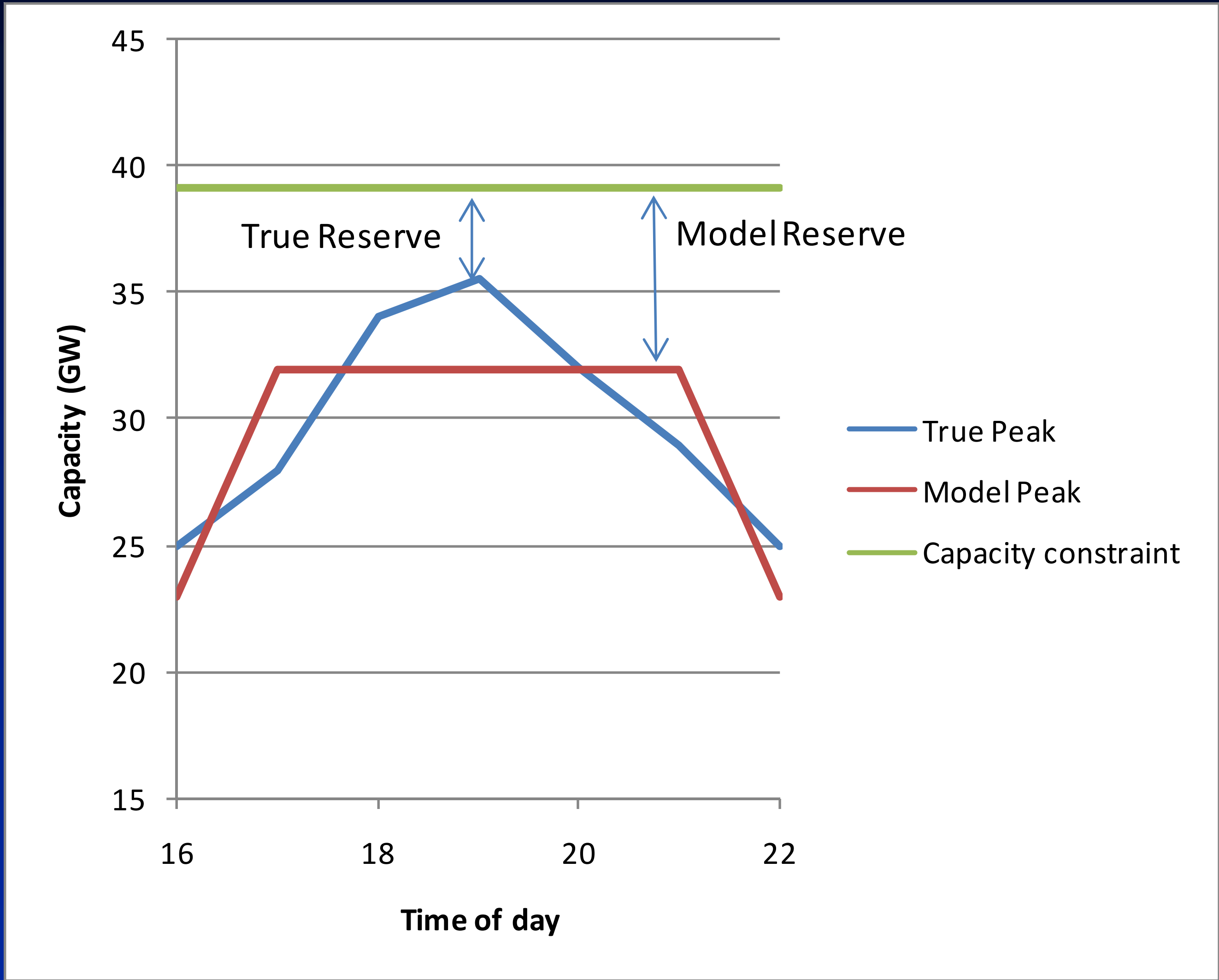
Load curve for a winter day



Reliability testing method

- Model used: MARKAL with 6 time slices
  - Peak not captured by load curve
  - No probabilistic reliability evaluation in place
- Model 'compensations'
  - 'Model reserve margin' set so that capacity built = 'true peak' + 'true reserve' (set initially to 15%)
  - 'True peak' calculated by applying scaling factor to 'model peak'
  - Probabilistic reliability evaluation done off-line using simulations (only in the peak hour) with:
    - build plan from model results,
    - 'true peak'
    - plant forced outage rates
    - unit sizes
  - LOLP used as measure to then iteratively adjust 'model reserve' (in MARKAL) before re-running

Model Reserve and True Reserve

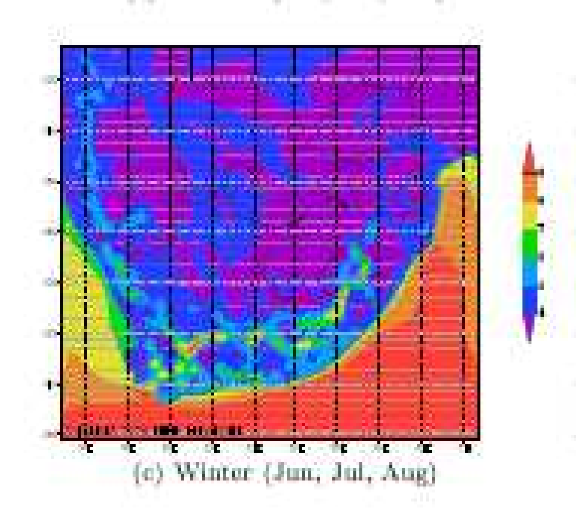


Wind component (1/2)

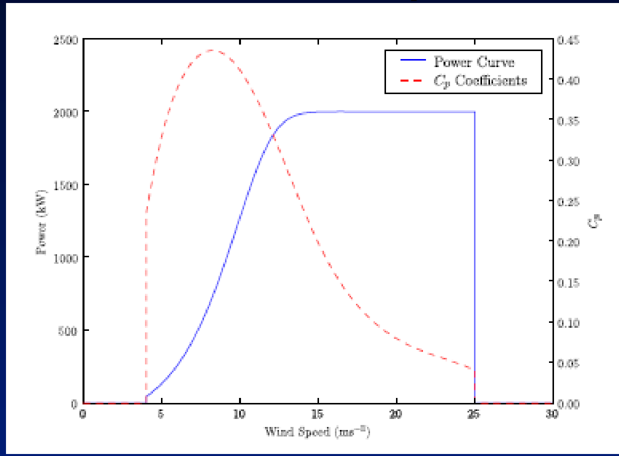
- In the estimation of LOLP (MC simulations), thermal units are either ON or OFF, using forced outage rate (FOR).
- For the wind component of the system, power output in the peak time is sampled from a pdf constructed using a Meteorological mesoscale model (MM5).
- The MM5 model generates a time-series for wind speed and direction for heights 60m, 80m and 100m, at a hourly temporal resolution, 18km spatial resolution.
- The expected power production of a standard Vestas V80 2MW wind turbine at each 18x18km grid cell is combined with the availability of road and transmission infrastructure.
- The pdf is constructed from a wind power output for cells close to infrastructure, and with at least a 25% annual availability, in the peaking hour of the winter months, in a carefully selected “average” year (62 points).

