RENEWABLE ENERGY SCENARIOS:

PRELIMINARY MODELLING FOR WA'S SWIS ELECTRICITY GRID, 2030

EXECUTIVE SUMMARY

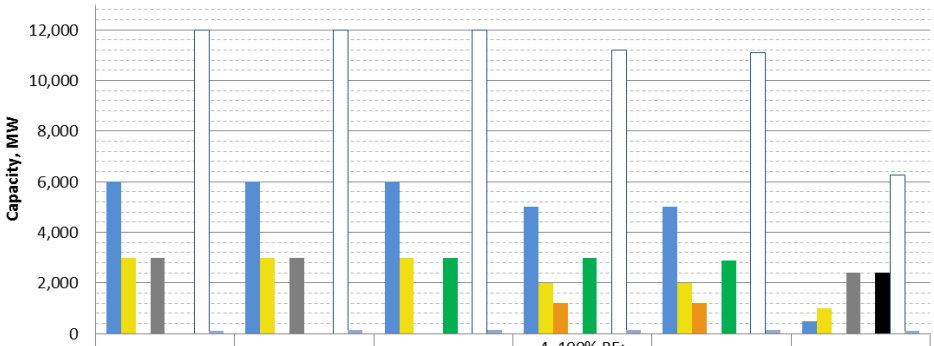
SEN has modelled six possible scenarios for energy generation options in the South-West Interconnected Grid (SWIS) of Western Australia. Five scenarios are based on renewable energy (RE) systems. A further scenario based on the current coal-based system ('Business as Usual' - BAU) is included for comparative purposes. Each RE scenario uses energy generated from wind and solar PV systems with different forms of storage (ie battery, pumped hydro, CST molten salt), with gas or bio-oil fuelled OCGT for power balancing.

Each scenario investigates the cost to build a new reliable power generation system and the amount of carbon emissions, in order to identify the most practical, efficient and cost-effective energy generation options for implementation by 2030.

KEY FINDINGS

1. **An 85% RE system is the cheapest scenario.** It would generate electricity for less than the cost of renewing the existing coal/gas based system.