Wind component (2/2)

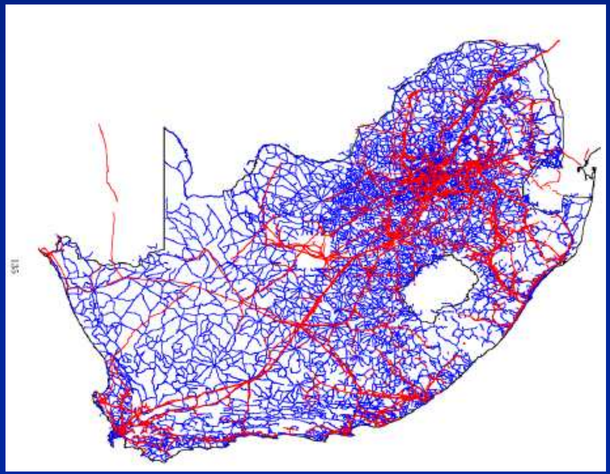
Wind map (time series)



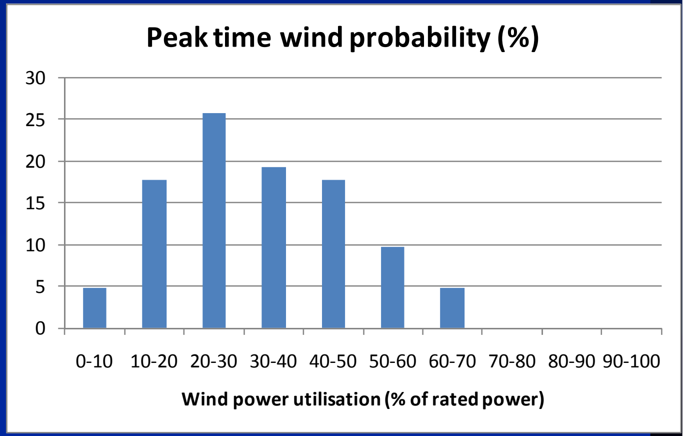
Power curve -> power map



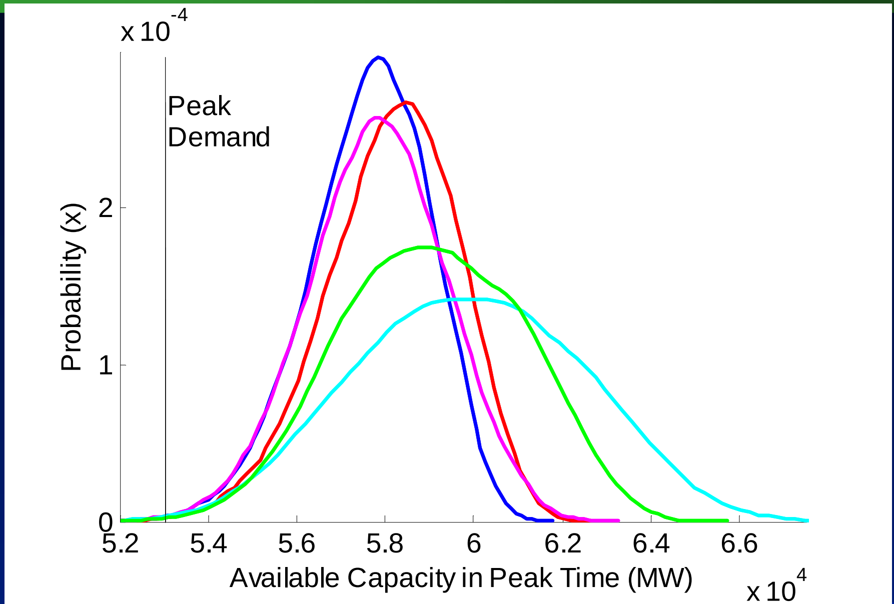
Infrastructure map

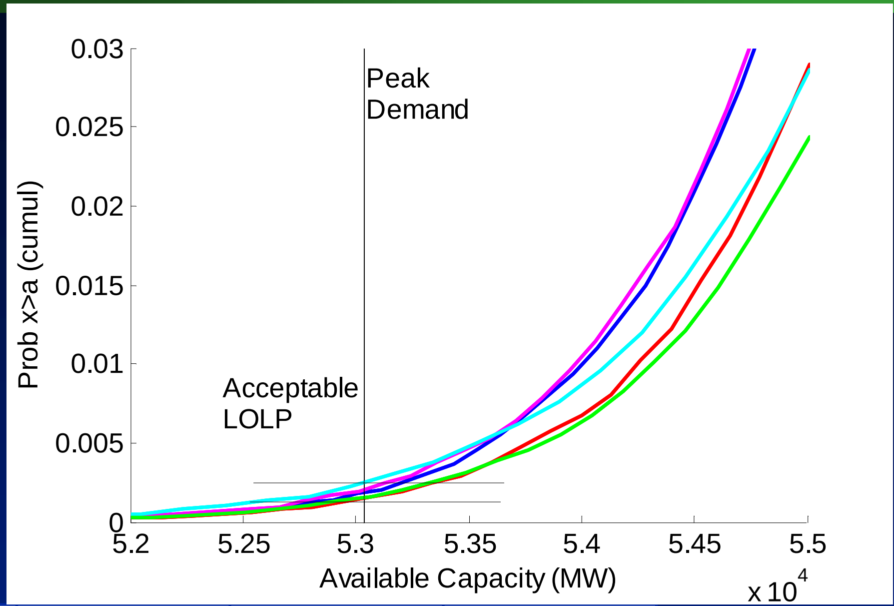


Peak wind power pdf



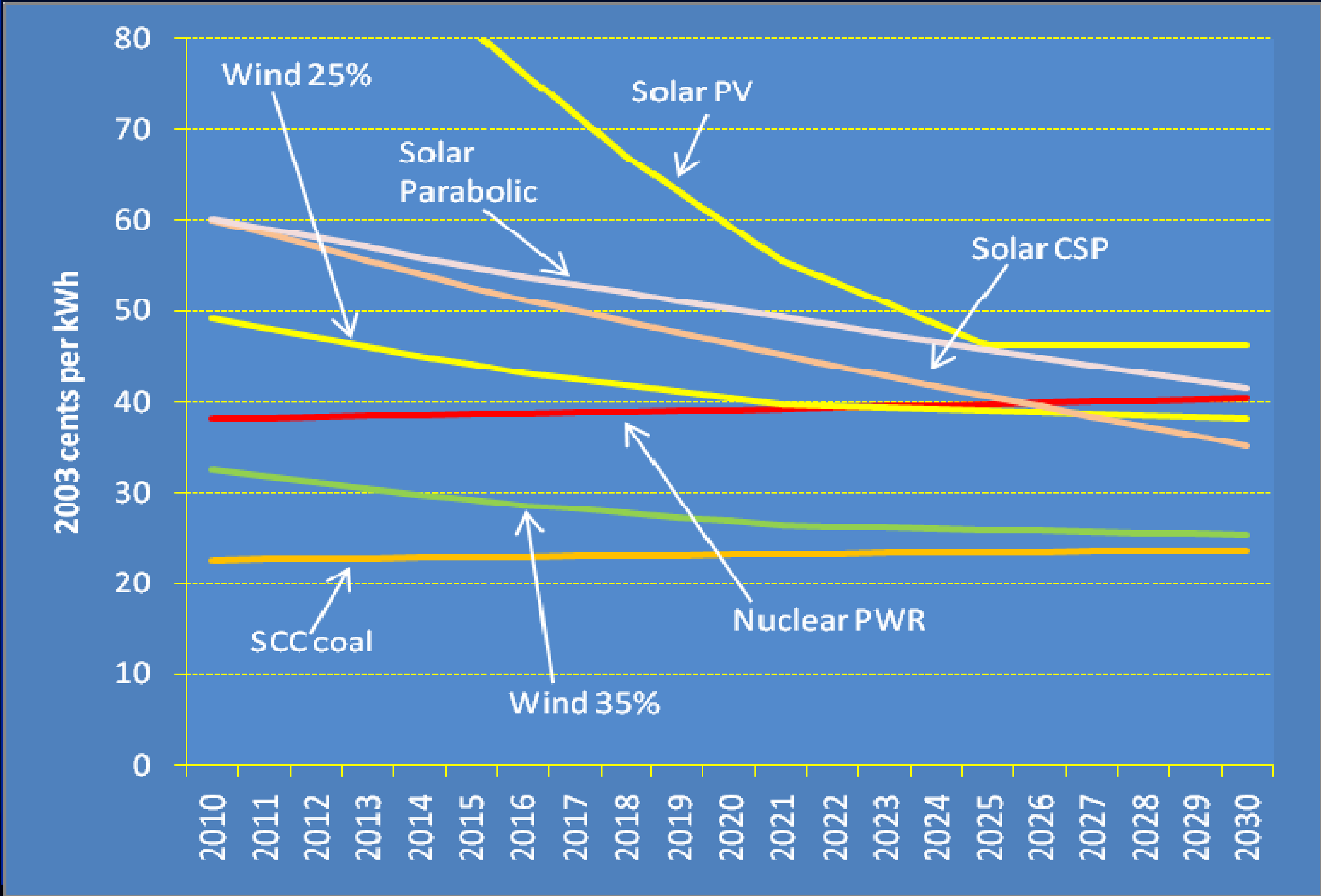
Some scenario results



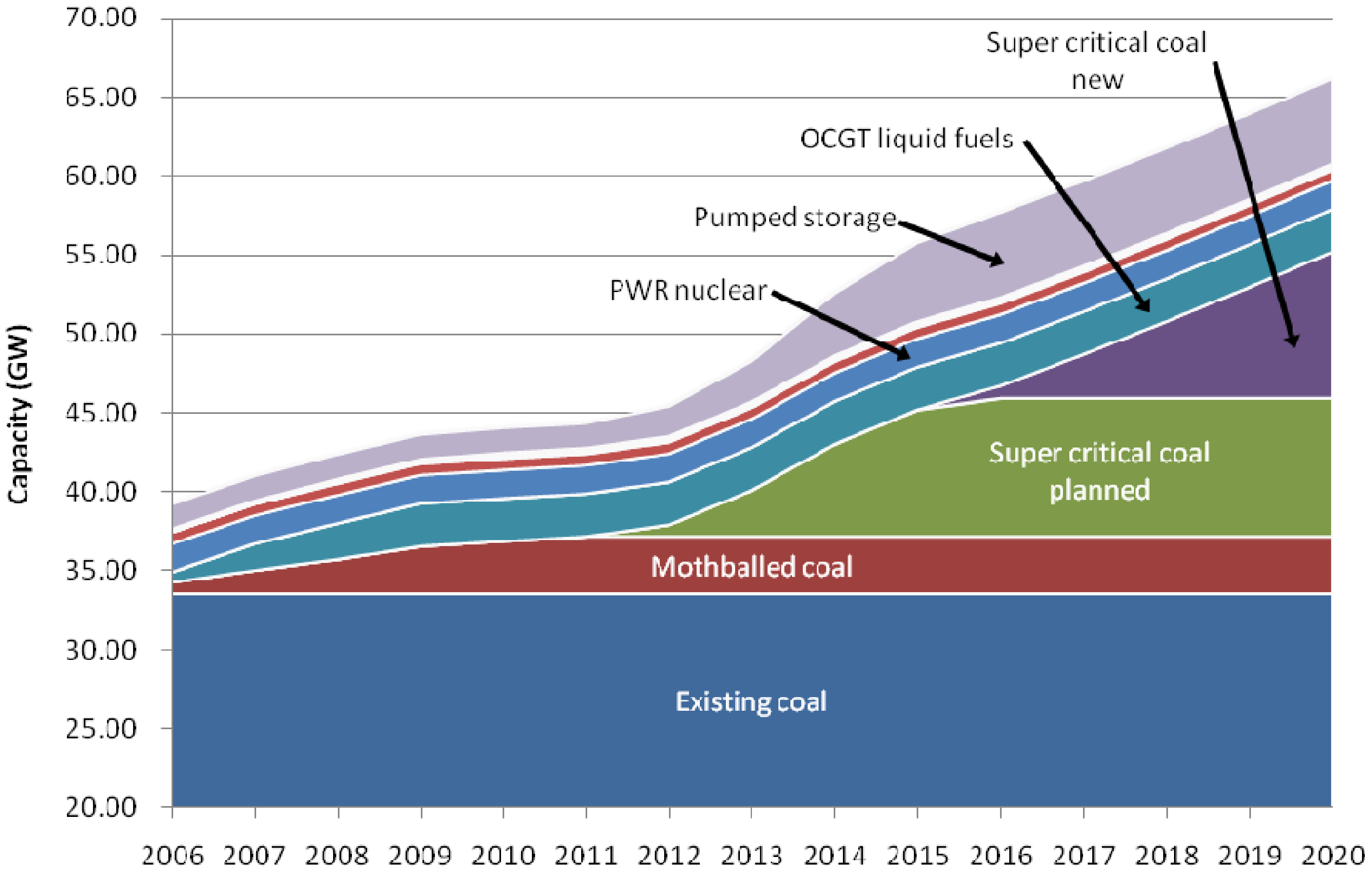


Demand 53GW	Reference (coal)	Nuclear Prog	Pessimistic wind (solar)	Optimistic wind	Opt wind+ (solar con)
Total Installed(GW)	61.8	62.4	65.6	73.5	67.2
Reserve Margin	16%	18%	24%	39%	27%
Coal	82%	67%	63%	63%	64%
Nuclear	3%	19%	3%	2%	3%
Wind	0%	0%	9%	23%	12%
Solar	0%	0%	11%	0%	7%
Other	15%	15%	14%	12%	14%