Fig 1: Power Generation Capacity – Comparative Scenarios

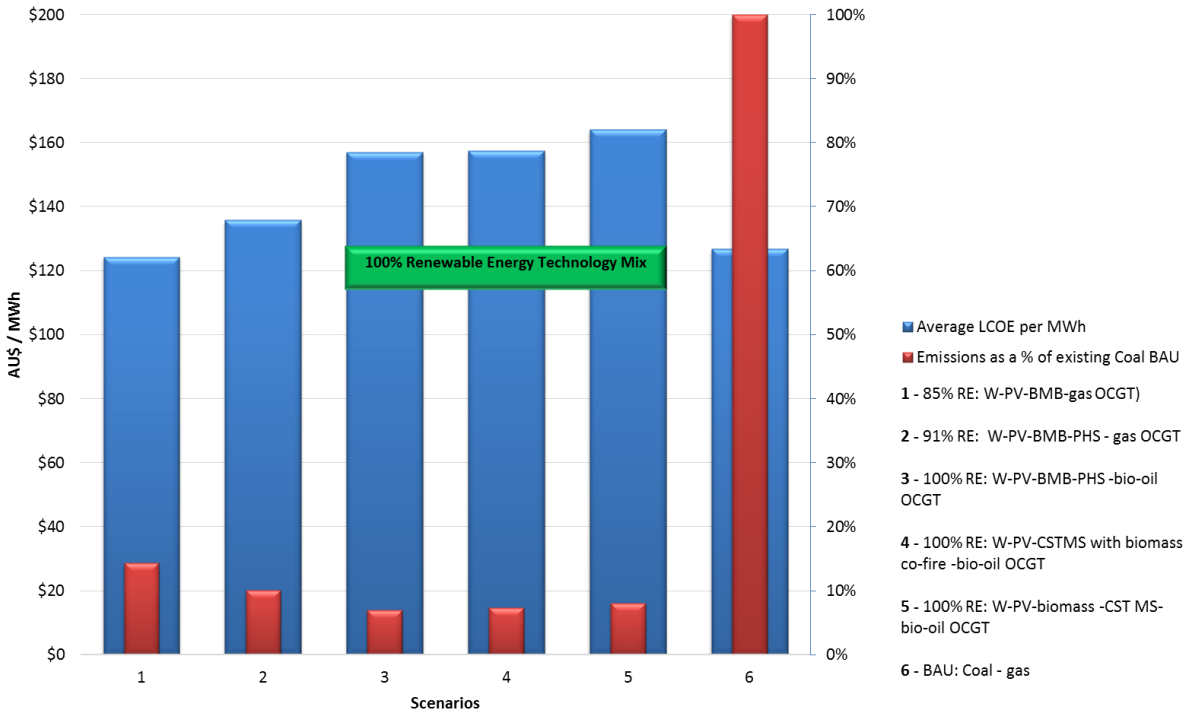


	1. 85% RE: W-PV-BMB-gas OCGT	2. 91% RE: W-PV-BMB-PHS - gas OCGT	3. 100% RE: W-PV-BMB-PHS -bio-oil OCGT	4. 100% RE: W-PV-CSTMS with biomass co-fire -bio-oil OCGT	5. 100% RE: W-PV-biomass - CST MS-bio-oil OCGT	6. BAU: Coal - gas
Wind	6,000	6,000	6,000	5,000	5,000	480
Solar PV	3,000	3,000	3,000	2,000	2,000	1,000
Solar CST	0	0	0	1,200	1,200	0
Gas (OCGT)	3,000	3,000	0	0	0	2,400
Biomass (OCGT &/or Co-fired)	0	0	3,000	3,000	2,900	0
Coal	0	0	0	0	0	2,400
TOTAL	12,000	12,000	12,000	11,200	11,100	6,280
Weighted average LCOE $/MWh	$124	$136	$157	$158	$164	$127

2. **Three ways to achieve a 100% renewable system have been illustrated.** These cost only 30-40 $/MWh (3.0-4.0 c/kWh) more than 'BAU' coal/gas.

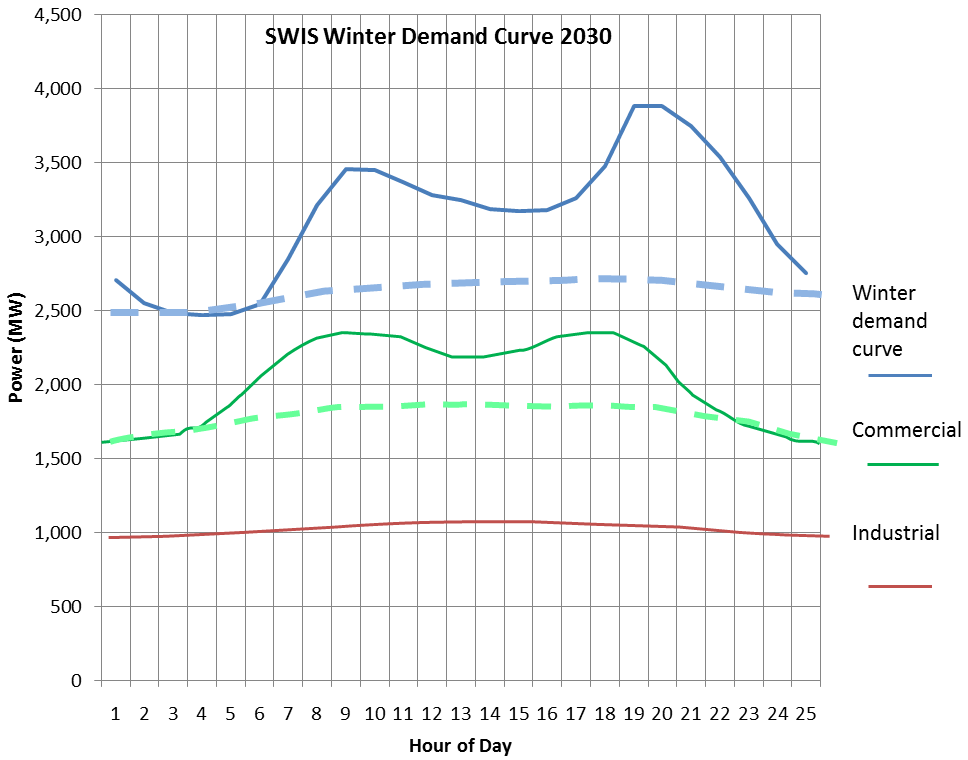
3. **RE costs will continue to drop**, resulting in even lower prices for electricity by 2030.

Fig 2: Summary of Scenario Costs and Carbon Emissions



4. **'Behind the meter' battery storage is likely to be a cost effective option** for both consumers with rooftop PV and without[1]. This will 'flatten' the demand profile, reducing the amount of expensive OCGT generation required (Fig. 3 below).

Fig 3: Effect of behind the meter batteries in 'flattening' demand profiles



[1] Assuming existing time-of-use tariffs are maintained and the cost of grid connection does not increase.