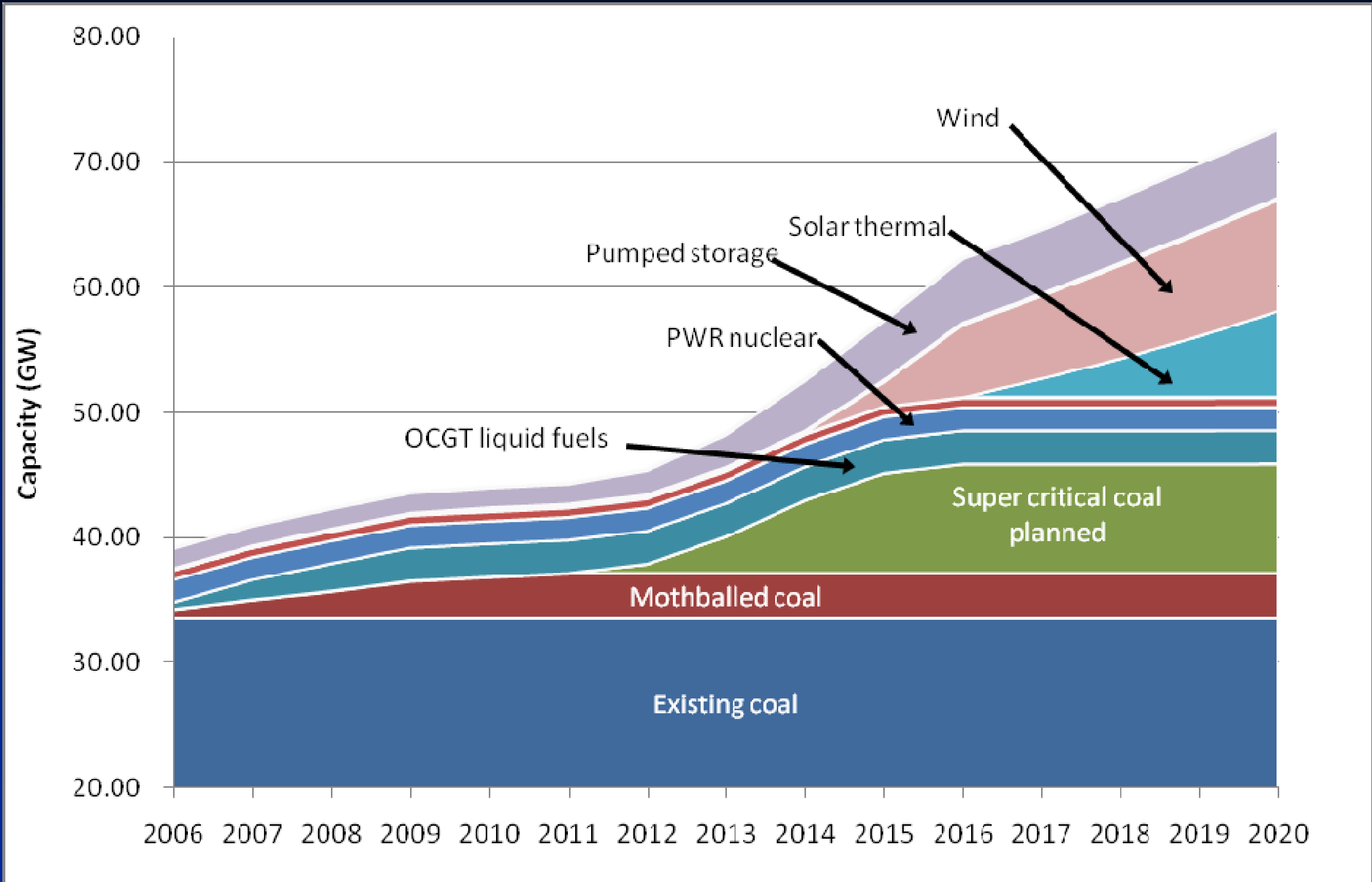
Levellised Costs of Electricity Plants



‘Business as Usual’



Case 1 – low wind assumptions



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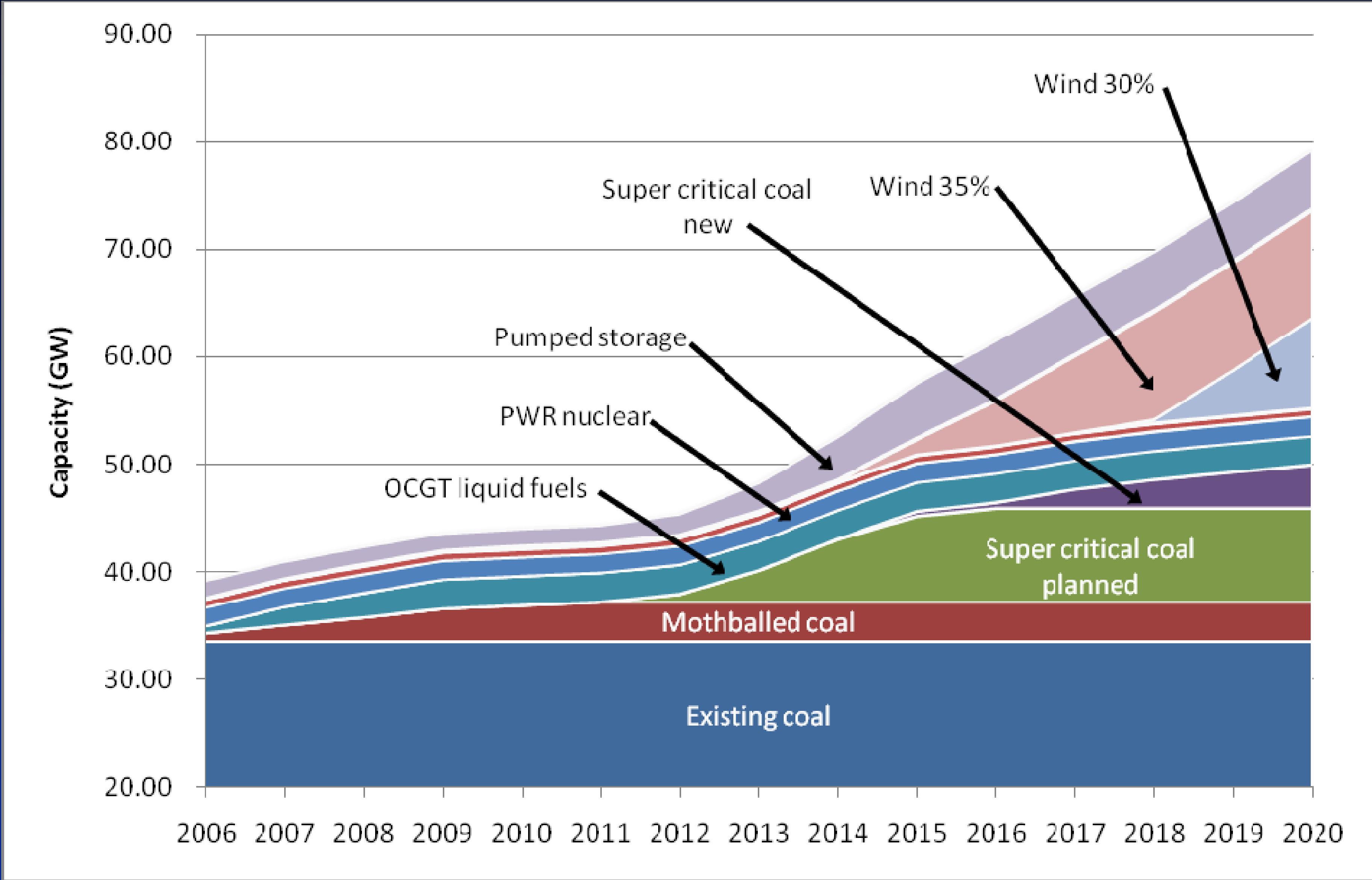
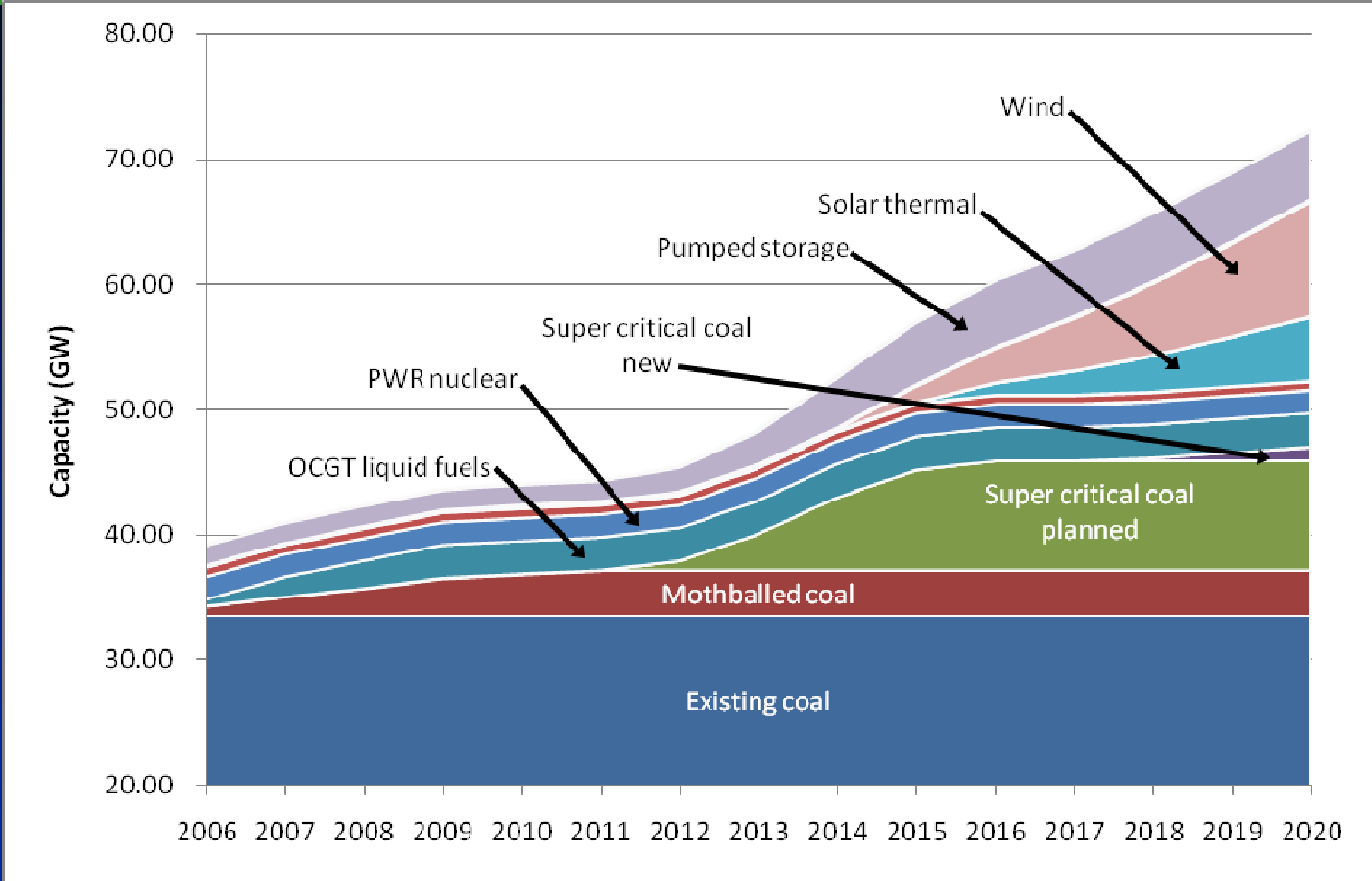
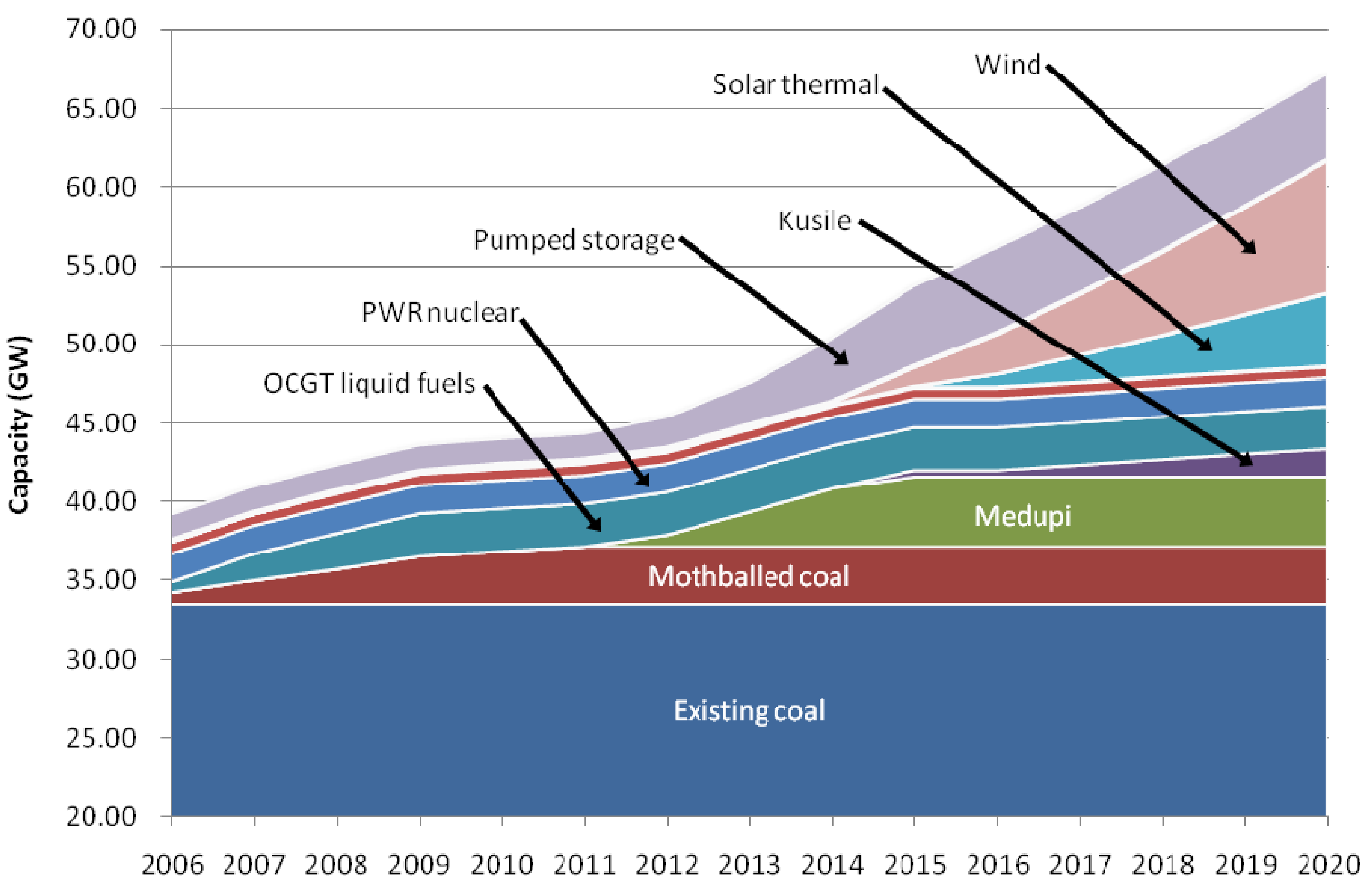
Case 2 – higher wind assumptions