5. **New transmission lines for RE scenarios will cost an additional $7 - $9/MWh[2].**
6. **Selling surplus RE cheaply**, for example at $30/MWh, it would raise nearly $100m, reducing the average LCOE by about $4/MWh and thus substantially offset the cost of new transmission infrastructure.
7. **Potential Cost savings from a modernized SWIS:**

   This study indicates that a dispersed wind and solar based system with battery storage would reduce network charges, and greatly reduce reserve capacity payments (CP) and tariff adjustment (TAP) costs.

   With hundreds of wind generators, thousands of PV installations and over thirty OCGT generators, the risk of failure of one large generator will be removed. The expensive large capacity generators currently kept in reserve can be closed down and this will greatly reduce CP costs.

   More than half of current residential and commercial tariffs are Western Power's charges for the distribution network of poles and wires (12.0c/kWh) and retailer (Synergy) margins. The energy cost (12.0c/kWh) comprises the wholesale electricity price (about 9.8c), reserve CP (about 0.6c) and TAP for rural customers (1.6c).

   Micro-grids with batteries will reduce the current need for thousands of kilometres of poles and wires (and hundreds of transformers) for remote connections and new subdivisions, reducing network and TAP costs.

Table 1: Summary of scenario costs and carbon emissions

Energy Generation Scenarios	**Avg LCOE per MWh**	**CO_2 Emissions: % BAU coal/gas**	**Total CO_2 emissions** (Ktonne)	**Cost per tonne CO_2 reduction from BAU**	**% surplus generation**	**Total annual energy cost incl. carbon price** ($M)	**LC of new trans-mission** $/MWh
1. 85% RE (W/PV/ battery/gas OCGT)	**$124**	14.4%	2,262	**$3**	21.8%	$2,933	$7 - 9
2. 91% RE (W/PV/ battery/PHS/gas OCGT)	**$136**	10.1%	1,593	**$22**	14.0%	$3,204	$7 - 9
3. 100% RE (W/PV/battery/PHS/bio-oil OCGT)	**$157**	7.0%	1,094	**$56**	14.0%	$3,705	$7 - 9
4. 100% RE (W/PV/ CSTMS with biomass co-fire/bio-oil OCGT)	**$158**	7.3%	1,149	**$57**	20.7%	$3,718	$7 - 9
5. 100% RE (W/PV/biomass/CST/MS bio-oil OCGT)	**$164**	8.1%	1,268	**$68**	22.7%	$3,872	$7 - 9
6. BAU Coal/Gas	**$127**	100.0%	15,706	**No Change**	0.0%	$2,945	$0

[2] Using single and double 330 kV lines from Geraldton and Merredin to the Metro area; and east of Albany connecting to the existing 33 kV network at Collie.

BASIS AND KEY ASSUMPTIONS

a) Carbon price $30/tonne of CO_2e.

b) All scenarios include:
   - New-build cost of the entire electricity generation and storage components.
   - New-build costs only for transmission lines & substations additional to existing.
   - No difference in costs of distribution system (poles & wires).

c) Cost of capital: 10% for all generation (based on BREE AETA[3]); Government low risk rate of 6% for transmission and pump hydro storage projects; 5% savings rate for 'behind the meter' PV and battery.

d) There is a single load source - the Perth Metropolitan Area.

e) Wind and solar energy costed is the energy transmitted to the major load source = (generated energy) - (transmission losses).

f) All wind and solar energy generated is costed at the following average LCOEs (BREE AETA Model[3] estimate for 2025 in 2015 net present value): Wind $85/MWh; Utility-scale fixed PV $110/MWh; Concentrated solar thermal (CST) with 6 hours storage: $165/MWh.

g) LCOE for rooftop PV is costed at $65/MWh (Solar Choice website, 2015)

h) Dispatchable (balancing) power and storage are costed differently: a fixed annual cost per MW capacity installed plus variable costs (including fuel) for each MWh of energy generated.

i) Wind and solar generation surplus to load is still fully costed in the LCOE, even though in reality it may be curtailed or sold more cheaply.

j) All wind turbines are onshore (land-based).

k) A nuclear option has not been included as nuclear fission generation is inherently non-renewable, is not available in the required timeframe and has significant unresolved safety, environmental and cost issues. Costing and issues for nuclear at SWIS grid scale will be discussed in the full Modelling Report.

GLOSSARY

BAU	Business as Usual
BMB	Behind the meter battery storage (household and commercial)
CO_2e	Carbon dioxide equivalent
CP	Reserve capacity payments
CST	Concentrated solar thermal
LC	Levelised cost
LCOE	Levelised cost of electricity
MW	megawatt
MWh	megawatt hour(s)
OCGT	Open cycle gas turbine
PHS	Pumped hydro storage
PV	Photovoltaic
TAP	Tariff adjustment payment

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[3] Bureau of Resources and Energy Economics: 'Australian Energy Technology Assessment Model' v.2.1; 14/01/14.