Case 3 – higher wind with solar



Case 3A – Case 3 with energy efficiency



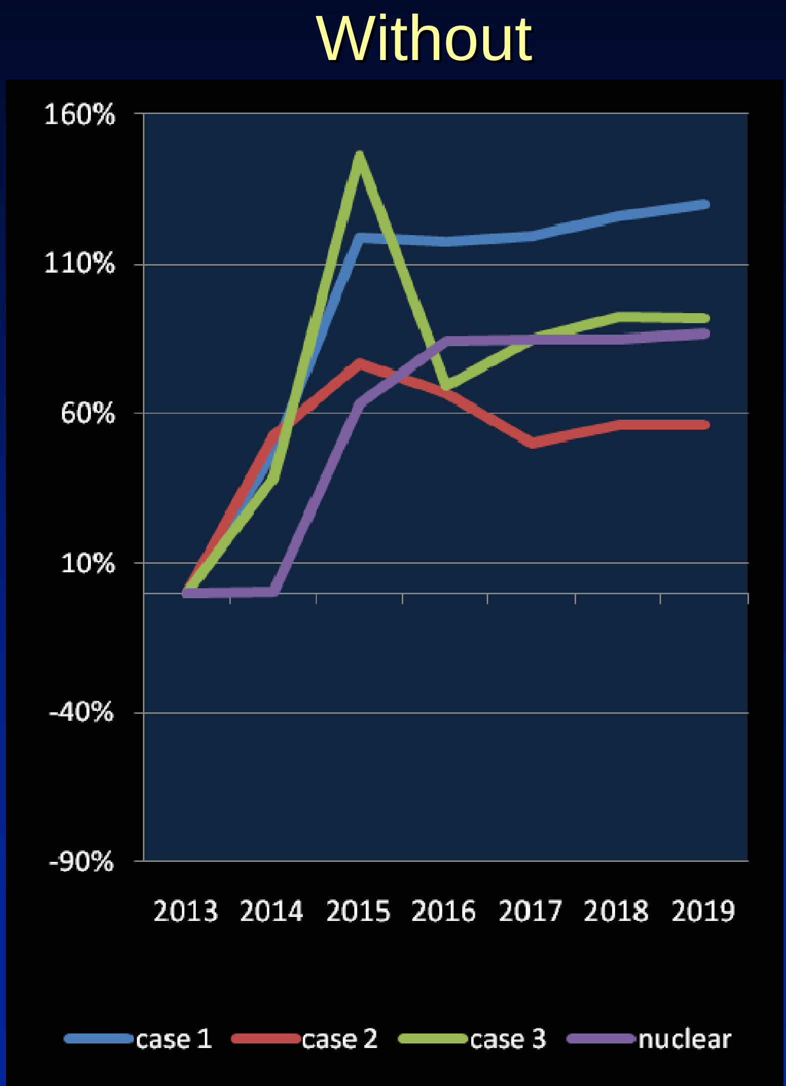
GHG emissions savings

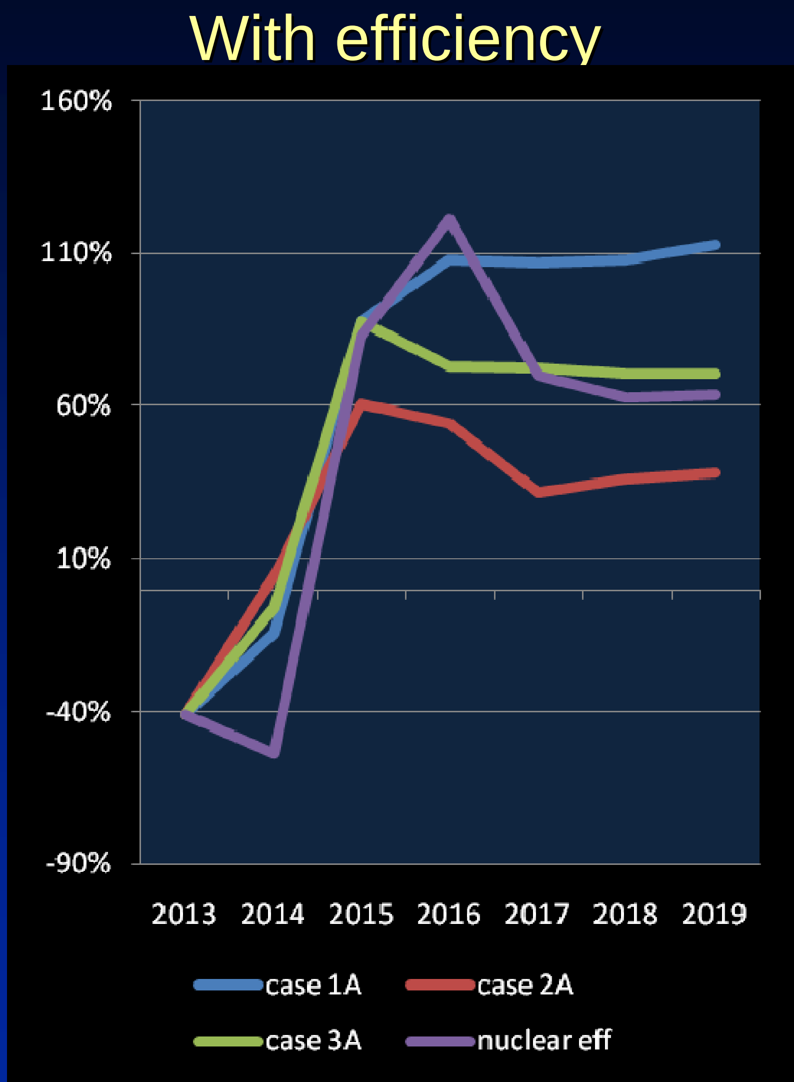
	GHG emissions saved (Mt CO2-eq)	% reduction from reference case	% reduction in electricity sector emissions	% of savings occurring from 2015 to 2020	% reduction in electricity emissions in 2020
Case 1	161	1.7%	3.9%	100%	14%
Case 2	169	1.8%	4.1%	100%	15%
Case 3	162	1.8%	3.9%	100%	14%
Case 1A	400	4.3%	9.6%	79%	22%
Case 2A	407	4.4%	9.8%	79%	23%
Case 3A	403	4.4%	9.7%	79%	23%
efficiency alone	248	2.7%	6.0%	66%	9%

Mitigation costs – using total system costs

	Rands per ton of CO_2-eq	Incremental costs as a % of GDP
Case 1	R141	0.10%
Case 2	R101	0.08%
Case 3	R104	0.08%
Case 1A	-R32	-0.05%
Case 2A	-R37	-0.07%
Case 3A	-R39	-0.07%
Efficiency alone	-R123	-0.14%

Investment requirements relative to reference case





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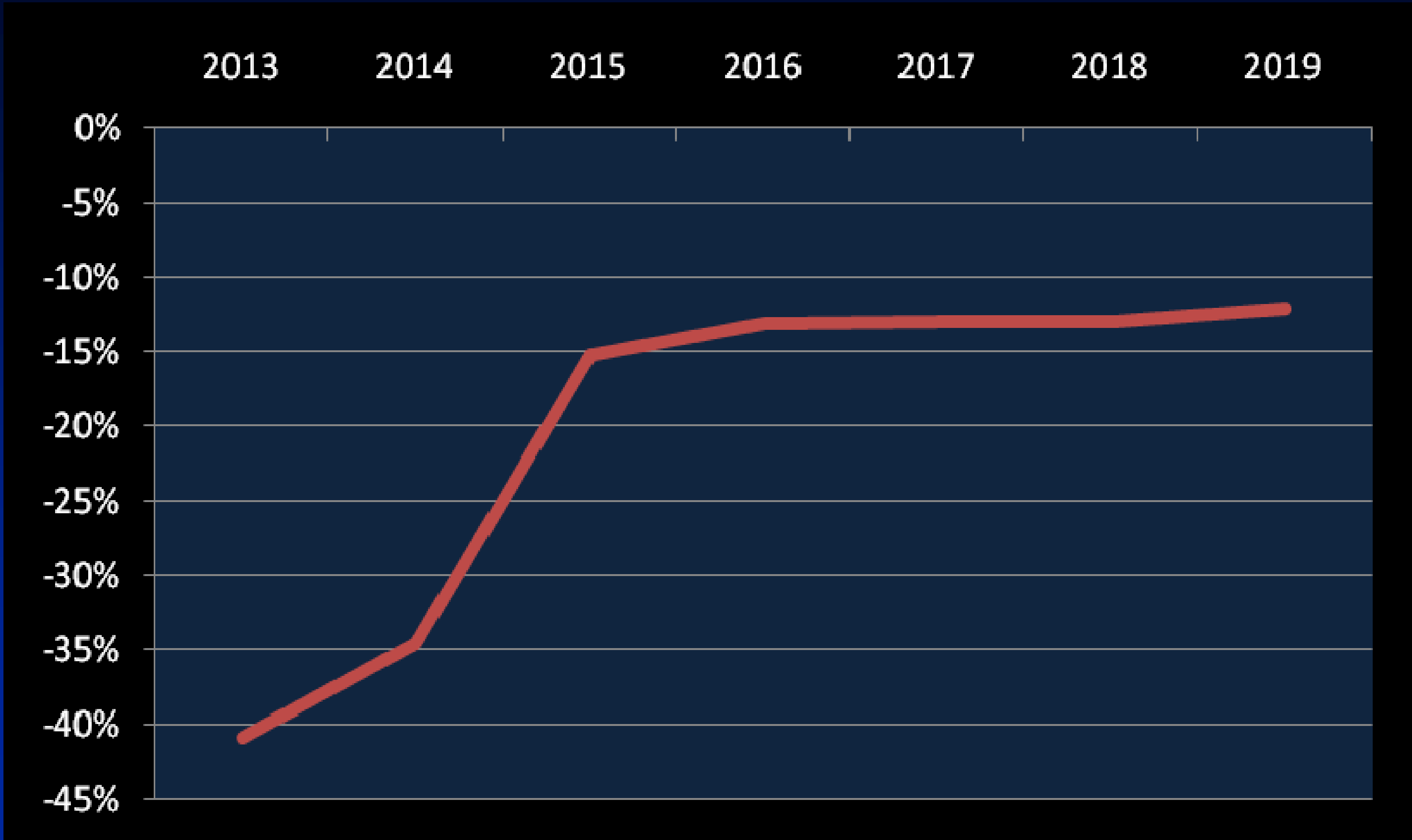
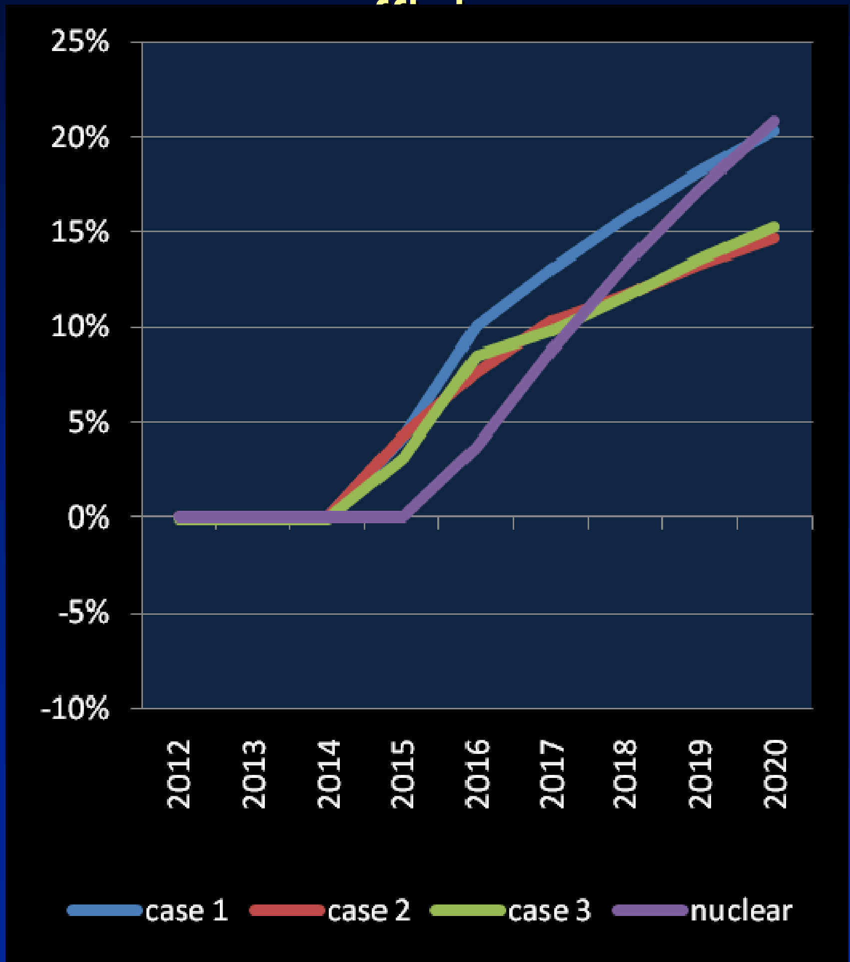
Impact of energy efficiency on investment requirements

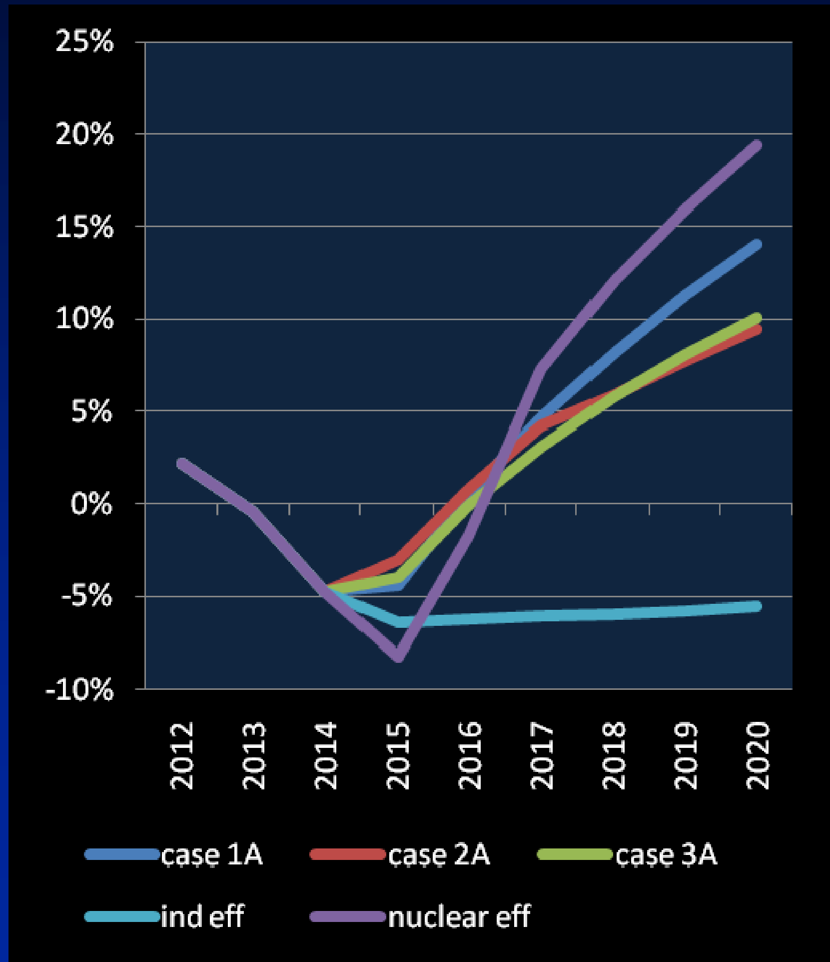


Average annual cost of producing electricity relative to reference case – proxy for electricity price

Without

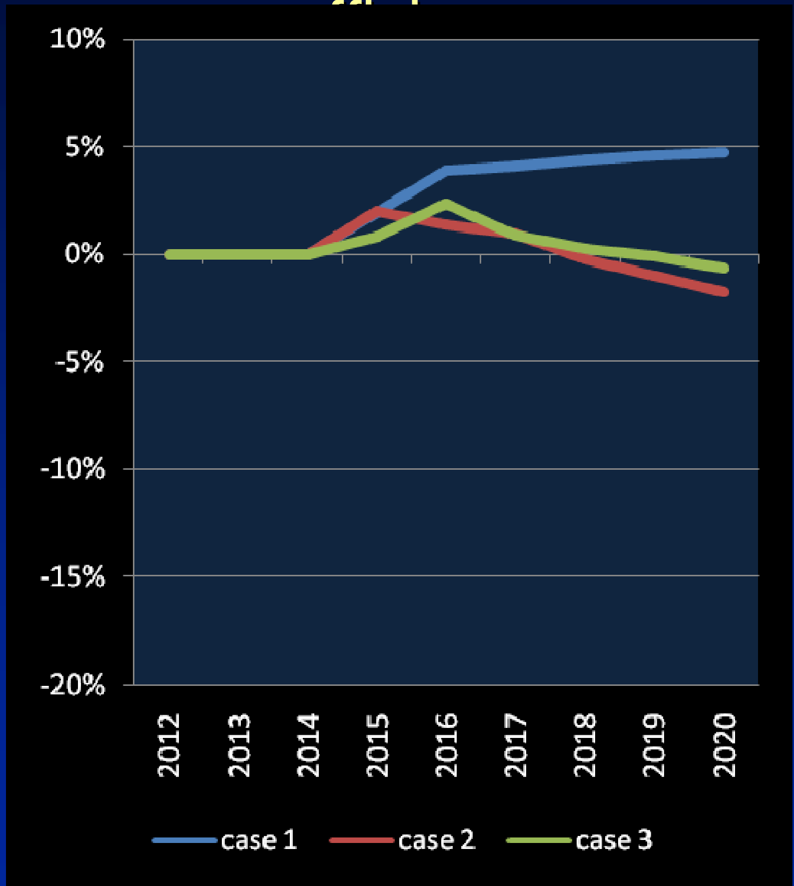


With efficiency

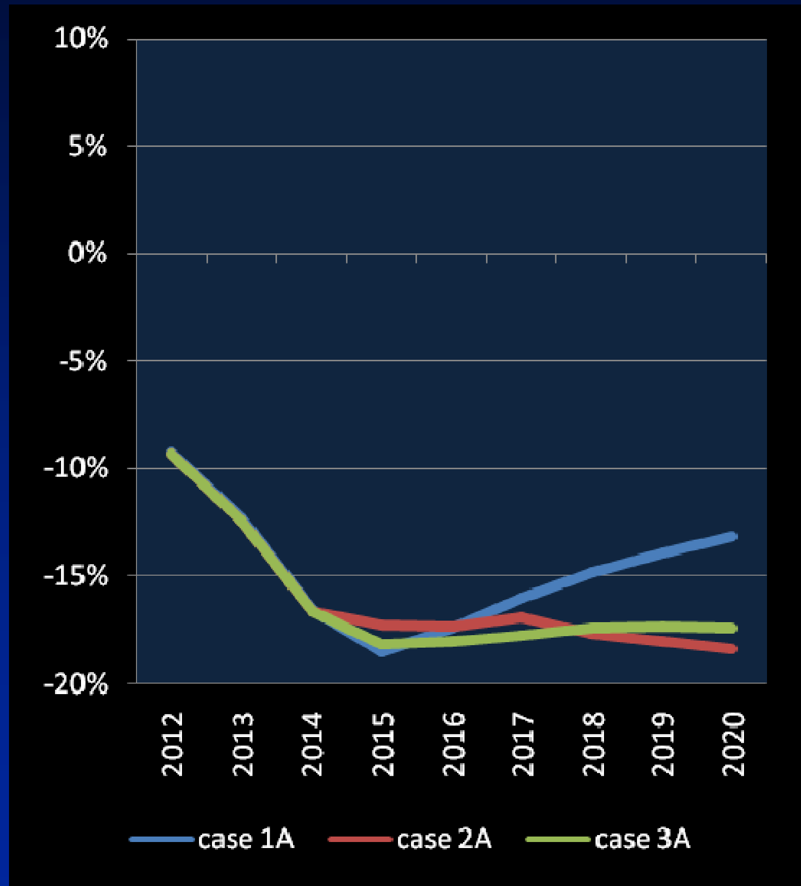


Average annual cost of producing electricity with a carbon price of 20 Euro / ton

Without



With efficiency



Impact on nuclear programme would depend on carbon regime (nuclear is currently disallowed under the CDM)

Co-benefits

- Total reduction in non-GHG emissions (Carbon Monoxide, NMVOCs, SOx, NOx) of between 2% and 5% from 2006-2020.
- Regional development benefits
- Job creation
- Potential for new industries particularly for solar thermal – economy-wide impacts modelled for LTMS study (CGE model) indicate local content is critical in economic cost/benefit.
- Energy security / diversification of supply
- Co-benefit of energy efficiency = no blackouts in 2012

Policy lessons and conclusions

- Cost of electricity will not be significantly affected, but investment requirements are a very significant challenge.
- Impact of investment requirements will depend on ability to develop ‘partner programmes’, specifically a) an energy efficiency programme, which will lower cost, and b) an industrial development strategy, which will help South Africa capture the development benefits of the programme – significant opportunities for solar thermal.
- Carbon finance will make a significant difference to the viability/attractiveness of the programme – price level is important.
- Significant institutional challenges.

Acknowledgements

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- Thanks to the following people for commenting on the method / outcomes and providing data: Harald Winkler, Glynn Morris, Roger Baxter
- Wind data was provided by Kilian Hagemann, whose ground-breaking work has made wind power a significant power generation option in South Africa.